

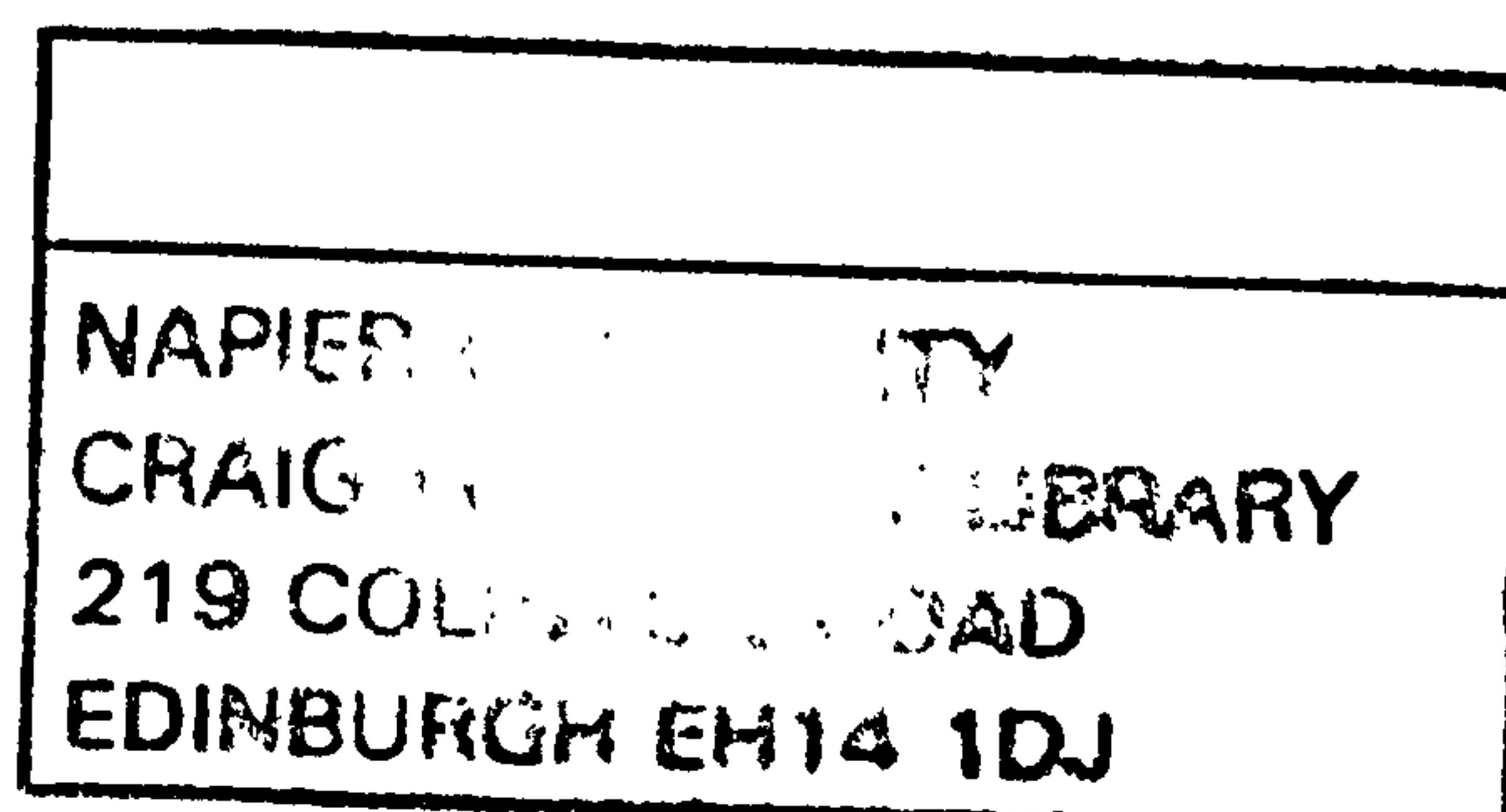
**A COMPUTER-BASED MICROWORLD FOR
THE ASSESSMENT AND REMEDIATION OF
SENTENCE PROCESSING DEFICITS IN APHASIA**

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ABSTRACT

This thesis investigates impairments of written sentence comprehension in 14 aphasic adults. The primary purpose of the research was to apply computer technology to the process of assessment, with the aim of improving diagnostic precision and thereby being able to offer better-targeted and more effective treatment.

To facilitate the study of sentence processing disorders a microworld was developed, populated solely by animate and inanimate balls, boxes and stars. This medium had two major advantages over natural English. Firstly, the restricted vocabulary and the small set of grammatical structures used permitted finer control of the linguistic environment, and secondly, all the test sentences were fully reversible with equal plausibility. The microworld formed the basis for a suite of patient-controlled computer programs dedicated to the study of two functions: the processing of verbs and the processing of locative prepositions. Computerisation enabled automatic, detailed and objective data collection in assessment mode, freeing the observing clinician to make important complementary observations. In remediation mode the software externalised the subtasks of sentence comprehension for clinical study.

The results of an efficacy study are reported in which the aphasic subjects were divided into two groups of seven and subjected to a cross-over design experiment. Group A received verb treatment before preposition treatment and Group B received the treatments in opposite order. Significant treatment effects were obtained which could be attributed confidently to the intervention applied and which included generalisation to 'real world' reading tasks. Many of the subjects maintained benefit of treatment after a non-treatment interval of five months.

The thesis presents a range of new data on aphasic performances including details of error patterns, response latencies and susceptibility of the different sentence structures to treatment. In addition the aphasics are compared with 45 normal subjects in their computer interface operation and on a new six-module Syntax Screening Test. Theoretical contributions to knowledge are made in the establishment of the dissociability of verb and preposition processing and in the interpretation of the clinical observations. The microworld and software created have potential application in many other areas of language research.

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| | |
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| Prof. Nathan Wolfe (economist), my companion | (16.9.1927 - 1.1.1988) |

AUTHOR'S DECLARATION

I declare that the contents of this thesis, including the design and implementation of all the software described herein, is my own unaided work. The copyright of this thesis is vested in the author - due acknowledgement must be given for the use in any form, of any part of it. The content and presentational formats of the assessment and remediation software are separately protected by copyright, any attempt to reproduce this software is an infringement of copyright.

The thesis was prepared by the author in the Microsoft Windows Graphical Environment (Microsoft, 1990a) using the Word for Windows word processing package (Microsoft, 1990b) and the graphics package CA-Cricket Graph (Computer Associates, 1990). The software was written in the Pascal programming language using Borland's software development environment (Borland, 1988) and the MEDC WIMPS software toolkit (MacMonnies, 1989).

The computer hardware used for software development and clinical work was an IBM PC AT compatible machine (286/12), with 640k RAM, 20mb hard disc, VGA monitor and Microsoft mouse, running under the MS-DOS operating system (version 4.01). The thesis was prepared on a machine of higher specification and conforms as far as possible to British Standard 4821.

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Alison Crerar
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CHAPTER 1

1.1 INTRODUCTION

This thesis presents a new computer-based microworld and an associated suite of software, aimed at the assessment and treatment of deficits of written sentence understanding in aphasic adults. The results of an efficacy study are reported which show significant and durable treatment effects in a number of stable long-term aphasic subjects. The benefits of computerisation are seen not only in the output of the assessment software, which provides diagnostic advantages over existing sentence processing tests, but in the remediation environment which facilitates study of the ongoing subtasks of sentence comprehension. The assessment and remediation software are both patient-controlled. This results in important observational advantages for the therapist over traditional clinical techniques and elevates the status of the patient in the partnership, with very favourable consequences. The methods developed have potential in many other areas of language research and rehabilitation. The organisation of the thesis is as follows:

Chapter 2 introduces the microworld and describes the selection of 14 aphasic subjects deficient in verb and preposition processing. The performances of the aphasic subjects are compared with those of 45 normal subjects to validate a new Syntax Screening Test, and the aphasics are repeat-tested to establish stability on the functions of interest prior to onset of remediation.

Chapter 3 describes a set of new assessment and remediation tools designed to fulfil the requirements of a multiple baseline with cross-over treatment study. It also describes the treatment protocol and discusses the formulation of therapy goals for individual patients.

The patients were divided into two groups of seven and subjected to different treatment orderings; Group A received verb treatment first and Group B received preposition treatment first. Chapter 4 presents the efficacy data and the results of an analysis of variance on the group results.

Chapter 5 probes the inter-group variations highlighted by the analysis of variance. It also provides supplementary data in the form of individual performance profiles, effects of therapy on the different sentence structures treated, speed data both for groups and individuals, data relating to an extended treatment phase with three subjects and data showing durability of treatment effects in seven of the other patients.

In the final chapter the major research findings are summarised and the most interesting clinical observations are discussed. Chapter 6 also includes information on the wider functional generalisation of microworld therapy, derived from questionnaires completed by the subjects (with help) and their carers. The thesis concludes by recommending modifications which might be incorporated in replication studies and highlighting promising directions for the extension of this work and for the application of the microworld approach to other language domains.

The current chapter consists of a literature survey and appraisal focusing on contemporary issues in clinical aphasiology, with particular emphasis on the state of the art in those areas which gave immediate impetus to the present study. In view of the volume of published material bearing upon this work, an exhaustive review is impracticable; instead, this chapter concentrates on those bodies of research which have collectively, and most directly, yielded a point of departure.

A brief overview of clinical aphasiology serves to introduce the parent field, and the key issues of diagnosis and treatment evaluation, which are central concerns. This is followed by reviews in the four main areas where the thesis offers a contribution. The first is agrammatism, which is the aphasia sub-category into which investigations of expressive and receptive syntax processing fall. The major antecedents of the present work are cited in this section, and the origins of the microworld credited. The second section on microcomputers in aphasiology surveys previous applications of the chosen assessment and remediation medium. The review of cognitive neuropsychology in the third section explains the overarching rationale behind the design and conduct of the present work, and also provides an account of progress in applying cognitive neuropsychological models to the diagnosis and treatment of language dysfunctions. Finally, the section on clinical research methodology encompasses issues relating both to the design of sound efficacy studies and to the inference of intact cognitive processing

from pathological cases. These are the main pillars on which the study stands. There are, of course, many other supporting literatures informing this work, notably those of linguistics, psycholinguistics, human-computer interaction, educational psychology and artificial intelligence. These are not candidates for independent review, but will be drawn upon in the body of the thesis, as appropriate. For example, psycholinguistics is an important source in Chapter 6 where the major clinical findings are discussed and related to relevant theory. Following the individual critiques, the final section in the chapter explains the scope and aims of the present study. It is hoped that this form of exposition will enable the research strategy, as it unfolds, to be related both to the traditions it follows and to the four frontiers it seeks to address.

1.2 BACKGROUND

The term aphasia covers a diverse range of acquired language dysfunctions, which may be present in differing combinations and severities, and which generally follow a cerebrovascular accident to the left hemisphere of the brain. The field of clinical aphasiology is of considerable interdisciplinary interest; doctors and therapists have a primary concern with the remediation and/or long term management of the patient, but increasingly, researchers in neuropsychology, neurolinguistics, linguistics and computational linguistics are exploring language dysfunction as a means to testing models of normal language processing.

Since 1861 when Broca published what has been described as the first truly scientific paper on language-brain relationships (Caplan, 1987a), investigative methods in all the participating disciplines have improved substantially, both in scope and sophistication. Neurology has produced better scanning techniques which permit more accurate localisation of lesions and the ability to measure levels and loci of activation during various cognitive tasks; phonology, phonetics and linguistics have provided formalised approaches to the description of sound systems and grammatical structures; aphasiology has attempted a classification of language disorders and developed an array of aphasia assessment batteries and treatment approaches, and psychology has offered a range of rigorous experimental designs, the application of statistical analysis techniques, and a wealth of data concerning the cognitive functioning of normal subjects. A particularly promising source of practical and theoretical support is found in computer science, which has provided not only the practical means to dynamic

modelling and interactive assessment, treatment and data collection, but also the conceptual framework and terminology of the information processing model, which has become the dominant paradigm in cognitive science.

In spite of such impressive progress in terms of techniques and equipment, and the development of new related sciences which have lent fresh perspectives to the endeavour, very little more is known about the neurophysiological mechanisms by which language processing is implemented in the brain's 'hardware', than was known by the early classical connectionists Broca and Wernicke.¹ Even at an implementation-independent² level, our understanding of the functions underlying normal, intact language input/output in all its modalities, and how they interrelate, remains extremely rudimentary. To quote Caramazza and McCloskey:

It is not an exaggeration to say that over one hundred years of research on cognitive disorders has shed little light on the nature of normal cognitive processes and the form of their dissolution in conditions of brain damage. (Caramazza and McCloskey, 1988, p. 519).

The study of acquired language dysfunctions, albeit in anecdotal form, can be traced back almost 5,000 years, yet not until 1869 did the English neurologist H. C. Bastian observe that aphasia often entails deficits of comprehension as well as of production (Howard and Hatfield, 1987, p.21). In recent times, the speech pathology profession (as its name suggests) has tended to concentrate on outward modes of communication; thus there is a bias in the literature towards studies of expressive problems, which receive more weight than receptive problems in the determination of aphasia sub-types by the Boston Diagnostic Aphasia Examination (BDAE; Goodglass and Kaplan, 1982) and Western Aphasia Battery (WAB; Kertesz, 1982). But more surprising than the relative neglect of comprehension problems, is the uncertainty that emerges from the published output of the last 30 years over fundamental questions such as how to tackle diagnosis, how to proceed from diagnosis to treatment, and whether the supposed benefits of therapy withstand scrutiny.

Turning first to diagnosis; a great deal of disagreement exists about whether the very widely used traditional aphasia classifications, categories such as Broca's,

¹ Caplan, 1987a, Chap.4 provides an historical account.

² The term 'implementation-independent' is used in its computing sense, to mean 'functional' rather than 'procedural', thus, making no presuppositions about how language functions are realised in the brain.

Wernicke's, Conduction etc., (Caplan, 1987a, chap. 11), are any longer tenable. The attempt to group patients into syndromes had its origins in the work of the early localisationists, the idea being to sort patients into homogeneous classes according to their symptoms. This procedure originally had a dual function: firstly to group patients by probable lesion sites (when this could otherwise only be done post mortem), and secondly to assign them to types based on a core of shared symptoms, thereby establishing a differential diagnosis upon which to base the design of appropriate remediation strategies. A notable result of classification according to putative lesion site was that it gave impetus to a range of alternative stimulation strategies, thought to utilise preserved areas, particularly the non-dominant hemisphere, (e.g. the melodic intonation therapy, MIT, of Sparks and Holland (1976) and the visual communication system, VIC, of Gardner, Zurif, Berry and Baker (1976)). Although syndrome classification has been very influential in aphasiology, being especially associated with the Boston School (Goodglass, Kaplan, Geschwind and others), it has not been universally embraced. Key among alternative philosophies was the unitary theory of aphasia proposed by Schuell (Schuell, Jenkins and Jimenez-Pabon, 1964), which considered aphasia to be a single disorder varying only in severity. Building on the earlier work of Wepman (1951; 1953), Schuell developed the Minnesota Test for the Differential Diagnosis of Aphasia (Schuell, 1965) and advocated a general stimulation approach to therapy aimed at facilitating language processes which were considered to be largely intact, though inaccessible.

Syndrome classification also provided the rationale for the design of group studies, from which much of the published evidence on aphasic language processing derives. However, there is now a growing realisation that the diversity of language impairments found among individuals assigned to the same syndrome invalidates the assumption of homogeneity upon which the integrity of group studies relies (Schwartz, 1984). With the expansion of the research database it has become obvious that the proposed aphasia categories are not mutually exclusive, that symptoms are shared, and that a significant proportion of patients do not fit neatly into the pigeon-holes provided (Spreen and Risser, 1981). The research community has responded either by advocating subdivision of the recognised syndromes to allow increased specificity (Shallice, 1979), or by arguing that syndrome classification could be abandoned for many purposes (Ellis, 1987).

Aside from the homogeneity issue, there are signs that the standardised aphasia batteries have been outgrown by clinicians of the cognitive neuropsychological

school (Byng, Kay, Edmundson and Scott, 1990). The main reasons for this are that the very small number of test items included in most test batteries for each function is insufficient to differentiate the underlying impairment(s), and that the assessment rationales have been superseded. The old broad-brush functions of 'spontaneous speech', 'auditory comprehension' and the like, with their equally imprecise qualifiers ('fluent', 'non-fluent', 'good', 'poor', etc.) are giving way to finer-grained analyses based on information processing models of language (Morton, 1981). By comparison with operating the old taxonomy, recent criteria advanced for satisfactory deficit analyses can appear dauntingly stringent, for example, Caplan and Hildebrandt propose that,

The account of an observed impairment in syntactic comprehension requires a theory of normal language structures, a theory of normal language processing, a theory of possible deficits, and a theory of adaptations to deficits. (Caplan and Hildebrandt, 1988, p.6).

The authors do admit that these are not easy to establish! There is no doubt that increased precision in the study of language breakdown is helping to advance our theories of language-brain relationships; however, it is equally certain that in the transitional period before practical techniques emerge which clinicians at large can embrace, the main effect for them will be an unsettling erosion of diagnostic footholds.

Concerning the relationship between diagnosis and therapy, a shortfall exists between clinical practice and the widely held ideal that therapy should be founded on a detailed deficit analysis and should be motivated by one of three therapeutic strategies: restoration, restitution or compensation (Howard and Hatfield, 1987, pp. 130-131). This is not surprising, since the necessary tools are not yet in place. Given that models of intact language processing are currently embryonic and that the standardised aphasia tests are insufficient, it would be necessary for the clinician to formulate a model of language processing and develop her own tests in order to attempt a diagnosis revealing the points of breakdown in each modality and a rationale for their occurrence. Having done this, she would find no necessary connection between diagnosis and therapy. An accurate diagnosis should guide the development of appropriate therapy, but it cannot be prescriptive (Ellis, Franklin and Crerar, in press). A notable disadvantage for therapists is that greater attention has been paid in the literature to exploring language disorders than to developing and testing treatments. At present there is a chasm between the growing knowledge generated by researchers using

pathological cases to illuminate intact and disordered cognitive processing and the working out of consequent therapeutic implications. Howard and Hatfield put it thus:

Since the Second World War, therapists have attempted to incorporate and use a large number of neuropsychological and neurolinguistic findings - but the relationship is entirely one way. Outside the Soviet Union and Eastern Europe, neuropsychology has, as far as we know, scarcely ever used any therapeutic findings as evidence, nor shown any interest in developing theories that could predict or explain the process of therapy itself. (Howard and Hatfield, 1987, p. 59).

The same authors hailed Beauvois and Derouesne (1982) and Byng and Coltheart (1986) as "the only good examples of the use of treatment studies to test theoretical claims" (p. 134). The situation has improved a little since they wrote, principally due to the appearance of other studies emerging from the cognitive neuropsychological school. However, from the foregoing it is both predictable and understandable that the day to day management of an aphasia caseload is seldom theoretically defensible, in any rigorous sense.

As far as the rehabilitation of aphasics is concerned, a bewildering range of approaches have been tried. Very broadly, alternative strategies may be divided into those that seek to re-teach (Lhermitte and Ducarne, 1965), those that aim to re-access (Schuell, Jenkins and Jimenez-Pabon, 1964; Wiegel-Crump and Koenigsknecht, 1973), and those that believe in circumvention of the impaired function(s) (Aten, Cagliuri and Holland, 1982; Davis and Wilcox, 1985). Section 2 of Howard and Hatfield (1987) provides a useful overview of the eight major schools and the outcome of associated efficacy studies, and a new appraisal is promised (Byng, forthcoming). Although the experience of aphasics, their relatives and therapists, suggests that therapy is beneficial, formal evidence on the efficacy of treatment has been very mixed. The literature reveals a striking discrepancy between reports of improvements after therapy in neurologically stable individuals (Basso, Capitani and Vignolo, 1979; Broida, 1977) and the rather less conclusive findings of group efficacy studies. The latter adopted the medical paradigm of randomised controlled trials (Bulpitt, 1983), seeking to answer the general question of whether aphasia therapy, on the whole, was effective. Several reviews of such clinical trials have appeared, and their conclusions have differed markedly. Darley (1979), for example, found

enthusiastically in favour of the benefits of therapy, while Miller (1984) considered the case for intervention unproven.

Howard and Hatfield roundly condemned the bulk of group studies on methodological grounds, as follows:

Clinical trials of aphasia therapy yield a confused picture. The trials with negative outcomes are exclusively English, and all involve small amounts of treatment. However, we have argued that these trials yield little useful evidence whatever their outcome. This is because they apply heterogeneous and undefined treatments to heterogeneous groups of patients using global and insensitive assessment techniques. Their group results cannot be generalised to any individual aphasic patient, and the treatment procedures involved can never be applied by another therapist because they are never described in detail. (Howard and Hatfield, 1987, pp. 118-119).

Recently, syndrome-based taxonomies and group studies emanating from them have been further undermined from the cognitive neuropsychological perspective by the appearance of a number of papers strongly arguing that *only* single-case studies allow valid inferences about intact cognitive processes to be made (Caramazza, 1986; Caramazza and McCloskey, 1988). Thus, a very exacting set of requirements confront investigators seeking both to avoid the pitfalls arising from the inherent complexity of aphasics as experimental subjects, and to relate their clinical findings to a model of intact language processing. These issues will be amplified in sections 1.2.3 and 1.2.4 below.

1.2.1 AGRAMMATISM

As already noted, aphasia is a generic term, covering the potential range of language impairment patterns following trauma to the dominant hemisphere of the brain. At a gross level, a distinction can be made between expressive and receptive problems; that is, between problems of input and output.³ These may be further subdivided into specific impairments of the individual input/output modalities. Many of these deficits have now acquired fairly precise diagnostic

³ The terms 'input', 'output', 'expressive' and 'receptive' are used throughout as indications of the manifestation of disordered language, and are not intended to imply cause.

descriptors. The focus of the present study is a receptive problem, disordered comprehension of written sentences, which falls within the ambit of agrammatism.

Throughout this thesis terms such as *receptive agrammatism* and *syntax processing* are utilised for convenience. In doing so, I overlook neither the ongoing debate about the extent to which agrammatism merits the status of a syndrome (Caplan, 1985, 1991; Miceli, Silveri, Romani and Caramazza, 1989), nor the enormously complex and heterogeneous set of processes subsumed under the umbrella of syntax processing (Goodglass and Menn, 1985). The term *receptive agrammatism* is adopted on an empirical basis to describe the manifestation of all forms of receptive asyntacticism, without meaning to impute homogeneity to the subjects so classified. *Syntax processing* is used to refer to the processes involved in extracting meaning from sentences over and above the meanings of the individual words. Both are used mindful of the probability that the underlying range of causes may include factors other than purely syntactic ones.

In the past, agrammatism has been viewed mainly as an expressive disorder characteristic of Broca's aphasics (Goodglass and Kaplan, 1982). These patients typically appear to have good comprehension, but dysfluent output involving incoherent, telegrammatic speech which shows a marked omission of verbs, function words⁴ and morphological inflections, and a reliance on concrete, highly imageable, content words and grossly simplified syntactic structure (Ellis and Young, 1988, Chap. 9 contains a useful digest). Some authors have upheld a distinction between agrammatism and paragrammatism, the latter being more fluent with better sentence structures but tending to show incorrect use of function words and grammatical morphemes rather than their omission (Kleist, 1916). However, Saffran, Berndt and Schwartz (1989) point out that this distinction is inadequate to cover the range and complexity of impairments found in individual patients, and that the distinction is hard to maintain when differences of fluency are ignored. Terminological debates notwithstanding, agrammatic speech is a very noticeable affliction, which has attracted corresponding academic interest. By comparison, receptive agrammatism can be easily missed. The reason is that sentence comprehension draws heavily on semantic and pragmatic knowledge and only when contextual cues are absent, or insufficient for

⁴ This term denotes the closed class (rarely extended) set of words including parts of speech such as articles, demonstratives, conjunctions, prepositions, and pronouns (Quirk and Greenbaum, 1982).

resolution, do syntax processing breakdowns become evident. Careful testing may well reveal the incidence among aphasics to be higher than supposed.

Contemporary studies have their origins in Russian and German research dating from the late eighteenth and early nineteenth centuries (Kleist, 1916). Expressive agrammatism is even more apparent in highly inflectional languages than it is in English, and this no doubt accounts for the early interest. For an overview of the state of knowledge in the 1960s, Goodglass (1968) is a useful source. Although dated, it provides an insight into the range of perspectives from which agrammatism was tackled. Some of these have been fruitful and continue to be explored, for example analysis of the prosodic features of spoken sentences. Other approaches proved less promising and have mostly been abandoned, for example the attempt to find a reverse relationship between losses in agrammatism and the acquisition order of structures in child language learning (the regression theory).

To summarise recent work; a number of studies have observed co-occurring deficits suggesting parallelism⁵ between syntactic disorders of production and comprehension (Zurif, Caramazza and Myerson, 1972; Saffran, Schwartz and Marin, 1980b; Schwartz, Saffran and Marin, 1980). These findings led to the assumption that both expressive and receptive syntax processing were mediated by a common cognitive subsystem, although proponents of this view differed as to whether the impaired function was syntactic⁶ (Zurif and Caramazza 1976; Berndt and Caramazza, 1980), phonological⁷ (Kean 1977; 1979) or lexical⁸ (Bradley, Garrett and Zurif, 1980). However, counter-evidence to the unitary theory of agrammatism was given by studies showing that agrammatic comprehension also occurs in subjects without agrammatism of speech (Caramazza and Zurif, 1976; Heilman and Scholes, 1976), and others demonstrating dissociation between expressive and receptive agrammatism (Kolk, Van Grunsven and Keyser, 1985; Miceli, Mazzucchi, Menn and Goodglass, 1983). Recent work seems to suggest that the notion of a single central syntax processing mechanism is untenable (Berndt, 1987; Caramazza and Hillis, 1989). Berndt (1987) examined six aphasic subjects principally with respect to their spoken sentence production but also

⁵ Kolk, Van Grunsven and Keyser (1985) provide a comprehensive overview of research into agrammatic parallelism.

⁶ The syntactic deficit theory is based on evidence including patients' better performance on non-reversible than on reversible sentences, (reversibility is explained over page).

⁷ The phonological theory is based on evidence from prosody rather than pure phonology, i.e. that function words are relatively unstressed in normal English speech.

⁸ The lexical theory postulated an alternative lexical access route for function words.

touching on auditory sentence comprehension. She looked at the co-occurrence and dissociation of four factors; dysfluency, agrammatism and structural simplicity in production and asyntactic comprehension. The patterns exhibited by Berndt's patients were tabulated with earlier results obtained by Kolk et al. (1985) and Miceli et al. (1983) to show dissociations and double dissociations suggestive of separately disruptable syntax handling functions. However, the question is still debatable, there being sufficient evidence of commonality between expressive and receptive agrammatism for Howard (1985) to feel that "The case for parallelism is clearly strong" (Howard, 1985, p.11).

Current theories of agrammatism include a lexical account (Branchereau and Nespoulous, 1989) which posits a selection disorder for specific grammatical morphemes (e.g. prepositions), and a mapping hypothesis (Schwartz, Linebarger and Saffran, 1985; Schwartz, Linebarger, Saffran and Pate, 1987) which proposes an inability to coordinate structural form and semantics in both expressive and receptive modes. Grodzinsky (1986; 1989) has formulated an account based on failure to coindex syntactic traces with their antecedent noun-phrases (NPs) - a characterisation grounded in the government and binding theory of Chomsky (1980; 1981), and Linebarger, Schwartz and Saffran (1983) have proposed impaired short-term memory (STM) as a primary cause of sentence processing breakdown. Some of the evidence is explored more fully below.

Utilising agrammatics' known reliance on contextual cues to disambiguate sentences, several studies have employed the technique of presenting reversible sentences to investigate the assignment of thematic roles (Byng and Coltheart, 1986; Jones, 1986). Reversible sentences are designed by a careful choice of vocabulary such that subjects and objects, (or agents and themes) can be interchanged with equal plausibility, (e.g. *The cow chased the dog / The dog chased the cow. The bridge is behind the house / The house is behind the bridge.*). This ensures that the meaning is not derivable by a lexico-pragmatic route, as it would be in a sentence like *The horse eats the carrot*. Further evidence of semantic dependency in aphasia, apart from animacy/inanimacy of content words and relative plausibility of interpretation, arises from a large number of studies which have reported a marked difference in the abilities of aphasics to recall and comprehend abstract content words, compared with more highly imageable, concrete ones (Myerson and Goodglass, 1972).

In an influential study, Caramazza and Zurif (1976) found that on picture-matching tasks where the correct interpretation was evident from the semantics, (e.g. *The apple that the boy is eating is red*), Broca's aphasics scored around 90%, but that performance fell to chance for both reversible sentences and those describing improbable events.⁹ However, Schwartz et al. (1980) point out that Caramazza and Zurif failed to include reversible sentences using canonical¹⁰ word order, thereby failing to test whether their patients could use simple word order significance rules. Further criticisms, both in the experimental method and in the uncritical adoption of their conclusions by others, were recently published by Grodzinsky and Marek (1988). Nevertheless, Caplan and Hildebrandt (1988, p.59), identify two important questions arising from Caramazza and Zurif's study, a) "What are the exact natures of the linguistic structures that aphasics can interpret and those they cannot?", and b) "Is a disturbance of syntactic comprehension secondary to some other aphasic impairment?".

Schwartz et al. (1980) investigated the aural comprehension of five Broca's aphasics using simple active declarative sentences, passive sentences and locative prepositional sentences, all in reversible form, in a series of picture-matching experiments. In the first trial, patients were found to be poorer at passives (no patients assigning thematic roles at better than chance level) than at actives (2 patients operating at better than chance level). Only one patient BL, showed any consistent tendency to apply the active subject-verb-object (S-V-O) mapping to passive sentences. The locative prepositional sentences were introduced to eliminate possible lexical variability (the nouns used, *square* and *circle* being pre-tested for recognition). This idea was later extended to verb sentences, where the authors created stick characters called *circle* and *square*, with heads of the appropriate shape, for use as protagonists. Noun-prep-noun (N-P-N) and noun-verb-noun (N-V-N) constructions were considered equivalent in this work. Patients were then compared in their ability to handle active verb sentences versus locatives. Schwartz and colleagues concluded that,

... these agrammatic subjects have a syntactic mapping defect such that they are unable to utilize a fixed and principled set of procedures to recover the relational structure of spoken sentences. Furthermore, since this deficit emerges even with simple active declarative sentences manifesting the canonical S-V-O structure of

⁹ The syntax processing performance of normal subjects does not degrade with reversibility or improbability (Forster and Olbrei, 1973).

¹⁰ Canonical word order is the basic or regular word order for a particular language, thus English is deemed to be a subject-verb-object language.

English, it can not be explained by reference to phonological structure.¹¹ (Schwartz et al., 1980, p.261).

Interestingly, in this third experiment, while BL performed at chance level on simple active declarative structures, auditorily presented prepositional sentences elicited the reverse role distractor on 21 out of 24 occasions. The authors reported that during the trial BL vocalised repeatedly the target sentence minus the initial noun-phrase (e.g. "is in the circle, is in the circle"). They observed that he appeared "to have adopted a strategy which maps the post-verbal NP into the role of subject of the sentence." (p.261) This observation certainly describes the results of his behaviour, but adds no insight into the underlying cognitive processes. One cannot tell whether the vocalisations were an attempt to refresh STM, or were particular to the prepositional sentences and indicative of an effortful working out of the spatial relationship between the objects. As only two distractors were offered, the target and the reverse, one cannot tell whether BL had remembered the initial noun or not. Schwartz et al. (1980) present BL as an especially unreliable performer who "adopts a limited set of heuristics which he applies in an inconsistent fashion from session to session." (p.261) This seems a harsh dismissal in view of the striking consistency of BL's preposition performance. BL's data prompted me to wonder whether successful processing of N-V-N and N-P-N structures might be dissociable.

A companion paper by the same authors (Saffran et al., 1980b) reported further investigations, this time of expressive agrammatism, using the same subjects. Speech output to target pictures proved hard to interpret because of its agrammatic nature. For example, the researchers could not be sure whether "*The wagon is pull the boy*" where *The boy pulls the wagon* was expected, was an attempt at a passive construction (and therefore correct), or an active sentence with agent and theme reversed. For this reason, the authors developed a second experiment where confronted with a target picture, the patients had to arrange three lexical cards to produce a sentence of the form N-V-N or N-P-N. The authors' main concern was to explore the question of whether animacy/inanimacy (A/I) contrasts, between subject and object, influenced error patterns. In this experiment, performance on the two sentence types was not distinguished in their analysis, so, for instance, the I/I condition only occurred in locatives and the A/A only in simple active declaratives. However, I noticed in this study too, that BL had a unique performance pattern. He made no errors in constructing 12 verb

¹¹ This refers to the prosodic theory of Kean (1977; 1979) mentioned earlier.

sentences, but operated overall at chance on a similar number of locatives (4 errors in the I/I condition and 2 in the A/I condition). In the subsequent verb processing experiment, BL, who had previously been reported inconsistent, achieved the highest score, 22 (n=24). The group data for Experiments 2 and 3 showed a marked difference in the combined performance of the five subjects between the two sentence types, (verbs and prepositions), for the I/I contrast: prepositions, total errors 11 (n=30); verbs, total errors 4 (n=30).

These observations added weight to my previous conjecture that verbs and prepositions might merit separate investigation. The large number of reversals in the locative I/I condition is interesting, particularly as Saffran et al. (1980b) reported frequent anomalous arrangements such as "The sink is in the pencil". Surprisingly, in these cases the tendency to reverse NPs had overridden obvious lexico-pragmatic cues. The authors' tentative speculations as to cause, cited below, found strong support in the behaviours of some of my own subjects discussed in Chapter 6.

The patients' behavior might possibly reflect other saliencies, such as a tendency to describe an array from top to bottom (Clark, 1974), or to begin a sentence with the NP that designates the larger of the two objects. This question will be left for future consideration. (Saffran et al., 1980b, p.273).

On the basis of their production data Saffran et al. (1980b) reached a "more radical hypothesis" than Schwartz et al. (1980) had done,

... agrammatic speech is generated without underlying structures that represent logical relations. We assume that the agrammatic speaker is capable of representing the to-be-verbalised relations in some cognitive form. What he lacks are mediating linguistic structures that correspond to the arguments of the relation: both very abstract ones like subject/predicate, and even semantic categories, like agent/patient." (Saffran et al., 1980b, p.278).

Both sets of data were re-analysed by Caplan (1983), who rejected the authors' explanation, arguing that the patients' performances could be accounted for in full by a simple and additive set of rules, (e.g. "1. Assume the patient is producing sentences in the active voice. 2. Assume that the patient tends to put animate nouns before the verb." (p.156)). By Caplan's account it was perfectly possible for patients to be in possession of the syntactic concepts denied them by Schwartz

and colleagues. As he saw it, the problem lay in their invocation of incorrect procedures. Caplan's interpretation finds a great deal of support from my own clinical observations which are discussed in Chapter 6.

The studies of Schwartz and colleagues played a catalytic role in the study of receptive agrammatism motivating many subsequent enquiries, including this one. A notable follow-up experiment was that of Kolk and van Grunsven (1985) who replicated the protocol of Schwartz et al. (1980) with minor modifications and with eleven patients. They also carried out sentence construction tasks, comparing Dutch sentences requiring S-V-O, S-O-V and V-S-O orderings. Kolk and van Grunsven obtained qualitatively similar results to Schwartz et al. but their patients proved to be less impaired. On the sentence construction tasks they found no significant difference between performance on V-S-O and S-O-V tasks overall, however, there were two sentence types tested for each of these orderings and these did differ significantly in the number of errors elicited. Kolk and van Grunsven found that patients were much more accurate if the cue to verb position was present within the clause to be ordered, rather than outside it. These authors attributed variation between subjects and between sentence types to temporal and memory limitations. They included an interesting section on the importance of adaptation strategies, pointing out that compensation can actually *produce* symptoms which are not a necessary or direct result of the brain damage.

Many studies following that of Schwartz et al. (1980) have added to the evidence that agrammatic subjects perform better when word order is consonant with thematic roles than when the object precedes the subject in position. For example, Ansell and Flowers (1982) found that aphasics made significantly fewer errors with reversible cleft-object sentences - *It was the woman that shot the man*, than with, *It was the woman that the man shot*'. Deloche and Seron (1981) found an interesting visual correlate among alleged Wernicke's aphasics, who were reported as having developed a strategy of matching sentence elements and picture elements in a simple left to right fashion. (This strategy was also observed in the present study, see section 6.1.2). Confirmation that plausibility of target sentences and sensibility of visual distractors influences aphasic performance was offered by Deloche and Seron (1981) and Kudo (1984) who studied French and Japanese subjects respectively. A number of studies (Heeschen, 1980; Lesser, 1974; Parisi and Pizzamiglio, 1970; Schwartz et al., 1980) have shown that aphasics are not always consistent in applying a word order strategy to the assignment of thematic roles, e.g. passives are not always wrongly treated. Jones

(1982) investigated the extent to which the decoding of meaning in sentences is bound to the semantic role of the verb. Subjects were tested with simple S-V-O sentences and it was found that the ability to use word order cues depended on the relationship between subject and object as signalled by the verb. Reversible sentences without motion verbs (e.g. *The vicar shoots the doctor*), were correctly identified in a picture matching test at a rate of 79% and sentences containing a non-directional motion verb (e.g. *The tramp kicks the airman*) were correct in 70% of cases, but sentences using directional verbs (e.g. *The miner passes the butler*) were only correct at a chance rate of 45%.

Zurif, Caramazza and Myerson (1972) discovered that agrammatic subjects fail to make appropriate judgements concerning the relatedness of words in sentences - thus being unable to derive the hierarchical structure perceived by normal subjects.¹² In particular, they observed a neglect of function words (as in agrammatic speech, a parallelism which was also reported by Kolk, Van Grunsven and Keyser, 1985). Further evidence of difficulty with function words was supplied by Heilman and Scholes (1976) who reported confusion resulting from the position of the article being altered, as in *He showed her bird the seed* and *He showed her the bird seed*. Commenting on the latter study, Caplan (1985) suggested that only the phrasal categories change, not the lexical categories, as a result of moving the definite article. "If the agrammatic is limited to the use of lexical category node information for semantic interpretation, these structural distinctions will not lead to differing interpretations." (Caplan, 1985, p.144).

Evidence is very mixed concerning the consistency of function word neglect and the reasons why it might happen. We have mentioned the prevalent theory that function words are neglected in agrammatic speech and auditory comprehension because they are unstressed in normal English prosody. Several studies were suggestive of within-sentence position (and thus perhaps stress) being a factor in function word omission in expressive agrammatics (Goodglass, Fodor and Schulhoff, 1967; Gleason, Goodglass, Green, Ackerman, and Hyde, 1975; Wales and Kinsella, 1981). Swinney, Zurif and Cutler (1980) found that in listening to orally presented sentences Broca's aphasics responded to a target content word by correctly pressing a button on detection in 93% of cases, whereas, when a function word was the target, performance declined to 33%. However, Bradley,

¹² A corresponding structural deficit is apparent in agrammatic speech, which is not correctable merely by the insertion, or correction, of function words and morphological inflections (Howard, 1985).

Garrett and Zurif (1980) observed that Broca's aphasics could recognise function words as known words, when these were presented singly in a word/non-word task. Curiously, Jones (1982) discovered that the verb processing problems outlined above, could be all but eliminated if reversible sentences including a verb of motion were expanded by the inclusion of a redundant preposition (function word)! Thus, *The policeman follows the fireman* became *The policeman follows behind the fireman*. Howard (1985) commented that the reason for this could have been that only the head of the sentence, *The policeman follows behind* was being processed, *behind* in this case being an adverb, not a preposition. From the foregoing evidence it appears that although function words are unquestionably a problematic category for both types of agrammatic patients, residual recognition capacities can be observed in subjects who are otherwise unable to generate/understand function words normally.

To investigate the processing of sentence structure, Caplan, Baker and Dehaut (1985) conducted three studies, testing large numbers of aphasic patients (56, 37 and 49) with nine sentence types, as follows:

| | |
|------------------------------|---|
| Active (A) | The elephant hit the monkey. |
| Passive (P) | The elephant was hit by the monkey. |
| Cleft subject (CS) | It was the elephant that hit the monkey. |
| Cleft object (CO) | It was the elephant that the monkey hit. |
| Dative (D) | The elephant gave the monkey to the rabbit. |
| Dative passive (DP) | The elephant was given to the monkey by the rabbit. |
| Conjoined (C) | The elephant hit the monkey and hugged the rabbit. |
| Subject-object relative (SO) | The elephant that the monkey hit hugged the rabbit. |
| Object-subject relative (OS) | The elephant hit the monkey that hugged the rabbit. |

The subjects were required to demonstrate the thematic roles by acting out the sentences with toy animals. A high degree of similarity was found between the performance of the three groups. The most marked finding (which supports data reported above on word order significance) was that sentences with canonical word order (A, CS, D, C and OS) were consistently found easier than their non-canonical counterparts (P, CO, DP, SO). Verb argument structure also affected performance (D being harder than A, and DP harder than P), and sentences with two verbs were harder than those with one. Sentence length was not, of itself, a determinant of complexity; the salient features appeared to be non-canonical word order, a three-argument verb or a second verb.

According to Caplan (1987a), the largest body of experience with a sentence comprehension battery derives from use of the Milan Token Test (de Renzi and Vignolo, 1962). The particular linguistic approach taken in the Token Test highlighted two potential sentence processing problems which may or may not be independent. The first was the effect of sentence length on point of failure, which could be ascribed to a limitation of STM (Lesser 1976). The second was the handling of modification, particularly when more than one adjective qualified a noun. The relative difficulty of modifiers was reported by Gleason et al. (1975), who tested Broca's aphasics with fourteen syntactic constructions and found the sequence *adj + adj + noun* to be the second hardest (*verb + indirect object + direct object*, as in *give friend dollar* was also found to be difficult pattern). These findings are suggestive of sentence construction and interpretation problems that cannot be explained by an account of agrammatism which only admits loss of function words and affixes. Concerning the involvement of STM in sentence processing, Caplan and Hildebrandt (1988), after a review of studies implicating STM, considered all the evidence to be compatible with a breakdown at the post-interpretive stage, that is during adjudication between interpretations derived syntactically (after a full parse), and lexico-pragmatically. The nature and role STM is discussed in section 2.6.1.

With respect to morphological inflections, tests of sentence comprehension have generated less data than tests of speech production. In a study of sentence completion, Goodglass and Berko (1960) found that patients were more likely to omit the possessive 's in its non-syllabic form (e.g. *dog's*), than in syllabic cases (e.g. *horse's*). This did not seem to be a phonological effect, because the morpheme /-iz/ in the plural form *watches* (timepieces), was more likely to be correctly produced than the third person singular form *watches* (looks), and that in turn, proved easier than the possessive form *watch's* (of the watch). These and related findings are discussed in Morton (1977). Morton attributed the following tentative summary to Jakobson (1964),

.. noun inflections (plural and possessive) are more likely to be expressed than verb inflections (past tense and third person agreement). There is also an effect due to level in the syntactic hierarchy; thus plural and past tense markings (i.e. agreement at the word level) are easier than possessive and third person markings (i.e. agreement at the phrase and sentence levels, respectively). (Morton, 1977, p.137).

De Villiers (1974) analysed spontaneous speech samples from eight non-fluent aphasics and found consistency in the morphemes produced/omitted. Average scores of 98% were achieved for plurals and -ing forms, but only 74% for articles, 66% for irregular past tenses and 65% for third persons singular. These results suggest that a corresponding ordering of difficulty may be discoverable in receptive mode. There have been a number of documented observations, including transcripts, showing that agrammatic output is characterised by greatly reduced frequency of bound grammatical morphemes and free-standing function words (articles, pronouns, prepositions, copula, modal auxiliaries, etc.). The phonological hypothesis, that agrammatics fail to produce those words or morphemes that are unstressed in English, fails to account for omissions in the latter category; these words often occur in stressed positions. It also fails to account for an important converse finding; that agrammatics do not have difficulty with the unstressed syllables of content words or with content words in unstressed positions.

In addition to such errors of omission (and sometimes of substitution), agrammatic speech is often structurally simplified, seldom yielding complete simple sentences and almost never realising grammatical sentences including embedded clauses (Byng and Black, 1989; Caramazza and Hillis, 1989; Saffran et al., 1980b). Since such speech samples are necessarily incomplete in form, and often ambiguous, it is very difficult to ascertain whether word order violations have occurred, or whether the strange utterances result from attempts to repair/circumvent the omission errors (Caramazza and Hillis, 1989). For the same reasons, Saffran et al. (1980b) found it difficult to be sure when role reversal errors had been made in their picture-to-speech experiment mentioned earlier. However, from subsequent experiments reported in their paper, it was apparent that these errors did occur in the constrained situation that patients had to construct sentences, from cards containing written sentence components, to describe target pictures.¹³ In contrast, Byng and Black (1989) reported a striking absence of reversal errors on testing spontaneous speech via the telling of a fairy tale. It seems from this evidence, that the reversal errors found in agrammatic comprehension (through reading-to-picture-matching) can be elicited in expression where the subjects are striving to satisfy a grammatical template, but are unusual in free spontaneous speech.

¹³ A similar device is used in the new computer-based remediation software described in Chapter 3.

The study of Saffran, Berndt and Schwartz (1989) was similar to that of Byng and Black (1989) in looking at spontaneous speech via fairy tale narration. However, apart from studying agrammatics, they analysed the speech of a group of non-agrammatic aphasics. Morphological deficits were rare in the latter group, but structural impairments were evident. Interestingly, the authors noted that there was some overlap between the two patient groups on almost all their production indices, including the morphological ones. This led them to wonder whether agrammatism affects all non-fluent patients at least to some degree. They conjectured as follows about possible causes,

One possibility is that these patients are impaired in syntactic operations *per se*. Alternatively, the source of the difficulty could lie elsewhere, in deficits of a conceptual nature that limit the complexity of the message ultimately expressed in sentence form, or in lexical or phonological limitations that affect the choice of syntactic structures. The latter possibility is a plausible one, in view of recent demonstrations that the structures generated by normal speakers are affected by such factors as ease of lexical retrieval and biases towards certain prosodic forms (Bock 1982; 1987a). (Saffran, Berndt and Schwartz, 1989, p.467).

This study alerted me to the likelihood that corresponding receptive deficits might also prove to be widespread in aphasia, and that subject selection should not be confined to the traditional agrammatic population.

Though the total number of studies conducted has not been great (and few of these have examined written sentence comprehension), methodologies have been varied, and evidence has raised more questions than it has answered, still, a nucleus of data has been amassed which suggests a core of linguistic symptoms common in agrammatism. These may be summarised as follows:

- a) Inability to derive an accurate surface syntactic structure for a sentence, and/or inability to map this on to the semantic components of the sentence.
- b) Inability to derive correct meaning without semantic cues such as plausibility, animacy, etc.
- c) Tendency to rely on word order for assignment of thematic roles (demonstrated by difficulty with all non-canonical forms).

- d) Poorer grasp of function words than of content words, which may be a manifestation of the general problem with abstract rather than concrete words.
- e) Particular difficulty with processing verbs (performance degrades both with increase of verbal arguments and with number of verbs in sentence).
- f) Problems with some morphological inflections, particularly non-syllabic ones, articles, irregular pasts and third persons singular.

It is clear from the foregoing review that there are many different types and gradations of syntactic disorder. However, it is equally apparent that an enormous amount remains to be done in identifying these deficits comprehensively, in exploring the associations and dissociations between them, and in designing and testing therapy. Caplan (1987a) having noted the emphasis on investigating thematic role assignment, summarised the current state of knowledge as follows:

When we consider that syntactic structures constrain and determine the assignment of other sentential semantic functions as well - co-reference, scope of quantification, assignment of modification - and that we have not even considered patients who do not understand semantically constrained sentences despite good single word comprehension, we gain some appreciation of the magnitude of the task that lies ahead of us as we search for the entire set of primary and secondary disturbances of sentence comprehension. (Caplan, 1987a, p.326).

The reported neglect of semantic difficulties in subjects with good single-word understanding is surprising, as the establishment of intact single-word comprehension is an obvious prerequisite for identifying disorders of syntax processing.

Treatment studies addressing receptive agrammatism and satisfying the methodological requirements outlined in section 1.2 above and amplified in section 1.2.4 below, are virtually non-existent. An exception is the study of Byng (1988) which applied cognitive neuropsychological principles and the mapping deficit hypothesis of Schwartz, Linebarger and Saffran (1985) to the investigation of expressive and receptive verb and preposition processing problems in two single cases. Byng's patients BRB and JG were six years and four and a half years post-onset respectively. Following a short amount of therapy on written locative sentences (cleverly devised so that the patient could self-administer at home),

BRB performed flawlessly in auditory and written modes. His improvements generalised to reversible active declarative sentences in both modalities (though these were not seriously impaired to start with), to Byng's own verb video test (which tests mapping without parsing by using video film sequences of verb pairs such as *buy/sell*), and to spontaneous speech. STM capacity was found to be static, as was performance on a range of single-word tasks. One of these was subsequently treated and improved in isolation, refuting any suggestion of spontaneous remission related to the previously targeted treatment. The benefits reported were thus attributable to the intervention and strongly supportive of the notion of a general mapping deficit underlying all tasks.

From Byng's point of view, JG's results were less satisfactory, but in the context of the present study, they were even more interesting. I cannot do justice to the detail Byng presents here, but the salient points are that JG, a more impaired patient, failed to respond to therapy for written locatives, this despite a different approach sensitive to his needs, extending over six weeks. He was then treated on simple active declarative structures and showed improvement on these, on the verb video test, but not on prepositions. This is obviously a difficult result to explain, however, Byng does speculate in terms which are tantalising considering my previous comments on Schwartz, Saffran and Marin's patient BL,

A fourth possibility is that there is a general mapping mechanism, but that locative sentences present some extra difficulty in processing because of the nature of the predicate, which really comprises a predicate within a predicate. Thus it may be that it is the added demand of processing a more complex predicate that prevents JG from comprehending the reversible locative sentences. (Byng, 1988, pp. 666-667).

This section concludes by drawing together some of the questions, omissions, ideas and techniques in the literature of agrammatism which have lent direction to the present study. Firstly, a number of limitations have been observed. There is an imbalance in the literature between studies of receptive and expressive agrammatism in favour of the latter. Although a set of common linguistic symptoms has been identified, there has been no systematic effort made to find out how these associate and dissociate in disorders of written sentence comprehension. While some work has been done on thematic role assignment in sentence understanding, very little has been done to investigate other possible deficits and there is no existing assessment of written sentence comprehension

which would aid such an investigation. On the positive side, sufficient research has been done to identify the processing of verbs and prepositions as worthy of further attention. The investigative technique of reversible sentences with accompanying candidate pictures is a well established and potentially very powerful method (subject to reservations discussed in Chapter 2). In spite of this there is a lack of published data giving details of assessment contents and analyses of error patterns using this method. There is also a paucity of treatment studies directed at agrammatism, although Byng's work gives hope that some patients may respond to therapy for sentence processing deficits several years post-onset.

In framing the present study and developing the computer-based tools to be described later, the following key influences can be identified: *Schwartz, Saffran and Marin*, whose use of stick characters to eliminate contextual cues in reversible scenarios inspired the computerised microworld, and whose patient BL first aroused my suspicion that verb and preposition processing might be dissociable; *Byng*, who provided a model of investigative procedure, cause for optimism about the outcome of treatment and the interesting case of JG (which again raised the question about whether N-V-N and N-P-N structures could be considered equivalent), and *Caplan, Baker and Dehaut* (see also Caplan and Hildebrandt, 1988), who supplied a very important component, namely the rationale for varying sentence complexity in verb sentences. *Caplan's* remarks (1987a), quoted above, gave shape to the modular Syntax Screening Test, (described in section 2.5), which incorporates, along with verbs and prepositions, the functions he highlighted as neglected. Much of the morphological evidence cited found its way not only into the Syntax Screening Test, but into a fuller Morphology Test, (described in section 3.2.3), against which the specificity of the verb and preposition treatments were measured.

1.2.2 MICROCOMPUTERS IN APHASIOLOGY

Considering that it is almost 25 years since Pizzamiglio and Roberts (1967) reported their use of a teletype machine (paper-tape controlled) to train written sentence completion and picture-naming tasks, a review of progress in the clinical application of computer technology to date is a disappointing exercise. Despite the incredible rate of advance in the power, reliability and portability of computer hardware during the intervening quarter century, and the fact that cost has plummeted in inverse ratio, computer provision and usage in clinical settings has remained in a comparatively primitive state. In the United Kingdom, part of the reason for this is undoubtedly limited paramedical resourcing; however, the situation cannot be expected to improve unless methodologically sound studies demonstrate that there are clear therapeutic and/or economic benefits to be gained.

In section 1.2 above it was noted that speech therapy techniques suffer from a lack of systematic efficacy evaluation and this also applies to the use of the microcomputer as an investigative and therapeutic tool. As computers offer unprecedented facilities to researchers it is surprising that they seem to have had little impact on furthering the mainstream debates. Research to evaluate the potential of microcomputers in the rehabilitative process, which of course the machines themselves can aid, is remarkably underdeveloped. The following survey of previous applications addresses itself to the use of computers in the treatment of language disorders. It is not concerned with computerised clinic management or the use of computers off-line to analyse results which have been obtained by traditional methods. In this connection, the appearance of a recent, review of computerised cognitive rehabilitation (Robertson, 1990) was both timely and reassuring. I had come to similar conclusions vis a vis the range and quality of published work in the language field, but wondered whether criticism from a computer specialist towards pioneers was perhaps inappropriate. Robertson dispelled these doubts and provided a useful digest to which frequent reference is made below.

There is a fundamental distinction to be drawn between the use of microprocessor-based prostheses to circumvent or to facilitate damaged language functions, and the use of microcomputers in a treatment role, where the ultimate

aim is to effect cognitive change. In the main, prosthetic devices are not of interest here. An exception, for a variety of reasons, is the work of Steele, Weinrich, Wertz, Kleczewska and Carlson (1989; also reported in Weinrich et al., 1989a; Weinrich et al., 1989b). This work had its origins in the teaching of symbolic languages to chimpanzees (Gardner and Gardner, 1969; Premack, 1971) and the extension of the approach to aphasic subjects (Gardner et al., 1976). The 1989 publications reported the computerisation, with enhancements, of the previous card-based system, to produce a limited iconic language as an alternative communicative medium. This computerised visual communication system (C-VIC) is of interest because the authors reported considerable success in training their subjects to use a sophisticated mouse-driven interface, and because they were concerned to build on residual language processing skills which they noted are often overlooked in traditional assessments:

A critical issue in the rehabilitation of the aphasic patient is the extent to which "the grammar of his thinking" (Critchley, 1970) is disturbed. Head (1926) agreed with Jackson's (1915) belief that "the speechless patient...cannot propositionize in any fashion." This contention has been difficult to refute because performance on traditional tests of cognitive function by severely global aphasics is difficult to interpret. (Weinrich et al., 1989a, p.401).

In spite of subjecting the patients to very long periods of training, ranging from tens to hundreds of hours, rather disappointing results emerged from this long-term study. Patients did not generalise well within the miniature language and the team reported that, "Use of the system has not affected subjects' natural abilities, which remain as impaired in all modalities as they were prior to training." (Steele, Weinrich, Wertz, Kleczewska, and Carson, 1989, p.423). It is of interest that verbs and prepositions were prominent among the word categories taught and tested. The reports singled out verbs as the most difficult linguistic concept to teach, and suggested that computer animation of these might be helpful in distinguishing verb icons from noun icons.

Turning to the use of computers in language rehabilitation, the landscape is bleak for two reasons; the first is the highly unimaginative nature of most of the applications reported, and the second is that almost all the associated publications have been anecdotal in nature, offering no sustainable case for the benefits or otherwise of the intervention. Robertson (1990) rightly pointed out that the majority of publications in this area are in unrefereed sources, many of which are

half magazine, half journal in nature, the formats of which preclude adequate analyses. Most of the applications seem to be entrenched in the drill and practice mould, whereby a small number of domain-specific (generally single-word) tasks are repeated with the computer as presentation medium. Simple A-B designs are common. Typical of these were the picture-matching and confrontation-naming programs of Katz and colleagues (Katz and Nagy, 1984; Katz and Nagy, 1985; Katz, Wertz, Davidoff, Shubitowski, and Devitt, 1989). For example, the latter study required the patient to type the names of animals depicted on the screen. Ten animal names were treated. The nine aphasic subjects did show some improvement, but only in the domain and modality treated. The 1985 study involved five aphasic subjects in a computerised word-picture matching task. Twelve items were treated, but as Robertson (1990) noted, the same items were tested pre- and post-therapy, so generalisation was not explored. In both these studies and others of the same ilk, there seemed very little rationale for computerisation. Moreover, no attempt was made either to provide a theoretical basis for the work, or to demonstrate benefits over traditional methods.

A series of typing to dictation studies, Deloche, Seron, Saillant, Moulard and Chassin (1976), Deloche, Seron, Rousselle, Moulard and Seron (1978) and Seron, Deloche, Moulard and Rousselle (1980), all using the same basic method, sought to detect generalisation effects to untreated words in handwriting to dictation mode. The therapist provided the spoken stimulus and the computer provided interactive feedback during the typing exercises by means of highlighting the position of the next letter to be typed and indicating correctness or otherwise of letters. All three studies reported benefits (which in the most recent study were across three measures of performance and maintained in four out of five patients six weeks after cessation of treatment), however, in none of the cases can improvement be unequivocally attributed to the treatment since a simple A-B design was used. The problem with simple before-after designs is that they do not,

..control for non-specific therapeutic effects, effects of repeat testing, spontaneous remission or similar threats to external validity. ...Hence many of the presumed training effects reported in the less rigorous literature may simply reflect the practice effects of tests administered by pleasant and supportive psychologists. (Robertson, 1990, p.383).

Another single-word cueing application was the study of Bruce and Howard (1987). They selected five subjects who had naming difficulties, but who knew the first letters of the words they sought and could respond to phonemic cues from a clinician. The subjects were trained on an Apple IIe computer with voice synthesiser. Fifty line drawings were presented and the patients, by depressing the key corresponding to the first letter of the object, could activate the appropriate synthesised phoneme. The ensuing study looked at performance over 50 treated and 50 untreated words, both with and without computer-cueing. Performance benefited from cueing and the effects of the treated/untreated condition was not significant, showing that some generalisation had taken place. The authors reported that one patient managed to internalise the cueing strategy, thus overcoming dependence on the prosthesis.

There have been some attempts to distinguish the performance effects of varying delivery and feedback mechanisms. In a study by Katz, Wertz, Lewis, Esparza and Goldojarb (1990), 22 aphasic subjects were randomly allocated to a computerised reading program, a computer stimulation program of the arcade game type, or to a no-treatment group. The two treatment groups received three hours exposure per week for 13 weeks. Robertson (1990) asserted that conclusions were drawn from the raw data without statistical analysis. He also argued that Katz et al.'s claim that improvement on the computerised reading led to improvement in conventional reading, and that the benefit was attributable to the language content of the treatment software, was simply not supported by the data,

That the computer-reading and the computer-stimulation groups showed equivalent (and tiny) changes with respect to the no treatment group leads to precisely the opposite conclusion ... i.e. the observed effects are non-specific placebo effects, if indeed they are anything more than random fluctuations in the data. (Robertson, 1990, p.386).

Two studies by Loverso and colleagues (Loverso, Prescott, Selinger, Wheeler and Smith, 1985; Loverso, Prescott and Selinger, 1988), based on earlier work on the elicitation of verbs (Loverso, Selinger and Prescott, 1979), set out to compare alternative treatment deliveries in bringing patients to predetermined criteria levels. In the earlier study Loverso et al. (1985) found that 67 computer sessions were needed, compared with 36 therapist sessions, to achieve the required levels of performance on six tasks, and a comparable improvement on the Porch Index of Communicative Ability (Porch, 1971). The 1988 study reported on 20 aphasic

subjects. The conclusions were that the unsupervised computer sessions were not as effective as the computer-assisted therapist sessions, and that the benefit of a clinician was apparent in both fluent and non-fluent subjects in the moderate to marked ranges of severity.

Kinsey (1990) conducted a study to compare the effects of delivery and feedback mechanisms on patient performance. Twelve aphasic patients were subjected to three experimental treatment environments; conventional, computer delivery and feedback, and computer delivery with conventional feedback. The stimuli were a series of multiple-choice linguistic and non-linguistic tasks. In the conventional situation the therapist administered the tests manually using score sheets and stop watch. However, conventional feedback must have been very difficult to administer spontaneously, as a complicated protocol was laid down based on percentages of positive, intrinsic, nonverbal, no response, inappropriate, etc. feedbacks, derived from clinical interaction data. Computer delivery and data recording was entirely automatic. Computer feedback comprised a high pitched sound with textual reinforcer for correct responses, and a low pitched sound with continued display of the task for incorrect responses. The results were analysed using analysis of variance and post-hoc tests. Nothing significant emerged in the non-linguistic tasks, which caused no difficulty for the group in any environment. However, Kinsey discovered that feedback type, rather than delivery type, was the salient factor in improving performance on linguistic tasks, the computer feedback being the better form. That the consistent computer feedback proved superior seems hardly surprising, given the constitution of the therapist-delivered variety. Unfortunately the study was weakened by using the same subjects to experience the different test conditions, conferring consequent opportunities for undesirable interference effects. Kinsey, to her credit, did acknowledge this.

Precisely because Kinsey attempted a more rigorous approach to her analysis than has been common in this field, the futility of the trends we have followed seems epitomised here. It seems a sorry state of affairs that a publication should appear in 1990, utilising first generation software (in the educational sense), to compare feedback mechanisms in an experiment where the manual version of the task was unsuitable for a clinician to administer, and the hybrid delivery/feedback option was nothing but a confusion. One can see why the experiment was set up as it was, but the contrasts examined were simply not worth the time and care expended.

In 1987, the clinical forum section of the journal *Aphasiology* (vol 1/2), was given over to a leading article by Katz (1987) on the efficacy of aphasia treatment using microcomputers, and to several responses. The primitive nature of the developments documented, and the light in which they were regarded, is clear from the tone and content of Katz's overview. 'Drill and practice' was the dominant paradigm and the major benefits of computers appeared to be in the increased amount of drill that patients could be given. The quality of observations arising from studies is exemplified by Katz's comments on his own work with Nagy (Katz and Nagy, 1983),

This study demonstrated that the computer can continually modify elements within a task with a high degree of precision. ... Computerised treatment could become more effective if programs were developed that could provide linguistically relevant cues when performance indicated the need. (Katz, 1987, p.144).

The responding papers raised a number of key issues. On methodology, Loverso (1987) pointed out that experimental designs used so far had failed to be able to demonstrate efficacy, and that software had not progressed beyond drill level. Wolfe (1987) complained that software developers failed to incorporate models of rehabilitation in their designs and Seron (1987) was concerned that software embodied only the transference of techniques that could equally well be applied by a clinician.

I am not very impressed by the studies Katz presents that compare clinical versus microcomputer efficacy in similar exercises. I believe we should first develop programs that are beyond the capacities of the clinician and thus not comparable with current practice. (Seron, 1987, p.162).

This statement encapsulates the fundamental problem with the therapeutic use of microcomputers to date. In the same collection, Enderby's (1987) reply stressed the neglect of the computer's role in assessment, pointing out the potential for increasing accuracy, greatly assisting data analysis and decreasing inter-observer error. She also made the important point that computerisation could erode the artificial separation of assessment and treatment by permitting monitoring during treatment.

At the end of his paper Katz looked forward to hardware and software developments that might benefit aphasiology, claiming, "By utilizing artificial

intelligence functions, treatment programs can make decisions about whether or not an intervention is needed, and if so, what cue should be selected." (Katz, 1987, p.148). One suspects Katz of underestimating Artificial Intelligence (AI) by misapplying the term *intelligent* to the most trivial computerised decision-making (as the title of Katz and Nagy (1984) suggests: *An intelligent computer-based spelling task for chronic aphasic patients.*). However, his naive approach was challenged by Seron who was adamant that in the current state of knowledge there was no possibility of offering an expert system in neuropsychology. This exchange is of interest in view of the recent appearance in the clinical forum section of the same journal of a leading article by Guyard, Masson and Quiniou (1990), reporting preliminary progress in applying AI techniques clinically. The system is the product of collaboration between linguist-clinicians and AI workers. This study is at the opposite extreme from the computerised exercises reviewed so far. It is ambitious, but to date has failed to deliver other than a few limited modules on nominal gender in French. While the spirit of the investigative processes described is in harmony with my own diagnostico-remediative philosophy outlined in Chapter 3, this study falls into the same trap as many AI projects, where the gulf between the ideal and the realisable proves insurmountable and the technology used is impracticable outside the laboratory. The French team have implemented their system on a SUN workstation using Prolog.¹⁴ The programming language is notoriously greedy with respect to processing overheads and the hardware necessitated is out of step with the most optimistic expectations of clinic provision, (even in France!). The proposal to scale down eventually to an Apple Macintosh seems unrealistic if what they have done so far cannot run in the target environment.

The most serious flaws in this work arise, however, from supposing that one can successfully automate procedures in a field where the domain knowledge is incomplete and ill-understood, and where critical dimensions of the diagnostic process are inaccessible to machines. Impenetrable barriers exist at present, which the authors appear to dismiss with claims such as, "We have based our approach on a theoretical model that explains most aphasic patients' behaviour" (p.611), and

To conclude, an expert system, relying only on the patient's written responses lacks knowledge to interpret the reality of the patient's reasoning. In some cases the therapist must take into account oral

¹⁴ Prolog is a logic programming language based on first order predicate calculus (Bratko, 1990).

comments. However, we think that these cases are rather limited, thus even an incomplete computer program seems interesting and useful. (Guyard et al., 1990, p.605).

This is a further example of what Robertson (1990) observed in the previous generation of software, i.e. that it had, ".. no underpinning theoretical rationale, other than that it was within the programming capacities of the author and within the processing capacities of his or her particular computer." (p.382).

In conclusion of this section, the clinical application of microcomputers has failed to keep pace with technological developments, with theoretical developments (such as models of rehabilitation and of cognitive functioning), and with the methodological requirements of sound experimental design and analysis. It seems that the initial phase of exploratory, anecdotal and promissory articles, to which I had a small input (Crerar and Dean, 1984; Dean, Crerar and Millar, 1987) has not been superseded by studies of greater depth and sophistication. One reason for this is the continuing lack of opportunity for clinicians to collaborate with interested computer professionals. The limited resourcing of paramedical services, to which I alluded above is a factor, but damage has also been done from within. For example Katz's book (1986), while acknowledging its pioneering qualities, perpetuated the myth that programming is child's play, by offering simple pieces of BASIC¹⁵ code for clinicians to use in the modification of programs, or in the building of their own. This attitude resulted in some clinicians panicking at their inadequacy and fearing that computer literacy to programming level was going to be necessary in order to stay at the forefront of patient care. It also inevitably depressed expectations about what computer-assisted therapy could be. It is clearly nonsense that applications should be limited by clinicians' imaginations and programming skills, for in what other professional sphere are the users expected to write their own software? However, in the non-acute, non-profit sector there seems little opportunity for skilled software support, and it is difficult to break out of this impasse.

The activities reviewed reveal a huge area of uncharted territory between the many single-word drill and practice routines, and the equally unsatisfactory embryonic expert system of Guyard et al. The applications have generally been

¹⁵ BASIC (beginners' all-purpose symbolic instruction code) is a rudimentary programming language widely used by computer hobbyists. BASIC is supplied as standard on most microcomputers and is thus the source language for a lot of games software and software for schools.

conceived by clinicians lacking insight into what computers can offer. The tendency has been to automate previous techniques, rather than to design new and different computer-inspired ones. The present study aims to bridge that gap by bringing a fresh perspective to the design of computer-based assessment and remediation materials. The results noted concerning unsupervised computer treatment, combined with the undoubted importance of vocal and gestural output which cannot be captured and interpreted automatically, suggests that the next generation of clinical software should strive for a clinician-computer partnership in which the strengths of each are exploited.

1.2.3 COGNITIVE NEUROPSYCHOLOGY

Throughout the history of Science there have been analogies for Mind in technology - physical models from water tanks, and pipes, of fires in boilers, of magnetic fields, telephone exchanges and now computers. (Gregory, 1981, p.565).

In line with this tradition, the dominant paradigm in cognitive science today is the Information Processing Model, which derives its concepts and terminology from an amalgam of Information Theory, (Shannon and Weaver, 1949), General Systems Theory (Open Systems Group, 1981) and Computer Science. The digital computer offers a qualitative advantage over all previous technologies for modelling brain processes, because of its general purpose nature; like the brain, it is a symbol processor. The vocabulary of Computing pervades Cognitive Neuropsychology, providing concepts such as input, output, hardware, software, interface, procedure, parameter, buffer, serial versus parallel operation, file organisation, access or retrieval mechanism, working store or main memory, on-line versus off-line, knowledge representation, channel capacity, real time processing and many more.

The main aims of Cognitive Neuropsychology may be summarised as two complementary goals:

to explain the patterns of impaired and intact cognitive performance seen in brain-injured patients in terms of damage to one or more components of a theory or model of normal cognitive functioning

and

to draw conclusions about normal, intact cognitive processes from the patterns of impaired and intact capabilities seen in brain-injured patients. (Ellis and Young, 1988, p.4).

In pursuit of these goals, a small number of central tenets have been superimposed on the information processing framework. They may be briefly identified as assumptions of subtractivity, modularity, and transparency, with advocacy of the single-case study approach (Ellis and Young, 1988). The three properties are considered below, leaving questions of research design until section 1.2.4.

The assumption of subtractivity (Saffran 1982) is critical to the viability of the cognitive neuropsychological approach. It holds that the patterns of cognitive impairment and preservation found in brain damaged subjects represent normal systems minus compromised components, and not the manifestation of structures absent premorbidly. The integrity of the discipline rests on this belief, as were it disproved, the advantages of studying pathological cases as a window on to normal functional characteristics would be largely abolished. This is not to deny that cerebral trauma may result in some reorganisation such that spared processes subsume tasks previously carried out by others, or that new strategies, conscious or subconscious, may be developed to circumvent or minimise loss. Such changes in no way invalidate cognitive neuropsychological research, though they may substantially hinder it.

The notion of subtractivity is founded on yet another crucial supposition, which Caramazza (1986) called the assumption of universality. This holds that the functional architecture of cognition is invariant in the normal population.¹⁶ Confidence in the subtractivity assumption is increased by the documentation of language difficulties in the normal population, such as anomia and tip-of-the-tongue states, which are found in exaggerated form after brain damage (Ellis and Young, 1988). The potential complexities of making sense of pathological data, and the pitfalls in using them to infer normal cognitive processes, are nicely encapsulated in the entertaining and salutary Montreal Expressway Problem (Seidenberg, 1988). The essence of this parable is as follows and I draw on Seidenberg's wording. There are two main routes to the airport in Montreal, the Deadly Expressway and the Crosstown Crunch. Ninety-five percent of traffic takes one or the other route. One day an enormous snow storm renders them

¹⁶ Whitaker and Slotnick (1988) raise interesting objections to simple accounts of universality and modularity without undermining the fundamental assumptions.

both impassable. The resourceful Montrealers are forced to find other means of catching their flights. Most set out on foot; of these some arrive in time for their planes, the journey having taken three times as long as usual, some miss their flights and yet others turn back because the side streets are blocked. One person hires a helicopter (he arrives faster than usual), another hitchhikes, a third catches a bus to Vermont and flies from Burlington airport. The point of the story is that there is a good theory of normal travel practice (a dual-route theory), based on an understanding of the task and of the two main methods used. When the system is disrupted a proportion of people still manage to perform the task. A great deal of time and effort could be spent in documenting all their various improvisations, times taken and costs. But Seidenberg asks,

..what would the theory of "how people get to the airport when the expressways are closed" be a theory of? Would it be a theory at all or merely a collection of facts? Would this collection of facts be informative about how people normally travel to the airport? *Is cognitive neuropsychology the study of the expressways or the side streets?* (Seidenberg, 1988, p.425).

The second premise of the cognitive neuropsychological school concerns the modularity of components within the information processing model. According to this hypothesis, mental functions are subserved by a number of autonomous, co-operating processes which communicate their various inputs and outputs via interfaces. The dedicated nature of these processes, their autonomy, and the well defined nature of the inputs they process has given rise to the term *information encapsulation* (Fodor, 1983). Since these self-contained modules are responsible for discrete functions and capable of independent execution, theoretically any combination may be spared/intact following cerebral trauma. An apparent module malfunction may thus be primary (i.e. due to damage to the underlying 'hardware' (neurological tissue)), secondary (i.e. due to receiving compromised input), or a combination of the two. Erroneous input may either be the incorrect output of a feeder module (for primary or secondary reasons), or faulty transmission, or again both. Co-occurrence of impaired functions may therefore be accounted for by neuroanatomical proximity, functional connectivity, or a dual relationship. Marshall and Newcombe (1973), in a frequently quoted passage, observe that for any system with n components, each of which can be spared or intact, there are $(2^n)-1$ possible patterns of impairment. Even this is a theoretical understatement, for it fails to include the additional possibility of errors arising in transmission between components. From this brief description, the difficulty of

constructing a model of normal language processing from glimpses afforded by breakdown data, will be appreciated. While many cognitive neuropsychologists are not concerned with how perceived functions are realised in the brain, it is noteworthy that corroborative evidence from Biology and Software Engineering shows that modular design makes for robust architectures, which are easier to 'debug' (diagnose) and maintain, and which tend to exhibit the quality observed in brain-damaged subjects (and desired in computer systems) of gradual rather than catastrophic or total breakdown (Marr, 1982; Pressman, 1982).¹⁷ Thus there is empirical evidence to favour the architecture posited.

The third assumption listed above is transparency (Caramazza, 1984). This is the requirement that systematic analysis of a patient's performance must allow valid conclusions about the nature and functions of the underlying processing components to be drawn.¹⁸ Without such an assumption the enterprise of Cognitive Neuropsychology would, of course, be impossible. However, even given the supposition of transparency, great care is needed in the interpretation of observations. Caramazza proposed that any disordered performance profile would reflect, in addition to the 'true' effects of the hypothesised damage to one or more processing components, a) individual premorbid performance variation, b) the effects of compensatory strategies developed post-onset and c) effects resulting from damage to other processing components (Ellis and Young, 1988).

Cognitive Neuropsychology extends its knowledge base by a principled testing of hypothesised functions, resulting in the establishment of associations and dissociations between processing components. In this way existing models are consolidated, enlarged or revised. A dissociation between cognitive tasks A and B is claimed when a subject shows an impairment in one and significantly less impairment in the other. A double dissociation is confirmed when a second individual presents with the opposite pattern of performance (Jones, 1983). Such evidence is critical to the discovery of the identity and functions of the major autonomous language processing components. The box and line diagrams used by cognitive neuropsychologists to depict these relationships are reminiscent of those constructed by the early localisationists (e.g. Broca, Wernicke), but their purpose

¹⁷ There is a view prevalent that only distributed systems exhibit 'graceful degradation', this is not so. Modular systems may do so in two ways: by 'de-coupling' so that intact functions operate in the total absence of damaged ones and/or by the continued operation of the system with one or more partially damaged modules.

¹⁸ Readers with a computing background should note that this usage is opposite in meaning to 'transparency' as a quality of human-computer interfaces, where it means that the underlying processes are *not* discernible to the user.

is slightly different. A cognitive neuropsychological model of a language processing subsystem is a functional representation, descriptive of the processes involved, their relationships and interdependencies, but not concerned with neuroanatomical correlates. Rather than being a weakness, this property of independence is an asset, since it results in a logical representation which is not limited by, or bound to, the state of neurophysiological knowledge.¹⁹

Although models are, in principle, implementation-independent, their properties may place constraints on feasible realisations. For example, through studying human cognitive performances and making calculations concerning channel capacities, input/output speeds and so forth, it may be inferred that certain processes in the model happen concurrently. However, the model remains a functional one, independent of actual neural apparatus. A piece of complex behaviour may thus elicit a variety of functional descriptions by different professional analysts, e.g. linguists, speech pathologists, cognitive psychologists - each valid for a different purpose. The accuracy and adequacy of each model can be assessed by its predictive performance, its intuitive appeal and its analytical utility.

The emergence of the Cognitive Neuropsychological School can be traced to the dyslexia studies of Marshall and Newcombe (1966; 1973) and Shallice and Warrington (1977; Warrington and Shallice, 1979; 1980), and Shallice and Warrington's investigations of memory (1970; Warrington and Shallice, 1972). Marshall and Newcombe (1973) observed in two contrasting cases, GR and JC, pathological evidence for the dual-route theory of reading, which had been proposed by cognitive psychologists on the basis of word reading experiments with normal subjects (Coltheart, 1978). JC could read simple non-words, but failed on irregular words, apparently applying the same grapheme-to-phoneme conversions in well-known exceptional cases, whereas GR failed on simple non-words and often made semantic paraphasias on real words. Thus JC seemed to have only a non-lexical route available to him while GR had only a lexical one. Many subsequent studies have built on these foundations and word/non-word, regular/irregular and concrete/abstract contrasts are now commonplace probes. The concentration of research effort has resulted in a refinement of investigative techniques, an expanding arsenal of test materials and a consequent increase in the specificity of diagnostic subtypes (Patterson, 1981; Coltheart, 1985; Ellis

¹⁹ The information processing model is not without critics, e.g. Schweiger and Browne (1988) argue that 'boxology' is anti-evolutionary and descriptive, rather than explanatory.

1984). The current position is that, while cognitive neuropsychological research into disorders of reading and naming is more advanced than in other areas of acquired language dysfunction, prevailing models are tentative, and only cover single-word processing. Absorption of this literature is nevertheless important, since ideally, the proposal of a syntax processing study presupposes the ability to identify and eliminate candidates with single-word difficulties. In practice, such pure cases may turn out to be uncommon, and it may be necessary to incorporate aspects of mild or intermittent dyslexia and anomia into a realistic account of sentence comprehension deficits in aphasia.

Ellis and Young (1988, chap. 8) contains an overview of the main thrusts of research activity, guidance through the profusion of diagnostic jargon and an exemplary approach to model-building from the sum of normal and pathological data. The chapter is valuable in showing how evidence gleaned from a variety of single cases has led to the proposal of a range of dyslexic categories, such as 'neglect dyslexia' (Ellis, Flude and Young, 1987), 'attentional dyslexia' (Shallice and Warrington, 1977), 'letter-by-letter reading' (Patterson and Kay, 1982), 'phonological dyslexia' (Patterson, 1982) and 'deep dyslexia' (Coltheart, Patterson and Marshall, 1980). It is also helpful in highlighting the nature and substance of current debates, such as whether word recognition in 'deep dyslexia' is mediated by the right hemisphere (Coltheart, 1983b). This is a question with serious implications for drawing conclusions about intact cognitive processes from aphasic performance. At present, the contribution of the right hemisphere in deep dyslexia remains uncertain, as does its role in the intact reading process. Another key issue is whether single-lexicon models are tenable in the face of the range of receptive and expressive problems observed. In the absence of contradictory evidence, cognitive neuropsychologists will assume minimum redundancy in a cognitive system, i.e. that resources such as internal stores are shared, and that processes common to tasks are not duplicated. Most theorists assert separate phonological and lexical systems, dealing with spoken and written words respectively, but there is division concerning whether input and output in those modalities utilise the same lexicon; Allport, Funnell and Coltheart in various combinations - (Allport, 1983; 1984; Allport and Funnell, 1981; Coltheart and Funnell, 1987) have put forward a single-lexicon account, while Campbell (1987) and Howard and Franklin (1987) have produced evidence that is hard to accommodate other than in a dual-lexicon model.

Two further bodies of evidence from the single-word reading literature are of special interest. One relates to morphological errors in reading; the other to selective impairments of access to word-meaning and word-sound. In section 1.2.1, one of the defining features of agrammatism was found to be difficulty with the production and comprehension of bound grammatical morphemes. In referring to reading, or comprehension errors, as 'morphological', one is supposing that the word stem has been isolated, and that the impairment relates to neglect of, substitution of, or failure to understand the meaning of, the associated morpheme. But Ellis and Young pointed out that all patients so far reported, committed visual and/or semantic errors in reading,

Thus one cannot be confident that a patient who misreads *edition* as "editor" is making a morphological error when that same patient also misreads *gravel* as "grave" and *pupil* as "puppy". (Ellis and Young, 1988, p.215).

This statement raises a thorny problem for the present study, not just in relation to morphology, but more generally, in the disentanglement of the various forms of dyslexia from deficits of syntax processing.

The second set of observations concerns the relatively preserved abilities of some patients to make synonym judgements, sort words from non-words, differentiate sensible and nonsensical sentences and assign words to appropriate semantic categories, while having little or no idea of pronunciation (Caramazza, Berndt and Basili, 1983; Ellis, Miller and Sin, 1983; Levine, Calvanio and Popovics, 1982). These findings suggest the presence of a direct-access route from print to semantics for known words (Kleiman, 1975), and simultaneously call into question the role of the *inner voice* so familiar to normal readers. On closer inspection, it turns out that Patient JS of Caramazza et al. (1983) exhibited performance patterns similar to those recounted in Section 1.2.1. He failed to picture-match reversible locative sentences reliably if an inverse distractor was offered, and whereas he could successfully reject semantically anomalous sentences, he could not detect the ill-formedness of *The girl will dressing the doll*. Similarly, patient MV of Bub, Black, Howell and Kertesz (1987) could not detect syntactically incorrect written sentences, although she rejected semantically anomalous ones in written mode, and both types on oral presentation.

The phonological recoding hypothesis²⁰ has been the subject of a number of psycholinguistic studies on normal readers (Garnham, 1989). These have yielded mixed evidence, some tending to show effects compatible with word-sound influencing lexical access (Meyer, Schvaneveldt and Ruddy, 1974), others suggestive of word-sound contributing to post-access checks (Forster, 1976). The results of experiments on normal subjects, under conditions of inner-voice inhibition, show greater disruption of syntax processing than of semantics, suggesting that grammatical analysis may operate on a phonological representation of input (Lesgold and Perfetti, 1981). An alternative to the dual-access theory has been proposed in the form of a cascade model (McClelland, 1979), which has generated a great deal of interest in the cognitive science and artificial intelligence (AI) communities in its computerised forms (McClelland and Rumelhart, 1988). This requires only one 'route' to the lexicon, accomplished by the spreading activation of candidate substrings and the inhibition of others, converging as the system stabilises on the most likely match.²¹ This parallel processing approach can be seen to have succeeded the earlier and influential Logogen model of Morton (1969; 1979). This argued for direct access to the lexicon via a set of feature counters or *logogens*, in contrast to the search-based mechanisms of Forster (1976; 1979). The direct access versus search debate takes its concepts and terminology straight from computer data processing, where these are alternative file access mechanisms.

Despite the convincing rationale promoting the aims and methods of cognitive neuropsychology as outlined above, there are two areas in particular where current practice seems wanting. Both may be seen as arising from an unfortunate compartmentalisation of effort in the related fields of AI, Computing, Psycholinguistics and Cognitive Neuropsychology. The first concerns modelling and the *diagrammatic representation* of models. The field of Computer Systems Analysis and Design has delivered numerous approaches to analysing information systems, each with its own rationale and symbology (Pressman, 1982). As these techniques have been developed to provide for the comprehensive representation of working (successfully automated), as opposed to purely theoretical systems, it is puzzling that cognitive neuropsychologists seem to have

²⁰ This is the proposal that the mental lexicon is accessed via sound patterns only.

²¹ There are a number of different connectionist models varying considerably in operational detail, (Anderson, 1983; Dell, 1986). Their common approach is to implement cognitive algorithms in networks of connected nodes, known as 'neural networks'. These architectures, in which nodes may 'fire' or be inhibited simultaneously, are described as 'parallel' and are said to support parallel distributed processing (PDP).

paid so little attention to them. Thus, by comparison, cognitive neuropsychological models appear under-specified. The most obvious shortcomings of current models of human language processing are:

- a) The lack of a common symbology and modelling terminology among researchers.
- b) The failure to distinguish between internal stores and the processes that operate upon them (Zurif, Gardner and Brownell, 1989).
- c) There is no means of diagrammatically representing partial or intermittent damage to a component or a transmission channel²² (Whitaker and Slotnick, 1988; Zurif, Gardner and Brownell, 1989).
- d) Current models often omit necessary components, the exclusion of any form of memory is a common example of this.

Zurif, Gardner and Brownell (1989) mention points b) and c), and argue that models are less computationally explicit than they could be, and too concerned with incorporating observed dissociations rather than with establishing the functional characteristics of each component and their interconnections. Similarly, Ellis and Young (1988) recognise that the model they provide (p.222), impressively derived as it is from experimental findings,

... is only half a theory. The missing half is the specification of how each module works and how it communicates with the other modules to which it is connected. (Ellis and Young, 1988, p.229).

They go on to say that computer simulations provide the opportunity to explore internal representations.

It seems feasible therefore that cognitive neuropsychologists could usefully increase the precision of their models, without compromising the commitment to a functional, as opposed to a procedural analysis. Moreover, it should be axiomatic that attempting to explain pathological performances with respect to a model of intact processing is only sensible if the model contains all the components thought to be involved.

²² This is a requirement peculiar to pathological modelling and finds no parallel in computer data processing. Current models tend to be of the intact system from normal and pathological data.

The emergence of connectionism seems to have caused some confusion about the representation of language processing and appears to have called into question the utility of the box-and-line models, since in fully distributed architectures there is no distinction between process and data. This difficulty diminishes if connectionist 'models' are regarded as implementations and diagrammatic representations respecting cognitive neuropsychological principles are seen as high-level implementation-independent schemas. The point being that a functional description including entities of significance to clinicians and psychologists will still be a useful, indeed a necessary tool for research, even if the most promising attempts to simulate brain processes omit explicit distinctions between such things as discrete processes and stores. In my view the most likely outcome of the connectionist endeavour will be the realisation that human language processing behaviour cannot be replicated without recourse to the inclusion of a variety of knowledge-bases (e.g. metalinguistic knowledge, semantic knowledge, domain-specific knowledge). A major challenge will then be the incorporation of these within a neural-type architecture. In Chapter 6 a preliminary model of the sentence/picture-matching task is offered in an attempt to account both for previous findings and for new insights gained during the treatment phase of the present research.

The second area where a weakness in the cognitive neuropsychological output is apparent is in the design of linguistic material for the testing of sentence processing problems.²³ Typically, results are reported without inclusion or justification of the sentences used. Where test sentences are reproduced, there is generally no attempt to explain how the vocabulary and sentence structures were chosen. Thus there seems to be a gap between linguistic theory and computational linguistics on the one hand, and cognitive neuropsychology and clinical aphasiology on the other. There is therefore no assurance that the test items are homogeneous and suitable with respect to the factors of interest.

The difficulty of ensuring that conclusions drawn from test materials are not suspect due to unaccounted factors is illustrated by the following observations.²⁴ The examples of a semantically and a syntactically anomalous sentence, from

²³ This is in comparison to single-word test sets, where care is taken to match for salient factors such as animacy, concreteness, frequency, word length, etc.

²⁴ The following example is chosen purely for illustrative purposes being from a paper cited earlier in this section. The problems mentioned are common ones. Almost any of the sentence processing studies might have been chosen to make similar observations.

Bub et al., quoted by Ellis and Young (1988, p.220), are different not just in those respects. The former, *The bird flew up the book*, cannot be rearranged to make a sensible sentence (a minimal repair would involve a substitution for *up*) whereas *They gave me ride a home* only requires a simple readjustment to become the sensible sentence that many a normal reader, on quick scanning, would take it to be. Even given a test environment in which the subject is expecting to see incorrect sentences, one would prefer both types of sentences to be 'irretrievably' wrong. In addition, the syntactically anomalous sentence violates word order only; as there are many different types of syntax transgression, categorisation and systematic exploration would be necessary before coming to conclusions about syntactic versus semantic performance. Likewise, the semantically anomalous sentence is not semantically ridiculous, but only incorrect in one feature, the function word *up*.²⁵ Since function words are notorious stumbling blocks for agrammatic patients, it seems a little odd that a 'semantic' error should be created in this way instead of, for example, by the use of an inappropriate verb.

These comments are intended simply as an indication of the range of factors to be considered in experimental sentence design. To draw any robust conclusions about sentence processing deficits it is necessary to ensure that errors could not be due to single-word difficulties, to uncontrolled structural factors, or to the nature of the test environment itself. These points are well made by Grodzinsky and Marek (1988) in their critique of Caramazza and Zurif (1976),

One cannot just take "syntax" to be a single, unanalyzed variable, as has been done often in the past. ...Only an analysis of the response type and the solution space, coupled with the syntactic construction in question, constitutes the actual "task analysis". This, we believe, is the only way to assign a coherent interpretation to data from the comprehension of brain-damaged people. (Grodzinsky and Marek, 1988, p.224).

What I am arguing here is that although a computationally explicit model of parsing is, quite properly, beyond the scope of cognitive neuropsychology, there is a higher level arena where cognitive neuropsychology must meet psycholinguistics if investigations of syntax processing are to avail themselves of a theoretical basis. Producing test batteries for syntax processing is a difficult business and must surely be guided by psycholinguistic data, for as Caplan and Hildebrandt remarked at the end of their chapter on previous studies,

²⁵ This could be satisfactorily replaced by a range of options such as *into*, *at*, *under*.

Perhaps the most striking aspect of the literature on syntactic-comprehension disorders to date is the nearly complete absence of references to existing models of the parsing process - both those suggested by implemented parsers and those consistent with the results of psycholinguistic experimentation. Despite repeated references to the role of the function-word vocabulary or of a short-term-memory system in parsing, almost none of the papers we have reviewed refer to specific aspects of a parsing model related to these vocabulary items or this memory system. (Caplan and Hildebrandt, 1988, p.84).

In conclusion of this section; evidence from the single-word studies of reading and naming, (especially with regard to so-called morphological problems), and investigations of the phonological coding hypothesis, connect this literature to the previously cited findings in agrammatism. The lessons to be learnt are cautionary. Venturing beyond current models involves 'navigating the minefields' of partially understood single-word disorders, and these, as we have seen, can easily obscure, indeed masquerade as, syntactic problems. However, the idea of constructing a microworld to eliminate contextual cues in reversible sentences (which was proposed in section 1.2.1 above, extending the example of Schwartz et al., 1980) promised an answer to some of these problems too. If a miniature artificial world could be created using only reversible scenarios and a minimal vocabulary, and if the lexical items could be demonstrated to be understood in isolation, then the resulting 'linguistic clean room' should enable combinatory disorders to be systematically explored. In addition, limitation both of the size of the microworld vocabulary and of the range of permitted sentence structures, should facilitate analysis of the error patterns arising, thereby providing a basis, not just for finer-grained diagnosis, but also for the design of therapy.

Further to the development of a Syntax Screening Test proposed in section 1.2.1, it was pleasing to find that the modular design suggested by the list of candidate functions found troublesome in agrammatism maps so well into cognitive neuropsychological theory. Thus by organising the test in linguistic modules it should be possible to discover patterns of spared and impaired performance among prospective subjects. In this way the structure of the screening test itself will be based on cognitive neuropsychological principles. With respect to treatment, we have already noted a dearth of treatment studies founded on cognitive neuropsychological concepts. In the present study an information processing approach is intended to unify all aspects of the work, from the

organisation and content of assessment and remediation material, through to the experimental design of the treatment phase and of course the design and implementation of the computer software itself.

1.2.4 CLINICAL RESEARCH METHODOLOGY

Two related issues are examined in this section; one concerns the inadequacy of most evaluative studies of language therapy, (a theme which was dominant in sections 1.2 and 1.2.2 above); the other is a philosophical debate that has polarised participants and occupied much space in learned journals, namely the question of whether single-case studies or group studies are the appropriate way of proceeding from pathological data to the inference of intact processes. These methodological issues are discussed in turn.

The conflicting reports of treatment results attributed to different types (usually under-specified) and durations of therapy have been mentioned in section 1.2 and need not be reiterated here. The salient point to notice is that there has been very little published evidence of efficacy (or the lack of it) that could resist close examination. The situation was summarised by Byng and Coltheart thus,

Certainly there are few examples of convincing demonstrations of treatment efficacy. On the other hand, of the many studies which have sought to investigate the efficacy of aphasia therapy, there are quite extraordinarily few which meet even the most elementary methodological criteria. Hence the situation at present is that we have almost no useful evidence concerning the efficacy of aphasia therapy. (Byng and Coltheart, 1986, p. 193).

Relatedly, Howard and Patterson (1989) observed that studying neuropsychological deficits in the hope of developing better treatment methods had so far been a one-way process from which researchers had gained a lot, and patients very little. The rationale for supposing that detailed deficit analyses will assist therapy is embodied in the following assumptions,

(a) that deficits tend to be highly selective and (b) that treatment for these deficits will be maximally effective only when the direction of treatment is determined by precise knowledge of the patients' processing capacities and incapacities. (Howard and Patterson, 1989, p. 4).

Moreover, without benefit of a model to assist the diagnostic process, there can be no hope of achieving an understanding of an individual's overall cognitive status. As Howard and Patterson pointed out, the same symptoms can be due to very different causes. They gave the example of two fictitious patients, one of whom could recognise printed words but could not speak, the other had the opposite capabilities, but both failed the oral reading section of a traditional aphasia assessment. Clearly, this finding should not consign both patients to the same treatment activities, although using such blunt diagnostic instruments and given less blatantly different symptoms, inappropriate treatment must regularly be given.

A consensus is emerging from a number of sources that the standardised aphasia batteries are neither suitable for diagnosis, nor for obtaining pre-therapy and post-therapy measures to support efficacy claims (Byng et al., 1990; Howard and Patterson, 1989). Before proceeding to evaluate a therapeutic technique, it is essential to be sure that patients subjected to it all suffer from the targeted impairment. This is only possible by devising tests sensitive to that particular linguistic function. In view of the unsuitability of the standardised assessments for this purpose, it is gradually being recognised that, "... at least at the present, researchers and therapists have no alternative but to make up their own sets of testing materials." (Byng and Coltheart, 1986, p.196). With respect to the design of treatment studies, the following recommendations, though not yet widely practiced, are cohering into a set of principles against which the merits of forthcoming studies are likely to be judged.

In order to demonstrate efficacy, it is desirable to show that treatment benefits are both function-specific and treatment-specific. The former means that the treatment effects are particular to the linguistic function targeted, not indiscriminate, and the latter places a burden on the researcher to show that any benefits claimed are not due to some non-specific effects of the treatment, such as that patients responded favourably to the extra attention (Byng and Coltheart, 1986; Howard and Patterson, 1989). According to these writers, investigators must be able to counter the challenge of spontaneous recovery and choosing patients who are several years post-onset is no longer considered a sufficient precaution. Neither is taking multiple baseline measures before and after therapy, since the functions of interest could still, by coincidence, be those enjoying spontaneous remission. The suggested method of accounting for all these possible

objections, was to utilise a multiple baseline study with cross-over (Coltheart, 1983a). In this experimental scheme, a variety of different linguistic (and perhaps non-linguistic) functions are pre-tested, one function is selected for therapy and afterwards the tests are repeated. If the treated function has improved significantly compared with the others, then there is good evidence for claiming function-specific and treatment-specific effects. This evidence is strengthened, and suggestions of spontaneous recovery laid to rest, if a second function is then singled out for treatment, and further post-tests show a similar pattern of selective improvement. The second treatment phase also allows the durability of results obtained in the first to be assessed. An additional layer of precision can be built in by devising test materials sensitive both to item-specific improvement and to generalisation within the treated task domain (Howard and Patterson, 1989).

The multiple baseline with cross-over design, just outlined, suits present purposes very well, since I have selected two functions, verb processing and preposition processing, and wish not only to try to treat them but also to discover whether performance in these two areas is dissociable. However, the complex nature of the cognitive tasks envisaged makes following other recommendations more problematic, most notably Howard and Patterson's (1989, p.28) injunction to ensure that pre- and post-treatment assessments contain a sizeable number of items, "A minimum of fifty items seems reasonable; we (Howard et al., 1985) used a naming test with three hundred items and provoked no protest." In a single-word processing environment, large test batteries are obviously both feasible and desirable. Statistically significant change is often only demonstrable with large numbers of observations and within-patient variability is likely to be less of a nuisance factor. However, moving into the realm of sentence processing, where response latencies to (written) sentence/picture-matching tasks may be up to one minute or more (and mentally exhausting), it is simply not possible to comply with these ideals. Compound this problem by the sheer number of assessments necessary to complete a multiple baseline study of the sort advocated, and it becomes readily apparent that if each assessment cannot be completed in a single session the enterprise will be quickly strangled by its own bulk, and any results (obtained over a number of sessions) will be extremely hard to interpret. Apart from the special constraints sentence processing assessment imposes, I wished to satisfy the self-inflicted aim of offering a *pragmatically* as well as theoretically sound design, by producing a research schedule suitable for implementation with a number of patients in parallel, in a working clinic environment. If cognitive neuropsychology is ever to inform clinical practice, and indeed to benefit from the

feedback that only widespread clinical data can provide, it is imperative that academic studies be seen to offer methodologies that are both replicatable and *workable*.

The second issue mentioned at the outset of this section, which also has an important bearing on the conduct of the present study, is the single-case study versus group study debate. Newcombe and Marshall (1988) set this dichotomy in historical perspective, alleging that the single-case studies characteristic of the nineteenth century gave way to group studies with the availability of large numbers of young, brain-damaged men, victims of the 1914-1918 war. During the following decades group studies were in vogue and single-case status receded to 'anecdotal'. The contemporary shift in emphasis is brought about because of the emergence of cognitive neuropsychology and its espousal of the single-case study approach (Coltheart, 1983a; Howard, 1986). Shallice's paper (1979) marks the beginning of an ongoing assault on group study advocates by those of the single-case persuasion. The most vociferous of these is Caramazza (1986; Caramazza and McCloskey 1988), who maintains a) that valid inferences about normal cognitive processing can *only* be made from single-case data, and b) that patient classification by syndrome type is useless for this endeavour. Point b) is widely accepted and was discussed in section 1.2, but the basis for point a) needs explanation. The essence of Caramazza and McCloskey's argument is as follows. The investigation of intact cognitive performance assumes the existence of a functional architecture (invariant across the normal population) and a set of experimental conditions, (under researcher control) giving rise to a set of observations - the performance data. Caramazza and McCloskey accept the principle of universality and are happy to subject such sets of data to group analysis. Their strong objection is to applying the same methods to pathological data. In the case of brain-damaged subjects, while the underlying functional architecture and experimental conditions are as before, each subject has a 'functional lesion' (or lesions) which are outwith the investigator's control and result in deviant performance. According to the authors, this data cannot be amalgamated without prior demonstration that all patients in the group have equivalent functional lesions. Their position hinges on the logical impossibility of foreknowing that this is the case.

While it is difficult to fault Caramazza and McCloskey in the main thrust of their argument, Whitaker and Slotnick (1988), in comments on the paper, observe that in their exposition, Caramazza and McCloskey accept several idealisations which

are, in principle, no less problematic than the heterogeneity of functional lesions. In particular they single out the assumption of universality, so named by Caramazza, and accepted by him and his colleague as a matter of pragmatic necessity. Whitaker and Slotnick point out that since each individual's functional architecture is presumably shaped by inheritance and experience, ipso facto, no two are identical. If such differences are theoretically relevant, then group studies of intact subjects are also illegitimate, and either way, accounts of pathological performance must consider variability of individual functional architectures as well as of functional lesions; Caramazza and McCloskey are hoist by their own petard! Whitaker and Slotnick raise a number of other issues pertaining to the over-simplification of cognitive neuropsychology's approach. They do so no doubt in rhetorical vein, realising that there is no escaping the dilemma: simplification is necessary to render the enterprise tractable, yet may inadvertently mask fundamentals, thus possibly jeopardising the effort.

The single-case study argument is based firstly on the heterogeneity of the aphasic population, and secondly on the fact that an observed dissociation of two functions in an individual, who was unexceptional premorbidly, is considered to be evidence that these functions are at least partially separate in the intact processing system (Shallice, 1979). That this line of reasoning should have led to a single-case *only* philosophy is open to considerable doubt (Newcombe and Marshall, 1988; Zurif, Gardner and Brownell, 1989).

Zurif et al., challenge many of the single-case only claims, such as that in group data outlying values can distort summary statistics, by pointing out that,

...averaging is part of an empirical - a statistical - test of the theoretical claim being advanced. ... Most often null results as well as results in the direction opposite to what was predicted by the theory are interpreted as failures to confirm a theoretical prediction. (Zurif et al., 1989, p.242).

They add that if data are suspected of being incompatible with parametric assumptions, nonparametric statistical tests are available. They also point out that extreme scores can equally well occur in single-case data, in fact that group studies are less prone to idiosyncratic results. In trying to minimise the latter by repeating tests, Zurif et al. claim that single-case data is susceptible to contamination by learning strategies developed over time. Similarly, they argue that, if studying single cases over protracted periods, researchers must be able to

show "that the patient is functionally the same at different points in his or her recovery" (p.243). The authors suggest that grouping patients according to symptomatology is uncontroversial in medicine, and moreover, that the whole of behavioural science relies upon the integrity of 'norms'.

Newcombe and Marshall (1988) are similarly opposed to throwing out group methodology hook, line and sinker. They maintain that group and single-case studies are complementary and that there are occasions when the former are indispensable. In particular, they feel that *typicality* measures, both of 'normal' and pathological populations, are important yardsticks by which the reliability of hypotheses concerning individual members, or one group compared with the other, can be ascertained. This paper, like the one by Zurif and co-workers, stresses the futility of adhering, a priori, to either extreme position in the 'study type' debate; the theoretical considerations in any particular instance should govern selection. Newcombe and Marshall precis their stance picturesquely as follows:

As previously noted, association of symptoms can arise from anatomical contiguity of the damaged areas. One black swan (with dissociated symptoms) or two black swans (with double dissociation) will not *necessarily* show that a majority association is psychologically spurious. The escape clause of strategic adaptation can always be invoked; or it may be that the dissociated case really is a biological "mutant". But a series of black swans with lesions subtly different from those found in the majority association would give grounds for acute suspicion. Likewise, when a theory that is plausible *on other grounds* predicts a dissociation, one may accept just one actual case of empirical dissociation as adequate proof and dismiss on the grounds of anatomical contiguity *all* other cases of association. (Newcombe and Marshall, 1988, p.561).

This section has considered two related matters, criteria to be fulfilled in the conduct of sound efficacy studies, and the debate as to whether only single-case studies offer appropriate evidence for the inference of intact functioning from pathological observations. The outcome for present purposes is that the multiple baseline design with cross-over, which answers all of the methodological objections to previous studies encountered in sections 1.2 and 1.2.2, seems ideal for the investigation of verb and preposition treatments. However, it has been noted that recommendations concerning the size of assessments, deriving from single-word studies, are unlikely to be applicable in a sentence processing

environment. As there are no suitable general syntax processing assessments existing, and none specifically devoted to the functions of interest (especially none respecting the proposed experimental design), and since I know of no published details of response latencies to such stimuli, the determination of size and content must be entirely new.

With respect to the single-case *only* dispute, the arguments of Newcombe and Marshall (1988) and Zurif et al. (1989) for 'the right groups and the right individuals' guided this work. The provision of a Syntax Screening Test and preliminary tests of single-word recognition ensured that the patients selected all manifested the functional deficits of interest and were therefore homogeneous in that regard. However data interpretation and therapy remained alert to the possibility of differences in the underlying causes. Also, the size of the patient cohort, (14 subjects), was large enough to enable the analysis of group reactions, yet not so large as to preclude me from either detailed analyses of each individual performance, or detailed knowledge of each patient's circumstances and clinical behaviour.

1.3 SCOPE AND AIMS OF THE PRESENT STUDY

The foregoing review has delineated the main bodies of research underpinning the present study, the state of knowledge in these areas, and the factual and methodological limitations prompting this inquiry. The aims of this study are stated below and for ease of association with the foregoing are collected under the four previous section headings. In reality, of course, there are no such boundaries, they were adopted for convenience and having served their purpose may be dissolved. Advances to the various subject areas proceed largely in parallel, working through the logical sequence of detection, assessment and remediation of the functions of interest. The remainder of the thesis is devoted to explaining the methods used, analysing the resulting data, discussing substantive findings, and suggesting promising directions for future work.

Agrammatism

1. To further knowledge about the nature and (functional) causes of acquired deficits of written sentence processing.

2. To produce a modular Syntax Screening Test based on the linguistic functions characteristically impaired in agrammatism.
3. To furnish data on the relative performances of normal and aphasic subjects on the above test.
4. To develop and test a new (computerised) treatment approach.

Microcomputers in Aphasiology

5. To develop and test a general-purpose human-computer interface and presentational format suitable for use by language-impaired hemiplegic subjects.
6. To create, and determine the utility of, a computerised microworld for diagnosis and treatment of sentence processing deficits.
7. To provide 'second generation' software tools for sentence processing assessment and treatment.

Cognitive Neuropsychology

8. To apply cognitive neuropsychological principles to the study of syntax problems.
9. To discover whether verb and preposition processing are dissociable functions.
10. To consider the implications of aphasic cases for the modelling of sentence comprehension.

Clinical research methodology

11. To offer a research model which is methodologically sound, but also compatible with sentence processing demands and with clinical logistics.
12. To provide improved assessment tools which are quantitatively precise, free of inter-observer variation and diagnostically informative.

CHAPTER 2

2.1 INTRODUCTION AND CLINICAL PROCEDURE

This chapter introduces the computerised microworld environment used subsequently for both the assessment and the remediation of sentence processing deficits and describes the creation and validation of the Syntax Screening Test (Crerar, 1990). The purpose of the Syntax Screening Test (SST) was to detect impairments in the two functions of interest, verb and preposition processing, and to compare subjects' performances in these with their abilities in other linguistic functions. In addition to providing an initial patient selection mechanism, the SST was created to monitor the performance of candidate patients over a period of months before onset of therapy. Clearly, a new test could not be used in this way without first subjecting it to a validation procedure. Likewise, the integrity of conclusions about aphasic performances in the microworld rests on being able to demonstrate that the computerised environment itself introduces no confounding factors. Normative data is therefore presented to establish that the SST is of a suitable standard such that 'the man in the street' can do it, and the results of two preliminary tests are reported, one to test interface operation independent of a language processing task and the second to check single-word recognition of the microworld vocabulary.

All the aphasic subjects reported here were referred to the study by qualified clinicians with medical approval where necessary. A few aphasic candidates were tested and not selected for the study, their data is not included below, but reference is made in the text to reasons for discarding them. None of the subjects, normal²⁶ or aphasic, was paid for participation. All the tests described in this chapter were conducted by the writer. Nobody else was present with normal subjects, but usually the referring therapist was present for the first of the aphasics' sessions if the patient had not previously met me. The environmental conditions were similar for all tests; a quiet room was used, with blinds and lighting adjusted for maximum screen clarity. Seating and visual display unit (VDU) angle and height were altered to suit individuals. All subjects were instructed that their responses would be timed, but that accuracy was more

²⁶ The term 'normal' is used throughout to refer to the 'non-brain-damaged' subjects who participated in the SST phase of the study.

important than speed. An effort was made to put all subjects at their ease. The simplicity of the Interface and Lexical Tests was very useful in instilling confidence in subjects, most of whom had never used a computer before and were therefore a little apprehensive at first.

Although a test session for each subject involved exposure to the Interface Test, Lexical Test and SST in that order, for ease of discussion each of the tests is considered separately below. The normal subjects were tested over February and early March 1990. Their results were analysed and one or two minor modifications made to the software (such as the addition of screen numbering so that I could more easily follow the progress of subjects through the 42 item SST) before trials with aphasic subjects commenced. As described below, the aphasic subjects, who are referred to by the identifiers P1, P2, ..P14, had three well-spaced test sessions, the dates of these are included in Table 13. The interested reader will thus be able to ascertain the temporal sequence of the results shown below, for example, all test 1, 2 and 3 results for P5 were obtained on 3/5/90, 9/7/90 and 5/9/90 respectively.

2.2 THE MICROWORLD

There were three main sources of inspiration for the computerised microworld. The stick figures 'circle' and 'square' of Schwartz, Saffran and Marin (1980) were acknowledged in section 1.2.1 above. The second source was literature concerning the use of miniature artificial languages (McLaughlin, 1980; Moeser, 1977) which have been used in the past for the exploration of language acquisition, and literature on the use of alternative iconic communication systems to explore the residual symbol processing capacity of aphasics (Steele et al., 1989; Funnell and Allport, 1989). Miniature artificial languages are characterised by a greatly simplified grammatical structure and phonological system and a very limited vocabulary of artificial words which have a one-to-one correspondence with their visual referents. In this way, a miniature linguistic environment is created in which experimental manipulation of specific variables is facilitated. Iconic languages use symbols instead of words, thereby simplifying the grammatical structure of natural English, but preserving real world referents and elements of symbol order significance. Steele et al. (whose work was referred to in section 1.2.2) used a mixture of realistic icons for nouns and more abstract ones for verbs and function words; Funnell and Allport used Blissymbols (Bliss, 1965). Thirdly, I was

attracted by the use of computerised microworlds for educational purposes, as in the learning-by-discovery environment of turtle graphics (Papert, 1980). Essentially, microworlds are highly circumscribed domains, (Papert's original work was in the field of teaching geometry to children), in which participants are given the tools for discovery and an environment that encourages exploration. Crucial to the success of educational microworlds is the delivery of immediate feedback, whereby cause and effect are experienced in a practical, interactive way. This paradigm was important to the remediation rationale (see Chapter 3); its main contribution to the assessment phase was to suggest a reversal of the usual passive role of the patient in the test situation.

The possibility of adopting or developing an iconic language as a means to probing natural language breakdown was rejected on the basis of the results of Steele et al. (1989) and the findings of Funnell and Allport (1989). The latter study found no communicative advantage to using a logographic system - Funnell and Allport's two patients failed to handle symbols for closed class words and had symbol ordering difficulties. If a Blissymbol could be used, so too could the corresponding written English word.

The idea of a miniature artificial language as a vehicle for exploring aphasic language dysfunction was strongly considered for this study. However, in view of the difficulty such patients encounter with natural language, it was considered inappropriate to attempt to teach a nonsense language. Firstly, there was a risk of increasing confusion, and secondly, considerable doubt as to whether difficulty acquiring a new 'language' after brain damage would shed light on dysfunctions in the original one. Thus, the idea of a miniature artificial *world* emerged. It was decided to adopt the idea of miniaturisation, but to apply this to a real world vocabulary and sentence structures. Thus the vocabulary and grammar used were those of natural English, but the scenarios were artificial, the protagonists being three fictitious characters, *ball*, *box* and *star*. These every-day names were chosen in preference to the geometrical ones of Schwartz et al. (1980) in the hope that they would be friendlier and more accessible. In addition, their use was extended in a very important way, both for the creation of reversible scenarios and for lexical economy; in the present microworld, ball, box and star can be *animate* or *inanimate*, allowing the construction of sentences such as: *The ball gives a box to the star* and *The box paints a star*.

The vocabulary for the SST is given in Table 1 below. These are the nouns, adjectives and verbs that were pre-tested for recognition. Determiners could not be tested in isolation and it was decided to exclude function words of interest (e.g. prepositions) at this stage, since I did not necessarily want to screen out subjects with lexical selection problems for these.

| Nouns | Adjectives | Verbs |
|---------------------|---------------------------------------|---|
| ball box star | blue red yellow big small | draws gives holds paints thinks |

Table 1. The microworld vocabulary.

The vocabulary chosen had the following properties important for the construction of test materials. All the words were short and in common usage.²⁷ It was unlikely therefore that patients suffering predominantly syntax processing difficulties would have problems recognising them. Graphical representations of the nouns and adjectives were easy to distinguish by their shapes, colours and sizes. The verbs comprised two semantically similar pairs, *draws/paints*, *holds/gives* and one more abstract verb, *thinks*. The verbs were all two-argument verbs, except *gives* which takes three arguments (*A gives B to C*). The particular nouns and verbs selected were chosen such that sentences constructed using them would be fully reversible with minimal pragmatic bias. The semantically similar pairs allowed the specifics of verb meanings to be checked against a verb close in meaning and also permitted me to verify that the visual-perceptual processes were capable of the corresponding discrimination. Thus, if a patient knew what *draws* meant compared with *paints*, I could be satisfied that he really was in possession of the full meaning of this verb in isolation, and furthermore, if he could point out the difference confronted with a picture of each, I could be confident that he was suitable for a picture-matching assessment. The verb *gives* introduced a three-argument functor to allow the manipulation of subject, object and indirect object and the verb *thinks* was chosen as a more abstract concept, to test whether aphasics' grasp at the two-argument level would suffer with increased abstraction.

²⁷ It was not necessary to establish relative frequency of use formally, since I was establishing a highly restricted domain of discourse in which subjects would be immersed after demonstrating single-word recognition.

2.3 INTERFACE DESIGN

Having selected a microworld vocabulary, the next consideration was the design of the human-computer interface (HCI). Robust interfaces for naive users are notoriously tricky to engineer. Aphasic clients present a tougher than usual challenge, since the interface must cater for hemiplegic users with impaired language and poor motor control. In view of these requirements a picture-matching paradigm with four pictures per target sentence, as in the Test for Reception of Grammar (TROG) by Bishop (1982), seemed the most appropriate assessment method. However, picture-matching tests have been criticised on the grounds that a constrained solution space limits the errors that can be made (Caplan, 1985; Grodzinsky and Marek, 1988). This is inevitably true and calls for very careful design of distractors, and Caplan is certainly correct in his view that,

Simply considering the number of sentences a patient interprets correctly as an index of his ability to understand a particular structure will often not reveal the details of the structures that he assigns and interprets. (Caplan, 1987b, p.142).

These objections were addressed as far as possible by a multi-layered approach to assessment, eliminating first, errors that could arise from the computer environment itself, then from the single-word vocabulary. Following the SST fuller assessment tests for verbs and prepositions only were devised, and finally, the remediation phase was heavily diagnostic, offering the opportunity to explore the causes of errors in yet more detail. A lot of thought was given to the provision of a 'don't know' option in the HCI; however, it was decided that this would probably be counter-productive, since patients might prefer to play safe than risk being wrong. In fact, when patients think they do not know, they often do, and vice versa, a fixed choice test shows this. The important thing to notice is that with four candidate pictures there is a 0.25 probability of guessing the right picture by chance, thus the probability of returning a high score by chance (on a test of say 40 items), and repeating the performance on re-testing, approaches zero. In fact, spurious accuracy was not found to be a problem. An important point in this connection is that while correct answers can occasionally be lucky guesses, errors are almost²⁸ always 'really' wrong, reflecting either the patient's firm belief about

²⁸ The only exception being a mistake of the sort arising when an incorrect window is inadvertently activated as the cursor is dragged from the correct window to the confirm button to invoke the next screen, and that the error is not rectified. This is *extremely* rare.

the meaning of the sentence, or his best guess. Close attention to error patterns is thus very diagnostically informative.

The microcomputer equipment used for this project was selected in the expectation that speech therapy clinics, on upgrading from the BBC model B machines which were ubiquitous in the 1980s, would be likely to choose the IBM PC standard. Thus all the software runs on an IBM PC compatible 286/12 machine with 640 kilobytes of RAM, a 20 megabyte hard disc and a VGA colour monitor. Likewise, cost and availability as well as patients' needs were taken into account in deciding on a mouse-driven interface. A mouse is a small device which fits comfortably into the palm of one hand and is equally suitable for left or right-handed use. It has a rotatable ball on the bottom, which when rolled across a desk surface, controls a cursor on the VDU screen. Having steered the cursor to the desired screen location, the user can invoke the associated function (or in this case register his picture choice), by clicking²⁹ a button³⁰ on the upper surface of the mouse. The interface software designed for the SST is, what is called in software engineering, a shell. In the present context this means a reusable program which takes care of screen display and data collection, and which can run with different graphics and text files (the assessment pictures and sentences). Thus all the assessment programs used the same shell. Apart from being good software engineering practice, the use of a common shell presented a uniform interface to the user, so that operational skills acquired by patients were transferable from one program to the next.

The most elegant assessment shell was considered to be a black background with four rectangular windows (dimensions 3.75" by 2.25"), one for each of the candidate pictures, and with the target sentence displayed boldly beneath them in yellow. Figure 1 illustrates the layout by means of a typical SST screen.

It was necessary to provide a mechanism for making a choice and also for changing it, the latter being a particularly important facility for those with poor motor control. To select a picture, the subject simply moved the cursor to anywhere inside the chosen window and clicked either mouse button, whereupon

²⁹ Clicking is the action of depressing and releasing with one finger. Single clicking is the only action required of the aphasic users and their 'click speed' is immaterial.

³⁰ The term 'button' is used in this field, both to denote the finger switches on the upper surface of the mouse, and to refer to screen locations which are 'clickable', that is, which when selected with the mouse invoke an associated function.

the window frame was highlighted in red.³¹ To change his mind the subject clicked on an alternative window, activating that frame and de-activating the previous one. The choice recorded for any sentence was the identification of the picture in the highlighted window at the time the circular confirm button (bottom left of Figure 1) was clicked to invoke the next sentence. The response latency, measured in hundredths of a second, was the time taken from onset of a screen display to selection of the final window choice, *excluding* the additional time taken to reach the confirm button.

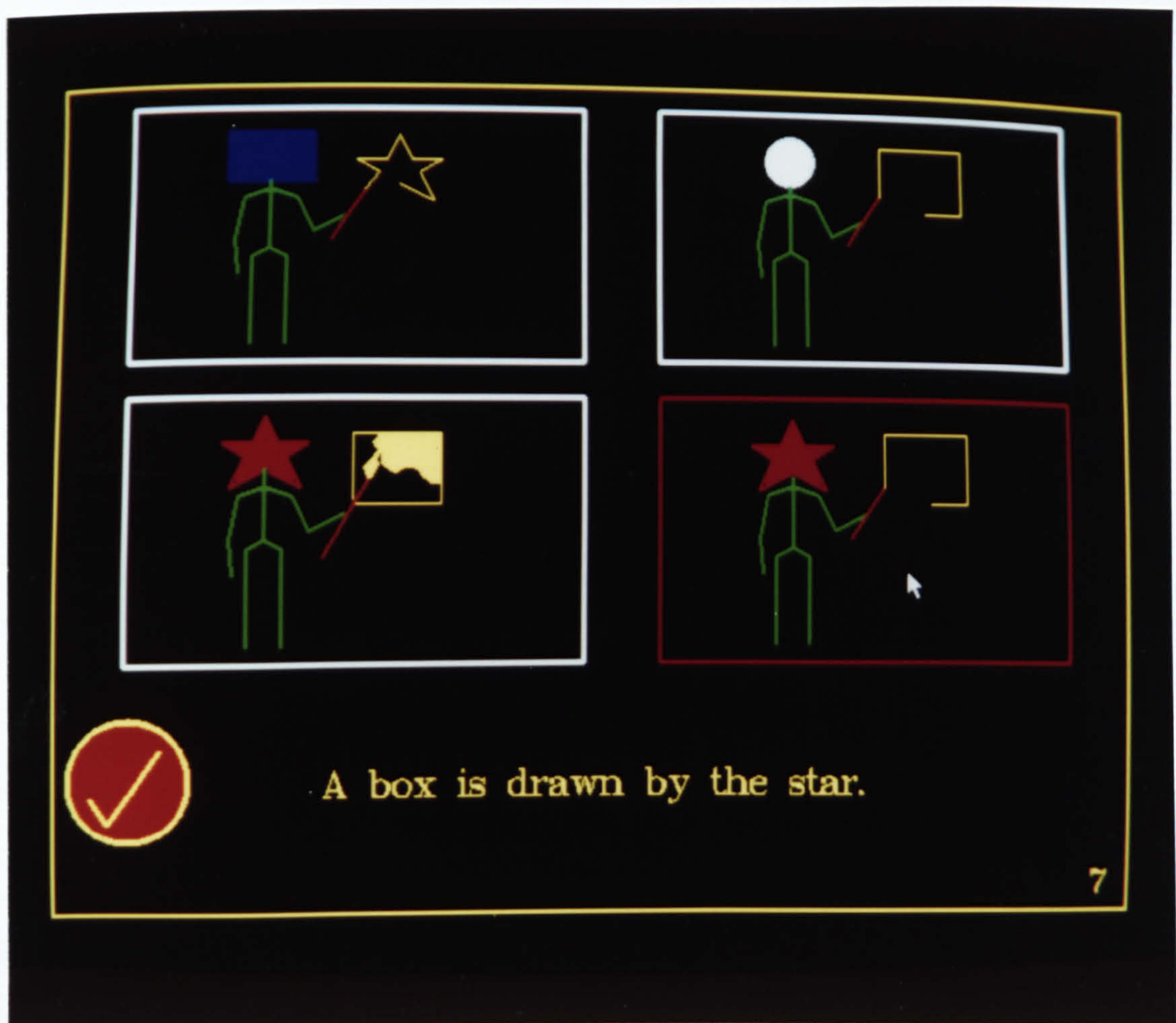


Figure 1. Typical screen from the Syntax Screening Test.
(This figure is in colour)

³¹ Early experiments with a prototype interface revealed that most subjects preferred a quiet interface to one that reinforced their actions with beeps.

In addition to timing responses, the software automatically recorded the identification of the picture chosen and the window position at which it was displayed (since picture positions were randomised). The purpose of the last facility was to help in the identification of any candidate with visual neglect of one or more quadrants of the screen, such a patient would not be suitable for computerised assessment and should be eliminated at an early stage. It is worth pointing out that the interface is convenient for operation by left or right-handed users, but since the majority of aphasics are left-handed users, I paid special heed to sinistrality in the design. Thus the confirm button would have been positioned more naturally at the bottom right for right-handers. In addition to the interface features visible in Figure 1, there was a (normally) invisible pop-up menu situated out of the aphasics' line of operation, at the bottom right of the screen. This could be called up by the clinician. The main purpose of the menu was to provide the facility of a pause,³² where program execution was temporarily suspended. The number of pauses taken and total pause time were recorded and the total elapsed time for test completion included pauses, but a pause was *not* added to the response latency of the stimulus on screen at the time.

2.3.1 THE INTERFACE TEST

In order to determine whether the proposed interface would be suitable for aphasic users, a version was created in which only the operational characteristics, i.e. the visual scanning and window selection were tested. The Interface Test program presented patients with 20 non-linguistic stimuli; each screen comprised four windows, three empty ones and a red rectangle, 1" by 0.75", placed in the centre of the fourth. The window position of the rectangle was randomly generated for each screen. Patients were required to use the mouse to move the cursor anywhere inside the window containing the red rectangle and to indicate their choice by clicking the mouse button. The program recorded each subject's score out of 20 and mean response latency. The Interface Test was given as a preliminary warming up exercise on each of the three occasions that the SST was administered, thus it was possible to monitor the durability or improvement in mouse skills over a period of months when there was no opportunity to practice between sessions. Only one patient (P1) had previously used a mouse. Before the

³² This facility, although a necessary feature, was used as sparingly as possible. Since patients were largely in control of their own assessments, with the clinician as observer, the onus was on them to decide to take a rest, although of course it was sometimes tentatively suggested!

first test, patients were instructed in the use of the mouse and given as much time as they needed to master it. On subsequent occasions they were allowed a short dummy run to refamiliarise themselves with the device before responses were timed. The accuracy of responses was 839/840 (14 patients over 3 test sessions), showing that the HCI and the patients were coping very adequately with each other. Table 2 gives the mean reaction times, in seconds, of the 14 patients finally selected for this study (patient details are given in Appendix 1). Inter-test gaps ranged from 4 weeks to 16 weeks, as shown in Table 13. No candidate was eliminated at the Interface Test stage.

| | Test 1 (secs) | Test 2 (secs) | Test 3 (secs) |
|-----|------------------|------------------|------------------|
| P1 | 1.84 | 2.15 | 2.54 |
| P2 | 25.39 | 16.21 | 5.26 |
| P3 | 3.09 | 3.55 | 3.85 |
| P4 | 2.80 | 2.95 | 3.83 |
| P5 | 15.37 | 7.26 | 2.17 |
| P6 | 23.47 | 7.56 | 5.45 |
| P7 | 19.57 | 12.83 | 6.02 |
| P8 | 12.06 | 7.24 | 4.55 |
| P9 | 4.75 | 2.57 | 1.76 |
| P10 | 7.78 | 2.70 | 1.98 |
| P11 | 4.63 | 4.61 | 4.29 |
| P12 | 11.11 | 9.66 | 7.29 |
| P13 | 7.23 | 3.79 | 2.37 |
| P14 | 3.71 | 2.89 | 2.98 |
| All | 10.20 | 6.14 | 3.88 |

Table 2. Mean response latencies (secs) of the aphasic subjects on the Interface Test.

The aphasics' mean reaction times to the Interface Test are reproduced in full³³ because, as far as I am aware, there are no comparable data available elsewhere. The figures are interesting in two main respects. They show that mouse skills not only endured, but improved between isolated interaction sessions and that all patients, no matter how severe their initial difficulties, eventually mastered the mouse. As an illustration, P2 on her first appointment, took around twenty minutes of tortuous effort before she could control the mouse well enough to undertake the Interface Test. This patient and possibly also P6 and P7 could easily have been rejected prematurely as having limb apraxia too severe for the

³³ Throughout the thesis as much detailed data as possible is included since there is no comparable source existing and it is hoped that the results may trigger further work.

motor control required. In fact all the patients continued to progress in competence beyond the formal testing of interface skills, until even the slower ones attained semi-automatic mouse control.³⁴

Forty-five normal subjects, mostly college employees, were recruited to validate the SST and thus were given mouse instruction followed by the Interface Test as an introductory exercise. The sample comprised 15 subjects in each of the age bands 25..39, 40..54, 55..69. Within each age band there were males and females in three educational classes (but not necessarily equal numbers of these two subgroups in each band),³⁵ thus the subjects ranged from heads of departments, to kitchen staff with no post-school education. Appendix 2 summarises the salient characteristics of the normal group. The conditions under which they took the test were the same as for the aphasic subjects' first test, except that the normal group were asked to operate the mouse with their non-preferred hand. Only four subjects had used a mouse before. The accuracy rate for the normal group was 899/900 and the mean response latency was 2.25 seconds with a standard deviation of 0.97 seconds. (Mean response latencies by ascending order of age class were 1.66, 2.21 and 2.91 seconds). From these figures we see that the aphasics were comparable to the normals in accuracy, and after two exposures to the system, were achieving very respectable operating speeds. From this comparison it is clear firstly, that the interface used for the other assessments reported in this study was extremely reliable in the hands of naive users (subjects could use it consistently to indicate their window choices), and secondly, that the proportion of the (often very long) aphasic reaction times to subsequent sentence processing tasks, attributable to mouse-movement, was very small indeed.

³⁴ As an indication of the durability of interface skills, P2 was given the Interface Test in May 1991, five months after she had last used the computer. She was given no familiarisation whatever and from a 'cold start' returned a mean reaction time of 3.15 seconds.

³⁵ Because of the composition of the College population and the desire to recruit more basic education subjects than others, the older age group has a higher proportion of these than the other groups. However, it also contains 4 members of higher academic status than in any of the other groups (3 heads of department and the college librarian), perhaps providing compensation.

2.4 THE LEXICAL TEST

A second preliminary test, the Lexical Test, was taken by the aphasic subjects on each occasion they were given the SST, and by the normal subjects in their single test session. The Lexical Test was always placed in logical sequence, after the Interface Test and before the SST. The Lexical Test used the same shell as the Interface Test, but tested the single-word vocabulary of the microworld. Thus subjects were confronted with a single target word and four candidate pictures, the correct one and three distractors. The Lexical Test was designed with several objectives in mind:

- a) To check the computer graphics created for the microworld for recognisability.
- b) To eliminate any aphasic subjects unable to discriminate the colours used as adjectives.
- c) To check aphasic candidates' single-word recognition for the microworld lexicon.
- d) To eliminate any aphasic subjects with severe visual scanning problems.

Evidence for point a) was sought from normal subjects. If they found the microworld concepts and depictions acceptable and unambiguous, then the system was deemed suitable for the aphasics, otherwise it was altered and re-tested. While severe difficulty with point d) should have emerged at the Interface Test stage, it was possible that a patient might find a single stimulus in a search space of three empty windows and one target window, yet fail with three competing distractors. Additionally, the Lexical Test required fairly fine visual discrimination especially in distinguishing the semantically similar verb pictures, thus it was more likely that scanning or visual processing problems would be found at this stage. The contents of the Lexical Test are summarised in word form in Table 3.

Most of the contrasts should be clear from the verbal descriptions. The first three screens showed large green shapes. *Cross* was introduced as another common shape that might be semantically confused with any of the others, or phonologically with *box*. Items 4..6 flooded the windows with appropriate colours.

Items 7 and 8 were similar in that, in the case of screen 7, a target *big* (green, box) was presented with a *small* (green, box), a (small green) *ball* and a (small) *red* (box). The red distractor was very visually appealing and could provoke an abandonment of the lexical target in favour of an odd-one-out strategy. Thus apart from testing the target adjectives, items 7 and 8 were useful in ensuring that the reading task was firmly understood. Items 9..13 introduced the animate microworld characters and thus tested the abstract and artificial aspects of the microworld. Figure 2 shows the first of these animate scenarios. For each screen, subjects were required to read the target word and use the mouse, as before, to select the window containing the matching picture.

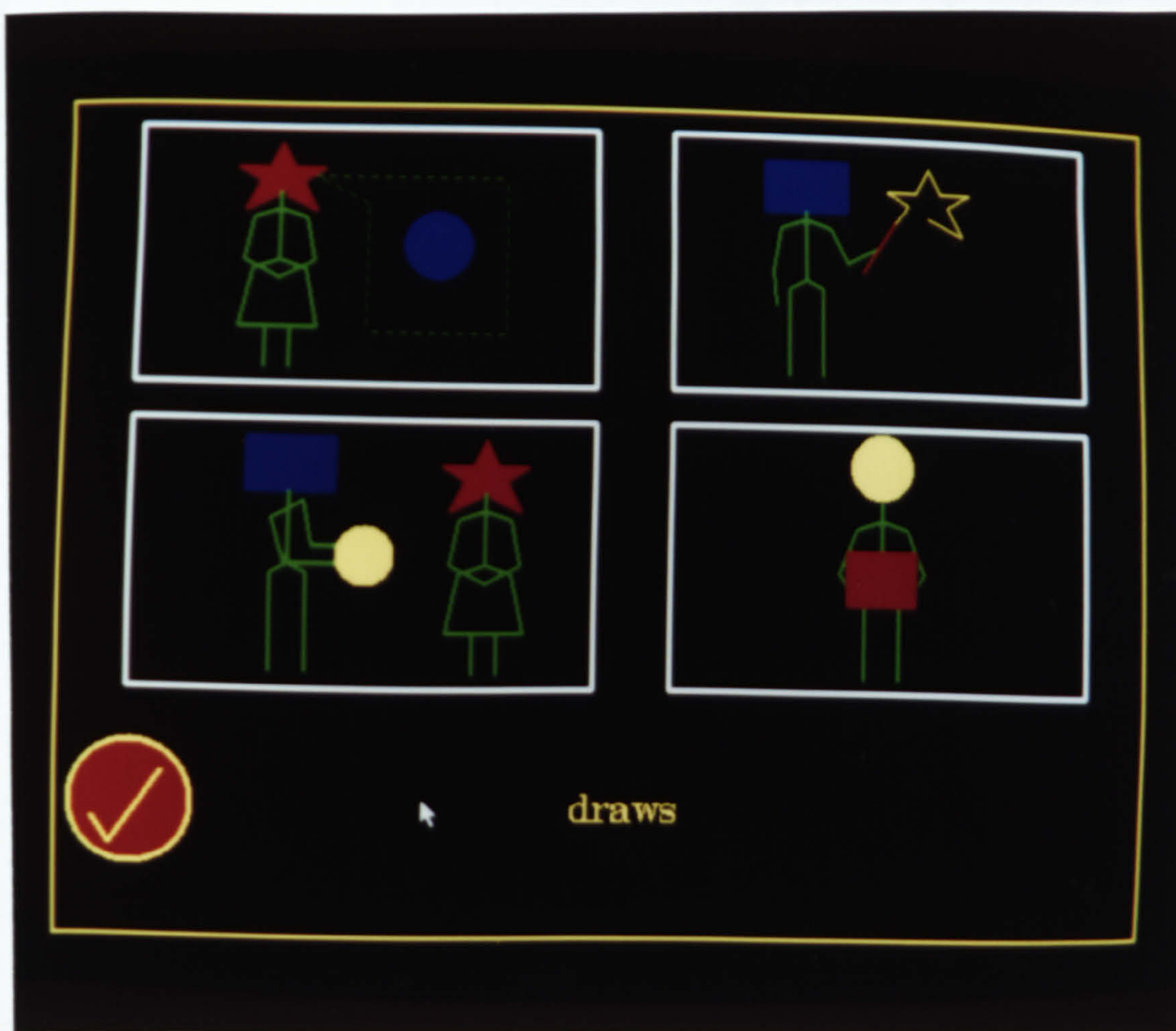


Figure 2. A Lexical Test screen for target word '*draws*'.
(this figure is in colour)

| Item no. | Target word | Distractors | | |
|----------|-------------|-------------|--------|--------|
| 1 | ball | box | star | cross |
| 2 | box | ball | star | cross |
| 3 | star | box | ball | cross |
| 4 | red | blue | yellow | green |
| 5 | blue | red | yellow | green |
| 6 | yellow | red | blue | green |
| 7 | big | small | ball | red |
| 8 | small | ball | big | red |
| 9 | draws | holds | gives | thinks |
| 10 | paints | holds | draws | thinks |
| 11 | thinks | holds | gives | paints |
| 12 | gives | holds | draws | thinks |
| 13 | holds | gives | draws | thinks |

Table 3. Composition of the Lexical Test.

The Lexical Test was taken by the 45 normal subjects, (their details appear in Appendix 2). No feedback was given until the test was finished. The results are summarised in Table 4. The accuracy rates were high, but it is noteworthy that *all* the errors were made on target verbs, with more trouble being experienced by the older, less educated subjects.

| | Overall | 25..39 | 40..54 | 55..69 |
|------------|-----------|-----------|-----------|-----------|
| Accuracy | 96.24% | 98.97% | 97.43% | 92.31% |
| No. errors | 22 | 2 | 5 | 15 |
| Mean RT | 4.57 secs | 3.87 secs | 3.90 secs | 5.94 secs |

Table 4. Lexical Test results overall and by age band for the normal group.
(n=195 for each age band)

On questioning them after the test, it turned out that the sudden appearance of the target verb *draws* (item 9) and the unfamiliar stick characters (see Figure 2) caused confusion which was compounded by the alien computer environment. One said that she did not know what to do, because as far as she was concerned, all the pictures had been *drawn* before her very eyes! One or two fanciful explanations were proffered, such as the lady who matched the target verb *thinks* with the picture of *holds* because, "He's *thinking* about throwing it ?".³⁶ If subjects

³⁶ This was eclipsed by P12, who explained his choice of *gives* to the target word *thinks* by saying, "He has got his brain in his hand and he is putting something into it". Having heard some of the 'normal' explanations, I regarded this one as not too outrageous a notion for a survivor of

had made an error or errors, I re-ran the Lexical Test and discussed the verb section before proceeding to the SST. On having their errors explained, all the normal subjects understood the pictorial representations of the verbs without trouble. Given the fact that most of the normal subjects made no errors at all, and those who did readily understood the graphics on second exposure, it was decided that there was no need to modify the pictures. However, on the basis of normal performance it was predicted that aphasics might need more acclimatisation to the system in view of their extra difficulties both with verbs and with abstraction.

The aphasic subjects took the Lexical Test during the three test sessions described in Section 2.3.1 above. Their results are given in Table 5.

| | Test 1 | | Test 2 | | Test 3 | |
|------|-------------------------|-------------------|-------------------------|-------------------|-------------------------|-------------------|
| | No. correct (max=13) | Mean RT (secs) | No. correct (max=13) | Mean RT (secs) | No. correct (max=13) | Mean RT (secs) |
| P1 | 10 | 10.62 | 13 | 9.15 | 13 | 12.27 |
| P2 | 10 | 33.09 | 13 | 26.91 | 12 | 15.02 |
| P3 | 9 | 14.88 | 13 | 13.18 | 12 | 11.00 |
| P4 | 12 | 13.16 | 12 | 9.40 | 13 | 9.66 |
| P5 | 13 | 17.95 | 13 | 12.53 | 13 | 5.03 |
| P6 | 8 | 23.01 | 11 | 17.30 | 9 | 18.05 |
| P7 | 11 | 29.24 | 11 | 11.12 | 12 | 8.01 |
| P8 | 13 | 40.62 | 12 | 17.20 | 13 | 12.81 |
| P9 | 13 | 20.46 | 12 | 6.60 | 12 | 8.25 |
| P10 | 11 | 6.08 | 12 | 4.25 | 12 | 4.07 |
| P11 | 11 | 15.78 | 13 | 23.01 | 12 | 9.95 |
| P12 | 11 | 49.48 | 13 | 61.14 | 11 | 31.76 |
| P13 | 12 | 20.16 | 13 | 23.30 | 13 | 7.87 |
| P14 | 11 | 10.05 | 13 | 8.07 | 13 | 6.47 |
| mean | 11.07 | 21.76 | 12.43 | 17.37 | 12.14 | 11.44 |
| % | 85.16% | | 95.6% | | 93.41% | |

Table 5. Lexical Test results for each aphasic subject and the patient cohort.

After self-administering the test in the usual way, with no feedback, while performance statistics were recorded automatically, the aphasics were given as much help and as many re-runs as necessary to achieve flawless performance before being allowed to continue to the SST. One candidate was eliminated at

neurosurgery! However, it turned out to be an early indication of visual processing problems which became more apparent later on (see section 6.1.2).

this stage without proceeding to the SST. She could only identify the colours correctly, having severe perceptual processing problems for whole pictures and an inability to understand the microworld environment. In no case did the Lexical Test elicit persistent single-word difficulties in the 14 subjects eventually recruited, neither were any visual scanning problems evident.

On the whole the aphasic group performed well on this test. Even P6, who shows up as noticeably weak, seemed to have mastered the picture-matching of the single words on each occasion, after some help. There was nothing apart from this one dip in the accuracy data at this stage to distinguish patients who later turned out to be very weak at the sentence processing tasks, or those who failed to respond to therapy. Turning to response latencies, the aphasics were, as one might expect, much slower than the normal group. By test 3, they were still operating at more than twice the normal group's mean even after discarding the outlier P12 (normals, 4.57 secs; aphasics, 9.88 secs). The reader will notice from Table 5 (p.78) that P12 was the slowest interface operator by a large margin in every test session. As each pair of interface and lexical tests were taken in quick succession, we may assume, in P12's case, that not more than about 7 seconds of each lexical response latency can be accounted for by mouse movement (c.f. Table 2). P12's excessively long response times persisted throughout the study: there will be reason to mention them again and their cause is discussed in section 6.1.2. It is sufficient to notice here that, with benefit of hindsight, I would recommend exploring the cause of response latencies of this size further before contemplating microworld therapy; however, it was necessary to work with P12 to find this out.

2.5 THE SYNTAX SCREENING TEST (SST)

The SST was created with the following objectives in mind:

- a) To develop a modular test for sentence processing founded on the sorts of linguistic impairments that previous research in agrammatism had shown to be problematic.
- b) To provide an efficient method of selecting patients with deficits in verb and preposition processing.

- c) To develop a test capable of highlighting patterns of spared and impaired linguistic functions.
- d) To discover what the relative difficulties of the various linguistic functions might be for normal and aphasic subjects.
- e) To develop a test with the preceding features, short enough to be completed by an aphasic subject in a single session.
- f) As a result of e), to be able to use the SST for monitoring stability of performance in candidate patients, for a period prior to onset of treatment.

In pursuit of these aims, six linguistic functions were selected for inclusion in the SST; verbs, adjectives, scope and quantification, pronouns, prepositions and morphology. On the basis of the clinical experience of colleagues in administering the 80 item TROG to aphasic subjects, it was decided to limit the number of sentences per module to 7, thus giving the SST 42 target sentences. The lexical items tested within each module and the way that sentence complexity was varied will be clear from the target sentences shown in Table 6. The digits to the right of each sentence are included for interest. They indicate by rank (1 being the easiest) the relative complexity of the sentences within each module as measured by the mean reaction times of the normal group. Obviously, the linguistic categories are not mutually exclusive; for instance, verbs were necessarily used in sentences designed to test pronouns. However, the contrasts of interest in each case were isolated by the careful use of distractors, for example, in sentence 26 the reflexive pronoun *himself* was the item of interest in the target sentence, the verb *thinks* simply provided a mechanism for testing it:

target: The star thinks of himself.
distractors: He (box) thinks of the star.
 The star thinks of her
 The star thinks of herself.

| Item no. | Target sentences | Rank |
|----------|--|------|
| | verbs | |
| 1 | The box draws a star. | 2 |
| 2 | The box is drawn by the star. | 1 |
| 3 | The box gives a star to the ball. | 4 |
| 4 | It is the ball that gives a box to the star. | 3 |
| 5 | The ball paints a box and thinks of the star. | 5 |
| 6 | The box that the ball paints holds a star. | 7 |
| 7 | The star paints the box that the ball holds. | 6 |
| | adjectives | |
| 8 | The red box. | 2 |
| 9 | The big blue star. | 1 |
| 10 | The small red ball and the big yellow box. | 4 |
| 11 | The small box and the big star are yellow. | 6 |
| 12 | The box, the ball and the star are big. | 3 |
| 13 | The star that is in the big box is blue. | 7 |
| 14 | The star in the ball is small and red. | 5 |
| | scope and quantification | |
| 15 | All the balls are blue. | 1 |
| 16 | Some of the stars are yellow. | 2 |
| 17 | None of the balls is red. | 3 |
| 18 | Only the box is red. | 4 |
| 19 | The star is blue and the box is not yellow. | 5 |
| 20 | Only the star and the box are not blue. | 7 |
| 21 | All but the big blue box are yellow. | 6 |
| | pronouns | |
| 22 | She draws. | 5 |
| 23 | She thinks of him. | 4 |
| 24 | The ball has a red star in it. | 1 |
| 25 | He thinks of them. | 2 |
| 26 | The star thinks of himself. | 3 |
| 27 | They give the ball to her. | 7 |
| 28 | The box paints itself. | 6 |
| | prepositions | |
| 29 | The star is in the ball. | 3 |
| 30 | The ball is under the box. | 1 |
| 31 | The star is behind the box. | 2 |
| 32 | The box and the ball are above the star. | 5 |
| 33 | The star is between the ball and the box. | 4 |
| 34 | The ball is in the star that is under the box. | 6 |
| 35 | The box behind the ball is under the star. | 7 |
| | morphology | |
| 36 | The boxes. | 1 |
| 37 | The balls and the stars are blue. | 3 |
| 38 | The ball is bigger than the box. | 2 |
| 39 | The star is the smallest. | 7 |
| 40 | The star painted the box. | 4 |
| 41 | The ball's box is red. | 5 |
| 42 | The ball's box is bigger than the star's. | 6 |

Table 6. Target sentences of the Syntax Screening Test.

Within-module rankings are by mean reaction times of the normal subjects, 1=easiest.

Lexical distractors were included only for the first two sentences of each module³⁷ (lexical distractors were pictures involving nouns not mentioned in the target sentence, for all modules except pronouns, where the substitution was of an incorrect verb). Lexical mistakes should not have occurred following successful performance on the Lexical Test, however, a small number of lexical distractors were included in case lexical errors were induced in the context of sentence processing. Appendix 3 gives as full an indication as words allow of the SST distractors.

The interface presented to users was exactly the same as for the Interface Test and Lexical Test, so subjects were thoroughly familiar with the operation of the system by the time sentence processing tasks were introduced. Each sentence was displayed with four candidate pictures, the correct one and three distractors (see Appendix 3). Some of the picture sets were entirely inanimate, for example all the adjectives, scope and quantification and prepositions. Ball, box and star characters performing various activities were used to convey the verb set and some of the morphological contrasts. The verb *thinks* was portrayed by the cartoon-like convention of a perforated 'think box' emanating from the head of the agent, and containing a depiction of the thing, person or scenario thought about. The pronouns were handled by creating a female body which could be attached to any of the head shapes, and which was distinguished from the stick 'men' by the presence of a skirt and more feminine stance, instead of simply two match-stick legs.

The computerised SST did *not* present the target sentences in the sequence shown in Table 6. To avoid subjects becoming sensitive to the linguistic contrasts of interest, as they might in a module by module presentation, the sentences were firstly ordered within modules intuitively, simplest first (the ordering in Table 6),³⁸ so that subjects would be eased into the test. The presentation algorithm selected randomly from among the first sentences in each module until all had been presented, then moved on to all the second sentences and so forth.³⁹

Since the algorithm was the same as for the preceding interface and lexical checking programs with respect to the random allocation of the four candidate pictures to windows, the reader can imagine the high degree of variability

³⁷ After the fashion of Bishop (1982).

³⁸ These intuitions can be readily compared with the ordering later obtained from the sample of normal subjects. That the two are not identical is of no consequence.

³⁹ I am grateful to Professor Andrew Ellis for this idea.

possible between runs. Apart from preventing subjects from developing 'module mindsets', it was hoped that this presentational mechanism would minimise familiarity due to repeat-testing in the aphasic subjects.

2.5.1 THE PERFORMANCE OF NORMAL SUBJECTS

The 45 normal subjects whose performances on the Interface Test and Lexical Test were reported above, were given the SST as the third and final assessment in their single test sessions. The SST was self-administered by the subjects with myself a silent observer throughout. The normal subjects were not told of the pause mechanism, since my experience with volunteer subjects during system development showed it to be unnecessary. All subjects were given the same instructions, namely that instead of single words, they would now see a whole sentence beneath the four pictures. They were told to read the sentence carefully and select the picture that matched it. They were told to pay close attention to the pictures since the foils were cunningly devised. Again, they were told that accuracy was more important than speed.

The results of the normal group are summarised in Table 7, showing performance for the whole group by age and educational category as detailed in Appendix 2.

| | Test completion time ⁴⁰ (minutes) | | | Mean no. errors | Mean % correct |
|------------|---|------|------|--------------------|-------------------|
| | Mean | Min | Max | | |
| ALL | 5.63 | 2.68 | 9.42 | 2.78 | 93% |
| Advanced | 4.89 | 2.70 | 8.12 | 1.07 | 97% |
| Intermed. | 4.48 | 2.68 | 7.03 | 2.40 | 94% |
| Basic | 6.76 | 4.82 | 9.42 | 4.25 | 90% |
| age 25..39 | 4.49 | 2.68 | 9.23 | 1.93 | 95% |
| age 40..54 | 5.82 | 3.16 | 9.42 | 2.13 | 95% |
| age 55..69 | 6.59 | 4.90 | 9.34 | 4.27 | 90% |

Table 7. Performance of the normal group on the Syntax Screening Test.

⁴⁰ These times are derived from the sums of the response latencies. Thus the total elapsed time from test start to finish would be slightly longer. It was only later, on realising that total time taken would be a useful clinical measure for aphasics, that the software was enhanced to include this facility. In order to estimate *total* time taken by the normal subjects, it would be practical to add about 1-2 minutes to the values shown here.

In terms of validating the SST, two key points emerged from Table 7. Firstly, the overall success rate was very high, and secondly, the times taken were modest. Both these points boded well. It will also be noticed that, as might be expected, speed and accuracy both degraded with lack of formal education and inversely with age. For example, the fastest of the basic education subjects attained the mean speed of the advanced education group, and there was a doubling of the mean number of errors made by individuals in the 55..69 age band compared with the previous band. Clearly, one would not want to pursue inter-group comparisons on this data set too far, since it was a small sample. A further point obvious from Table 7 is that the advanced and intermediate education groups were reasonably homogeneous, but that the basic group stood apart.⁴¹ Wanting to bias recruitment towards the 'man in the street', 20 basic subjects, 10 intermediate subjects and 15 advanced subjects were selected, the expectation being that the intermediate group might be closer in performance to the basic group than to the advanced one. In fact, it seems that the bias might have been slightly in the other direction, but this is of little consequence for present purposes because I simply wished to establish that the test was pitched at the right level so that non-brain-damaged subjects could easily do it. However, it was equally necessary to determine that the standard and contents of the test were such that aphasic subjects' performances would be distinguishable. Before proceeding to that, there are other observations to be made on closer scrutiny of the performance data.

It was of interest to know what the relative difficulty of the six linguistic modules was for the normal subjects. A good indication was obtained by calculating the mean response latencies for each, and ranking the results. Table 8 reveals that there was considerable uniformity in the ranking of modules; the column headings are arranged in descending order of overall difficulty and the rankings for each sub-group are provided.

This result is of interest, for it is an early indication that modularising assessment design in this way may lead to new and meaningful indices of cognitive effort.⁴² Further, the two functions most commonly cited in connection with agrammatic patients were found to be unequivocally first and second in order of difficulty for

⁴¹ The basic subjects had no further education since leaving school, the intermediate ones had sub-degree level qualifications ranging from secretarial to HNC and the advanced subjects had at least one degree.

⁴² By this we do not necessarily mean to suggest a simple gradation between one module and the next, but more the potential for dissociation.

this pilot group of normals. Prepositions, my elected second function of study, on the other hand, seemed not to have caused trouble.

| | Verbs | Morp. | Scope | Pron. | Prep. | Adj. |
|-------------|-----------------|----------------|----------------|----------------|----------------|----------------|
| Advanced | 1 | 2 | 5 | 4 | 3 | 6 |
| Intermed. | 1 | 2 | 3 | 4 | 6 | 5 |
| Basic | 1 | 2 | 3 | 4 | 5 | 6 |
| age 25..39 | 1 | 2 | 3 | 6 | 4 | 5 |
| age 40..54 | 1 | 2 | 3 | 4 | 5 | 6 |
| age 55..69 | 1 | 2 | 4 | 3 | 5 | 6 |
| All mean RT | 11.61 (secs) | 8.62 (secs) | 7.54 (secs) | 7.26 (secs) | 6.78 (secs) | 6.48 (secs) |

Table 8. Syntax Screening Test modules for the normal subjects ranked in order of difficulty according to mean response latencies. (1=hardest)

Despite the very high accuracy of the normal group, it was instructive to examine the data further, to discover whether any particular sentences were especially error prone, and relatedly, if the errors that occurred were clustered at all under distractors, so that there was a common misinterpretation. It could be, for example, that the faster modules, the ones I have called 'easy', in fact produced more errors, and that the 'harder' ones provoked more thought, but were more accurately done for that. Should errors have been clustered under certain distractors, two interpretations sprung to mind; firstly the computer graphics may have been ambiguous, perhaps one of the distractors provided a quite reasonable representation of the sentence, or the salient features of the target picture were not clear. A second possibility was that the sentence in question contained a point of grammar insecure in many normal subjects.

For ease of association with Table 6 above, errors are first of all presented by sentence number. The left-hand column of Table 9 shows a sequential sentence number which matches the same in Table 6, so that the corresponding sentence can be easily retrieved. Readers interested in discovering what the most heavily selected distractors were, are referred to Appendix 3 where the full contents of the SST are described. For example, 10 out of 11 subjects who made an error on sentence 42 (*The ball's box is bigger than the star's*) chose picture 4. In Appendix 3 the three sentences beneath each target sentence correspond to distractors 2, 3 and 4 respectively, thus one finds that 10 subjects failed to attend to the final 's and selected a pictorial representation of *The ball's box is bigger than the star*.

| Item no. | Distractor chosen | | | Total errors |
|----------|-------------------|---|----|--------------|
| | 2 | 3 | 4 | |
| 1 | 0 | 0 | 4 | 4 |
| 2 | 0 | 0 | 2 | 2 |
| 3 | 1 | 0 | 0 | 1 |
| 4 | 0 | 1 | 2 | 3 |
| 5 | 1 | 1 | 13 | 15 |
| 6 | 4 | 5 | 3 | 12 |
| 7 | 0 | 3 | 2 | 5 |
| 8 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 |
| 10 | 0 | 1 | 0 | 1 |
| 11 | 1 | 1 | 0 | 2 |
| 12 | 0 | 0 | 0 | 0 |
| 13 | 0 | 3 | 0 | 3 |
| 14 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 1 | 1 |
| 18 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 |
| 20 | 0 | 3 | 0 | 3 |
| 21 | 1 | 0 | 0 | 1 |
| 22 | 0 | 1 | 0 | 1 |
| 23 | 0 | 0 | 1 | 1 |
| 24 | 1 | 1 | 0 | 2 |
| 25 | 1 | 0 | 0 | 1 |
| 26 | 1 | 1 | 0 | 2 |
| 27 | 1 | 0 | 4 | 5 |
| 28 | 3 | 0 | 2 | 5 |
| 29 | 1 | 0 | 0 | 1 |
| 30 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0 | 0 | 0 |
| 32 | 0 | 1 | 0 | 1 |
| 33 | 0 | 2 | 0 | 2 |
| 34 | 2 | 0 | 1 | 3 |
| 35 | 0 | 5 | 5 | 10 |
| 36 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 |
| 39 | 0 | 1 | 9 | 10 |
| 40 | 1 | 6 | 2 | 9 |
| 41 | 1 | 0 | 7 | 8 |
| 42 | 0 | 1 | 10 | 11 |

Table 9. Total errors per sentence and error types on the Syntax Screening Test for the normal group.
(n=45 for each item)

Table 9 shows that most of the errors were concentrated in sentences 1..7 and 36..42, the verbs and morphology modules. This was interesting in view of the normal group having spent longest on these. Generally speaking the errors consisted of two types, those due to a contrast missed, (e.g. *him/her* (27), *smaller/smallest* (39), *paints/painted* (40)), and those due to the structural complexity of the target sentence (5,6,35). It is worth stressing at this juncture, that with simple errors, one can be fairly certain that the distractor verbalised in Appendix 3 represents the subjects' mental model of sentence meaning; however, with more complex sentence structures, one cannot be sure what the aberrant interpretations were. For example, one third of the normal subjects made an error on sentence 5, *The ball paints a box and thinks of the star*, of these, 13 subjects chose picture 4, *The star thinks of the ball painting the box*. From the picture choice, we cannot know why so many subjects failed to parse the sentence as a straightforward conjunction of actions by the subject, the ball. Thus the verbal descriptions in Appendix 3 are to allow the reader to imagine (or sketch) the candidate pictures rather than to suggest that errors made were due to parsing exactly as stated. To help in consideration of this general point, a screen for sentence 5 is reproduced at Figure 3.

On observing the normal group and speaking to them about the test afterwards, it appeared that many of the older and less well educated subjects found the test genuinely taxing. Where they failed, they did so because they were fully stretched, and not, as can be seen from the response times, that they were eager to beat the clock. The possessive was not well understood, as can be seen from the failure in sentence 41 as well as 42. The only place where it seemed that subjects across the board were weak was in distinguishing comparative and superlative. The graphics were fine, but the subjects (including several in the advanced education group) admitted later that they truthfully had not appreciated the difference between *smaller* and *smallest*, i.e. that superlatives apply to comparisons of three or more objects. Perhaps sentence 39 should be replaced in favour of a different morphological contrast before more general distribution of this program, (normals seem to be able to live without the superlative), but it was not considered crucial before trying the system with aphasics. However, consideration of the few errors made on the reflexive at sentence 28 did result in an improvement to the target picture by way of brightening the paint colour, which made the action of self-painting clearer.

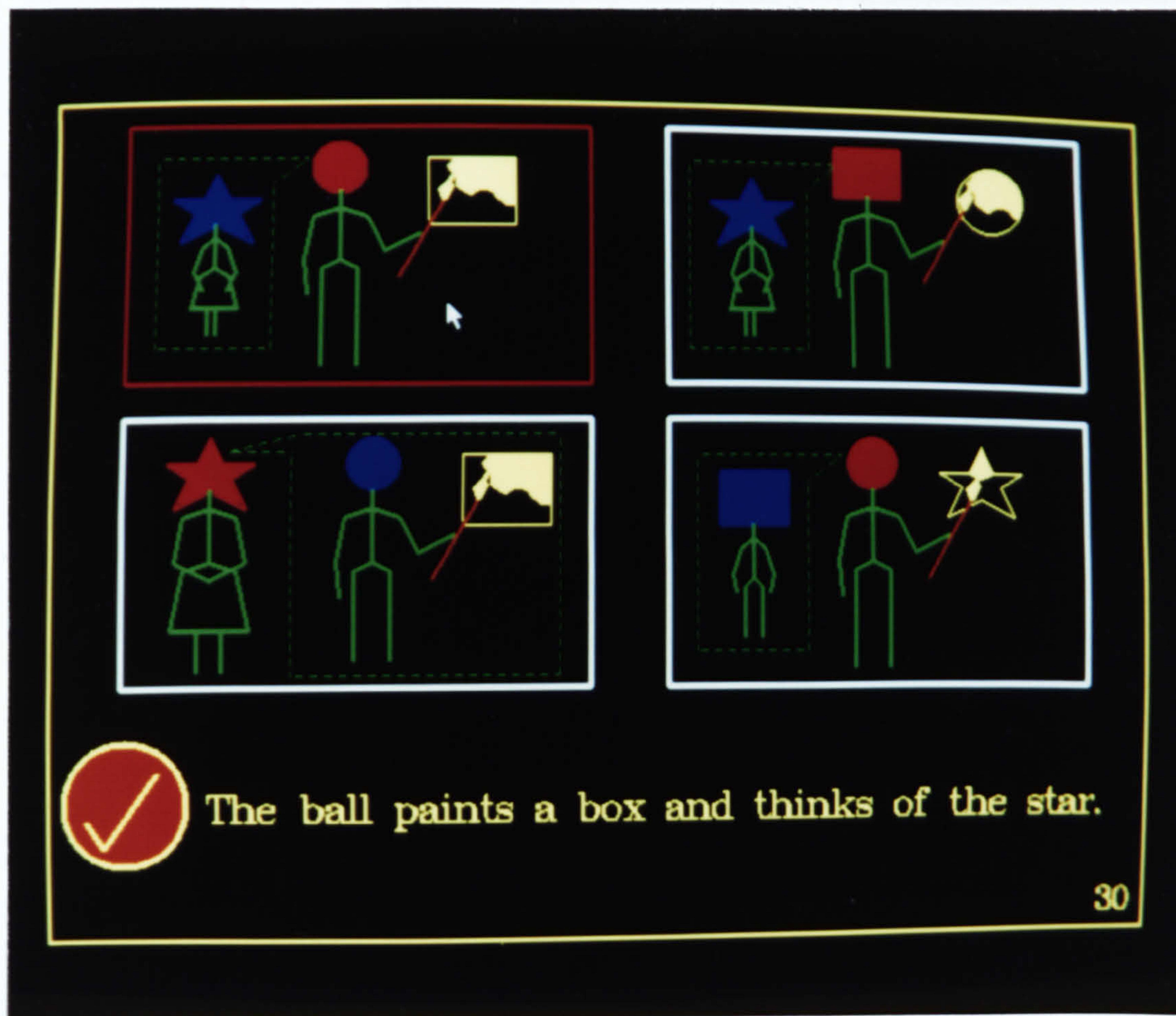


Figure 3. A Syntax Screening Test screen for target sentence 5.
(This figure is in colour)

I have concentrated, naturally enough, on the errors made, but it was also curious to note seemingly complex sentences which elicited almost no errors, for example sentences 20, 21 and 34. Before leaving the normal data, it was informative to sort the individual sentences by mean response latency and look at the total errors made alongside each, since there was reason to suspect that an interesting relationship obtained. Table 10 confirms this; there was a high positive correlation ($r=0.75$),⁴³ between response latency and error rate. From the table one can distinguish the more complex sentences which took more processing time and still elicited errors, from a sentence like number 20, which obviously took some working out, but only 3 subjects failed it. The sentence ordering shown in Table 10 is not proposed as an absolute ranking of sentence difficulty, some relative response times are likely to be artifacts of the order of presentation.

⁴³ The Pearson product-moment coefficient of correlation is used throughout.

| Item no. | Target sentence | Mean RT (secs) | Total errors |
|----------|--|----------------|--------------|
| 9 | The big blue star. | 3.31 | 0 |
| 15 | All the balls are blue. | 3.51 | 0 |
| 8 | The red box. | 3.72 | 0 |
| 30 | The ball is under the box. | 4.09 | 0 |
| 31 | The star is behind the box. | 4.18 | 0 |
| 16 | Some of the stars are yellow. | 4.37 | 0 |
| 36 | The boxes. | 4.51 | 0 |
| 17 | None of the balls is red. | 4.79 | 1 |
| 29 | The star is in the ball. | 4.87 | 1 |
| 24 | The ball has a red star in it. | 5.29 | 2 |
| 38 | The ball is bigger than the box. | 5.57 | 0 |
| 25 | He thinks of them. | 5.74 | 1 |
| 33 | The star is between the ball and the box. | 5.97 | 2 |
| 26 | The star thinks of himself. | 6.06 | 2 |
| 12 | The box, the ball and the star are big. | 6.07 | 0 |
| 10 | The small red ball and the big yellow box. | 6.36 | 1 |
| 37 | The balls and the stars are blue. | 6.55 | 0 |
| 18 | Only the box is red. | 6.81 | 0 |
| 23 | She thinks of him. | 7.09 | 1 |
| 22 | She draws. | 7.38 | 1 |
| 19 | The star is blue and the box is not yellow. | 7.49 | 0 |
| 32 | The box and the ball are above the star. | 7.60 | 1 |
| 2 | A box is drawn by the star. | 8.05 | 2 |
| 34 | The ball is in the star that is under the box. | 8.24 | 3 |
| 14 | The star in the ball is small and red. | 8.31 | 0 |
| 11 | The small box and the big star are yellow. | 8.31 | 2 |
| 1 | The box draws a star. | 8.76 | 4 |
| 40 | The star painted the box. | 8.80 | 9 |
| 41 | The box's ball is red. | 8.84 | 8 |
| 28 | The box paints itself. | 9.12 | 5 |
| 13 | The star that is in the big box is blue. | 9.27 | 3 |
| 4 | It is the ball that gives a box to the star. | 9.59 | 3 |
| 27 | They give the ball to her. | 10.13 | 5 |
| 21 | All but the but blue star are yellow. | 10.97 | 1 |
| 3 | The box gives a star to the ball. | 11.05 | 1 |
| 42 | The box's ball is bigger than the star's. | 12.30 | 11 |
| 35 | The box behind the ball is under the star. | 12.52 | 10 |
| 5 | The ball paints a box and thinks of the star. | 13.69 | 15 |
| 39 | The star is the smallest. | 13.74 | 10 |
| 7 | The star paints the box that the ball holds. | 13.97 | 5 |
| 20 | Only the star and the box are not blue. | 14.87 | 3 |
| 6 | The box that the ball paints holds a star. | 16.13 | 12 |

Table 10. Mean response time (RT) and total errors for each sentence in the Syntax Screening Test, normal group. (n=45 for each item)

This is the most likely explanation for the reversal of the expected order of the simple active and passive (sentences 1 and 2). What can be deduced with certainty from the minimum and maximum group latencies is that the test material spans a large range of difficulty. However, from the normals' range of test completion times (see Table 7), there seemed a good prospect that aphasic subjects would be able to complete the test in one sitting. Further, from the analysis of accuracy and error rates, it seemed that the desired balance might have been struck: the test was not too easy (the poorest individual performers made 10 errors, 76% accuracy) yet overall no subgroup dropped below 90% accuracy. The next step was to see whether the test would be successful in discriminating aphasic subjects from normal ones.

2.5.2 THE PERFORMANCE OF APHASIC SUBJECTS

The aphasic subjects attended for three preliminary test sessions over a period of 6 months before the therapy study began. The Syntax Screening Tests associated with those test sessions are referred to here as SST1, SST2 and SST3. The purpose of the first session was to assess the SST itself with aphasic clients for usability, for success in distinguishing aphasic performances from normal ones, and for ability to detect subjects with deficits in the functions of interest. Of about 22 subjects tested, the 14 reported here were selected on SST1 results. The high 'hit rate' was due to the fact that the subjects tested were referred to the study by clinicians who were aware of the selection criteria. Of the candidates eliminated at SST1, one patient was too competent (41/42), his residual problems were higher level (discourse instead of sentence processing). SST1 was aborted in the case of two patients, one broke down inconsolably after only 8 sentences, (she had a previous history of breakdown in clinical assessment; this was the only occasion that any patient became distressed using the system). The other patient was struggling so much that the decision was made to terminate the program (her mean response latency to the Lexical Test had been 48.85 seconds and her single-word recognition had been suspect). Several patients were rejected for logistical reasons, principally due to transportation problems. One of these, JD, was of considerable interest because he returned a profile suggesting the dissociability of verbs and prepositions. This was an exciting piece of evidence for two reasons; it was a further shred to support the hypothesis of dissociability between these two functions and it was a promising sign that the SST was capable of detecting selective impairments. JD's results are given in Table 11.

| | Verbs | Adj. | Scope | Pron. | Prep. | Morp. |
|-------------------|-------|------|-------|-------|-------|-------|
| Score | 1 | 3 | 4 | 7 | 7 | 4 |
| Mean rt (secs) | 13.51 | 9.91 | 12.14 | 10.91 | 12.73 | 9.78 |

Table 11. Syntax Screening Test 1 results for patient JD

While the results of a single performance must be interpreted cautiously, it is extremely unlikely that this patient was not more impaired in verb processing than in preposition processing. His results further convinced me that the hypothesis that the comprehension of N-V-N and N-P-N structures is dissociable, was certainly worthy of exploration. Table 11 also shows that prepositions were in second place in order of difficulty for JD as measured by mean latency, but interestingly, despite this the patient got all his prepositional sentences correct.

The SST1 results for P1..P14 in each of the linguistic modules, are shown in Table 12. The scores given are out of a maximum of 7. (See Table 13 for a full list of scores for SST1..SST3).

| | Verbs /7 | Adj. /7 | Scope /7 | Pron. /7 | Prep. /7 | Morp. /7 | Total Time Taken (mins) |
|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|----------------------------|
| P1 | 3 | 4 | 6 | 5 | 1 | 4 | * |
| P2 | 2 | 5 | 3 | 4 | 2 | 4 | 43.97 |
| P3 | 3 | 5 | 5 | 2 | 4 | 5 | 22.45 |
| P4 | 3 | 7 | 6 | 7 | 3 | 4 | * |
| P5 | 3 | 4 | 5 | 6 | 5 | 3 | 25.29 |
| P6 | 3 | 2 | 5 | 6 | 3 | 3 | 39.86 |
| P7 | 0 | 7 | 5 | 5 | 2 | 3 | 23.54 |
| P8 | 1 | 3 | 6 | 6 | 6 | 3 | 37.77 |
| P9 | 2 | 6 | 4 | 5 | 1 | 4 | 22.05 |
| P10 | 3 | 6 | 5 | 5 | 2 | 3 | 9.13 |
| P11 | 1 | 5 | 5 | 3 | 0 | 1 | 41.23 |
| P12 | 2 | 5 | 2 | 6 | 6 | 4 | 38.74 |
| P13 | 1 | 2 | 5 | 4 | 4 | 3 | 22.93 |
| P14 | 3 | 5 | 4 | 3 | 3 | 2 | 24.52 |
| ALL mean rt | 47.78 (secs) | 30.99 (secs) | 36.84 (secs) | 32.18 (secs) | 36.99 (secs) | 34.28 (secs) | 29.29 (mins) |
| % correct | 30% | 67% | 67% | 68% | 43% | 47% | |

Table 12. Syntax Screening Test 1 results for P1..P14.

* time not available (feature added to software after this date).

The bottom row of Table 12 summarises the overall accuracy rates of the aphasic group in the six linguistic modules. The aphasic results were significantly depressed compared with the normal group both in accuracy and speed, and were especially weak in verbs, prepositions and morphology, with verbs being very much poorer, and taking very much longer, than any of the others. On the basis of these results, the SST was considered to have been successful in satisfying the objectives listed at the beginning of section 2.5 and P1..P14 were invited to take part in the remainder of the study.

Each patient was recalled for two further SSTs prior to commencement of therapy. The dates on which testing took place and the three sets of results for each subject are given in full in Table 13 overpage.

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| | DATE (1990) | Verb /7 | Adj. /7 | Scope /7 | Pron. /7 | Prep. /7 | Morp. /7 | Total Time Taken (mins) |
|-----|----------------|------------|------------|-------------|-------------|-------------|-------------|-------------------------------|
| P1 | 16/3 | 3 | 4 | 6 | 5 | 1 | 4 | * |
| | 6/6 | 2 | 6 | 6 | 5 | 2 | 2 | 39.35 |
| | 27/9 | 5 | 5 | 5 | 7 | 2 | 2 | 38.46 |
| P2 | 21/6 | 2 | 5 | 3 | 4 | 2 | 4 | 43.97 |
| | 25/7 | 2 | 4 | 1 | 3 | 3 | 2 | 52.60 |
| | 23/8 | 0 | 4 | 4 | 5 | 5 | 4 | 52.58 |
| P3 | 25/6 | 3 | 5 | 5 | 3 | 4 | 5 | 22.45 |
| | 24/7 | 5 | 4 | 6 | 6 | 3 | 4 | 22.68 |
| | 2/10 | 3 | 4 | 7 | 4 | 2 | 2 | 22.57 |
| P4 | 19/3 | 3 | 7 | 6 | 7 | 3 | 4 | * |
| | 27/6 | 3 | 5 | 7 | 6 | 2 | 6 | 39.58 |
| | 5/9 | 2 | 5 | 7 | 7 | 4 | 6 | 36.16 |
| P5 | 3/5 | 3 | 4 | 5 | 6 | 5 | 3 | 25.29 |
| | 9/7 | 4 | 4 | 6 | 4 | 6 | 3 | 22.19 |
| | 5/9 | 2 | 5 | 5 | 5 | 4 | 5 | 20.15 |
| P6 | 28/6 | 3 | 2 | 5 | 6 | 3 | 3 | 39.86 |
| | 21/8 | 1 | 3 | 3 | 6 | 3 | 4 | 31.17 |
| | 26/9 | 5 | 3 | 3 | 5 | 2 | 4 | 22.70 |
| P7 | 9/5 | 0 | 7 | 5 | 5 | 2 | 3 | 23.54 |
| | 5/7 | 3 | 5 | 6 | 6 | 3 | 4 | 20.78 |
| | 6/9 | 1 | 4 | 4 | 6 | 4 | 2 | 22.58 |
| P8 | 10/5 | 1 | 3 | 6 | 6 | 6 | 3 | 37.77 |
| | 10/7 | 4 | 5 | 6 | 6 | 5 | 4 | 42.99 |
| | 4/9 | 4 | 4 | 6 | 5 | 6 | 5 | 43.13 |
| P9 | 17/5 | 2 | 6 | 4 | 5 | 1 | 4 | 22.05 |
| | 29/6 | 0 | 4 | 5 | 6 | 2 | 4 | 24.45 |
| | 10/9 | 1 | 5 | 5 | 4 | 2 | 2 | 21.00 |
| P10 | 23/5 | 3 | 6 | 5 | 5 | 2 | 3 | 9.13 |
| | 11/7 | 3 | 4 | 6 | 5 | 4 | 3 | 6.93 |
| | 5/9 | 3 | 5 | 3 | 2 | 3 | 4 | 7.36 |
| P11 | 3/7 | 1 | 5 | 5 | 3 | 0 | 1 | 41.23 |
| | 21/8 | 1 | 3 | 5 | 6 | 0 | 2 | 51.87 |
| | 25/9 | 2 | 5 | 1 | 3 | 0 | 1 | 40.57 |
| P12 | 9/7 | 2 | 5 | 2 | 6 | 6 | 4 | 38.74 |
| | 15/8 | 2 | 5 | 5 | 3 | 6 | 5 | 50.36 |
| | 24/9 | 2 | 6 | 6 | 6 | 6 | 4 | 35.51 |
| P13 | 25/7 | 1 | 2 | 5 | 4 | 4 | 3 | 22.93 |
| | 23/8 | 4 | 5 | 4 | 4 | 6 | 3 | 20.07 |
| | 28/9 | 4 | 4 | 6 | 4 | 6 | 5 | 20.50 |
| P14 | 26/7 | 3 | 5 | 4 | 3 | 3 | 2 | 24.52 |
| | 24/8 | 1 | 5 | 4 | 3 | 3 | 3 | 26.05 |
| | 24/9 | 0 | 5 | 4 | 3 | 4 | 2 | 19.24 |

Table 13. Scores of P1..P14 on the three Syntax Screening Tests (SST1..SST3).

* time not available (feature added to the software after this date).

Table 14 summarises the performances of the aphasic group over the three test sessions, in the same format as Table 7 (p.83) did for the normals' SST. Table 14 shows that the aphasics' group results on repeat testing were remarkably stable both for speed and accuracy. In addition, the rank ordering of modules by mean response latency was very consistent, as shown in Table 15.

| | Test completion time ⁴⁴ (minutes) | | | Mean no. errors | Mean % correct |
|---------|---|------|-------|--------------------|-------------------|
| | Mean | Min | Max | | |
| SST1 | 25.26 | 6.79 | 36.10 | 19.29 | 54% |
| SST2 | 27.64 | 5.25 | 47.98 | 18.21 | 57% |
| SST3 | 25.27 | 5.64 | 47.52 | 18.57 | 56% |
| Overall | 26.06 | 5.25 | 47.98 | 18.69 | 56% |

Table 14. Summary of the performance of P1..P14 over three exposures to the Syntax Screening Test (SST1..SST3).

| | Verbs | Prep. | Scope | Morp. | Pron. | Adj. |
|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| SST1 | 1 | 2 | 3 | 4 | 5 | 6 |
| SST2 | 1 | 2 | 3 | 4 | 5 | 6 |
| SST3 | 1 | 4 | 3 | 2 | 5 | 6 |
| Overall | 1 | 2 | 3 | 4 | 5 | 6 |
| ALL mean rt | 50.64 (secs) | 38.04 (secs) | 37.50 (secs) | 36.18 (secs) | 32.30 (secs) | 29.95 (secs) |

Table 15. Module rankings by mean response latency for P1..P14 over three exposures to the Syntax Screening Test. (1=hardest).

As with the normal data, the aphasic results were analysed to determine the correlation between mean response latency and total number of errors made on each sentence. In doing this, the results of the three SSTs were merged; as for the normal group, there was a strong positive correlation ($r=0.8$).

⁴⁴ Calculated as for Table 7. In some cases the *total* time taken by aphasic subjects was quite a lot more than the cumulative response latencies, (c.f. Table 13), so a comparison of Tables 7 and 14 is generous to the aphasics. Differences arose because of the additional times taken to reach the confirm button after window selection. Large differences were due to pauses taken.

2.5.3 INTERPRETATION OF INTER- AND INTRA-GROUP RESULTS

Comparing Table 15 with Table 8 (p.85), it is apparent that there was some commonality between the relative module difficulties for the two groups ($r=0.6$). Both the aphasic and the normal group ranked verbs, scope and quantification and adjectives, 1, 3 and 6 respectively, and the relative ordering of morphology and pronouns was the same in both cases. However, prepositions, which were ranked 5 by the normal group were second in order of difficulty for the aphasics. This was an interesting finding because it suggested that for reasons unknown, the aphasic subjects were finding prepositions disproportionately difficult. The relative accuracy of the two groups, overall, across the six linguistic modules tested, is shown in the histogram at Figure 4. The discrepancy between the aphasics' performance in each module (over SST1..SST3) and the normals' performance is visually striking; expressed as a percentage of normal performance, taking the modules shown in Figure 4 in left to right order, the aphasic group achieved 39%, 66%, 70%, 72%, 51% and 57% respectively.⁴⁵

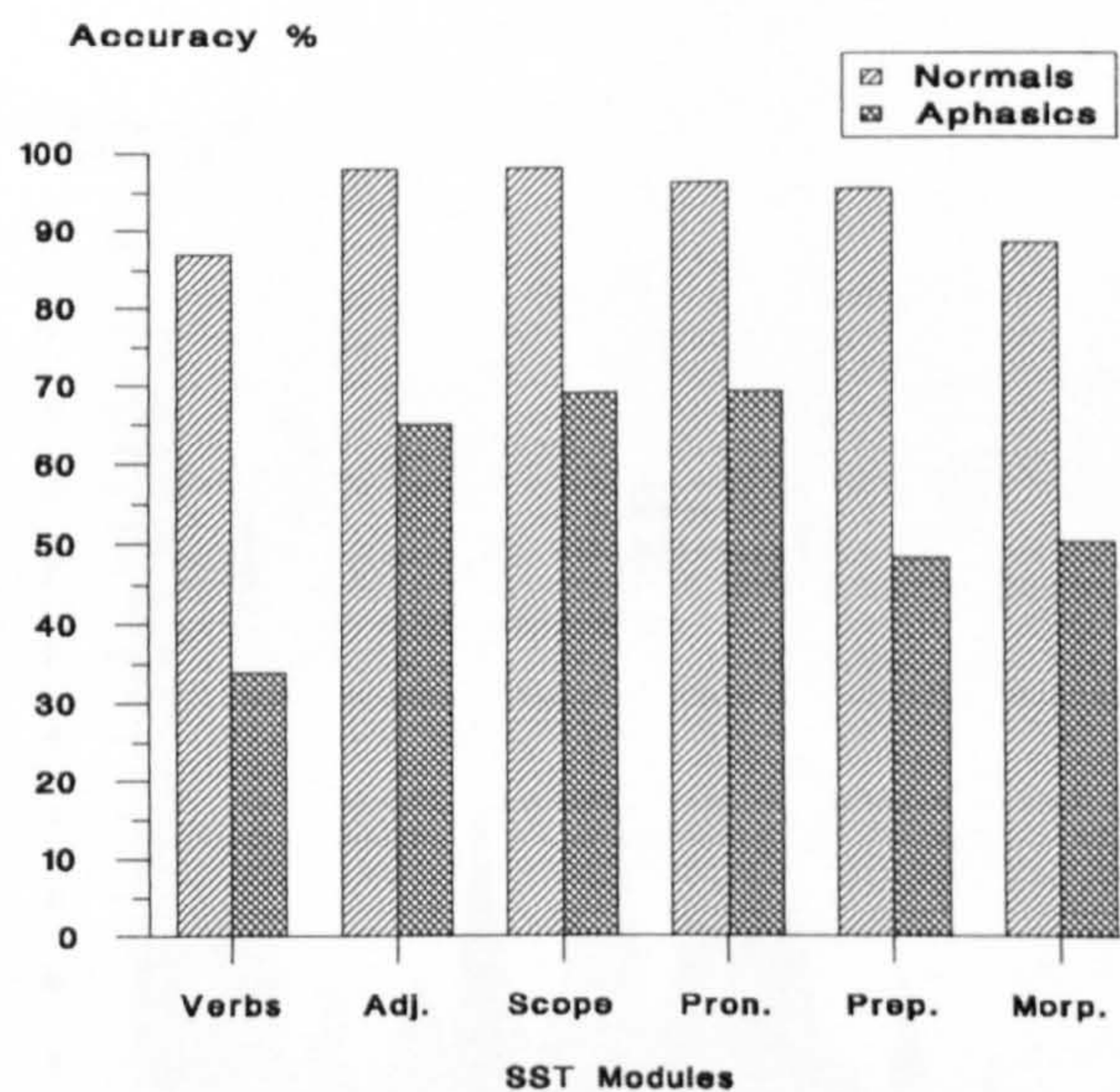


Figure 4. Aphasic and normal performances over the Syntax Screening Test modules.

⁴⁵ This does not mean, of course, that individual aphasic and normal subjects did not overlap in any module. Some of the aphasics proved to have preserved abilities in some functions as shown in Table 13 (e.g. P4 in pronouns and scope and quantification). Four of the normal subjects showed depressed scores, more typical of the aphasics as follows: C24 and C30 3/7 verbs; C37 and C38 4/7 verbs; C37 4/7 morphology.

To discover the extent of consistency between the aphasic subjects and the normal subjects in their ranking of the 42 SST sentences by mean response latency, the overall ranking by the 45 normal subjects was compared with the ranking over 42 performances by the aphasic subjects (14 subjects on 3 occasions). A high positive correlation between the two groups was found ($r=0.82$).

From the data presented in the foregoing subsections, it is clear that the aphasic group and the normal group were readily distinguished by the SST, both in speed and accuracy. However, it was of interest to compare the individual performances in both samples to see if, and how, the two groups overlapped. This was done first of all for accuracy. I wanted to know, for each group, how the errors made were distributed, and also if overlap occurred. The 45 normal performances were examined, along with the total of 42 performances by the aphasic subjects. Figure 5 charts the number of errors made on each SST (horizontal axis) against the number of subjects returning that performance (vertical axis). The results are visually conspicuous. The two groups abut.

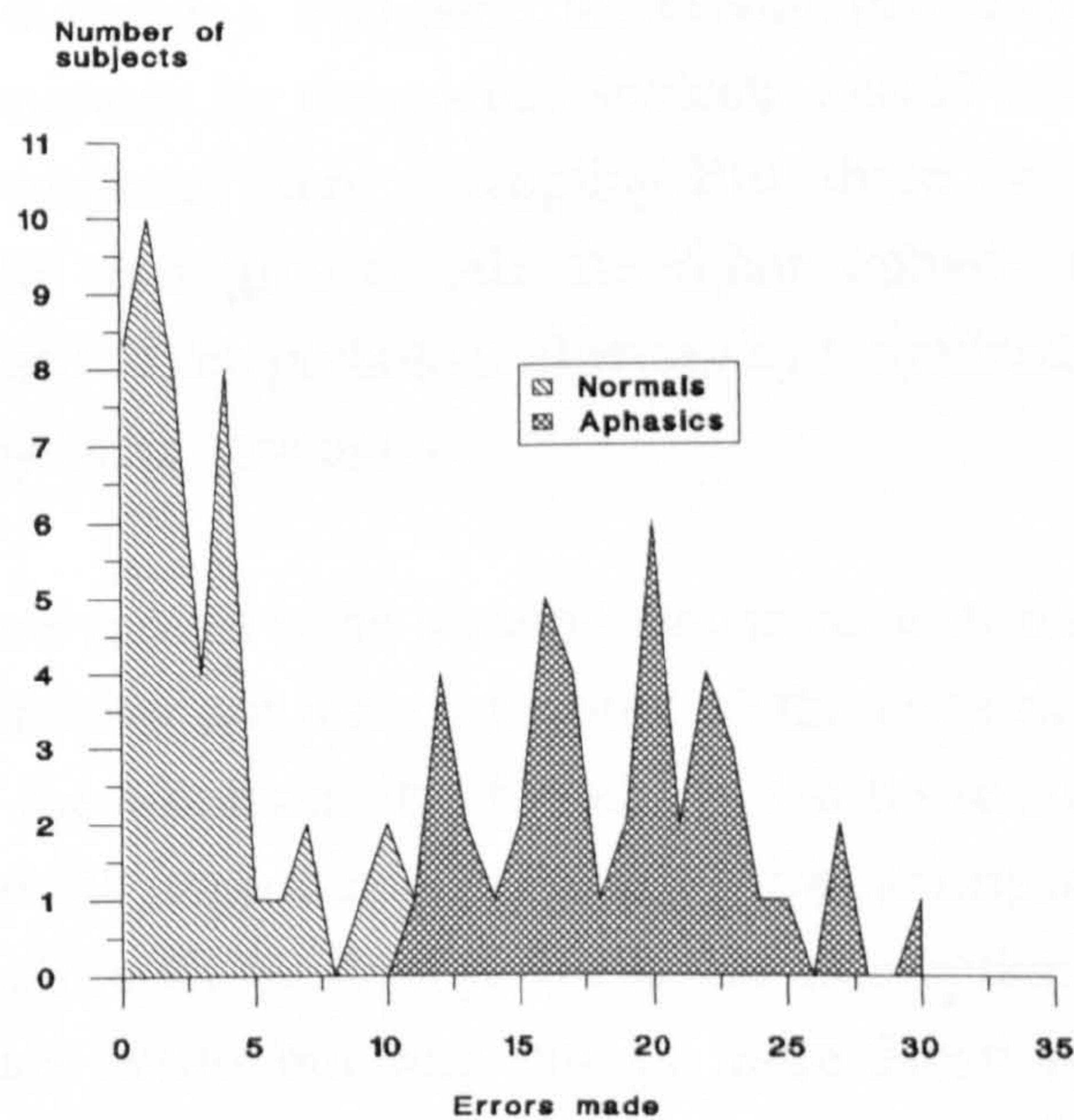


Figure 5. Error rates for aphasic and normal subjects on the Syntax Screening Test.

The normal subjects ranged in their error-making from 0..10, while the aphasics made between 11 and 30 errors. Not only that, but the shape of the two distributions is quite different. The performances of the normal subjects were positively skewed, the vast majority of subjects making 0..5 errors, whereas the aphasic performances showed no such clustering around the accurate end of their range. On the contrary, the aphasic performances were fairly uniformly distributed across their range, with peaks at 12, 16, 20 and 22 errors. Thus the demarcation by error rate is clear-cut for individuals as well as for the two groups.

Obviously, it would be unsafe to judge an individual boundary case to be either 'poor normal' or 'pathological' on error rate alone. Further evidence was needed and this was obtained from timing data. Figure 6 charts cumulative response latencies accurate to the nearest minute (horizontal axis), against the number of subjects returning that performance (vertical axis). This comparison was generous to the aphasics, since it looked only at cumulative response latencies, ignoring the sometimes much longer *total* time taken (see footnote 44, p.94).

The two groups were even more widely separated than they were on accuracy. P10 was an exceptional individual, who was well below normal on accuracy but operated at normal speed (his 3 values in Figure 6 are clearly seen at the right of the 5, 6 and 7 minute bars). P10 aside, the maximum and minimum values were 3 minutes and 10 minutes for the normal subjects, and 17 minutes and 47 minutes for the aphasic subjects. Thus, excepting P10, there was no overlap between individuals in the two groups. All the other aphasic individuals could be confidently assigned to the pathological group by a combination of error rate and speed, and P10 by error rate alone.

The SST therefore proved to be a useful diagnostic instrument. The inter-group results were interesting not just on account of the large differences evident, but also because of the commonality found. It will be recalled that section 1.2.3 above mentioned the importance to the cognitive neuropsychology enterprise of the precept of subtractivity. Briefly, this is the assumption that damaged brains operate like intact brains but with one or more functional lesions, so that by studying pathological performances insights may be gained into the working of the undamaged brain. Despite the huge differences in error rate and speed between the aphasic and normal samples, a key question to ask was, do they look as if they originated in the same underlying population, or are the aphasic performances so aberrant that one cannot find within them the kernel of normality?

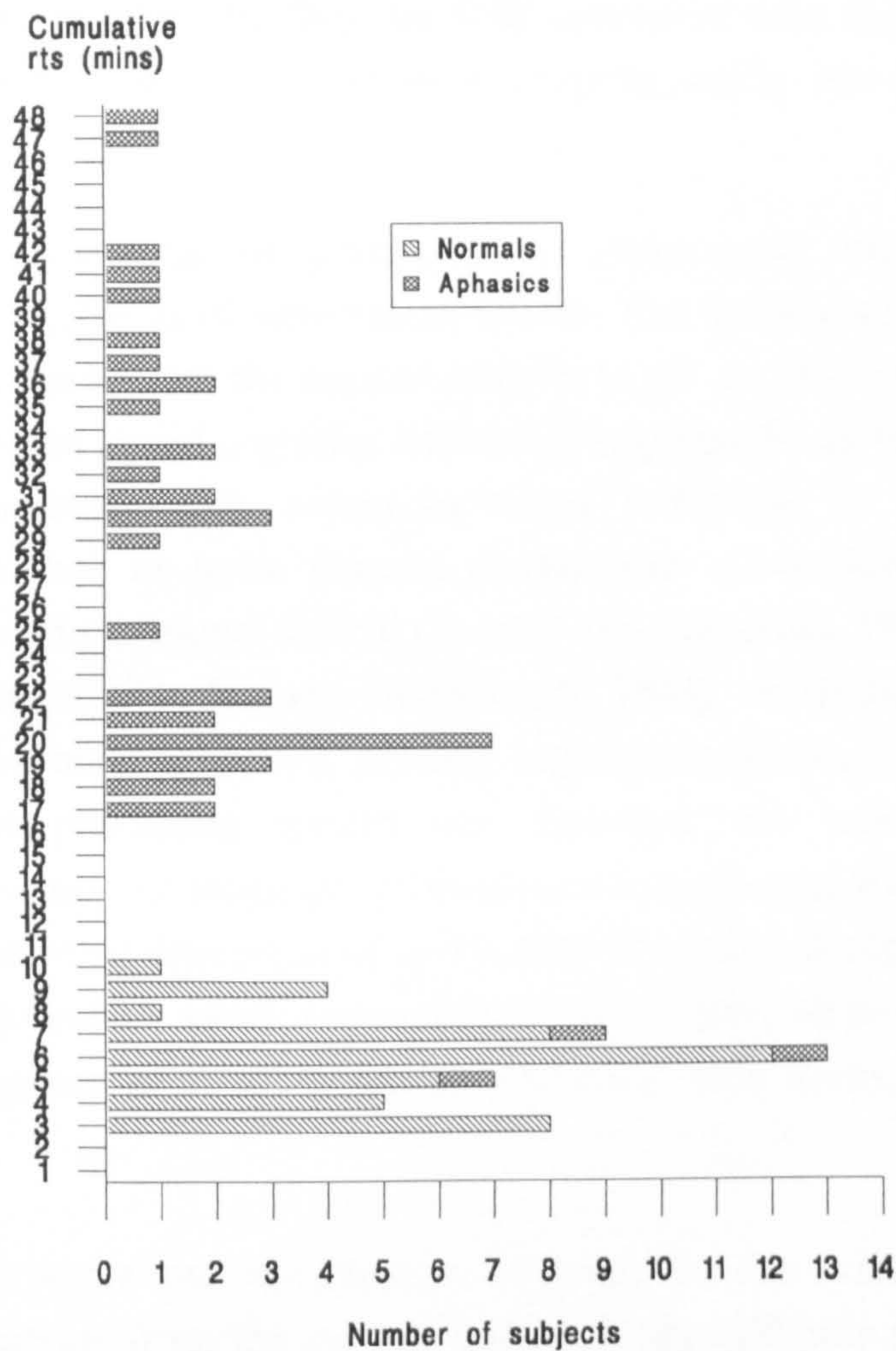


Figure 6. Cumulative response latencies for all subjects on the Syntax Screening Test.

In fact, the data indicated a strong relationship between the two groups on the following three indices; relative difficulty of linguistic modules measured by mean response latency, correlation between mean response latency and error rate for SST sentences and correlation between the rankings of SST sentences by mean response latency. Thus the aphasic subjects were found to operate like their normal counterparts in making more errors the longer they considered sentences, and there was strong agreement between the two groups in their ranking of the sentences in order of difficulty. There was an overall similarity in the ordering of linguistic modules, although the aphasics showed more difficulty with prepositions than would have been anticipated from the normal results. A further important

feature was the consistency of the aphasics' repeat performances. Their results appear not to be a set of random, haywire responses, bearing little relation to the intact set; on the contrary, they are fully consistent with the output of brains, functioning as they did intact, but now compromised in one or more functional components.

The inter-group comparison permits us to make some tentative speculations concerning the patterns of impairment found. The aphasic subjects' scores were depressed compared with the normal subjects in all six linguistic modules tested, this suggests some global cognitive deficit for language.⁴⁶ In terms of a model of language processing, this across-the-board reduction in capacity suggests impairment in one or more general mechanisms subserving all the functions tested, e.g. a 'computational deficit' (Frazier and Friederici, 1991) or 'decrease in parsing workspace' (Caplan and Hildebrandt, 1988). A speed-based account of this might have been proposed, possibly implicating memory (i.e. that a global diminution of processing speeds was upsetting the safe completion and intercommunication of language processing subtasks) had P10 not presented a dissociation between disruption of speed and disruption of accuracy. In addition to the general decline, which appears to be about 30% on normal performance, the aphasic group showed increased difficulty with verbs, morphology and prepositions.

Problems with verbs and morphology, although not the extent of them, could have been forecast from the normal data, but the difficulty aphasics had with prepositions could not. This latter problem was peculiar to the aphasic group. However, to confound matters further, individual subjects presented quite different performance patterns across the modules, for example, it appears from the results of JD (1/7 verbs, 7/7 prepositions) and P12 (6/21 verbs, 18/21 prepositions), that deficits in verb and preposition processing are dissociable and that preposition processing is not uniformly difficult for this group. Interestingly, I did not encounter a subject who showed the opposite pattern of performance, that is intact verbs and impaired prepositions. (However, in Chapter 6 I report having induced this opposite pattern in three patients, most notably P1, after verb therapy.) What was found, (see Table 13, p.93), was that one or more of verbs, prepositions and morphology can be severely impaired in the face of much stronger performances in all of adjectives, scope and quantification and pronouns

⁴⁶ The alternative is to adopt the much less plausible view that the impairments are all independent.

(e.g. P1, P7, P9, P11). However, the number of observations was small and one must be cautious about drawing premature conclusions from what was only a screening test. Nonetheless there were clearly some module-specific deficits on top of the global impairment.

In concluding this discussion, it is worth remarking that confidence in the integrity of the SST was increased by the outcome that the linguistic functions found to be most impaired in this sample of aphasic subjects were precisely those that previous studies of agrammatism had highlighted as especially troublesome (section 1.2.3).

2.6 ADDITIONAL PRE-THERAPY TESTS

In addition to repeat-testing with the SST to establish the cognitive stability of the patients over a period of time prior to onset of therapy, three other tests were administered before commencement of the treatment phase. These were a computer-based test of (visual) digit-span recall (DSR), produced by the writer, a subset of the Western Aphasia Battery (WAB) (Kertesz, 1982) and a written adaptation of the TROG (Bishop, 1982). The last two tests were included largely to enable other researchers familiar with them to gain an impression of the pre-therapy status of P1..P14, but also to compare the performances of the patients on these widely used traditional assessments with their performances using the new computerised ones. The additional tests were repeated after completion of the remediation phase to monitor any more general changes (see section 4.2).

2.6.1 VISUAL DIGIT-SPAN RECALL TEST

The nature of short-term memory (STM) and its role in language processing is the subject of much debate. Allport (1985) used the term *language memory* to distinguish it from memory for general knowledge and memory for past events (episodic memory) and regarded memory impairment to be at the heart of acquired language disorders. His view of memory, however, was not of a working store or buffer into which representations are temporarily written and from which they can be accessed by processes (the information processing model). Instead, he argued for the concept of distributed memory, in which information is encoded in auto-associated neuronal activity patterns. In this sense, memory is not a separate functional component as in a modular view of cognition, but simply

a perceived attribute of the language system in operation. Allport (1985) asserted that there is now no convincing evidence to sustain the once popular distinction between long-term and short-term memory and that the behavioural characteristics of repetition span under different conditions and with different stimuli are consistent with the view that the phonological lexicon is the mechanism involved.

Caplan and Waters (1990) reviewed evidence of the role of STM in sentence comprehension. Two competing theories emerged. The first was that phonological STM is involved in the process of parsing and deriving meaning from sentences (Baddeley, Vallar and Wilson, 1987; Caramazza and Berndt, 1985); the second was that STM becomes involved only when there is a requirement to adjudicate between conflicting syntactic or lexico-pragmatic interpretations (Butterworth, Campbell and Howard, 1986; McCarthy and Warrington, 1987). Caplan and Waters came to the view that STM is not normally called upon in sentence understanding where the meaning is contextually consistent and derivable from a one-pass operation, however it may be necessary in cases of disambiguation.

The role of articulatory rehearsal mechanisms in maintaining sentence components long enough to make sense of them is obviously more crucial in auditorily presented sentences than in written ones, where the text is available for reconsultation. Nevertheless, it was of interest to explore the relationship between limitation of temporary storage and sentence processing difficulties as a sideline in the present study. Having devised a microworld in which lexico-pragmatic strategies were minimised, if the post-parsing adjudication account of STM involvement was accurate, then memory span impairment should have little effect on processing of the computer-based reading tasks.

It was decided to do this through a *visual* Digit-span Recall Test (DSR) (Crerar, 1990). Numbers were chosen as stimuli to try to minimise confounding (lexical) reading problems and responses were made by visual selection to avoid articulatory demands. The test seemed ideally suited to computerisation, indeed, it would have been hard to organise otherwise. A computer program was therefore designed, again with a mouse-driven interface, for the aphasic subjects to self-administer. The salient features of the program were as follows.⁴⁷ During presentation of the stimuli, the screen was blank except for a single, central

⁴⁷ I am grateful to Professor Andrew Ellis for suggesting several aspects of the protocol.

window in which the digits were displayed sequentially. The duration of exposure for each digit was constant at one second; consecutive digits in the same string followed without a gap. Once the digit, or digit string had been presented, the patient was confronted with a screen like that shown at Figure 7.

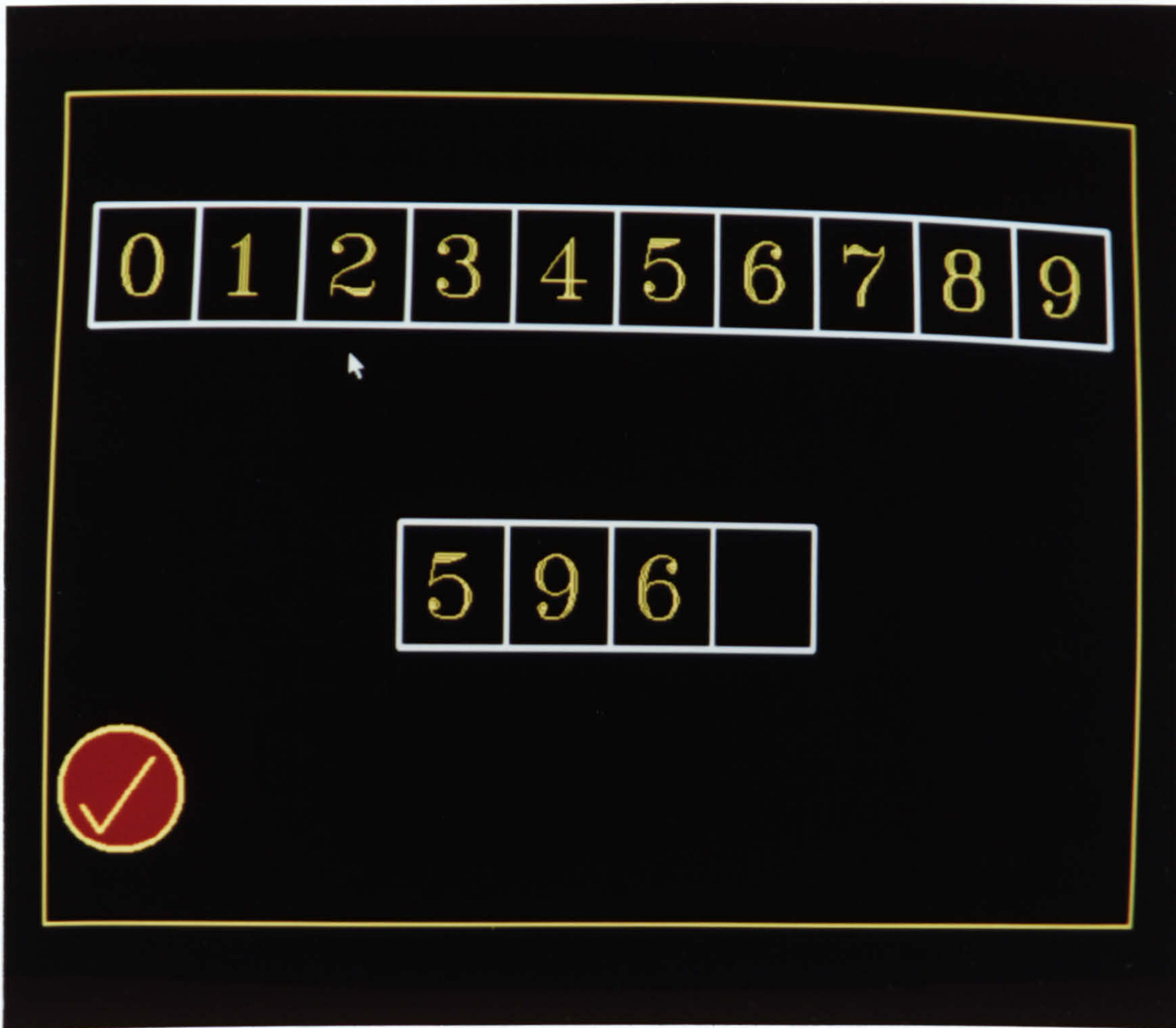


Figure 7. Typical Digit-span Recall screen with a four-digit response in progress.
(This figure is in colour)

By clicking in the appropriate cells in the numerical palette at the top, subjects filled the answer boxes left to right, in order of digit presentation. It was possible for the patient to correct any component of his answer, or indeed to leave one or more boxes empty. It was also possible for him to fill the answer boxes in any order he chose, although subjects rarely used this facility. To invite the next stimulus, the patient clicked on the familiar confirm button (bottom left of Figure 7). The program was progressive, beginning by presenting single digits and gradually working towards a maximum of seven. In order to progress to the next level, a subject had to get at least four out of five answers correct at the preceding

level. Thus the program terminated when a subject reached the limit of his or her capacity. The stimuli consisted of randomly generated digits (0..9), subject to the following constraints: no digit was repeated in a string, no more than two (numerically) consecutive digits occurred contiguously in a string, and successive stimuli differed by more than absolute(1). These checks were introduced to try to minimise especially memorable patterns within multi-digit stimuli and between consecutive stimuli. The program recorded every target string and response and produced performance summaries for each patient.

P1..P14 were given the DSR test on the third of their SST sessions. It was placed after the Interface Test so that subjects would be refamiliarised with the mouse, but mentally fresh. Without exception they mastered the operation of the program with ease. Very little explanation was necessary. Subjects were given a dummy run or runs to be certain that they understood the requirements. The digit-span recalls (DSRs) recorded in Table 16 were the best performances by each patient, although there was very little within-subject variability. Digit spans were recorded as an integer representing the longest digit string correct in at least 4 out of 5 cases, followed by an integer in square brackets representing the number of times (out of 5) the next level was correctly handled, e.g. 3[2] is the result of a patient secure at a digit-span of three and returning 2/5 at a digit-span of 4.

| | DSR | | DSR |
|----|------|-----|------|
| P1 | 4[0] | P8 | 2[3] |
| P2 | 1[3] | P9 | 2[2] |
| P3 | 4[1] | P10 | 3[1] |
| P4 | 2[1] | P11 | 3[0] |
| P5 | 2[1] | P12 | 3[0] |
| P6 | 2[2] | P13 | 3[3] |
| P7 | 2[3] | P14 | 3[3] |

Table 16. Pre-therapy visual digit-span recalls of P1..P14.

All the DSR scores were depressed compared with normal values (Caplan and Waters, 1990). Premorbid levels of numeracy do not seem to have been a factor because P4, P11 and P14 showed no better results than the manual workers (see Appendix 1 for the patients' former occupations). No meaningful association could be found between DSR results and patients' results on the SST; for

example, P4 had the highest overall score summing correct responses over SST1..SST3, yet only P2 had a poorer DSR. P10, who returned amazingly fast SST times had a DSR similar to others who took many times longer. Likewise, there were very large timing discrepancies between subjects with the same DSR (e.g. P7, 22.58 minutes (SST3); P8, 43.19 minutes (SST3)). Thus, an impairment of visual STM was found in all the aphasic subjects, but there was no apparent relationship between degree of impairment and SST results. In section 4.2.1 it is reported that digit-span recall did not improve with improvement in sentence processing, tending to suggest that STM, or certainly the variety exercised by the DSR test, plays little part in sentence understanding.

All this is highly speculative. We do not know whether it is sensible to talk of STM as if it were a single shareable scratch-pad, whether different cognitive functions have separate, dedicated, temporary stores or whether, in line with the distributed associative model mentioned above, the entity of STM is a fiction. If the latter is true, then, of course, it makes no sense to try to investigate the effect of memory on language processing - they are inseparable. Even granting STM, it may well be that the STM used to 'store' digits presented visually is not the same as that used to 'store' the results of linguistic subprocesses. A further complication is that inner rehearsal of digits is likely to be language-mediated, so judgements about memory capacity may be confounded by aphasic subjects being unable to recall a digit's name (or to access and repeat them with normal facility), or perhaps making internal semantic paraphasias and thus outputting the incorrect sequence.

Degraded DSR cannot be ruled out as a contributory factor in sentence processing *accuracy* since all the subjects tested had reduced DSRs and all were impaired compared with normals on sentence comprehension. What does appear to be the case, on the evidence of P10, is that normal DSR capacity is not necessary to accomplishing sentence processing at normal *speed*.⁴⁸

This test was repeated post-therapy with ten of the aphasic subjects, the results appear in section 4.2.1.

⁴⁸ P10's accuracy results reported after therapy (section 5.1) confirm that he was *completing* sentence understanding tasks at this speed.

2.6.2 WESTERN APHASIA BATTERY

The Western Aphasia Battery (WAB) is one of the most widely used of the standardised assessment tests. Despite its shortcomings as a diagnostic tool and aware of the arguments pointing to the futility of the associated syndrome classifications, it was considered useful to include a traditional assessment of P1..P14 here. The reason was that all the data presented in this thesis would otherwise have been derived from tests which were wholly new, thus making it difficult for other investigators to be able relate P1..P14 to previous cases, or indeed to gain an impression of their overall pre-therapy status. Additionally, it was of interest to discover the relationship between performances in the microworld environment and on traditional tests, and perhaps also to be able to examine pre-therapy performance on traditional tests in looking back for factors predictive of responsiveness (or lack of it) to therapy. A further useful aspect of the WAB for present purposes was that the subtests required to calculate an aphasia quotient are based exclusively on spoken output and auditory verbal input. Reading, for this purpose, is ignored. By administering these subtests before onset of treatment and again at the end of the study, one could monitor the effect of treating (written) sentence understanding on performance in other language modalities.

Scoring of the WAB is open to inter-observer variability as subjective judgements are required on spoken language. For this reason all the WAB tests were administered, and the results calculated, by the same person, who is an experienced clinical colleague. The first WAB tests were conducted in September 1990. The results are shown in Table 17. The post-therapy WAB results appear in section 4.2.2.

The rank orderings of P1..P14 on the pre-therapy WAB and over the three pre-therapy Syntax Screening Tests were compared and only a modest correlation found ($r=0.48$). Thus *using these measures*, there was not a high degree of agreement between severity of impairment in spoken input/output and in written sentence comprehension. This finding supports similar conclusions reached by Caplan and Hildebrandt (1986).

| | FL | CP | RP | NM | AQ | APHASIA SUBTYPE |
|-----|----|------|-----|-----|------|---------------------|
| P1 | 4 | 7.90 | 4.3 | 7.3 | 65.0 | Broca's |
| P2 | 5 | 9.70 | 5.1 | 8.5 | 72.6 | Conduction |
| P3 | 5 | 9.25 | 9.6 | 5.6 | 74.9 | Anomic |
| P4 | 9 | 9.10 | 8.7 | 8.5 | 90.6 | Anomic |
| P5 | 5 | 9.45 | 8.2 | 8.5 | 80.3 | Anomic |
| P6 | 2 | 8.90 | 2.1 | 3.0 | 42.0 | Broca's |
| P7 | 8 | 8.50 | 7.9 | 7.9 | 83.3 | Anomic |
| P8 | 4 | 9.45 | 8.1 | 7.6 | 72.3 | Transcortical motor |
| P9 | 4 | 8.60 | 2.9 | 3.7 | 50.4 | Broca's |
| P10 | 5 | 9.40 | 9.0 | 7.8 | 78.4 | Anomic |
| P11 | 6 | 8.25 | 8.9 | 6.9 | 78.1 | Anomic |
| P12 | 8 | 9.65 | 9.8 | 8.2 | 87.3 | Anomic |
| P13 | 4 | 9.35 | 8.2 | 7.4 | 73.9 | Transcortical motor |
| P14 | 2 | 7.45 | 6.0 | 5.1 | 55.1 | Broca's |

Table 17. Pre-therapy WAB results for P1..P14.

The column headings are FL=fluency, CP=auditory verbal comprehension, RP=repetition, NM=naming, AQ=aphasia quotient.

2.6.3 TEST FOR RECEPTION OF GRAMMAR

The third additional test which was carried out with P1..P14 was the test for Reception of Grammar (TROG) (Bishop, 1982). This is a test which was designed for assessing auditory verbal comprehension in children, but is often used with adults. TROG is a picture-matching test and of the traditional paper-based tests, most like my SST in concept. In order to use TROG to test written sentence comprehension, the target sentences were typed out and presented to the patients along with the sets of four candidate pictures. Scoring of TROG is objective, since picture selections are either right or wrong. The conduct of the TROG tests was shared, the bulk of the tests being administered by one or other of two experienced clinical colleagues. The pre-therapy TROGs were carried out in two batches, half at the end of August 1990 and the rest in the second week of October. The results are summarised in Table 18. The post-therapy Trog results are discussed in section 4.2.3.

It was reassuring to find a strong positive correlation ($r=0.87$) between the individual pre-therapy TROG results and the results of P1..P14 collapsed across the three Syntax Screening Tests. The TROG would thus have ranked the patients similarly for degree of sentence comprehension deficit. However the

SST was found to be superior in a variety of ways. One obvious benefit was that it was half the length. It also provided much more detailed performance data automatically (including response latencies), this was visually displayed, printable and stored on computer disc enabling further analysis without manual calculation or data entry. A very important consequence of this was that instead of the patient being passive and the clinician being cast in a clerical role, the patient was in control of test administration, releasing me to concentrate on aspects of behaviour that the computer could not monitor. This mode of working facilitated detailed observations concerning, for example the significance of gesture, subvocalisation, eye movement, cursor movement and so forth, which contributed to diagnostic hypotheses and which simply would not have been possible had I been busy shuffling pieces of paper, as was the case in administering the written version of the TROG.

| | TROG max=80 |
|------|-----------------|
| P1 | 61 |
| P2 | 47 |
| P3 | 65 |
| P4 | 68 |
| P5 | 60 |
| P6 | 43 |
| P7 | 60 |
| P8 | 67 |
| P9 | ? ⁴⁹ |
| P10 | 60 |
| P11 | 47 |
| P12 | 70 |
| P13 | 58 |
| P14 | 47 |
| Mean | 57.92 |

Table 18. A summary of the Pre-therapy TROG results for P1..P14.

⁴⁹ Unfortunately P9 was inadvertently missed out in the pre-therapy TROG tests, so his results had to be omitted from the summary calculations.

CHAPTER 3

3.1 INTRODUCTION TO THE TOOLS OF THE TREATMENT PHASE

In answer to the methodological weaknesses of the majority of previous speech therapy efficacy studies (section 1.2), and in particular of those applying computer-based methods (section 1.2.2), it was decided (section 1.2.4) to employ a multiple-baseline across function design with cross-over (Coltheart, 1983a) for the present study. This framework was chosen to enable detection of treatment-specific, function-specific, and (by careful construction of within-function test materials) item-specific effects of therapy. Chapter 2 introduced the computerised microworld which was the experimental environment, and described the development of the Syntax Screening Test (SST) used to select the 14 aphasic patients (P1..P14) with deficits in verb and preposition processing, who took part in the treatment phase of this research. It also described the use of the SST to monitor the performance of those patients over a period of months before commencement of therapy (see Table 13, p.93). The present chapter describes the design of the assessment tests and remediation software which were developed to satisfy the experimental requirements of the treatment phase. It also explains the conduct of the treatment study and illustrates how analysis of patients' response patterns to pre-therapy assessments in verb and preposition processing enabled the formulation of individual therapy objectives.

3.2 ASSESSMENT TESTS

The experimental design adopted required that the two functions of interest, verbs and prepositions, be distinguished; thus separate assessments for these were needed to satisfy the function-specific aspect of the protocol. To be able to detect item-specific change, it was necessary to include in each of these assessments a set of sentences which were to be treated, and a balanced set which were not. Treatment-specific and function-specific claims can be strengthened by the assessment of a linguistic function which is not treated. Morphology was chosen as the function for this purpose because it, too, was significantly depressed in P1..P14's SST results (see Figure 4, p.95). If treatment effects were specific, in

turn, to verbs and prepositions, morphology should remain static throughout. Finally, since all the assessment and treatment took place in a miniature artificial world, the therapy could not be considered successful unless it could be shown that any benefits had generalised to real world instantiations of the structures treated, away from the computer environment. For this reason a paper-based Real World Test was also designed.

On the basis of the time and effort required by the aphasic subjects to complete the SST (see Table 13), and considering that tests devoted solely to verbs and prepositions would be even harder for them, it was decided to set the length of these two assessments at 40 sentences each. The Morphology Test, which did not require division into treated and untreated items, was set at 20 items. For the Real World Test it was decided to combine verbs and prepositions, 20 sentences of each type, so that this test, too, could be completed in a single session. Each set of 20 'real world' items was further subdivided into an equal number of 'treated' and 'untreated' items.⁵⁰ The design and content of each of these tests is discussed below.

3.2.1 THE VERB TEST

The Verb Test (Crerar, 1990) is a 40 item picture-matching test utilising the same program shell as was used for the SST and preliminary tests. The 40 item maximum, dictated by the patients' performance on the SST, permitted only 20 treated sentences if the test was to be subdivided into treated and untreated sets of equal size. This was a relatively small number of items for analysis purposes. In order to be able to draw conclusions about patients' performances on different sentence types within the treated set, it was decided to limit the sentence structures treated to four. The treated set thus contained four sentence structures and five instances of each. It was further decided to subdivide the microworld verbs into treated and untreated verbs. The treated verbs were *paints*, *holds* and *gives*; the untreated verbs were *draws*, *thinks* and *puts* (the latter was a new verb, not previously seen in the SST, and introduced to provide an untreated, common, three-argument verb to match *gives*). The *untreated* sentence set was composed of a) treated structures with treated verbs (TS/TV), that is, untreated sentences comprising a treated verb and grammatical structure, but with noun-phrases not seen in that combination in therapy, b) treated structures with untreated verbs

⁵⁰ That is, using treated /untreated verbs or prepositions in treated/untreated sentence structures, in naturalistic scenarios. See section 3.2.4 for more detail.

(TS/UV), c) untreated structures with treated verbs (UT/TV) and d) untreated structures with untreated verbs (UT/UV). The target sentences of the Verb Test are given in Table 19, from which the foregoing contrasts should be clear.

From the left-hand column of Table 19 the progressive nature of the four structures chosen for treatment can be seen, viz., simple active declarative sentences, simple passive sentences, three-argument active dative sentences, and two-verb sentences with a relative clause qualifying the object. These contrasts were chosen after Caplan, Baker and Dehaut (1985) cited in section 1.2.1, as interesting structures to compare in remediation, since Caplan and colleagues had found non-canonical word order, verb-argument structure and number of verbs in a sentence to be indicators of sentence complexity. The three untreated sentence structures (structures 5..7 on the right side of Table 19) were conjunct sentences, cleft subject datives and two-verb sentences with a relative clause modifying the subject, (the latter being non-canonical in word order).

The sentence structures were conceived as templates and an effort was made to make them as stereotypical as possible - thus, the contrast between animate and inanimate items was heightened for the patients by the use of the article 'the' preceding animate nouns and 'a' preceding inanimate nouns (as in sentence 1, The ball paints a box). The animate characters were presumed to be 'known personalities' to the patients by this time (so the definite article was appropriate), the import of the sentences was therefore to explain their various activities (Grieve, 1973a). Thus, in the sentence just cited the fact that the ball was painting a box was being expressed, no particular box, but a box as opposed to a ball or a star. In structure 2 (e.g. A box is painted by the star) it was hoped that the use of an initial 'A' (in contrast to the initial 'The' in the other sentence sets) would be helpful in alerting patients to the reversal of the usual agent/theme ordering, i.e. in topicalising the inanimate object (Bock, 1977; Grieve, 1973b). In structure 3 the action described was the giving of an inanimate object by an animate character to another animate character (e.g. The box gives a ball to the star). In structure 4 the meanings of the sentences were better conveyed by the usual stressing of the object with the article 'the'. Thus, sentence 16 (The star paints the ball that the box holds) conveyed the information that the star was painting a particular ball (the one that the box was holding). The use of 'a ball' here would have subtly changed the meaning (implying that the box held more than one ball).

| Treated items | Untreated items |
|--|--|
| <p>Verbs : paints, gives, holds. Structures :</p> <p>1 The <noun> <verb> a <noun>.</p> <p>2. The <noun> is <verb> by the <noun>.</p> <p>3. The <noun> <verb> a <noun> to the <noun>.</p> <p>4. The <noun> <verb> the <noun> the <noun> <verb>.</p> | <p>Verbs : draws, thinks, puts. Structures :</p> <p>5. The <noun> <verb> a <noun> and <verb> a/the <noun>.</p> <p>6. It is the <noun> that <verb> a <noun> to the <noun>.</p> <p>7. The <noun> that the <noun> <verb> <verb> a <noun>.</p> |
| <p>Structure 1</p> <p>1. The ball paints a box. 2. The box paints a ball. 3. The star paints a box. 4. The box holds a star. 5. The star holds a box.</p> <p>Structure 2</p> <p>6. A box is painted by the star. 7. A star is painted by the box. 8. A ball is painted by the box. 9. A box is held by the ball. 10. A ball is held by the box.</p> <p>Structure 3</p> <p>11. The box gives a ball to the star. 12. The star gives a ball to the box. 13. The ball gives a star to the box. 14. The box gives a star to the ball. 15. The star gives a box to the ball.</p> <p>Structure 4</p> <p>16. The star paints the ball that the box holds. 17. The star holds the box that the ball paints. 18. The box paints the ball that the star holds. 19. The ball paints the box that the star holds. 20. The box holds the star that the ball paints.</p> | <p>TS</p> <p>21. The ball paints a star. TV 22. The box holds a ball. TV 23. The ball draws a box. UV 24. The box draws a star. UV</p> <p>TS</p> <p>25. A ball is painted by the star. TV 26. A star is held by the ball. TV 27. A box is drawn by the ball. UV</p> <p>TS</p> <p>28. The ball gives a box to the star. TV 29. The ball puts a star on the box. UV 30. The star puts a ball on the box. UV</p> <p>TS</p> <p>31. The ball paints the star that the box holds. TV 32. The box holds the ball that the star paints. TV 33. The star draws the box that the ball paints. UV 34. The ball thinks of the star that the box draws. UV</p> <p>Structure 5 US</p> <p>35. The ball paints the box and holds a star. TV 36. The star draws a ball and thinks of the box. UV</p> <p>Structure 6 US</p> <p>37. It is the box that gives a ball to the star. TV 38. It is the ball that puts a star on the box. UV</p> <p>Structure 7 US</p> <p>39. The star that the ball paints holds a box. TV 40. The ball that the box holds draws a star. UV</p> |

Table 19. Target sentences of the Verb Test.

It was hoped that constructing the assessment in homogeneous sentence sets would maximise patients' sensitivity to the syntactic forms within sets and to the syntactic contrasts between sets. Moreover, for diagnostic purposes, the aim was to be able to document dissociations between the patients' abilities to interpret sentence types, and to trap non-linguistic strategies which might produce correct responses in some circumstances and incorrect ones in others (Caplan and Hildebrandt, 1988).

Appendix 4 gives a verbal account of the distractors used in the Verb Test. To assist in visualising the more complex distractors, a typical screen for sentence 32 is reproduced as Figure 8.

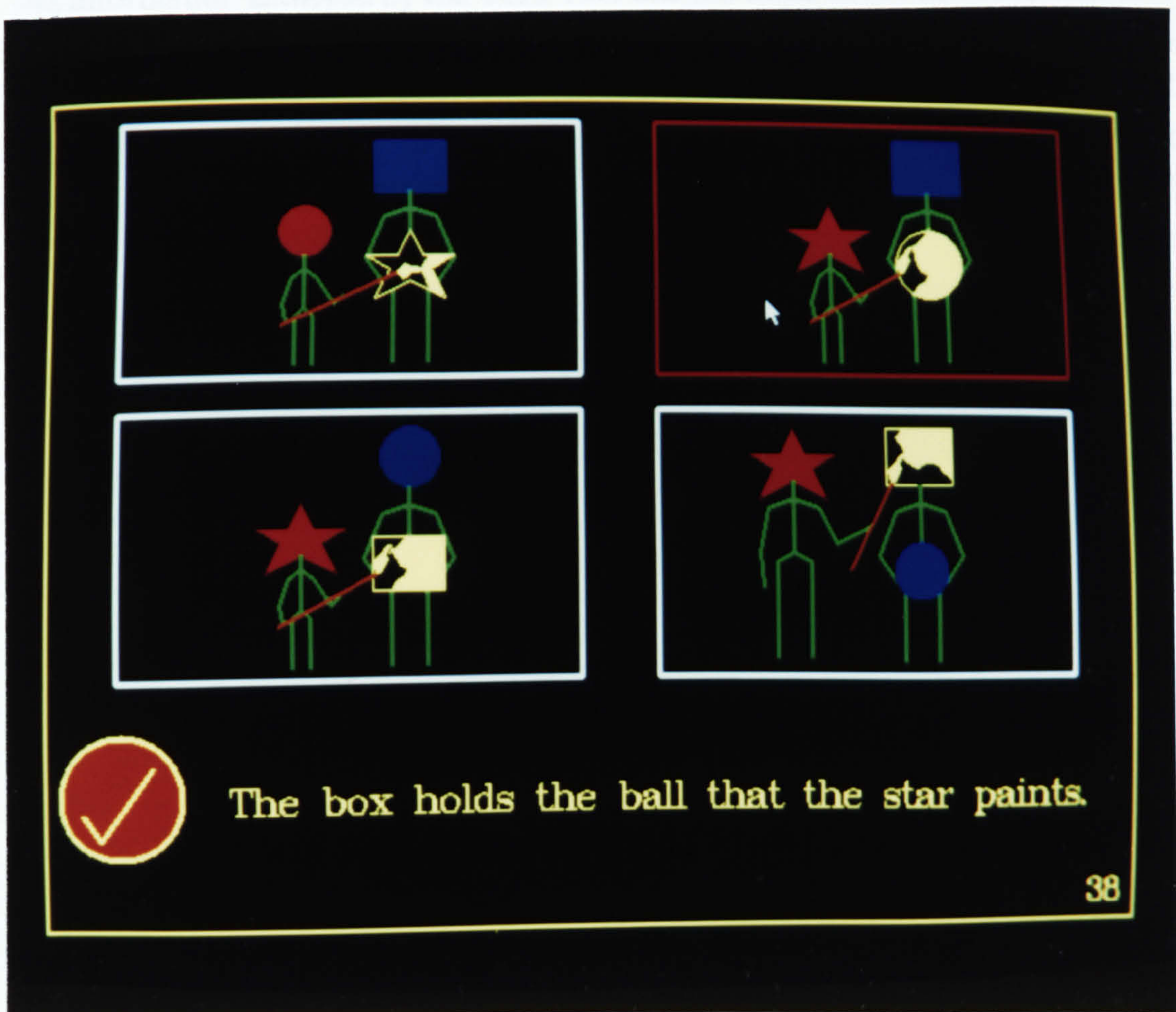


Figure 8. A Verb Test screen for target sentence 32.
(This figure is in colour)

The order of presentation of Verb Test sentences was fixed, instead of being semi-randomised as for the SST. There were several reasons for this. One was the realisation that a test exclusively on the items of greatest difficulty, and progressing in order of difficulty, would offer no respite, and that the hardest sentences would come when the patients were tiredest. It was therefore considered better to arrange the order of presentation so that the simpler sentences were well dispersed. A second consideration was that treated and untreated sentences should be evenly distributed across the test, so that neither one set nor the other should be disproportionately affected by tiredness. Finally, realising that reaction times are influenced by context, that is that the time taken to process a sentence is to some extent affected by the item(s) most recently seen, a fixed order was considered preferable. This was so that any comparisons of reaction times to individual items across tests could not be due to a different order of presentation.

The information gathered by the Verb Test was the same as for the SST; response latency for each item presented, the identification of the picture chosen and its window position (the latter being randomised), the number of pauses taken, total pause time and total time taken for the test. A specimen output sheet for this test is reproduced as Appendix 5. By studying this, in conjunction with Table 19 and Appendix 4, it is possible to relate the output data to the target sentences and to the distractors chosen. For example, from Appendix 5 it is apparent that P7 chose picture number 2 for sentences 6, 7, 8 and 10. Referring to Table 19, it is evident that all these errors were made in the passive block of the treated sentences. Picture number 1 is always correct and pictures 2, 3 and 4 correspond to the three distractors listed beneath the target sentences in Appendix 4. Thus, P7 is shown to have interpreted 4 out of 5 treated passive sentences as actives.

3.2.2 THE PREPOSITION TEST

Like the Verb Test, the Preposition Test (Crerar, 1990) is a 40 item picture-matching test using the same program shell. The target sentences of the Preposition Test are shown in Table 20, and the full list of distractors appears in Appendix 6. As before, the target sentences were divided into 20 treated items and 20 untreated items. There were 3 treated sentence structures in the Preposition Test; 8 instances of structure 1 and 6 instances each of the other two.

| Treated items | Untreated items |
|---|---|
| <p>Prepositions : in, under, behind.</p> <p>Structures :</p> <p>1. The <noun> is <prep> the <noun>.</p> <p>2. The <noun> is <prep> the <noun> and the <noun>.</p> <p>3. The <noun> is <prep> the <noun> that is <prep> the <noun>.</p> | <p>Prepositions : above, between, beside.</p> <p>Structures :</p> <p>4. The <noun> and the <noun> are <prep> the <noun(s)>.</p> <p>5. The <noun> <prep> the <noun> is <prep> the <noun>.</p> |
| <p>Structure 1</p> <p>1. The ball is under the box.</p> <p>2. The box is under the ball.</p> <p>3. The ball is behind the box.</p> <p>4. The box is behind the ball.</p> <p>5. The ball is in the box.</p> <p>6. The box is in the ball.</p> <p>7. The star is behind the ball.</p> <p>8. The ball is in the star.</p> <p>Structure 2</p> <p>9. The ball is under the box and the star.</p> <p>10. The box is under the ball and the star.</p> <p>11. The box is behind the ball and the star.</p> <p>12. The star is behind the ball and the box.</p> <p>13. The ball is under the star and the box.</p> <p>14. The box is behind the star and the ball.</p> <p>Structure 3</p> <p>15. The ball is in the star that is under the box.</p> <p>16. The star is in the ball that is under the box.</p> <p>17. The ball is behind the star that is under the box.</p> <p>18. The box is behind the star that is under the ball.</p> <p>19. The ball is under the star that is behind the box.</p> <p>20. The star is under the ball that is in the box.</p> | <p>TS</p> <p>21. The star is in the ball. TP</p> <p>22. The star is under the ball. TP</p> <p>23. The star is above the ball. UP</p> <p>24. The box is beside the ball. UP</p> <p>TS</p> <p>25. The star is under the ball and the box. TP</p> <p>26. The ball is behind the box and the star. TP</p> <p>27. The box is above the ball and the star. UP</p> <p>28. The ball is between the star and the box. UP</p> <p>TS</p> <p>29. The box is in the ball that is under the star. TP</p> <p>30. The star is behind the box that is under the ball. TP</p> <p>31. The star is beside the ball that is under the box. UP</p> <p>32. The ball is above the star that is in the box. UP</p> <p>Structure 4 US</p> <p>33. The ball and the star are behind the box. TP</p> <p>34. The ball and the box are under the star. TP</p> <p>35. The ball and the star are above the box. UP</p> <p>36. The box and the ball are between the stars. UP</p> <p>Structure 5 US</p> <p>37. The box behind the ball is under the star. TP</p> <p>38. The ball in the star is under the box. TP</p> <p>39. The box in the ball is above the star. UP</p> <p>40. The box above the ball is under the star. UP</p> |

Table 20. Target sentences of the Preposition Test.

The prepositions selected for treatment were *in*, *under* and *behind*; the untreated prepositions were *above*, *between* and *beside*. The *untreated* sentence set was composed of a) treated structures with treated prepositions (TS/TP); that is, untreated instantiations of treated sentence structures with treated prepositions, b) treated structures with untreated prepositions (TS/UP), c) untreated structures with treated prepositions (UT/TP) and d) untreated structures with untreated prepositions (UT/UP).

All the candidate pictures in the Preposition Test were composed of inanimate shapes, as was the case in the SST. This guaranteed fully reversible sentences with minimal pragmatic interference. Thus, *The ball is in the box* and *The box is in the ball* are equi-plausible in the microworld (*in* meaning 'contained within the boundary of' in a two-dimensional representation) in a way that, for example, *The bird is in the sink* (from the animate/inanimate set of Saffran et al. (1980)) and *The key is in the suitcase* (from the inanimate/inanimate set by the same authors) are not. Each picture was composed of two or more objects from the known set [ball, box, star]; the equal status of the picture elements was signalled by the use of the article 'the' in all noun-phrases. The left column of Table 20 shows the progressive nature of the preposition sentence structures; structure 2 being derived from structure 1 with a conjoined noun-phrase and structure 3 being a two-preposition structure, again derived from structure 1, but with an appended relative clause. The untreated structures (structures 4 and 5) test conjunct subjects and subject-relatives respectively, although in the latter cases 'that is' is implicit. The rationale for the preposition structures is therefore very similar to that which guided the choice of verb structures.

For the same reasons as explained in connection with the Verb Test, the order of presentation of the target sentences in the Preposition Test was also fixed, to disperse treated and untreated sentences evenly, and to relieve the harder structures by interleaving easier ones. The assignment of pictures to windows was randomised, as for all the assessments. In addition, the colours of ball, box and star were varied automatically, within the limits of a few predefined sets of contrasting colours, to enhance the inter-run variability (again to minimise the chances of familiarity on repeat testing). The data produced by the Preposition Test was the same as for the Verb Test. A specimen output sheet for the Preposition Test is reproduced as Appendix 7; as before the sentence numbers on the output sheet match the sentence numbers in Table 20. By drawing a conceptual line under the results for sentence 8 and for sentence 14 in Appendix

7, to subdivide the data into treated structure types, it is possible to examine P7's performance across the 3 treated sentence structures. Errors of type 2 were always subject/object reversals for simple sentences, so the 3 errors in treated structure 1 were of this type. Appendix 6 may be used to find out the distractor chosen for any particular sentence, so for example, for sentence 18, *The box is behind the star that is under the ball*, P7 chose a picture corresponding to, *The box is behind the star that is above the ball*.

3.2.3 THE MORPHOLOGY TEST

A 20 item Morphology Test (Crerar, 1990) was designed as a control function, performance on which was not expected to change as a result of treating verbs and/or prepositions. The format of the test was the same as for the preceding two tests, that is, it was a picture-matching test, using the same program shell and the same microworld environment. Table 21 shows the target sentences of the Morphology Test. The presentational order was invariant, but differed from that of Table 21 so that patients would not be primed for the morphological contrasts. A full list of distractors for the Morphology Test is given in Appendix 8, from which it is possible to envisage the salient features of each set of pictures.

| Item no. | Target sentences |
|----------|---|
| 1 | The yellow stars. |
| 2 | The balls and the stars are blue. |
| 3 | The boxes are big. |
| 4 | The balls, the boxes and the stars are small. |
| 5 | The red boxes are big. |
| 6 | The box's ball is red. |
| 7 | The star's ball is big. |
| 8 | The ball's box is yellow. |
| 9 | The box's ball is bigger than the star's. |
| 10 | The star's box is smaller than the ball's. |
| 11 | The ball is smaller than the box. |
| 12 | The box is bluer than the ball. |
| 13 | The box is starry. |
| 14 | The ball is blueish. |
| 15 | The star is the smallest. |
| 16 | The ball is boxless. |
| 17 | The star drew a ball. |
| 18 | The ball painted the box. |
| 19 | The star is the painter. |
| 20 | The box the ball gave is reddish. |

Table 21. Target sentences of the Morphology Test.

A specimen screen from the Morphology Test is reproduced at Figure 9. This is a typical screen for sentence 19, and shows how past tense was conveyed. An output sheet from the Morphology Test is included as Appendix 9. As with the previous tests, the specific error made for any response can be determined by locating the distractor chosen in Appendix 8. For example, Appendix 9 shows that P7 chose picture number 4 for sentence 10, *The star's box is smaller than the ball's*. Appendix 8 reveals that the final distractor to sentence 10 was a representation of *The star's box is smaller than the ball*, thus P7 failed to attend to the final possessive marker (an error common among normal subjects, recall Table 9 (p.86) item 42).

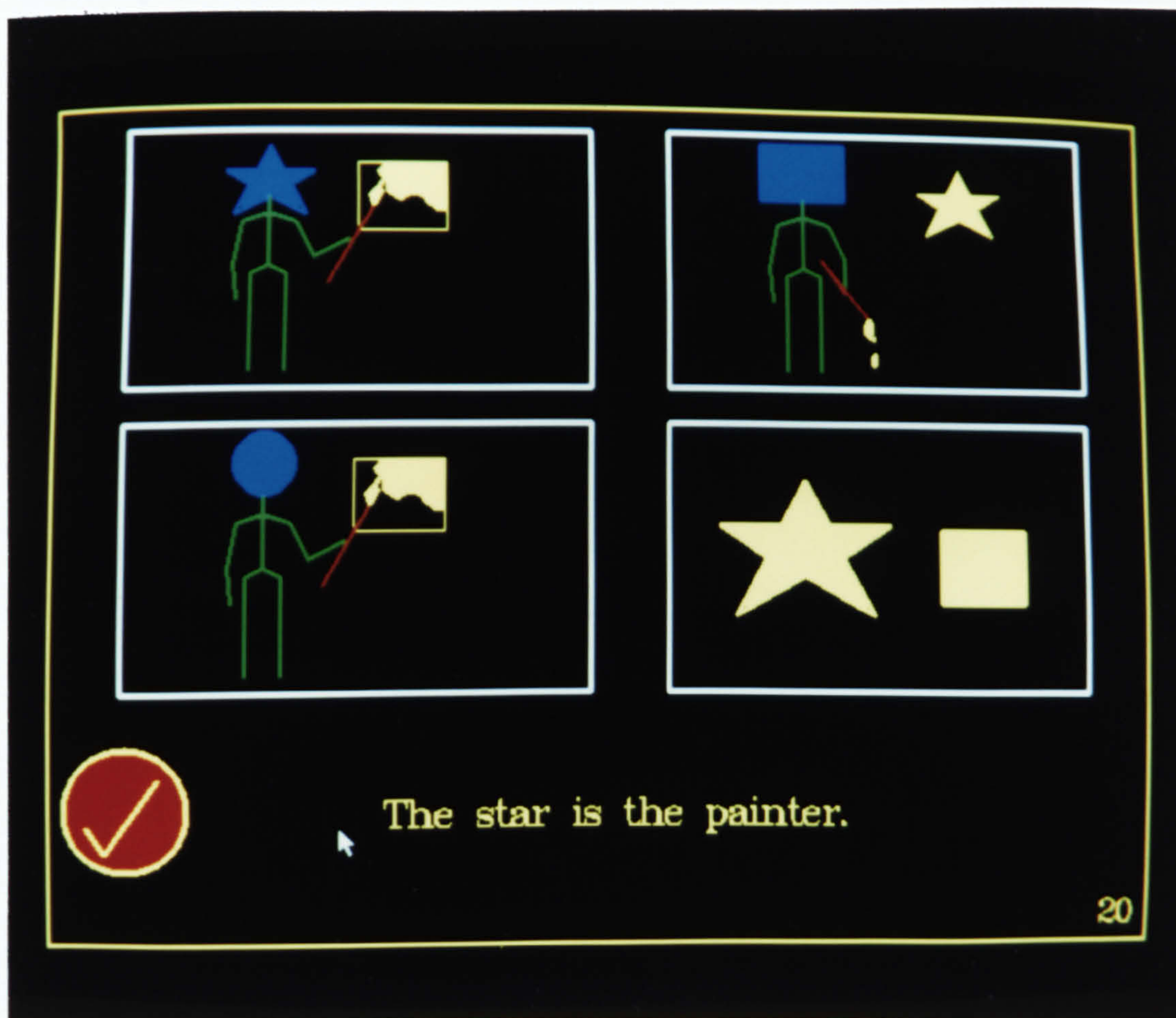


Figure 9. A Morphology Test screen for sentence 19.
(This figure is in colour)

The performance examples given for this and the preceding two tests were included purely for introductory purposes. Using Appendices 4, 6 and 8 in this way will facilitate the examination of the errors made by individual patients (reported later in this chapter and subsequently), and aid an appreciation of the improvement in diagnostic precision afforded by this approach to assessment.

3.2.4 THE REAL WORLD TEST

The Real World Test (Crerar, 1990) was designed to provide an indicator of whether, as a result of treating verbs, prepositions and grammatical structures in the computer-based microworld, improvement would generalise to real world scenarios independent of the computer environment. For this purpose it was necessary to devise a test which would fulfil the objective without introducing the need for skills which had not previously been shown to be intact. To make the Real World Test anything other than a picture-matching test (for example an object-manipulation test) would have introduced a potentially confounding factor, the new medium. It was therefore decided to make the Real World Test a paper-based version of the computerised assessments, creating a 'half-way house' between the artificial, stylised world of ball, box and star, and the real world in which we live and about which we read. A much larger, but still simple and circumscribed vocabulary was chosen for the Real World Test. This is shown in Table 22. The vocabulary was carefully selected to ensure that all the target sentences constructed would be fully reversible, and the sentences and candidate pictures were devised to try to ensure that the target and reverse role interpretations were equi-plausible. From Table 22, it will be seen that all the nouns are new, but that the prepositions and verbs contain both those treated in the microworld (*in, under, behind, paints, holds, gives*) and some new ones which were not treated.

In depicting verbs and prepositional relationships which had been seen in the microworld (whether they had been treated or not), an effort was made to maintain consistency between the computerised and the more naturalistic pictures. Thus, for example, when characters were thinking, giving or holding etc. in the Real World Test, the actions were drawn as similarly as possible to the microworld representations. Likewise, for example, the preposition *in* is used in the Real World Test in the same sense as it was used in the computerised

environment, that is to mean 'contained within the boundary of', and not 'located inside' as in *The spoon is in the cup*.

| Nouns | Prepositions | Verbs |
|-----------|--------------|--------|
| bed | above | chases |
| biscuit | behind | climbs |
| book | beside | draws |
| boy | between | gives |
| cat | in | holds |
| chair | under | paints |
| clown | | pulls |
| cup | | thinks |
| dog | | |
| door | | |
| flower | | |
| girl | | |
| ladder | | |
| newspaper | | |
| pencil | | |
| picture | | |
| saucer | | |
| table | | |
| tea | | |
| window | | |

Table 22. Vocabulary of the Real World Test.

The target sentences of the Real World Test appear in Table 23. The Real World Test contained 40 items divided into two blocks; 20 verb sentences and 20 preposition sentences. In each block of 20, 10 sentences were treated structures with treated verbs or prepositions (these are in the left column of Table 23), and the remaining 10 were divided into two groups of five; treated structures with untreated verbs or prepositions, (sentences 11..15 and 31..35), and untreated structures with untreated verbs or prepositions, (sentences 16..20 and 36..40). The presentational order of sentences in the Real World Test conformed to the sentence numbering in Table 23.

The Real World Test was produced as black line drawings and black text on a yellow background, the only other colour used being a dab on pictures illustrating the verb *paints*. An effort was made to make the scenarios as realistic as possible. The assignment of pictures to 'windows' had, of course, to be fixed for this test; the allocation was carried out to ensure an even distribution of candidate types

across window positions. Figure 10 shows a typical page from this test. A full list of target sentences and distractors is given in Appendix 10.

| Verb sentences | |
|--|--|
| 1. The clown paints a girl. | 11. The girl draws a boy. |
| 2. The girl holds a boy. | 12. The dog thinks about the cat. |
| 3. The boy paints a clown. | 13. The girl pulls the dog. |
| 4. A girl is painted by the clown. | 14. A boy is chased by the dog. |
| 5. A clown is painted by the boy. | 15. A clown is drawn by the boy. |
| 6. A boy is held by the girl. | 16. The clown draws a girl and thinks of the dog. |
| 7. The clown gives a flower to the girl. | 17. The girl draws a clown and thinks of the boy. |
| 8. The girl gives a cat to the boy. | 18. It is the clown that gives a cat to the girl. |
| 9. The boy holds the ladder that the girl climbs. | 19. The clown that the boy draws holds a flower. |
| 10. The girl paints the ladder that the boy holds. | 20. The girl that the dog pulls holds a newspaper. |
| Preposition sentences | |
| 21. The dog is under the bed. | 31. The cup is above the tea. |
| 22. The cat is behind the door. | 32. The tea is above the biscuits. |
| 23. The picture is in the book. | 33. The cup is between the tea and the biscuits. |
| 24. The cups are under the tea and the biscuits. | 34. The dog is between the boy and the girl. |
| 25. The boy is behind the girl and the dog. | 35. The cup is above the tea and the biscuits. |
| 26. The tea is under the cups and the biscuits. | 36. The tea and the biscuits are between the cups. |
| 27. The biscuits are behind the cup and the saucer. | 37. The girl and the boy are behind the door. |
| 28. The pencil is under the book that is behind the cup. | 38. The cat is above the tea and the biscuits. ⁵¹ |
| 29. The cat is under the table that is behind the chair. | 39. The dog in the window is above the cat. |
| 30. The dog is behind the cat that is under the chair. | 40. The girl on the ladder is above the boy. |

Table 23. Target sentences of the Real World Test.

Appendix 11 shows a typical score sheet designed to accompany this test. The correct answers were preprinted (that is the window positions at which the correct pictures were located, numbered 1, 2, 4, 3 from top left, clockwise, as for the computer screen). Description of the actual pictures chosen can be found by matching the patient's responses shown on the score sheet with the *window position numbers* given in parentheses after the distractor descriptions in Appendix 10.

⁵¹ Sentence 38 is in fact a treated *structure*. I regret that this minor flaw was not noticed before the test was used with patients.

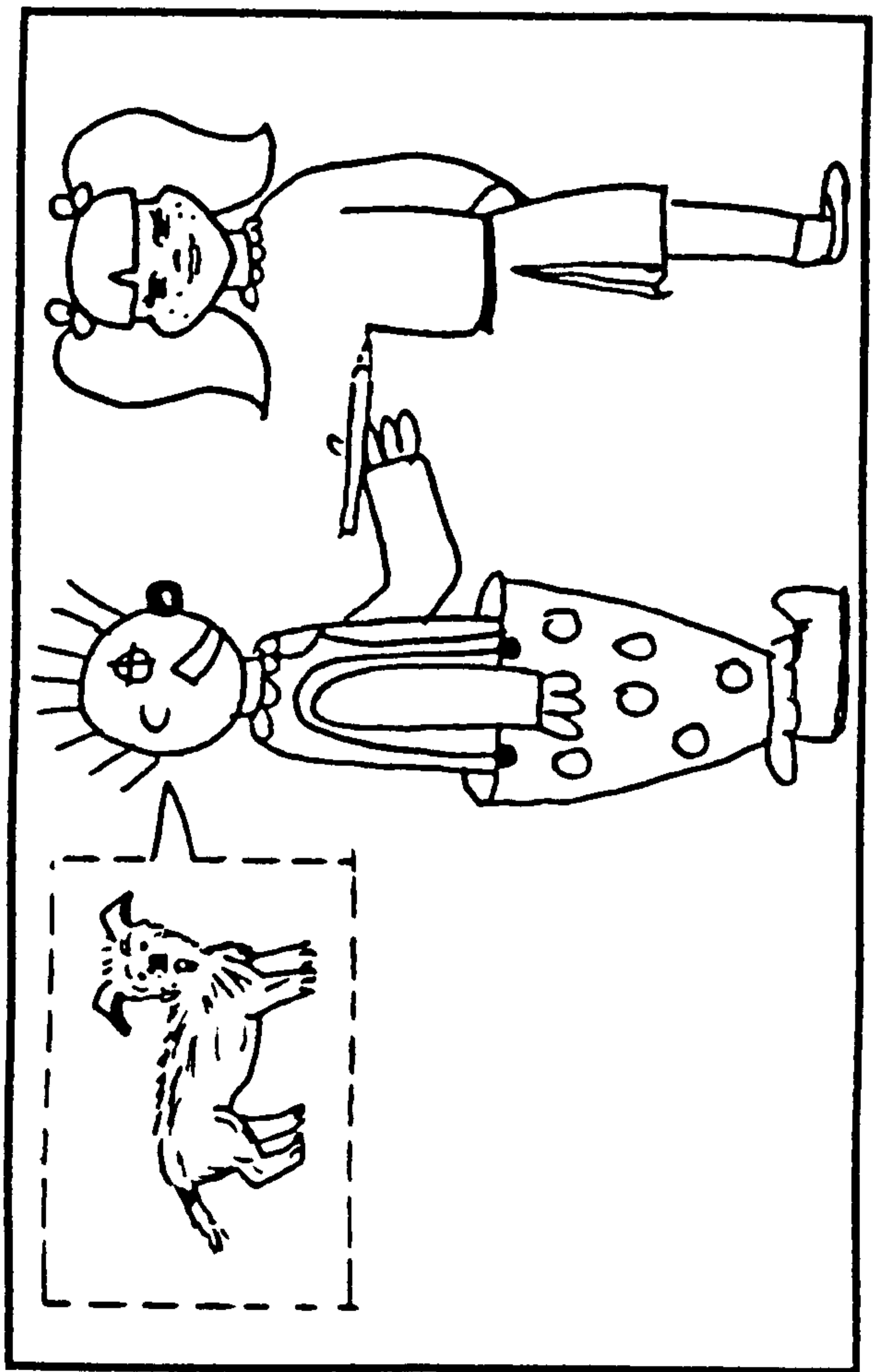
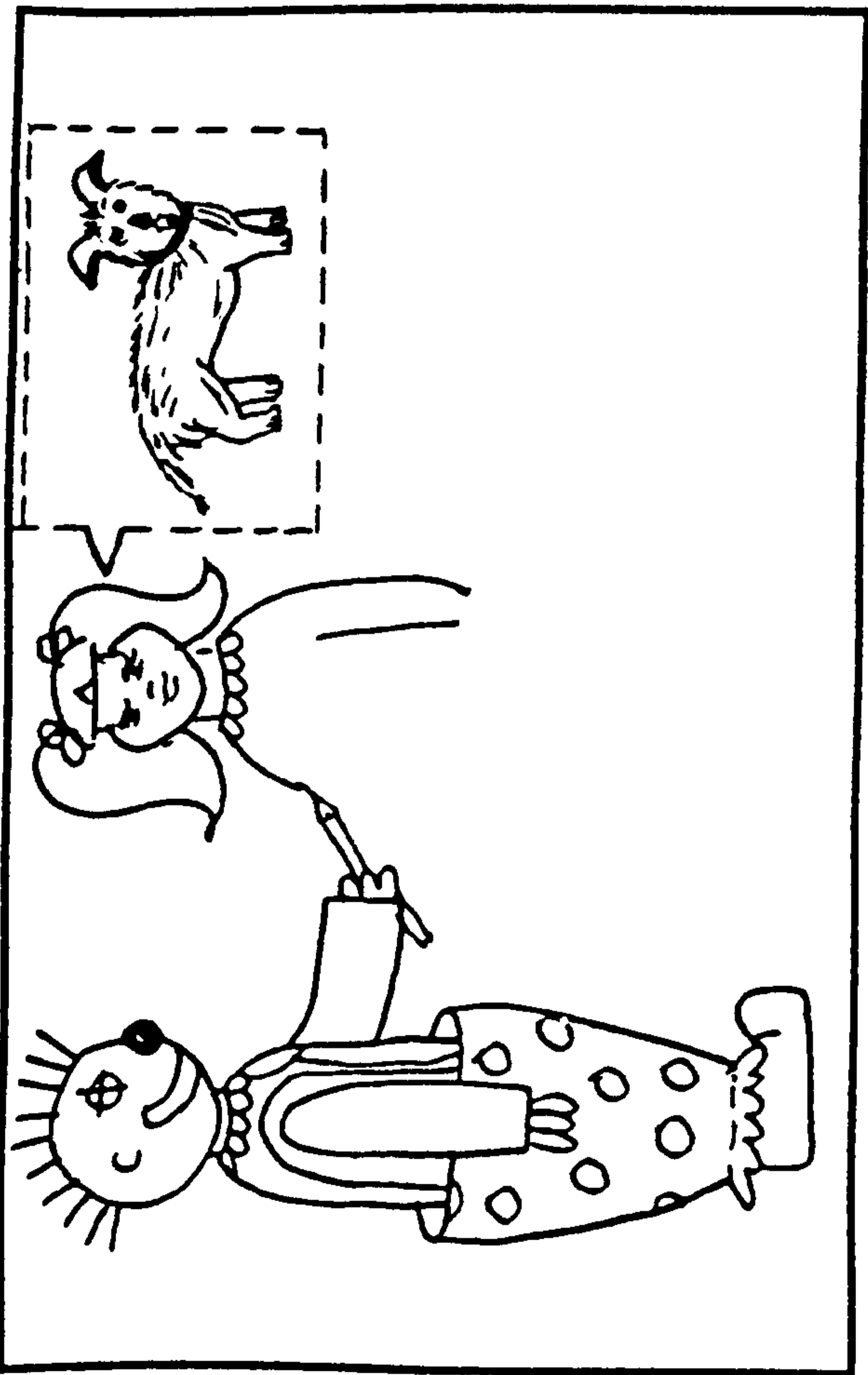
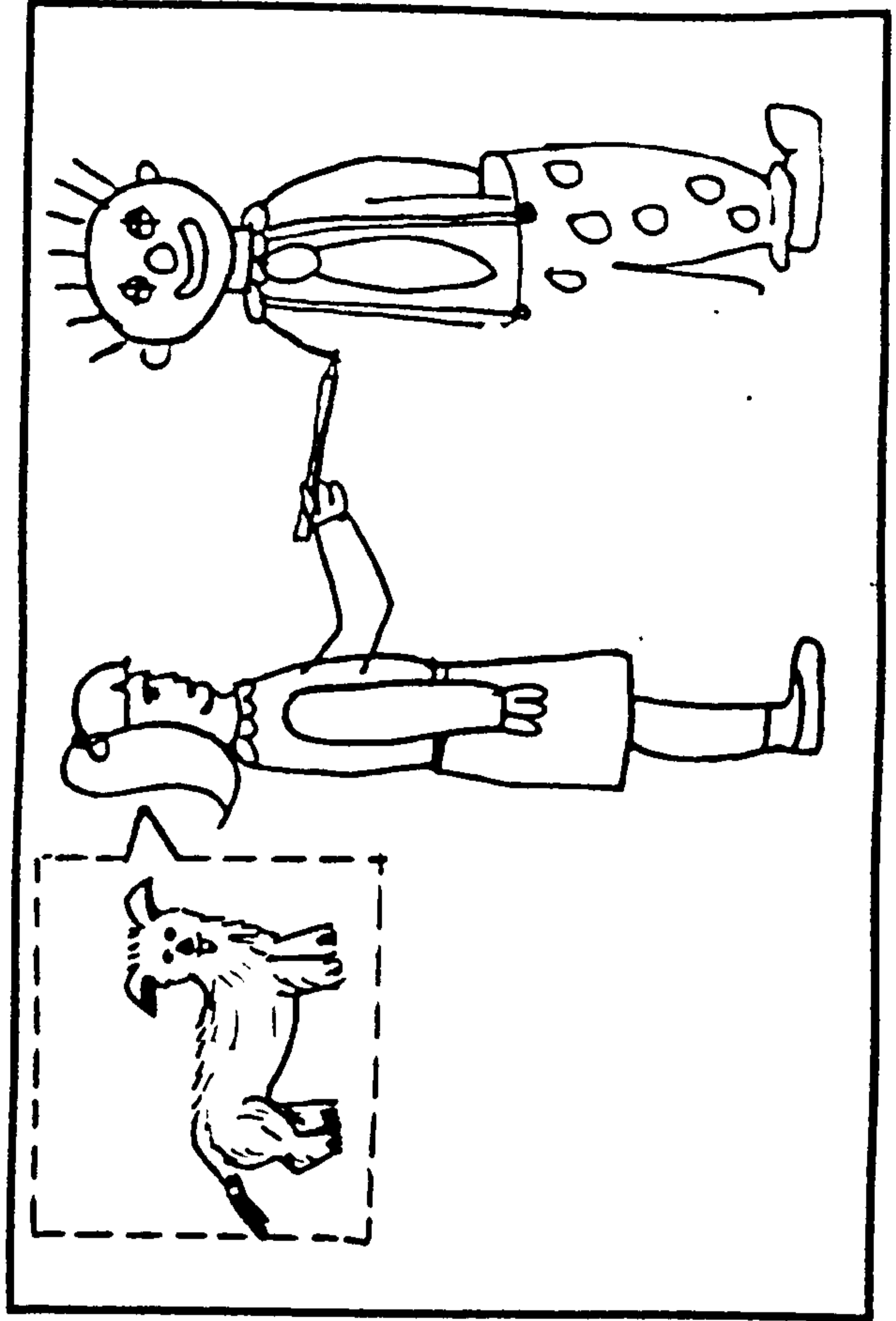
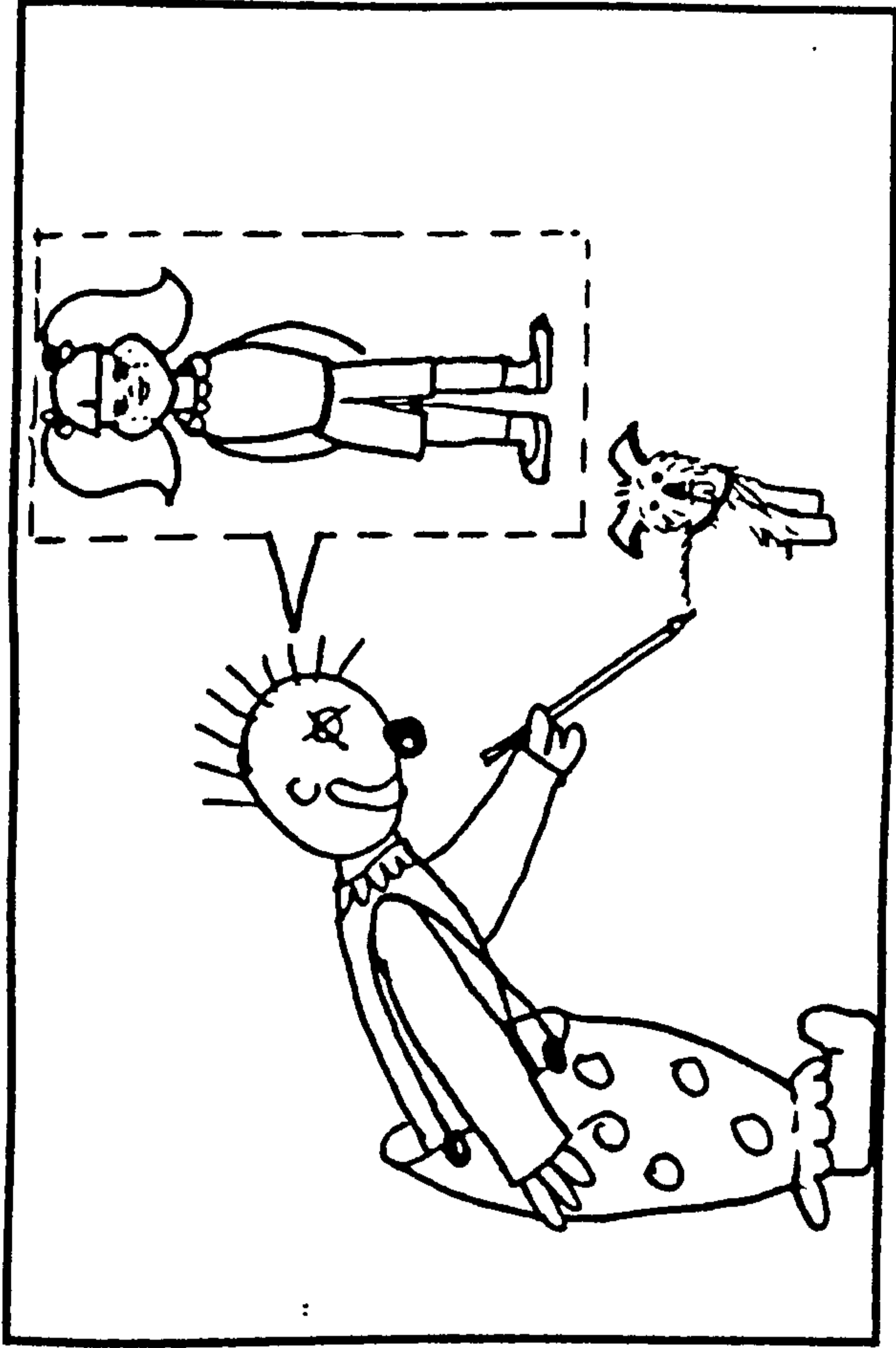


Figure 10. A typical page from the Real World Test.

The clown draws a girl and thinks of the dog.

For example, Appendix 11 shows that on P3's first exposure to the Real World Test, he made errors in the verb block on sentences 1, 12, 15 and 20. The nature of the error made on sentence 12, *The dog thinks about the cat*, can be determined by turning to Appendix 10, where his response (3) identifies the distractor *The dog thinks about the rat*. By the same method it may be discovered that on sentence 15, P3 reversed the subject and object in passive voice (or interpreted a passive sentence as active).

3.3 PRINCIPLES OF THE REMEDIATION SOFTWARE

Just as all the computer-based assessment programs were consistent in format, utilising the same program shell and thereby presenting a uniform interface to the patient, the remediation programs were likewise based around a common philosophy and HCI. The remediation strategy and the common operational characteristics of the Verb Remediation Program (VRP) (Crerar, 1990) and the Preposition Remediation Program (PRP) (Crerar, 1990) will be described first, before moving on to the rationale behind the software and the unique features of each program.

Underlying the design of the remediation programs was the conviction that the traditional compartmentalisation of 'assessment' and 'treatment' is inappropriate in the current state of knowledge about sentence processing deficits. It may be more generally unproductive, fostering the impression that diagnosis ceases before treatment commences, but that is a separate issue. Certainly, in the case of sentence processing dysfunctions, the complexity of the diagnostic problem-space is such that it is impossible for assessment to be complete and comprehensive before treatment is offered. For this reason a multi-layered approach to exploration was taken. The SST provided an overview of the patients' performances across six linguistic functions, pointing up weaknesses in speed and accuracy. The Verb Test and Preposition Test followed, to yield performance data on selected sentence structures and lexical items. By means of the latter two tests it was possible to focus quite specifically on areas of deficit, and if the error patterns were regular, to hypothesise about possible reasons for the problems. However, even at this level of analysis (which goes well beyond the detail that existing tests permit), one can still only know *what* a patient gets wrong, and not with any surety *why*.

In the present research the remediation phase was more accurately 'diagnostico-remediative', the idea being that after formal assessment during which there was no collaboration, the 'treatment' phase saw the clinician and patient as partners in an interactive quest for a deeper understanding of the patient's difficulties. The nature of this process dissolved the usual roles of therapist and patient; the patient was an active contributor, not the passive recipient of therapy, the clinician was responsive to every new shred of evidence, guiding the discovery process, not working through a predetermined treatment regime. This concept of 'joint adventurers' was at the heart of the remediation software: I wanted to build an environment which would, at one and the same time, facilitate deeper, interactive assessment and enable remediation based on the resulting insights.

The microworld language and characters provided an ideal way of approaching these requirements. As the miniature world aided the precision of formal assessment by providing a closed and controlled linguistic environment, appreciation of which could be tested by non-linguistic means (picture-matching), the same environment offered a route to finer diagnosis and therapy. This may seem an obvious point, but to my best knowledge this is the first attempt to provide an integrated assessment and therapy environment. In the present formal assessment, the patient simply chose the one picture from four that he thought matched the target sentence, thus, unless subjects did a lot of verbalising or gesturing, the working out behind selections was largely unavailable to the observing clinician. While receptive language is fairly straightforward to *test*, the underlying processes have, heretofore, been notoriously difficult to penetrate (Garnham, 1985, p.221). The next stage, after having identified the linguistic functions with which a patient has consistent trouble, is to devise a method whereby the mechanisms behind his aberrant performances are amenable to scrutiny. The remediation programs do just this in two complementary ways, picture-building mode (PB mode) and sentence-building mode (SB mode).

PB mode is the easier. In this mode the patient is confronted by a target sentence and is required to build a picture to match it, element by element. Conversely, in SB mode, the patient is given a completed picture and is required to construct a sentence to describe it; this technique is similar to the procedure used by Saffran et al. (1980) adopted from the Sentence Order Test of von Stockert (1972). Each of these modes is explained in more detail below. The 20 sentences treated in each of the remediation programs were listed above in Table 19 (verbs) and Table 20 (prepositions). Within a remediation program the clinician can access any sentence in either mode at any time. This is done by entering the sentence

number, followed by an 'a' for PB mode, or a 'b' for SB mode. For example, inside the PRP, a request for sentence 9a will invoke a picture-building task for *The ball is under the box and the star*, while inside the VRP, a request for sentence 9b will bring on the sentence-building task for *A box is held by the ball*. If the clinician does not divert the order of presentation, the program will work automatically through the treated structures, first in PB mode, then in SB mode (thus for the PRP, 1a..8a, 1b..8b, 9a..14a etc.).

A specimen PB mode screen is reproduced as Figure 11. The target sentence *The box is under the ball* appears at the bottom of the screen on the *text line* and is identified as sentence number 2a (PRP). The three small windows at the top of the screen are *picture palettes* (there are always three of these), and the large window in the centre of the screen is known as the *working window*.

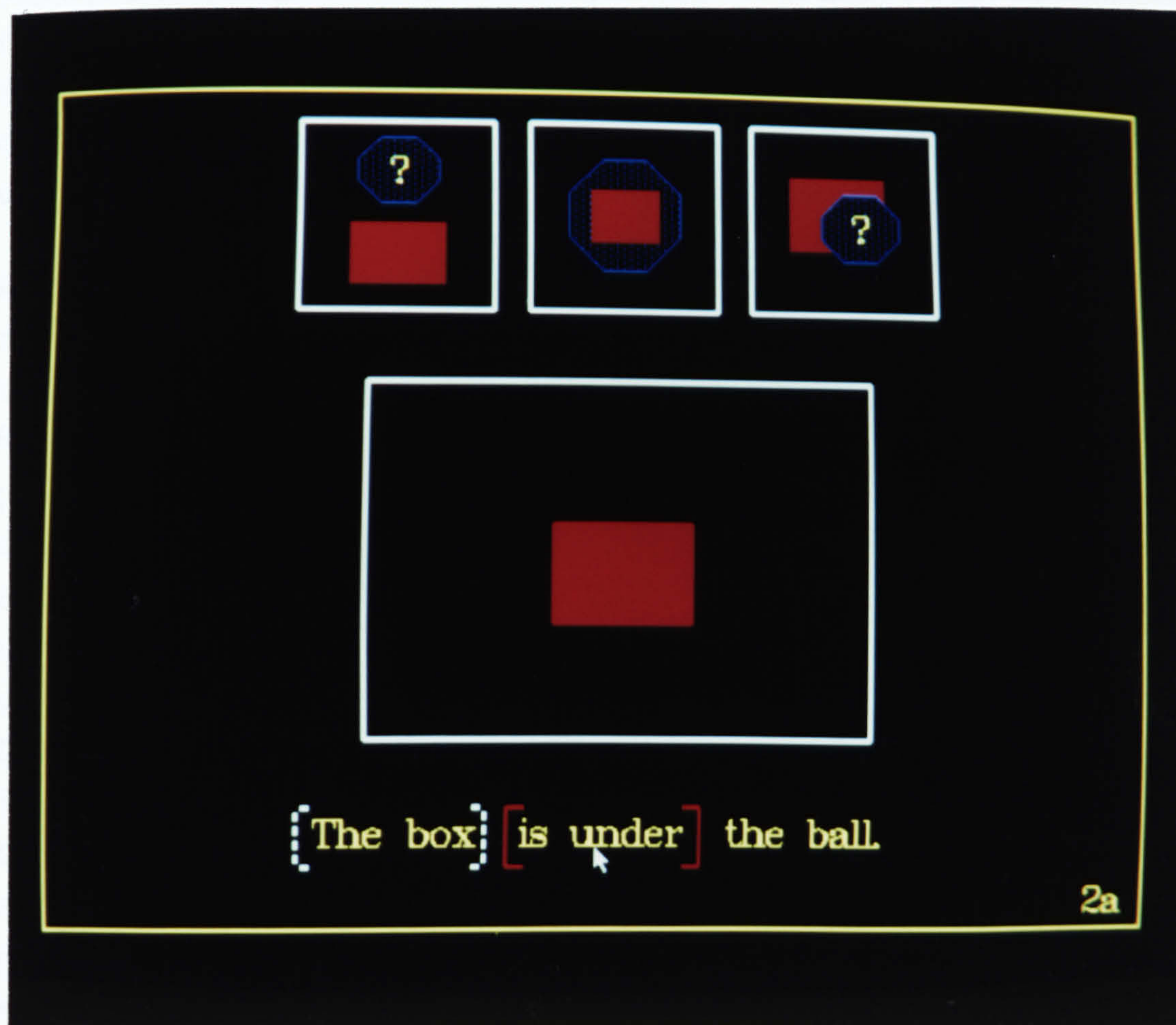


Figure 11. A Preposition Remediation Program screen for sentence 2a.
(This figure is in colour)

At onset of a PB mode task, the picture palettes and the working window are empty, and the target sentence has solid, white, square brackets around the first 'semantic chunk' (in this case, '[The box] is under the ball.'). At this point, the only valid action is to activate the bracketed component by clicking the mouse with the cursor positioned between the brackets. This results in the brackets turning red and the picture palettes offering three pictorial choices (*ball*, *box* and *star*) for the active lexical component (The box). The assignment of pictures to picture palettes is randomised at the beginning of each task and thereafter remains unchanged. Thus ball, box and star, as subject or object, animate or inanimate, will appear in the same palette position throughout a picture-building task. Similarly with the use of colour; each (pictorial) noun has a colour allocated to it at the beginning of a picture-building task and retains that colour throughout. Selection of a picture is achieved by moving the cursor into the desired picture palette and clicking the mouse, whereupon the working window is updated to reflect the choice(s) so far, the picture palettes are cleared, the brackets around the selected lexical chunk are changed to broken white (to indicate that this component has been done but is available for alteration), and the next 'semantic chunk' is shown to be ready for selection by means of solid, white brackets.

Figure 11 depicts the task with the user having activated the second sentence component, *is under*. The red brackets indicate that this component is active and the picture palettes offer a choice of three spatial relationships *in*, *under* and *behind* (the three treated prepositions). Notice that the objects in the picture palettes are a box (because that has been selected at stage one) and an octagonal object with a question mark at its centre (because the second object is as yet unknown). Had the user erroneously chosen a ball to match the subject of the sentence, the picture palettes would show balls instead of boxes. On successful completion of a PB task, the picture palettes disappear, the brackets fall away from the target sentence, and the frame of the working window changes to red. The sentence and correct picture are maintained until the mouse is clicked with the cursor anywhere inside the working window. On the other hand, if the user constructs a picture, one or more components of which is incorrect, the picture palettes remain, the working window frame is not highlighted, and broken, white brackets delineate all semantic chunks. The software gives no help with the source of the error(s), this is for the patient (with assistance from the therapist, if appropriate) to find out. Because of the consistent use of colour coding, it is easy for the patient, even on the more complex sentences, to check the lexical

selections by clicking on the suspect sentence component and checking to see whether the object in the working window, of the same colour as the objects in the picture palettes, is indeed correct for the activated sentence component. If the patient has occasion to return to a verb or preposition after the instantiation of its second argument, the picture palettes will, of course, reflect both nouns selected.

Switching to SB mode, the patient's ability to construct the same sentences he has responded to in PB mode can be tested by this time presenting a completed working window and filling the palettes with sentence components instead of with pictures. Figure 12 illustrates a typical screen.

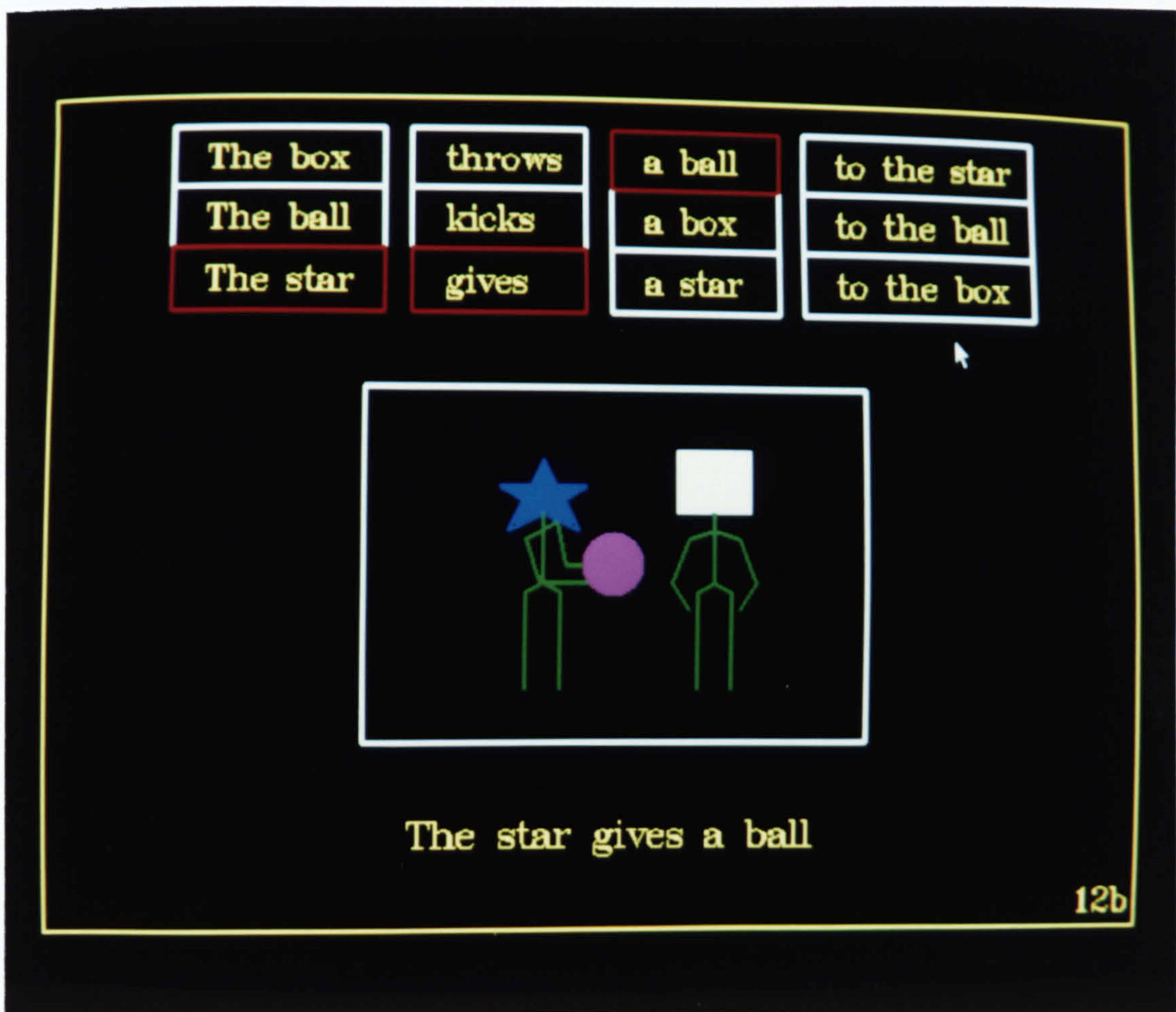


Figure 12. A Verb Remediation Program screen for sentence 12b.
(This figure is in colour)

Here, the user is part way through completion of sentence 12b (VRP). At onset of a task in SB mode, the text line is empty, the working window is complete, and the *lexical palettes* (of which there are as many as semantic chunks in the final

sentence) each display three options. All the lexical choices remain on screen for the duration of the task. The patient's job is to select one component from each of the lexical palettes in turn.⁵² He must tackle this in left to right order, but may at any time alter a previous choice. A selection is made by moving the cursor anywhere inside the frame bordering an option, and clicking the mouse, whereupon the frame is highlighted in red, and the selected sentence component is appended to (or in the case of a correction, substituted in) the text line. Figure 12 shows a task in progress. The user has correctly chosen the first three sentence components, as reflected in the lexical palettes and text line, and is about to choose an indirect object from the fourth lexical palette. Correct completion of this task results, as in PB mode, in the disappearance of the lexical palettes and the highlighting of the working window, allowing the patient to contemplate the matching sentence and picture for an unlimited time (or to discuss various aspects of the screen with the clinician) before proceeding. Incorrect completion produces no change in the screen; the patient must in this event proceed to 'debug' his solution.

It should be pointed out that the remediation software does no data collection: this is in keeping with the exploratory nature of it. The type of observations more appropriate at this level are made by the clinician and are recorded manually on purpose-designed observation sheets.

A verbal description of the system can only be a poor substitute for seeing it demonstrated, or better, using it; however, it is hoped that the foregoing gives a comprehensible overview of the operational characteristics of the remediation software. Having explained in general how it works, the underlying rationale is offered below, followed by the specifics of the verb and preposition versions.

3.3.1 REMEDIATION SOFTWARE RATIONALE

Section 3.3 introduced the diagnostico-remediative philosophy that underpins the treatment phase. In designing the remediation software, the aim was to create an environment in which the needs of the therapist and patient would be simultaneously met; that is, an environment in which the same features that might help a patient improve his sentence processing would also render his cognitive processes transparent, in the cognitive neuropsychological sense, to the clinician.

⁵² None of the patients had any difficulty with the fairly fine motor control required, the previous computer-based assessments had served them well in this respect.

In essence, by disciplining the patient to decompose subtasks systematically, and by controlling the subtask and the options before him at any point, it should be possible to gain a more accurate understanding of *where*, and perhaps *why*, his sentence processing is breaking down. Clearly, the use of a visual medium both for assessment and treatment yields important advantages, notably that patients' understanding of language can be gauged through a relatively preserved modality. This allows us to tap residual symbol processing capacities which may not be accessible through language-only channels.

It is easy to see how the microworld is useful diagnostically, but perhaps less apparent that it should be a promising treatment medium. The intention in devising the treated sentence structures within the microworld can be best explained by analogy with algebra. Algebra is a sort of generalised mathematics which uses letters to stand for variable quantities. In learning algebra, one acquires the principles of how to work with equations and, having mastered them, can handle *any* real world problem in which those 'place-holders' are instantiated with actual values. To put it simply, the power of mastering addition, multiplication and the laws of precedence governing an expression like $a+b*c$, is to be able to handle *any* similar expression, *whatever* the values of a, b and c happen to be. Ball, box and star are a linguistic a, b and c. It was hoped that by treating language dysfunctions in this parsimonious and abstract environment, general principles could be imparted that would translate to real world situations. Thus, behind the idea of teaching in a microworld was the goal of restoring general principles, such that patients who mastered, for example, *The box is under the ball* and *The star is under the box* might then, subject to recognising the lexical items, be able to understand anything under anything else.

Obviously a key problem in designing the software, and one that relates both to SB and to PB mode, was to decide how to tackle parsing. The literatures of linguistics, psycholinguistics and computational linguistics yielded very little of direct help in approaching the restoration of sentence processing skills. The search was largely fruitless because formal accounts of the theory of language and of automated parsing are, respectively, theoretically and practically useful, but not as a means to understanding *how* humans perform the parallel tasks and certainly not for teaching humans how to perform the tasks. An example might be the difference between on the one hand a rigorous, mathematical exposition of the physics of bicycle-riding, including human physiology, the principles of cycle construction and a set of equations to encapsulate balance maintenance on rough

terrain (such as would be needed to teach a robot to ride a bicycle), and on the other hand what a five year old knows and does in riding his machine competently. This is not as fanciful a comparison with language as might be thought at first sight, for both intact language and proficient bicycle-riding are automatic skills. One of the problems confronting aphasiologists is how best to approach the reinstatement of skills that were not previously subject to conscious introspection, and about which the patient probably had virtually no formal theory.

In deciding how best to go about the remediation of the treated sentence sets, three guiding criteria were adopted. Firstly, that the method chosen should be couched in terms of language components likely to be feasible as subjects of clinical discussion (i.e. understandable to the patients); secondly, that the method of decomposition used should be diagnostically useful in allowing breakdowns to be ascribed to meaningful units of understanding and finally, that the procedure should explicitly take account of current insights into how aphasic subjects do in fact attempt to understand sentences, and of their reduced computational capacity.

This pragmatic approach found support in the psycholinguistic literature relating to language understanding in normal subjects:

Thus people remember neither the syntax nor the semantics of what they hear, but rather its content, in a more general sense. They produce a representation of what the *world* would be like if the passage were true - a representation that is not closely related to any linguistic description of the text, and which should not be called a semantic representation. A more appropriate name for it is a *mental model* of a situation in the real or an imaginary world. (Garnham, 1985, p.141).

The idea of a mental model (Johnson-Laird, 1983) was a seductive one, especially in view of the computer software providing a visual, interactive medium whereby an explicit representation on the screen could be compared with an internal model, or indeed, could be instrumental in helping to construct such a mental model, element by element. Furthermore, it turned out to fuse well with the first criterion mentioned above, of wanting to find an approach to grammar suitable for clinical use. The approach taken here owes a great deal to the notion

of *structural semantics*, (Garnham, 1985) with overlays, from the domain of Artificial Intelligence. By this view, the treated sentences are simple propositions, the processing of which is regarded as giving rise in the patient to a mental model the truth value of which is determined with respect to a candidate picture. Thus the mental model is a general abstraction of the salient relationships (structural semantics) in the proposition, such that any picture (or state of affairs in the real world) can be judged consonant with it, or not. Rather than imagining the target sentences to result in a full syntactic parse in the traditional sense, it was proposed that patients derive from them, or be encouraged to derive from them, a list of sub-propositions, each of which could be checked for veracity against the target stimulus (and each of which was thereby externalised for the clinician to study). In conceptualising this a first order logic, or Prolog⁵³-type representation is useful, though, of course, such a formalism was not used explicitly with patients. For example, the meaning of sentence 16 (VRP), *The star paints the ball that the box holds*, can be represented as follows:

sent16 := star(x), ball(y), box(z), paints(x,y), and holds(z,y).

This should be read as, 'sentence 16 is true if (there exists an x, a y and a z such that) x is a star, and y is a ball, and z is a box, and x paints y, and z holds y. Similarly with a prepositional sentence, we can represent the meaning of sentence 9 (PRP), *The ball is under the box and the star*, as below:

sent9 := ball(x), box(y), star(z), and under(x,y), and under(x,z).

Notice that the list of conjunct goals on the right side of each expression needs no further decomposition, since the predicates can be considered primitives in the microworld vocabulary which have been shown to be intact in patients through the use of the preliminary assessments.⁵⁴

The literature of aphasiology proved very sparse in detail concerning how patients actually perform language processing tasks, the reason being that most studies have been concerned with documenting impairments and very few with trying to treat them. On the whole, there is a chasm between the highly technical accounts of breakdown allied to various formal theories of parsing (e.g. Grodzinsky, 1984; 1986) and the procedures by which patients are supposed to arrive at their

⁵³ Prolog is a functional programming language (Bratko, 1990).

⁵⁴ Remediation PB mode does allow lexical semantics for the primitives (non-decomposable elements) to be checked.

interpretations. Although the analytical work of Caplan and colleagues and the formulation of their test batteries were based on government-binding theory and the Berwick-Weinberg parser (Berwick and Weinberg, 1985), it was in this source that the most practical insights were found. Caplan and Hildebrandt (1988) reported an overall computational deficit in all their patients on top of which individual deficit patterns were apparent. They called this general reduction in capacity *a decrease of parsing workspace*. They performed in-depth analyses on the types of errors made to a wide variety of sentences structures to try to account for the underlying processes in terms of residual language-specific knowledge, language-universal factors or non-linguistic heuristics; their conclusions were illuminating:

The error patterns we have documented can all be accounted for by the application of simple interpretive rules to linear sequences of major lexical categories.... We have not found it necessary to postulate hierarchically organized phrase markers as the structures to which interpretive rules apply to yield erroneous interpretations. Moreover, the interpretive rules themselves are very simple; they assign thematic roles on the basis of the absolute position of a noun in a sentence, simple precedence relations among the items specified in a linear sequence of categories and a few lexical items (such as *by*)..... These features testify that nonlinguistic factors are at work in the determination of the interpretive aspects of the compensatory mechanisms employed by the aphasic patients..... We may indeed ask whether there is any truly linguistic aspect to the heuristic rules we have described, or whether they are entirely due to a pre-linguistic portion of human cognition that provides primitive structures and simple interpretive algorithms. (Caplan and Hildebrandt, 1988, pp. 283-287).

These insights alerted me to the possibility that aphasic subjects might be operating according to compensatory strategies developed post-onset, that these might be simple rule-based procedures and that some of them at least might be being consciously invoked. In this case it seemed possible that some of the rules might be discoverable and that if the patients had the capacity to develop and apply them, they might be capable of learning corrected versions. Thus therapy sought to operate at this level and to these ends.

In assisting patients to derive an appropriate mental model from the treated sentences, the method of parsing chosen was one of *semantic chunking*, which has

elements in common with the *case grammar* approach of Fillmore (1968; 1971) and with the *case-frames* of Schank (1975), both of which were influential in Artificial Intelligence. Both approaches defined a set of syntactic primitives over a set of relations such as *verb*, *agent*, *object*, and *instrument*. Thus the syntactic categories were *semantically-driven* and could be considered as *slots* to be filled, or instantiated, with the values of a particular proposition. The treated verb and preposition structures (see Tables 19 and 20) were considered to be sentence templates, instantiated by sentences 1..20 in each table. In PB mode, the patient was guided through the parsing of a sentence in left to right order by the use of square brackets, as described in section 3.3. The square brackets bound what may be termed the 'semantic closures' of the sentence - the important units of meaning. The term *closure* has been used previously to denote the breaking up of a sentence into manageable units for the parser to handle, generally phrases, and much has been written about optimal closure points (Frazier and Fodor, 1978). In the present work, this idea has been applied to what are considered to be the salient morphological units, in order to reduce the burden on processing capacity. The integration of these is taken to be the formulation of a mental model.

Thus, given a sentence such as the *The box paints a star*, the patient is encouraged to abstract from the written sentence a mental model of the sort:

| | | | | | | |
|-----------|----------|----------|---|--------|---|--------|
| [The box] | [paints] | [a star] | = | AGENT | : | box |
| | | | | VERB | : | paints |
| | | | | OBJECT | : | star |

All the software has been built with the constraint of a processing capacity of three units in mind. From Tables 19 and 20 it will be clear that there are three nouns at most (*ball*, *box* and *star*) to consider in any sentence, no matter what its structure. Only one of the treated verbs, *gives*, takes three arguments (agent, object, indirect object), all the others require less (only the mapping of an agent and object). The remediation software presents just three options for every element, whether in PB mode or SB mode, and in assessment the correct picture can be found by eliminating three candidates in the worst case. Where the more complex sentences have more than three chunks, considered linearly, completed portions of *agent*, *verb*, *object*, or *agent*, *prep*, *object*, can be 'packed' or 'closed' into a larger unit to free capacity. For example:

[The ball] [gives] [a box] [to the star] := [[The ball] [gives] [a box]] [to the star]

By enforcing left to right parsing the idea was both to inculcate a good working habit in the patient and to provide a means for the clinician to know exactly what he was attempting to do at any point. In PB mode the text line served as a prosthetic buffer, allowing the patient to reconsult the target sentence and to tackle it in stages in a way not possible with auditory-verbal delivery. The text line also *externalised* his progress through the sentence for the clinician. The *working window* was, of course, so named by analogy with *working memory*. This served the crucial functions of giving the patient immediate feedback on the ramifications of his choices, an essential feature of learning-by-discovery environments, and of externalising the mental model under construction for the clinician.

In PB mode it was possible to check whether the meanings of the semantic chunks were intact, independently of a patient's ability to derive meaning from the purely syntactic aspects of the sentences. This allowed us to check whether the meanings of the nouns, verbs and prepositions were understood, divorced from the confounding factors of word order significance and phrase structures. This feature was obviously very important in tracing the locus of a problem. It was quite possible for a patient to perform extremely well in PB mode without being able to parse reliably. However, it was hoped that watching the picture being built up in the working window, and comparing the completed picture with the target sentence, would aid learning through the process of associating cause and effect.⁵⁵

SB mode was more challenging for aphasic subjects because they had to select words rather than pictures, and furthermore, they had to decide on the correct assignment of objects in the picture to semantic slots in their sentence template. Although they were constrained by the software to select from the lexical palettes in left to right order, 'lookahead of one' was often needed to know which object to mention first (or next). For example, in responding to a 'preposition picture' in the working window, the patient had first to consider the relationship prevailing

⁵⁵ In fact, the aphasic subjects were much less able to form logical deductions in this way than I had hoped. For example, they could work through passive sentences in PB mode perfectly well and then get them all wrong in SB mode, demonstrating that they had failed entirely to notice the difference between the way the pictures had been built up in active and passive voice. This inability to draw inferences in the way that a normal subject would is interesting in itself, and is a very clear indicator of the extent to which expert clinical support is vital in anything but the most trivial of drill and practice environments.

between the items (from the options *in*, *under* and *behind*) before he knew which item to mention first in the sentence. Likewise with verb sentences, he needed to check the voice of the sentence in lexical window 2 before making his first selection. Obviously, the patient had a little more latitude in this mode than in PB mode (he was not forced to look at the picture elements in any particular order), so the onus was on the clinician to be both vigilant and inventive in getting to the bottom of the *reasons* for any errors made.

It is very hard in a static exposition of this sort, to convey the dynamic nature of the system and the flexibility it offers an innovative clinician in going about diagnosis and treatment. She may flip between modes at will, demonstrating via the picture palettes, or via the working window, any combination of features from the sentences she cares to imagine (because, of course, the software will illustrate any combination of choices, not just those correct for the treated sentences). She can construct incorrect pictures to target sentences for the patient to correct, or incorrect sentences to target pictures for the patient to fix. Sentence types, for instance actives and passives, can be juxtaposed for illustrative purposes or to check that the structures are secure outwith their homogeneous sets. The cursor itself is a very useful device: patients use it not just for making selections, but for scanning sentences and examining picture components.⁵⁶ The clinician uses it to control the order of presentation (often at the patient's behest) to point out the salient features of palettes, or to draw the patient's attention to some feature of the working window or the text line. Thus, the mouse passes between patient and therapist scores of times during a session, in a very synergistic way.

3.3.2 THE VERB REMEDIATION PROGRAM

The four treated sentence structures in the VRP were subdivided into semantic units as shown below for the first sentence in each group:

[The ball] [paints] [a box.]
 [A box] [is painted by] [the star.]
 [The box] [gives] [a ball] [to the star.]
 [The star] [paints] [the ball] [that the box] [holds.]

⁵⁶ On being asked why he kept moving the cursor into the working window in SB mode (when the only clickable screen locations are the lexical palettes), p5 said, "It helps me to think."

It will be noticed that the boundaries do not always conform to those which would have been obtained by a phrase structure analysis. My contention is that the components shown above better capture the potential for the errors that subjects actually make (e.g. in the passive voice there is potential for choosing one or more incorrect protagonists, for reversing the protagonists, for choosing the wrong verb or for interpreting the verb as active, likewise with the dative sentence, the problems are likely to be with the meanings of one or more of the nouns, of the verb, or with the assignment of the three arguments around the verb).

In PB mode, each of the semantic units had three candidate pictures associated with it, the pictures being invoked by clicking on the corresponding sentence component. In SB mode each semantic unit gave rise to a lexical palette with three options on it. Table 24 gives the identity of the distractors used for each target word. Thus, if the target word was any of the words in a row in the left column, the picture items, or lexical items, were the three in the same row in the right column. Pictorial versions of ball, box and star were, of course, appropriately animate or inanimate.

| Target words | Options offered |
|---|---|
| ball, box, star holds, paints gives | ball, box, star draws, holds, paints gives, kicks, throws |

Table 24. Target words and distractors in the Verb Remediation Program.

I mentioned in the general discussion that candidate pictures for each noun in the sentence were colour-coded to assist with identification, in the working window, of the object or character selected for a particular sentence component. This was especially useful to patients in 'debugging' the longer sentences. In PB mode, the picture palettes for verbs were updated to reflect the patient's previous choices. Thus the choices for animate or inanimate nouns were always just the simple ball, box and star characters or objects, but the verb selections always reflected the current state of instantiation of the verb's arguments. For example, clicking on the first component of sentence 1a, [*The ball*] *paints a box* produced ball, box and star characters, with the same colour of head, in the picture palettes. Selection of one of these resulted in *that* character appearing in all three picture palettes for the second semantic component, but as the second verb argument was still to be

selected, the character would be drawing, painting and holding the unknown octagonal object (in a contrasting colour). Supposing that the patient erroneously selected a star instead of a box for sentence component three and backtracked to the verb, the picture palettes at this point would show the character he selected drawing, painting and holding a star, and so forth. In passive mode, on first selection of the verb, the object chosen in slot one was drawn, painted and held by someone yet unnamed, so the agent in each window had an octagonal head with a question mark inside it.

As mentioned above, even the more complicated sentences were designed in the hope that 'packing' completed compound elements would enable the complexity of the whole to be overcome through the requirement to integrate the meanings of only a small number of units. In this regard, structure 4 sentences can be seen as structure 1 sentences plus a qualifying appendage. Thus it was envisaged that the process of handling such a sentence might proceed as follows:

- step 1 : [The star]
- step 2 : [The star] [paints]
- step 3 : [The star] [paints] [the ball]
- step 4 : [[The star] [paints] [the ball]]
- step 5 : [[[The star] [paints] [the ball]] [that the box]
- step 6 : [[[The star] [paints] [the ball]] [that the box] [holds]

At step 4 the semantic unit [The star paints the ball] is packed, so that processing can still proceed with a notional processing capacity of three units. A further step 7 may well be to recover the meaning by mentally rearranging the semantic units as follows; [The star] [paints] [[the ball] [that the box] [holds]].⁵⁷ Although the role of memory in sentence processing is unclear, as all the patients showed deficits in digit-span recall and a general reduction in capacity compared with normal subjects across all SST modules, it seemed sensible to try to take processing capacity into account in framing the tasks and providing a parsing strategy. As this approach to diagnosing and treating language was visually mediated, the computer providing prosthetic 'memory' which was not limited in duration, there seemed some prospect in this supportive environment of training a way of working which might be within the patients' 'standalone' capacity.

⁵⁷ This account of delayed integration squares with what patients seemed to do. The function of 'that' was so ill-appreciated that, a step 5 of, for example, [[The star] [paints]] [[the ball] [that the box] would be over-optimistic. This would presuppose structural knowledge and hence anticipation that did not seem to be present. However, therapy sought to reinstate it.

SB mode needs no further elaboration, except to say that as structure 4 pictures could be correctly described from the lexical palette options in two ways, for example, *The star paints the ball that the box holds* or *The box holds the ball that the star paints*, it was decided to provide the first noun-phrase at the onset of display. To illustrate this, Figure 13 shows the screen confronting the user at onset of sentence 16b.

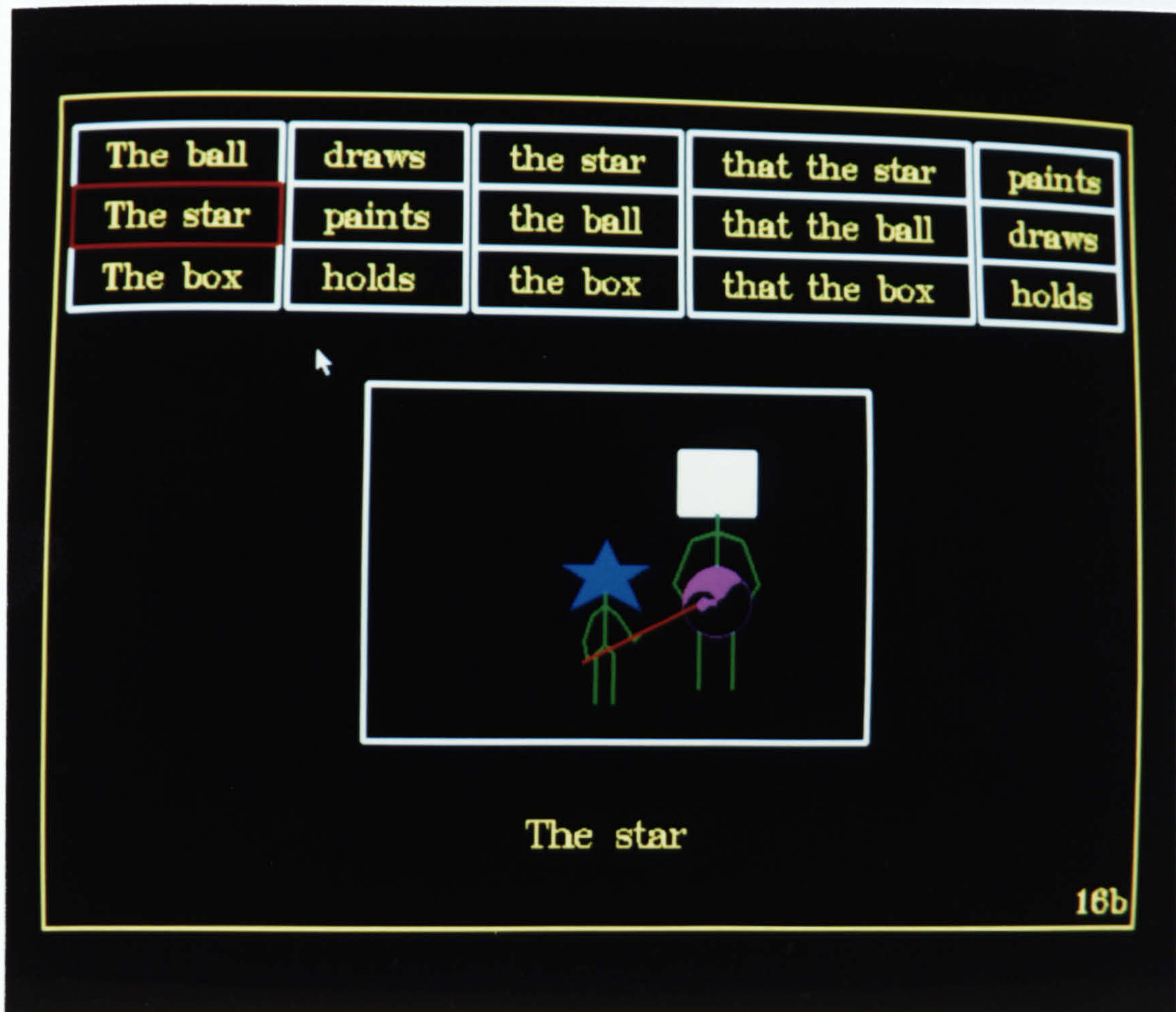


Figure 13. Onset of display for sentence 16b, Verb Remediation Program.
(This figure is in colour)

3.3.3 THE PREPOSITION REMEDIATION PROGRAM

The three treated sentence structures in the PRP were partitioned as indicated below for the first sentence in each group:

[The ball] [is under] [the box.]
 [A ball] [is under] [the box] [and the star.]
 [The ball] [is in] [the star] [that is under] [the box.]

It will be clear from the composition of the sentences that they are progressive - structure 2 being derived from structure 1 by extension, and structure 3 comprising in effect a conjunction of two sentence 1 types. Thus, as with the example given above in section 3.3.2, it was hoped that completed subsections could be concatenated to reduce the overall processing load.

In PB mode, each of the semantic chunks had three candidate pictures associated with it, the pictures being invoked by clicking on the corresponding sentence component. In SB mode each semantic chunk gave rise to a lexical palette with three options on it. Table 25 gives the identity of the distractors used for each target word.

| Target words | Options offered |
|-------------------|-----------------------|
| ball, box, star | ball, box, star |
| behind, in, under | behind, in, under |
| behind, under | behind,between, under |

Table 25. Target words and distractors in the Preposition Remediation Program.

Thus, if the target word was any of the words in a row in the left-hand column, the picture items, or lexical items, were the three in the same row in the right-hand column. There were no animate characters in the PRP, all the prepositional relationships being illustrated with inanimate objects.

Rows 1 and 2 of Table 25 applied to all choices in both modes except structure 2 in SB mode, where the prepositional choices were those in row 3 column 2.

Feedback from colleagues on an earlier version of the program that included target sentences of the form *A ball is in the box and the star* persuaded me to omit *in* as a treated preposition in this sentence structure. The objection was the confusion that the introduction of a duplicate item (the second ball) might cause. It was considered that the ball seeming to be in two places at once was not a good idea. Also, since the noun picture palettes were never cumulative, the result of selecting a star for the third item in this example was a star with a ball inside it appearing in the working window beside the box with a ball inside it! Such a picture can still be built, by selecting the wrong preposition in PB mode, but having eliminated *in* target pictures in SB mode, it was decided to introduce *between* as a better lexical distractor.

The same principles apply to this program as to the VRP in terms of the characteristics of the picture palettes and the assignment of unique colours to the noun pictures. Thus taking a sentence such as

[The ball] [is in] [the star] [that is under] [the box.]

in PB mode as an example, having selected the picture of a ball for the initial component, on first activation of the component [is in], the ball is depicted in the three prepositional relationships with the unknown, octagonal object. After the second object has been selected, any return to the [is in] component will see the picture palettes reflecting both instantiated objects. The same holds for the second prepositional component [that is under], where the corresponding picture palettes are updated to display the current status of the objects selected in the semantic units on either side of it. Figure 14 may be helpful in illustrating this mechanism. The photograph shows a typical screen for sentence 18a. The user has completed the sentence, as the broken brackets show, but has made a mistake on the second preposition, choosing the picture for *star in* instead of for *star under*. He is now poised to correct this. Figure 14 shows the [that is under] component activated, and the picture palettes displaying the three objects selected in the candidate relationships; 'The box is behind the star that is in the ball', 'The box is behind the star that is behind the ball', 'The box is behind the star that is under the ball'. The reader will appreciate that these are not trivial concepts for a patient deficient in preposition processing!

In SB mode, the software permitted the final two objects to be mentioned in either order, thus to a target picture, the responses 'The ball is under the *star* and the *box*' and 'The ball is under the *box* and the *star*' were equally acceptable.

Although it was not strictly necessary to supply the first lexical component for structure 3 sentences as it was for structure 4 in the VRP, since there was only one way of getting them right, this hint was maintained in the PRP in view of the difficulty of the tasks.

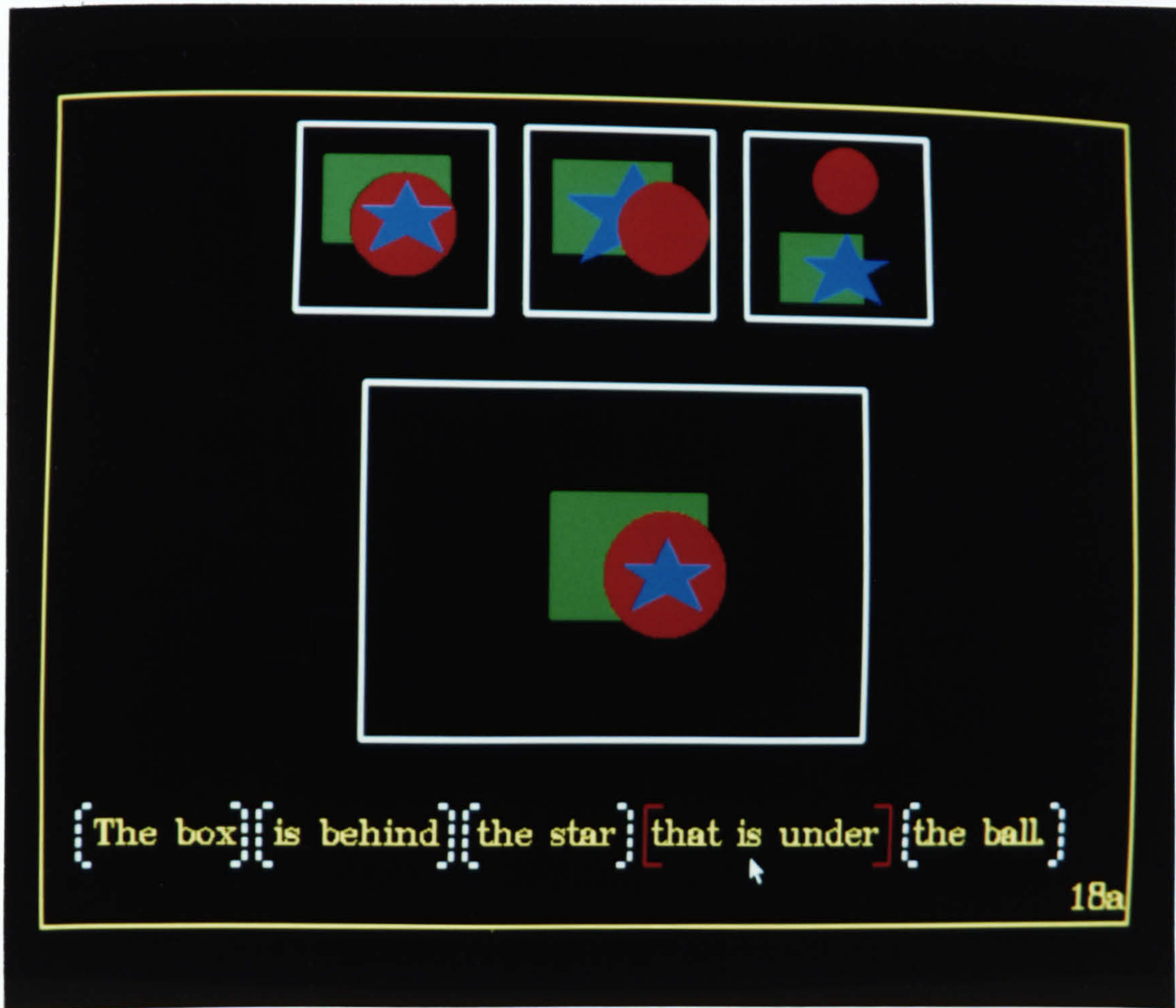


Figure 14. Preposition Remediation Program sentence 18a in progress.
(This figure is in colour)

3.4 CONDUCT OF THE TREATMENT PHASE

Chapter 2 described the procedure by which patients were selected using the Syntax Screening Test (SST1), and repeat-tested on two further occasions (SST2 and SST3) before the start of treatment. In that Chapter the results of the aphasic subjects (P1..P14) were compared with a group of 45 normal subjects, and the aphasics were found to be well differentiated by the test with respect to speed and accuracy. The aphasic scores were depressed across all six linguistic functions examined, but showed particular weaknesses in the areas of verbs, prepositions and morphology. A summary of the performance data of P1..P14 on the SST was given in Figures 4, 5 and 6 (pp. 95-98).

In readiness for therapy P1..P14 were randomly allocated to two treatment groups - Group A (verbs treated first) and Group B (prepositions treated first). The only exception was P12, who was deliberately assigned to the prepositions first group, because he was close to ceiling (18/21) on this function across SST1..SST3, and it was of interest to find out whether preposition treatment would have any effect on his verb processing which, by comparison was markedly slower and less accurate (6/21). Despite high accuracy on prepositions, P12 did not achieve near normal speed on this function, so the goal of preposition therapy for him was to reduce his processing time. Table 26 shows the allocation of patients to treatment groups, it also indicates the assignment of patients to myself (MAC) and a colleague Elizabeth Dean (ECD), and shows the venues at which the treatment sessions took place. QMC denotes the Speech Therapy Clinic, Queen Margaret College, Edinburgh; AA, the Speech Therapy Clinic at the Astley Ainslie Hospital, Edinburgh, and PP, the Prestonpans Health Centre, Prestonpans, East Lothian.

| GROUP A Verbs treated first | | | GROUP B Prepositions treated first | | |
|--------------------------------|-------|---------|---------------------------------------|-------|---------|
| Clinician | Venue | Patient | Clinician | Venue | Patient |
| MAC | QMC | P1 | ECD | QMC | P4 |
| MAC | PP | P2 | MAC | AA | P6 |
| MAC | QMC | P3 | ECD | QMC | P8 |
| MAC | QMC | P5 | ECD | QMC | P9 |
| MAC | QMC | P7 | ECD | QMC | P11 |
| MAC | QMC | P10 | MAC | AA | P12 |
| MAC | PP | P13 | ECD | QMC | P14 |

Table 26. The allocation of patients to two treatment groups.

The main treatment phase of the research commenced on Monday 1st October 1990 and terminated on Thursday 21st December 1990. Longitudinal work with three patients continued into 1991 (see section 5.5) and several of the patients were re-tested for durability of results in May 1991 (see section 5.6).

One of the aims stated in Chapter 1 was to develop an experimental design and therapy regime which was clinically feasible, rather than possible with one or two dedicated patients in an intensive laboratory environment. To this end, a timetable was organised which permitted the 14 subjects to undergo therapy in parallel, within the normal day to day operating constraints of the three venues shown in Table 26. The QMC clinic operated on Wednesdays and Fridays, so on those days my colleague and I treated in parallel in adjoining rooms, for five one-hour sessions, three in the morning and two in the afternoon. These sessions were often attended by a student therapist, several of whom were involved with the research as part of their clinical experience. On Mondays and Thursdays, I saw P6 and P12 at the Astley Ainslie Hospital in the mornings and P2 and P13 at Prestonpans in the afternoons. These sessions were rarely attended by a third party. If patients had preferences for appointment times, these were respected as far as possible, otherwise appointment times were dictated by sensible transportation schedules. Each patient attended at the same time of day throughout the study, barring illness or other impediment, when an alternative session was provided. Despite inevitable fluctuations in health and circumstances⁵⁸ the patients were extremely reliable in keeping appointments or giving us the opportunity to re-schedule. The result was that all 14 subjects completed the study and no sessions were missed.

The experimental design was mapped onto the 12 week treatment period such that each patient had two, three-week treatment blocks. These were preceded, separated and followed by a two-week block of assessments. To take an individual patient's programme as an example, P1 spent his first four appointments doing the Verb Test, Preposition Test, Morphology Test and Real World Test respectively. He then had six one-hour periods of verb therapy followed by a repetition of the four tests. P1 then received six one-hour periods of preposition therapy, before the four assessment tests were administered for the third and last time.

⁵⁸ To give some examples, major fit (P14), minor fit (P3, P7, P8), operation to insert prosthetic eye (P3), falls (P7, P6), major domestic crisis involving loss of home (P6).

The conduct of the computer-based assessments was as described in Chapter 2 for the SST and associated tests. I briefed my colleague verbally, instructed her in the use of the software, and provided detailed written instructions on the conduct of tests to ensure invariant test conditions for all patients. The procedure was that patients were to self-administer the tests with no interference from the observer except a) if the patient indicated that he did not know which was the correct picture, the clinician should respond, 'just pick the one you think best' (this would usually result in a selection being made), b) if the patient insisted that he *really* did not know the answer and was unhappy about making a selection, the clinician should make a (wrong) selection for him and record the details on the observation sheet provided, c) if the clinician judged that the patient was tiring and needed a pause she should tentatively suggest it, leaving the decision to the patient and d) in the unlikely event that a patient selected a window, and on the way to the confirm button inadvertently activated another one without noticing, the clinician should intercept if possible, and ask the patient if the highlighted window was the one he wanted. In practice, situation d) almost never occurred and b) was extremely rare. The patients were put at their ease, told how many sentences to expect and roughly how long the test would take. They were asked to read the sentences and to examine the pictures very carefully, and to suggest a pause if they felt the need. It was impressed upon them that accuracy was more important than speed. The results of the computer-based tests should be entirely free of inter-clinician variability as identical protocols were used, the assessments were patient-controlled and the scoring was automated.

Concerning the conduct of the remediation sessions, it was neither possible nor desirable to be as rigidly prescriptive. In this respect, I am in accord with the sentiments of Byng (1988), although in the present research the uniform treatment environment precludes individual differences as marked as in the cases of Byng's patients BRB and JG (mentioned in section 1.2.1).

The remediation software guaranteed that only the 20 verb and preposition sentences on the treated sides of Tables 19 and 20 were tackled (since the programs contained no others and we disciplined ourselves never to discuss untreated items e.g. the preposition *above* was not mentioned while treating *under*). However, the patients had different backgrounds, capabilities, and profiles of impairment as measured on the assessment tests. Moreover, the two clinicians inevitably brought different insights and strategies to the teaching tasks, the one being a computing lecturer with no previous clinical training, the other an experienced speech therapist new to these particular software tools and to this

approach to language breakdown. I instructed my colleague in the operation of the remediation software, but since at the outset neither of us had any experience in its clinical use, it was decided to do the best for each patient within the confines of the treated set. This might mean concentrating on one structure more than another, or appealing to a particular teaching approach sympathetic with a patient's multi-deficit profile, or his background. Further, in keeping with the complex nature of the sentence understanding tasks and the avowed diagnostico-remediative purpose of the software, it was proper that the sequences in any treatment session be non-deterministic, in response to the ongoing patient-therapist dialogue. We agreed to exchange information, useful techniques and difficulties as the treatment proceeded, and I monitored the progress of all patients session by session throughout the study, often making comments and suggestions in the files of those I was not seeing personally.

In order to provide tangible goals for therapy and to make sure that the two groups were operating within the same conceptual framework, I provided readily assimilable analyses of all the patients' performances on the sentences to be treated, from the assessment data. Thus, prior to the first therapy block, the Verb Test results for Group A and the Preposition Test results for Group B were examined, and prior to the second therapy block an analysis was carried out taking into account evidence from the two sets of test results on the function still to be treated. The information derived from this was total score out of 20 on the treated side of the most recently attempted test (i.e. the gross measure we should aim to improve), total score for each sentence structure (these were very revealing measures, pointing up patterns of spared and impaired performance across sentence types) and, from an analysis of the choices of incorrect pictures, comments were included on possible reasons for the errors. At this stage these comments could only be speculative, providing hypotheses to be explored in therapy. This accuracy-based analysis was supplemented by speed-related goals where the patient was excessively slow on assessment. In such cases increased speed was considered to be a priority for attaining useful performance. In addition, I provided a list of the sentences to be treated, with the sentence numbers highlighted of those sentences that had been incorrect in assessment. This was a convenient guide to individual sentences that might benefit from special attention.

A file was prepared for each patient, comprising his biweekly treatment schedule, indicating the test or treatment to be administered, and whether a computer printout of results was required. Purpose-designed colour-coded observation

sheets were provided for every session, be it assessment or treatment, so that in the former case, observations complementary to the quantitative ones recorded by the computer could be captured, and in the latter case, so that a record could be made of what took place in treatment sessions. A Real World Test score sheet was included for the paper-based test (see Appendix 11). The analysis data discussed in the previous paragraph was inserted in each file.

3.4.1 THE FORMULATION OF THERAPY GOALS

Mention was made in the previous section of the use of assessment data to summarise a patient's pre-therapy status for the two functions of interest, and to formulate goals for therapy. This process is important enough to merit amplification since there are no existing diagnostic assessments that work in this way, and the sort of approach these new computerised assessments encourage are fundamental to a well-targeted therapy. The value of the assessments lies in their precision, which is a function both of their structure and of the data they collect. Specifically, the organisation of the (to be) treated side of the test material in blocks of homogeneous sentence structures allows one to begin, at least, to isolate potential causes of sentence processing problems. It is worth describing the process of hypothesis formulation from assessment data in more detail, since the insights provided by a careful consideration of distractors chosen were crucial in knowing how to approach each patient's problems.

Below are a series of illustrative examples. Readers wishing verbal descriptions of distractors chosen are referred to Appendix 4 (verbs) and Appendix 6 (prepositions) where the three sentences listed beneath each target sentence are descriptions of pictorial distractors 2, 3 and 4 respectively. Pre-therapy data for all patients is available in Appendix 12 (the first data row for each subject), which gives a full list of responses to all Verb Test and Preposition Test items for the three test sessions. Because of the variety of sentence structures included in the tests (the more complex ones offering more scope for the design of distractors) and that two functions were treated, the meaning of the response types shown in the tables below sometimes differs. Response '1' always indicates the correct answer. Response '2' always indicates a reversal error (e.g. *The ball paints/is under the box => The box paints/is under the ball* although in structures with three noun-phrases different reversals may occur). Responses '3' and '4' in preposition sentences generally indicate incorrect prepositions (e.g. *The ball and*

the star are above the box => The ball and the star are in the box). In verb sentences response '3' usually indicates an incorrect protagonist (e.g. *The box holds a star => The box holds a ball*) and response '4' an incorrect verb (e.g. *A box is drawn by the ball => A box is held by the ball*). Useful 'rules of thumb' in examining patients' response profiles are that responses '3' and '4' are further from the target than response '2' and that a sequence of identical responses to sentences of the same structure indicates a consistent, incorrect interpretation.

P14 returned a score of 3/20 on the to-be-treated side of his pre-therapy Preposition Test. Table 27 shows his response to each of the 20 sentences, correct responses are emboldened.

| | | | | | | | | | |
|-------------|--------------|----|----|----|----|----|----|---|---|
| Structure 1 | sentence no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | s1 response | 3 | 3 | 2 | 3 | 1 | 2 | 4 | 2 |
| Structure 2 | sentence no. | 9 | 10 | 11 | 12 | 13 | 14 | | |
| | s1 response | 1 | 4 | 3 | 4 | 4 | 2 | | |
| Structure 3 | sentence no. | 15 | 16 | 17 | 18 | 19 | 20 | | |
| | s1 response | 3 | 3 | 3 | 3 | 1 | 2 | | |

Table 27. P14's pre-therapy Preposition Test performance.
(only to-be-treated items are shown)

's1' indicates that these results were obtained during the first block of assessments, referred to collectively as session 1.

An eye scan of the mixture of distractor types chosen indicates that this patient is suffering from serious multiple confusions. He presents an inconsistent set of errors, containing a large number of preposition misselections, interspersed with 3 right answers and 5 role reversals. If we examine the errors in structure 1 alone, we find *under => in* (2)⁵⁹; *behind => in*; *behind => above*; a role reversal around *behind* and two role reversals around *in*. These errors suggest difficulty both with preposition meanings and with word order significance. The goal for P14 was to try to reinstate preposition meanings first and to concentrate heavily on sorting out structure 1 sentences before proceeding to the others.

Contrast P14's results just discussed, with the performance of P1 recorded after verb therapy and before the onset of preposition therapy. P1 also scored 3/20 on

⁵⁹ Read this as 'under interpreted as in'. The digit in parentheses indicates the number of times this incorrect substitution was made.

the to-be-treated items, but returned a more consistent set of responses, as shown in Table 28.

Notice that on a simple comparison of scores, these two patients would be considered equivalent, whereas in fact they are quite different. From the evidence that P1 always selected the reverse role picture for structure 1 sentences, and for half of structure 2 sentences, it was reasonably certain that noun and preposition meanings were secure. The working hypothesis for P1 was a purely syntactic deficit for word order significance. His two type 4 errors in structure 2 (*under* => *behind*) suggest either a slight tendency to interpret *behind* pictures as *unders*, as if viewed from above (although this interpretation did not occur in structure 1 and was not present in his first Preposition Test), or some added element induced by increased sentence complexity. Without further clinical evidence it was impossible to guess at the processes behind the structure 3 errors - whatever was going wrong in subject/object assignment would be compounded in two-preposition sentences, in addition we might be seeing the results of other processing limitations.

| | | | | | | | | | |
|-------------|--------------|----|----|----|----|----|----|---|---|
| Structure 1 | sentence no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | s2 response | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Structure 2 | sentence no. | 9 | 10 | 11 | 12 | 13 | 14 | | |
| | s2 response | 4 | 4 | 1 | 2 | 2 | 2 | | |
| Structure 3 | sentence no. | 15 | 16 | 17 | 18 | 19 | 20 | | |
| | s2 response | 2 | 1 | 1 | 4 | 3 | 4 | | |

Table 28. P1's second pre-therapy Preposition Test performance.
(only to-be-treated items are shown)

's2' indicates that these results were obtained during the second block of assessments, referred to collectively as session 2.

P1's difficulty with subject/object assignment was corroborated by the results of his second Real World Test. His behaviour here was interesting. Note that P1, who had tremendous difficulty with prepositions and was well aware of it, was forced by the nature of the experiment, to submit to *two* preposition and real world assessments prior to preposition therapy. He found this vexing. Understanding that the computer required a definite picture selection, he

complied. However, realising that the Real World Test was not so constrained, he indicated that he would prefer to point out a pair of candidate pictures where he could not adjudicate between them! He understood that this would result in being marked wrong. I was happy to operate in this way, since it was likely to yield extra information. In fact, P1 could not decide between the target picture and the reverse role on 17 out of 20 occasions. When he did venture a single answer he was right twice and picked the reverse role picture in the other case. This was fascinating in the light of P1's Preposition Test performance. In the Real World Test he reported that the pictures were equally likely and was reluctant to commit to a decision, yet forced in the microworld to select one or the other, he preferred the reverse role with a probability much exceeding chance (0.5). There had to be a reason, and a consistent reason, for this. The prime therapy goal was to find out what it was. Clearly P1's problem had not been resolved by verb therapy, (what verb therapy *had* done was to simplify his error pattern into predominantly type 2 errors, see Appendix 12), *despite his subject/object assignment in treated verb sentences now being secure (19/20)*.

P10's first set of Preposition Test results were deceptive. He scored 10/20 and all his errors were role reversals. On first sight he seemed to have a problem like P1's but less intense, suggesting secure noun and preposition meanings but a problem of mapping word order around prepositions. However, P10's first Real World Test did not bear out a straightforward word order significance hypothesis, he scored 15/20 and only two errors were reversals. P10's better performance in the Real World Test suggested that the abstractness of the microworld was exacerbating fundamental weaknesses. After verb therapy P10's preposition pattern changed. His two pre-therapy performances are presented in Table 29.

The second set of responses contains error types not previously elicited, although the overall accuracy rate remains constant (11/20). This is a difficult profile to interpret. P10 is operating at much better than chance level (as he is now making errors other than reversals, we must consider chance to be 5/20) but row-wise and column-wise comparisons show that he is inconsistent both between similar sentences in the same test, and the same sentence on repeat testing. The second performance demonstrates problems with preposition meanings (*in => under, behind => under, behind/under => behind/behind*) and also with word order, (reversals (4), the A is <prep> the B and the C => The B is <prep> the A and the C (2)). The latter two errors plus errors made on the Real World Tests where sentences such as *The dog in the window is above the cat, The cat is under the table that is behind the chair, The boy is behind the girl and the dog* were all interpreted

as if the underlined preposition referred to the following noun(s), suggests a word order problem. However, because of P10's insecurity with preposition meanings, it was impossible to be sure, for example, that the last of these errors was not due to *behind* being interpreted as *in front*.

| | | | | | | | | | |
|-------------|--------------|----|----|----|----|----|----|---|---|
| Structure 1 | sentence no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | s1 response | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 |
| | s2 response | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 1 |
| Structure 2 | sentence no. | 9 | 10 | 11 | 12 | 13 | 14 | | |
| | s1 response | 2 | 2 | 1 | 1 | 2 | 1 | | |
| | s2 response | 2 | 1 | 4 | 3 | 3 | 1 | | |
| Structure 3 | sentence no. | 15 | 16 | 17 | 18 | 19 | 20 | | |
| | s1 response | 1 | 2 | 2 | 1 | 1 | 1 | | |
| | s2 response | 2 | 1 | 1 | 3 | 1 | 2 | | |

Table 29. P10's two pre-therapy Preposition Test performances.
(only to-be-treated items are shown)

s1 refers to session 1, the first block of assessments and
s2 to session 2, the second block of assessments.

Indeed, in analysing aphasic data one must be continuously aware that correct, as well as incorrect responses, can be the products of faulty processes (Caplan and Hildebrandt, 1988, p.8). There are many ways this could happen (including the odd lucky guess) for instance, a double error on the target sentence *The box is behind the ball*, where *behind* => *in front* and *behind the ball* => *ball is behind* would result in selecting the right candidate picture! Clearly P10's performance demanded further probing with the remediation software. Clinical goals for P10 were to try to tease apart the semantic and syntactic components of his errors and to attempt to discover reasons for his unreliability. P10 was the only patient who operated at normal speed. In view of his error rate it was considered that a slowing down in assessment might be beneficial, by its very nature the remediation software encouraged this.

Many of the remarks made about P10 apply to other patients, especially in respect of inconsistency and the problems of isolating the different facets of aberrant processing. From the preposition data contained in Appendix 12 it will be clear that the patients presented a wide spectrum of starting positions. P8 was very accurate on structures 1 and 2 showing a firm grasp of noun and preposition meanings and of simple sentence structures but had difficulty with structure 3,

which was the focus of his therapy; In addition to P14 already mentioned, P6, P9 and P11 exhibited very dense multiple error patterns indicating a great deal of diagnosis still to do.

An analysis of the performance data of groups A and B on the to-be-treated items of the baseline Preposition test is summarised, by sentence structure, in Table 30. The results are expressed as percentages because the sample sizes were unequal (for ease of comparison, the Verb Test results which follow are presented in the same way). Unfortunately, by restricting the number of sentences in each structure to a clinically manageable number for assessment and treatment according to the present experimental design, I have sacrificed the ability to be able to test the null hypothesis that the response patterns were drawn from the same population.⁶⁰ This means that it was not feasible to furnish a confidence level in support of a claim, for example, that one sentence structure was handled significantly less accurately than another. Despite this disadvantage it was still possible using descriptive statistics, to supplement the analysis proper (see Chapter 4) with a great deal of meaningful explanatory detail (see Chapter 5).

Table 30 summarises the performance of the aphasic subjects overall and by treatment groups on the three to-be-treated preposition sentence structures. The overall accuracy rate for Group A was 45.0%, and for Group B, 42.2%, hence the two groups were found to be of a similar standard on to-be-treated preposition items at baseline.

| | Structure 1 | Structure 2 | Structure 3 |
|---------|-------------|-------------|-------------|
| Group A | 44.6% | 54.7% | 35.7% |
| Group B | 48.2% | 45.2% | 33.3% |
| Overall | 46.4% | 50.0% | 34.5% |

Table 30. Pre-therapy accuracy by sentence structure, Preposition Test.
(to-be-treated items only, at session 1)
n=140 per group (structure 1 n=56, structures 2 and 3 n=42)

⁶⁰ The reason for this is that the usual way of comparing sets of related samples to determine whether they could have come from a population with the same median, involves ranking the data (Siegel and Castellan, 1988). If the number of observations in each condition (here sentence structure) is very small, it becomes impossible to rank the data satisfactorily because of the high incidence of ties (equal numbers of correct responses across sentence structures).

Table 30 shows that for both groups of patients, extending the simple locative prepositional sentences (e.g. *The ball is under the box*) by adding a third noun in structure 2 (e.g. *The ball is under the box and the star*) did not have an adverse effect on the error rate.⁶¹ However, structure 3 sentences (e.g. *The ball is behind the box that is under the star*), not surprisingly, proved substantially harder than the others for both groups.

Turning next to the pre-therapy Verb Test results, three individual cases illustrate how adopting a modular approach to assessment greatly helped to target therapy where it was most needed. Table 31 shows P7's pre-therapy verb results. Apart from one lexical error at sentence 2, P7's errors were all structural and very consistent. She interpreted all the passives as actives, and in all but one of the complex sentences failed to parse the *that*-clause correctly, thus for example, *that the star holds => that holds the star*. These errors suggest failure to attend to function words and verb endings. The plan for P7 was to revise verb meanings and to concentrate on determining the reasons for, and attempting to remedy, errors in structures 2 and 4.

| | | | | | | |
|-------------|--------------|----|----|----|----|----|
| Structure 1 | sentence no. | 1 | 2 | 3 | 4 | 5 |
| | s1 response | 1 | 4 | 1 | 1 | 1 |
| Structure 2 | sentence no. | 6 | 7 | 8 | 9 | 10 |
| | s1 response | 2 | 2 | 2 | 2 | 2 |
| Structure 3 | sentence no. | 11 | 12 | 13 | 14 | 15 |
| | s1 response | 1 | 1 | 1 | 1 | 1 |
| Structure 4 | sentence no. | 16 | 17 | 18 | 19 | 20 |
| | s1 response | 4 | 1 | 4 | 4 | 4 |

Table 31. P7's pre-therapy Verb Test performance.

(to-be-treated items only shown)

's1' indicates that these results were obtained during the first block of assessments referred to as session 1.

P1 exhibited many of the same errors as P7, but also some others. Table 32 shows his pre-therapy profile. P1 had the same need of verb meaning reinforcement

⁶¹ The fact that Group A found structure 2 on the whole easier than structure 1 supports the clinical observation that the presence of the third noun-phrase often seemed to serve the role of a checking mechanism. A misreading of either of the first two noun-phrases was picked up when patients encountered the noun for a 'second time' - since they realised that the lexical items were never duplicated in a sentence. This finding may therefore be an artifact of the microworld.

(structure 1). He displayed the same problem with interpreting actives as passives. He also had marked difficulty with structure 4, but his errors were not confined to the subordinate clause. At sentence 19 he reversed the subject and object around the first verb, indicating that confronted with more complex sentence structures, sentence components which had been secure in isolation (structure 1) could breakdown. In addition, P1 had a consistent problem with structure 3 sentences; on four out of five occasions he reversed the object and indirect object. Because the aphasic group as a whole found structure 3 to be relatively straightforward, P1's therapy plan was to revise verbs in structure 1, and to treat structure 3 before proceeding to the harder passives and two-verb sentences.

| | | | | | | |
|-------------|--------------|----|----|----|----|----|
| Structure 1 | sentence no. | 1 | 2 | 3 | 4 | 5 |
| | s1 response | 1 | 4 | 1 | 1 | 1 |
| Structure 2 | sentence no. | 6 | 7 | 8 | 9 | 10 |
| | s1 response | 2 | 1 | 2 | 2 | 2 |
| Structure 3 | sentence no. | 11 | 12 | 13 | 14 | 15 |
| | s1 response | 3 | 3 | 3 | 1 | 3 |
| Structure 4 | sentence no. | 16 | 17 | 18 | 19 | 20 |
| | s1 response | 1 | 3 | 4 | 2 | 3 |

Table 32. P1's pre-therapy Verb Test performance.
(to-be-treated items only shown)

's1' indicates that these results were obtained during the first block of assessments referred to as session 1.

Finally, P6 presented as a far more severely impaired patient. His second set of pre-therapy verb data is given in Table 33 below. P6's structure 1 performance revealed nouns and verbs to be insecure (*paints => holds, holds => paints, box => ball* (2)). His previously mixed structure 2 performance had resolved to three passive => active errors (but clearly, he was not applying a consistent rule here). In structure 3 he did not make the more usual type 3 errors as he had done in the first assessment, but instead produced *A gives B to C => C gives B to A* (2), and *A gives B to C => B gives A to C* (2) (again he was inconsistent). In structure 4, three of his errors involved subject/object reversals around the first verb and his other error was in a subordinate clause, *that the ball paints => that paints the ball*. This

was a chance performance with so many potentially interacting problems, including lexical insecurity, that the therapy plan could only be to work through each of these, starting with the most basic, i.e. nouns and verb meanings in structure 1. Given P6's pre-therapy status, it was unrealistic to expect to be able to treat all the structures within six treatment sessions; structures 1 and 3 were therefore targeted for more concentrated help.

| | | | | | | |
|-------------|--------------|----|----|----|----|----|
| Structure 1 | sentence no. | 1 | 2 | 3 | 4 | 5 |
| | s2 response | 1 | 4 | 3 | 4 | 3 |
| Structure 2 | sentence no. | 6 | 7 | 8 | 9 | 10 |
| | s2 response | 2 | 2 | 2 | 1 | 1 |
| Structure 3 | sentence no. | 11 | 12 | 13 | 14 | 15 |
| | s2 response | 4 | 2 | 4 | 2 | 1 |
| Structure 4 | sentence no. | 16 | 17 | 18 | 19 | 20 |
| | s2 response | 3 | 4 | 2 | 1 | 2 |

Table 33. P6's second pre-therapy Verb Test performance.
(to-be-treated items only shown)

's2' indicates that these results were obtained during the second block of assessments referred to as session 2.

The pre-therapy verb performances of P1..P14 are summarised in each patient's first data row in Table H and first two data rows in Table I (Appendix 12). Some very interesting patterns are evident. Particularly striking is the preponderance of reverse role errors (response type 2) on passive sentences (structure 2), these passives being interpreted as actives. Indeed, many patients (P1, P2, P3, P7, P13, P8, P9, P14) made *only* type 2 errors to passive targets. This pattern often co-occurred with relatively intact performance in structure 1 (e.g. P1, P2, P7, P13), pointing to preserved word order significance in active voice, and highly suggestive of a failure to appreciate the function of the structural template *is <verb>ed by*.

Still looking at global performances, it is clear that structure 3 (the three-argument verb sentences) was relatively intact in many patients compared with structure 4 (the two-verb sentences). Of the errors made in structure 3, type 3 errors dominated; in all these cases *A gives B to C => A gives C to B*. The hypothesis here (Caplan, 1983; Caplan and Futter, 1986) was that patients were

not attending to the *to* in the structure, or to the indefinite article, but simply registering for instance, *The box gives the ball the star*, or even *Box gives ball star*. Therapy sought to discover the reason(s) for this very common error.

While the main pattern that emerged from these results was structures 1 and 3 relatively preserved compared with structures 2 and 4, some patients were conspicuous in being weak in all four sentence types, notably P6 and P11. Error type 4 in structures 1 and 2 indicates that a lexical selection problem for the verb occurred, despite the precaution of the Lexical Test. In these cases reinforcement of verb meanings through picture building mode of the remediation software was designated as a first priority.

An analysis of errors by sentence type, based on the to-be-treated items of the first Verb Test, confirmed the relative difficulty of the structures surmised by eye, see Table 34. The supposed increase of complexity in moving from a two-argument verb (structure 1, e.g. *The ball paints a box*) to a three-argument verb (structure 3, e.g. *The ball gives a box to the star*) (Caplan and Hildebrandt, 1988) was not borne out by these results.⁶² However, the passive sentences and the two-verb sentences were considerably harder for both groups than the simple active declaratives and the three-argument-verb sentences. The overall accuracy rate for Group A was 50.0% and for Group B, 46.4%. The performances of the two groups on the to-be-treated verb items was therefore very similar at baseline.

| | Structure 1 | Structure 2 | Structure 3 | Structure 4 |
|---------|-------------|-------------|-------------|-------------|
| Group A | 77.1% | 25.7% | 74.3% | 22.9% |
| Group B | 60.0% | 34.3% | 62.9% | 28.6% |
| Overall | 68.6% | 30.0% | 68.6% | 25.7% |

Table 34. Pre-therapy accuracy by sentence structure, Verb Test.
(to-be-treated items only, at session 1)
n=140 per group (structures 1, 2, 3 and 4 n=35)

Interestingly, both groups were poorer on simple locative prepositional sentences than on simple active declarative sentences, the discrepancy being much larger in the case of group A (a difference of 32.5%). This tendency was the reverse of

⁶² Limiting the microworld nouns to three was probably a helpful factor in supplying an in-built lexical checking mechanism, as described in the preceding footnote on preposition items of structure 2.

that observed in the sample of normal subjects (Chapter 2) who were both more accurate and faster on locatives and indicates that these aphasics had particular difficulty with locative prepositions.

The range of accuracy rates across the various sentence structures in the initial verb and preposition assessments indicated that for efficacy evaluation, the comparison of pre- and post-therapy (overall) test scores might be too gross a measure to capture many of the facets of change. For example, the results summarised in Tables 30 and 34 suggested that it was unrealistic to expect uniform improvement across sentence structures. For this reason, the statistical analysis of group accuracy data in Chapter 4 is followed in Chapter 5 by a series of supplementary and more descriptive analyses on individual performances, the effect of treatment on patients' speed and the responsiveness of individual sentence structures to treatment.

This chapter introduced four new picture-matching tests, the Verb Test, Preposition Test, Morphology Test and Real World Test, the first three of which were computer-based. The Verb Test and Preposition Test comprised 40 target sentences divided into two sets of 20, the sentences subsequently to be treated and a matched set devised to assess generalisation both to untreated sentence structures and to untreated verbs/prepositions. The Morphology Test was a 20 item test containing various bound grammatical morphemes, comprehension of which was not expected to change as a result of verb or preposition therapy. The Real World Test was a paper-based test comprising 20 verb sentences and 20 preposition sentences designed to test any generalisation of improvements within the computer-based microworld, to the comprehension of similar real world sentences composed from a much larger vocabulary and illustrated by naturalistic pictures.

Descriptions of these tests were followed by sections explaining the operational characteristics of and rationale behind the remediation software. Both the Verb Remediation Program (VRP) and the Preposition Remediation Program (PRP) utilised the assessment microworld, but the previous picture-matching paradigm was exploded into two complementary task environments, picture-building mode (PB mode) and sentence-building mode (SB mode), which were designed to enable the subtasks involved in sentence comprehension to be systematically explored.

The sections on assessment and remediation tests were followed by a description of the conduct of the treatment phase of the research including the protocol and the temporal sequence of the assessment and treatment blocks. The chapter concluded by illustrating how individual therapy goals were established on the basis of patients' pre-therapy Verb Test and Preposition Test responses.

CHAPTER 4

4.1 STATISTICAL ANALYSIS OF THE TREATMENT DATA

This chapter presents an analysis of variance (ANOVA) on the efficacy data by treatment group. In addition, it includes the results of the post-therapy Digit-span Recall, WAB and TROG tests (pre-therapy results were reported in section 2.6). The allocation of patients to the two treatment groups (Group A, verbs treated first and Group B, prepositions treated first) was shown in Table 26. The results analysed below were obtained during assessment blocks administered pre-therapy, after treatment on the first function treated and finally after treatment on the second function treated. These assessment blocks are referred to as session 1, session 2 and session 3 respectively and the intervening treatment blocks are described as having taken place 'between sessions'. The treatment blocks for each function were of 6 hours duration, 2 single hours per week. Each test session was allocated 4 hours in total, again 2 single hours per week. Thus the whole programme lasted 12 weeks. The test sessions comprised assessment using the following tests which were described in Chapter 3; Verb Test, Preposition Test, Morphology Test and Real World Test. Each test was completed in a single sitting.

The outcomes for the two treatment groups were different, the results of Group A being clearer and easier to interpret. ANOVA on the accuracy scores showed that performance on verbs improved significantly between sessions 1 and 2 as a consequence of verb treatment. There was a degree of generalisation both to untreated items in the Verb Test and to more naturalistic items in the paper-based Real World Test. Accuracy on prepositions was unchanged following verb treatment. Results at session 3 showed that prepositions improved following treatment on that function, with generalisation effects again being evident, but that verb results stayed static. The control function, morphology, remained at the baseline level throughout.

Group B, on the other hand failed to produce a complementary cross-over pattern. ANOVA showed an overall improvement on the computer-based tests and Real World Test between sessions 1 and 2, coinciding with the treatment of

prepositions. However, this improvement applied as much to verbs as to prepositions and as much to untreated as to treated items. As with Group A, morphology remained static throughout.

The details of the group analyses are given below. In chapter 5 additional, exploratory analyses are employed to probe the within and between-group variations further and to examine other aspects of the treatment data, such as the effects on test completion times and on accuracy in individual sentence structures. The sources of inter-group variation are also discussed section 6.1.1.

4.1.1 ANALYSIS OF VARIANCE GROUP A (verbs treated first)

The following terminology is used below; *Sessions* 1, 2 and 3 are the three blocks of tests, treatment occurred between sessions 1 and 2 for the first function treated and between sessions 2 and 3 for the second function treated. *Function type* refers to verbs and prepositions, and *Treatment set* to treated and untreated items.

Treatment data. The accuracy scores of Group A for the Verb Test and Preposition Test across the three test sessions are given in Table 35. The summary rows in Table 35 are shown graphically in Figure 15, from which the classic cross-over pattern obtained is clearly seen.

Analysis of variance was carried out on the treatment data for Group A with 3 within-subjects factors and no between-groups factors. The within-subjects factors were Sessions (3 levels: session 1, session 2 and session 3), Function type (2 levels: verbs and prepositions) and Treatment set (2 levels: treated and untreated).

There was a significant main effect of Sessions, $F(2,12) = 13.83$, $MSe = 154.55$, $p < .001$. The means for sessions 1, 2 and 3 collapsed across Function type and Treatment set were 10.1, 12.1 and 14.8 respectively (max=20). Post-hoc Newman-Keuls tests ($p < .05$) showed performance in session 1 to be significantly worse than in session 2, which in turn was significantly worse than session 3.

The main effect of Function type was also significant, $F(1,6) = 5.93$, $MSe = 61.71$, $p = .05$, with verbs (13.2) being overall easier than prepositions (11.5). The main effect of Treatment set was not significant, $F(1,6) = 2.35$, $MSe = 5.76$, ns,

showing that improvement was not confined to treated items. The overall means for treated and untreated items were 12.6 and 12.1 respectively.

| | session | VERB TEST | | | PREPOSITION TEST | | |
|---------|---------|----------------|------------------|--------------|------------------|------------------|--------------|
| | | treated /20 | untreated /20 | total /40 | treated /20 | untreated /20 | total /40 |
| P1 | s1 | 7 | 9 | 16 | 5 | 7 | 12 |
| | s2 | 19 | 15 | 34 | 3 | 8 | 11 |
| | s3 | 19 | 15 | 34 | 20 | 15 | 35 |
| P2 | s1 | 7 | 10 | 17 | 10 | 9 | 19 |
| | s2 | 16 | 13 | 29 | 9 | 8 | 17 |
| | s3 | 18 | 14 | 32 | 17 | 12 | 29 |
| P3 | s1 | 12 | 11 | 23 | 8 | 15 | 23 |
| | s2 | 18 | 12 | 30 | 9 | 8 | 17 |
| | s3 | 16 | 15 | 31 | 15 | 12 | 27 |
| P5 | s1 | 12 | 9 | 21 | 11 | 11 | 22 |
| | s2 | 13 | 11 | 24 | 10 | 11 | 21 |
| | s3 | 17 | 15 | 32 | 14 | 15 | 29 |
| P7 | s1 | 10 | 10 | 20 | 7 | 11 | 18 |
| | s2 | 13 | 13 | 26 | 10 | 14 | 24 |
| | s3 | 16 | 11 | 27 | 10 | 6 | 16 |
| P10 | s1 | 10 | 13 | 23 | 10 | 11 | 21 |
| | s2 | 14 | 13 | 27 | 11 | 15 | 26 |
| | s3 | 16 | 17 | 33 | 16 | 15 | 31 |
| P13 | s1 | 12 | 12 | 24 | 12 | 13 | 25 |
| | s2 | 15 | 14 | 29 | 11 | 13 | 24 |
| | s3 | 13 | 10 | 23 | 19 | 17 | 36 |
| mean s1 | | 10.00 | 10.57 | 20.57 | 9.00 | 11.00 | 20.00 |
| mean s2 | | 15.43 | 13.00 | 28.43 | 9.00 | 11.00 | 20.00 |
| mean s3 | | 16.43 | 13.86 | 30.29 | 15.86 | 13.14 | 29.00 |

**Table 35. Verb and Preposition Test results for Group A.
(verbs treated first)**

There were significant first order interactions between Sessions and Treatment set, $F(2,12) = 7.59$, $MSe = 27.51$, $p < .01$, and Function type and Treatment set, $F(1,6) = 8.94$, $MSe = 19.05$, $p < .05$. The first order interaction between Sessions and Function type was not significant, $F(2,12) = 3.31$, $MSe = 33.04$, ns, but there was a significant second order interaction between Session, Function type and Treatment set, $F(2,12) = 4.67$, $MSe = 9.55$, $p < .05$. The form of this interaction is shown in Figure 15. Post-hoc Newman-Keuls tests ($p < 0.5$) showed that treating verbs between sessions 1 and 2 led to a significant improvement in performance on both treated and untreated items. Verb performance did not improve significantly between sessions 2 and 3 when prepositions were being treated.

Performance on prepositions (both untreated and to-be-treated) did not improve significantly between sessions 1 and 2 when verbs were being treated, but treating prepositions led to a significant improvement in performance on treated items between sessions 2 and 3, (the improvement in untreated items failed to reach significance using this test).

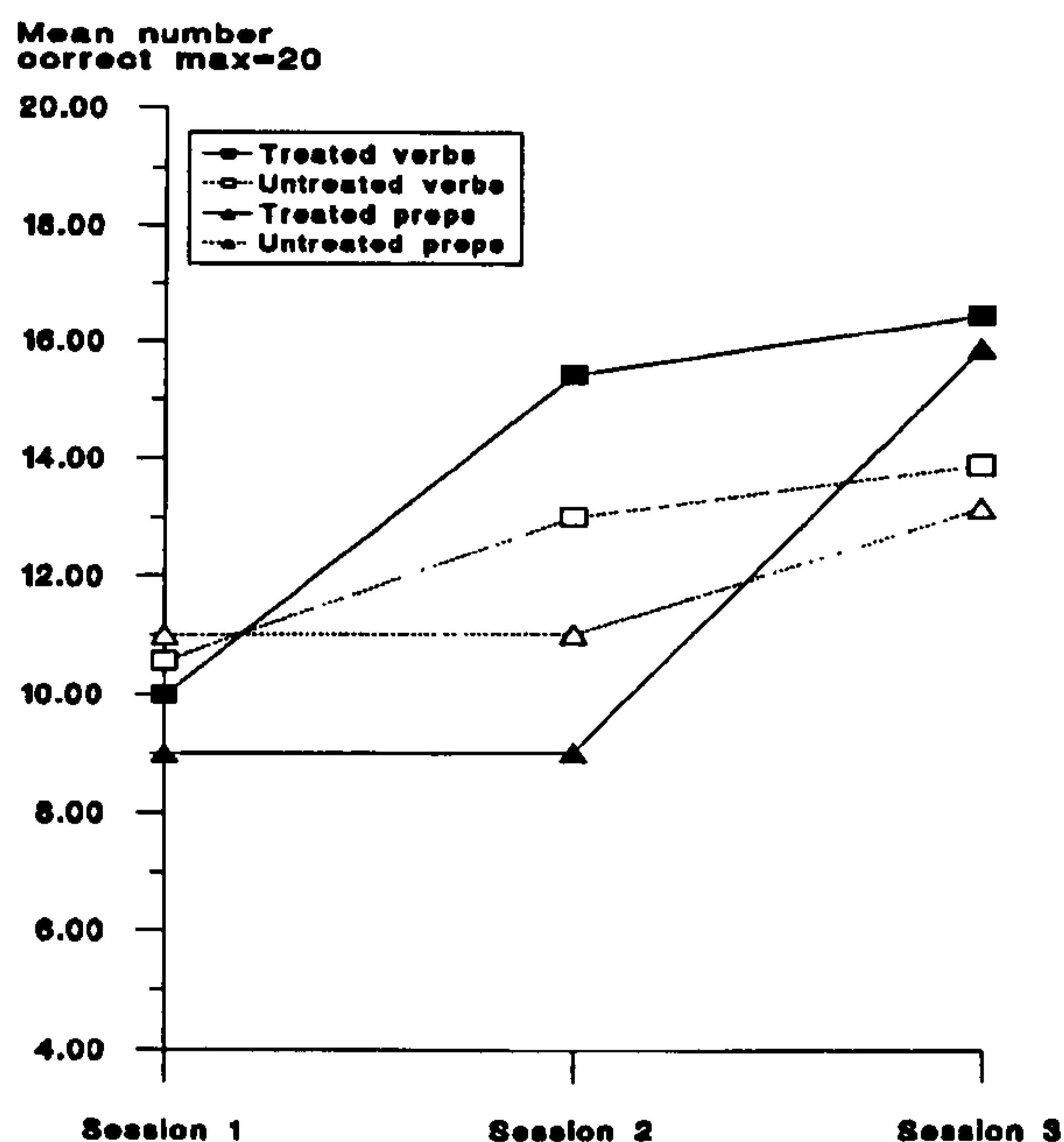


Figure 15. Verb and preposition treatment results for Group A.

The post-hoc tests also showed that in session 3 performance on treated verbs was significantly better than on untreated verbs, and that performance on treated prepositions was significantly better than on untreated prepositions. This last contrast occurred despite the fact that in sessions 1 and 2 performance on prepositions to be treated later was, if anything, worse than performance on untreated prepositions (see Figure 15).

Real World Data. The performance of Group A on the Real World Test across the three test sessions is shown in Table 36.

| REAL WORLD TEST | | | | | | | |
|-----------------|---------|----------------|------------------|--------------|----------------|------------------|--------------|
| | | VERBS | | | PREPOSITIONS | | |
| | session | treated /10 | untreated /10 | total /20 | treated /10 | untreated /10 | total /20 |
| P1 | s1 | 8 | 5 | 13 | 2 | 3 | 5 |
| | s2 | 9 | 6 | 15 | 0 | 2 | 2 |
| | s3 | 10 | 7 | 17 | 9 | 9 | 18 |
| P2 | s1 | 6 | 4 | 10 | 7 | 4 | 11 |
| | s2 | 6 | 3 | 9 | 5 | 7 | 12 |
| | s3 | 10 | 5 | 15 | 7 | 5 | 12 |
| P3 | s1 | 9 | 7 | 16 | 4 | 10 | 14 |
| | s2 | 9 | 6 | 15 | 9 | 6 | 15 |
| | s3 | 10 | 8 | 18 | 9 | 8 | 17 |
| P5 | s1 | 6 | 3 | 9 | 7 | 5 | 12 |
| | s2 | 10 | 8 | 18 | 7 | 6 | 13 |
| | s3 | 10 | 7 | 17 | 8 | 10 | 18 |
| P7 | s1 | 6 | 6 | 12 | 4 | 6 | 10 |
| | s2 | 9 | 8 | 17 | 7 | 6 | 13 |
| | s3 | 7 | 6 | 13 | 7 | 7 | 14 |
| P10 | s1 | 9 | 5 | 14 | 7 | 8 | 15 |
| | s2 | 9 | 6 | 15 | 7 | 7 | 14 |
| | s3 | 9 | 6 | 15 | 7 | 10 | 17 |
| P13 | s1 | 8 | 5 | 13 | 8 | 8 | 16 |
| | s2 | 10 | 7 | 17 | 9 | 9 | 18 |
| | s3 | 10 | 4 | 14 | 10 | 8 | 18 |
| mean s1 | | 7.43 | 5.00 | 12.43 | 5.57 | 6.29 | 11.86 |
| mean s2 | | 8.86 | 6.28 | 15.14 | 6.29 | 6.14 | 12.43 |
| mean s3 | | 9.43 | 6.14 | 15.57 | 8.14 | 8.14 | 16.28 |

Table 36. Real World Test results for Group A.

All real world items were untreated. *Treated* and *untreated* columns refer to whether the verbs/prepositions concerned were treated in the microworld.

The means for the verb and preposition items are shown graphically in Figure 16. Analysis of variance showed a significant main effect of Sessions, $F(2,12) = 5.93$, $MSe = 25.23$, $p=.01$. The means for Sessions 1, 2 and 3 collapsed across Function type and Treatment set were 6.07, 6.89 and 7.96 respectively (max=10). Sessions did not interact significantly with either Function type ($F(2,12) = 1.85$, $MSe = 5.25$, ns) or Treatment set ($F(2,12) = 0.51$, $MSe = 1.11$, ns), showing that

the improvement was not specific to either verbs or prepositions, or to 'real world' sentences containing verbs/prepositions treated in the microworld, rather than those containing untreated verbs/prepositions. Post-hoc Newman-Keuls tests ($p < .05$) showed no significant difference between performance in sessions 1 and 2, but performance in session 2 was significantly worse than in session 3.

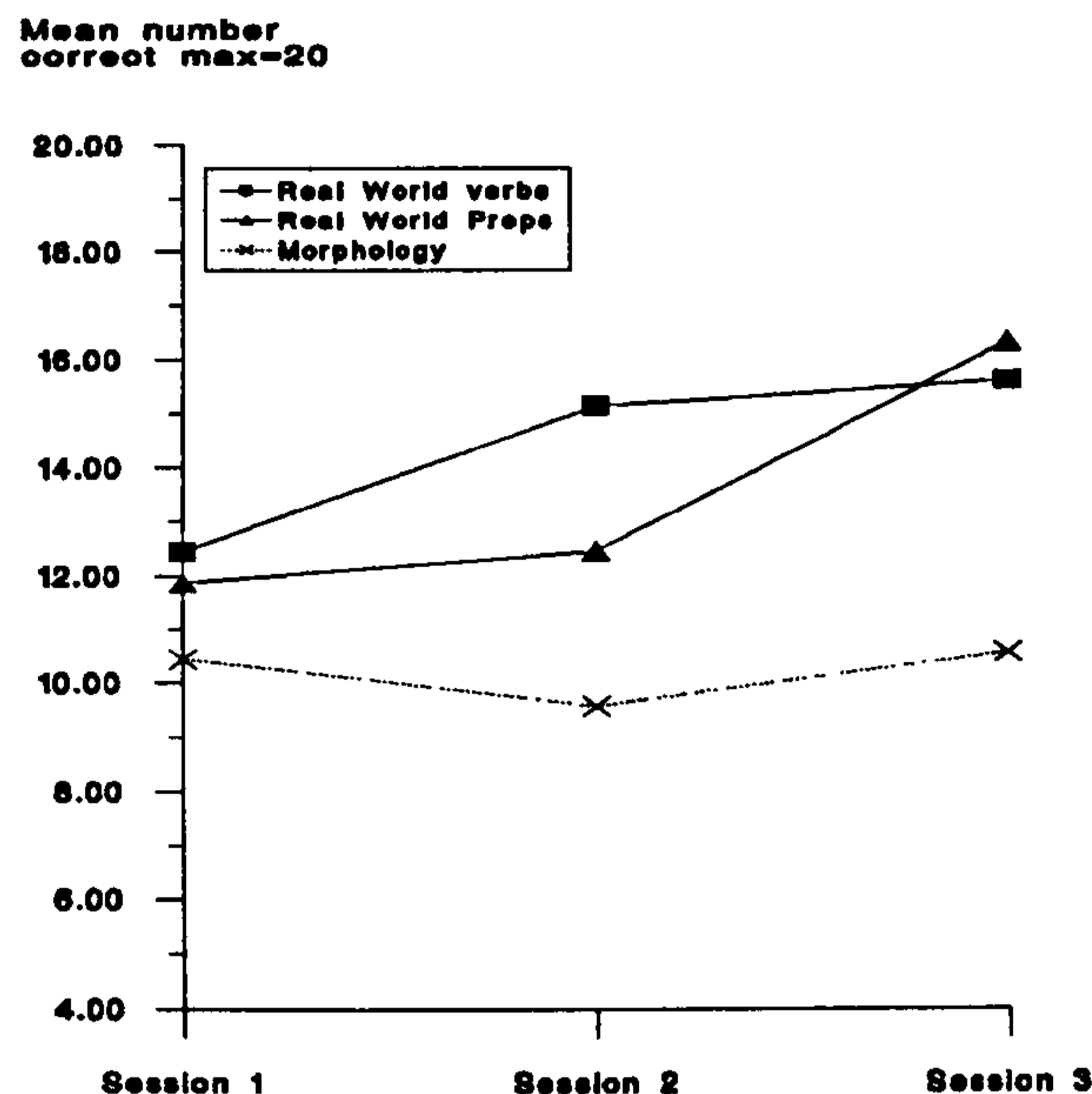


Figure 16. Morphology and Real World Test results for Group A.

There was also a significant main effect of Treatment set, $F(1,6) = 19.61$, $MSe = 34.71$, $p < .01$, with treated items (7.62) being overall better than untreated items (6.33). Unfortunately, in session 1 the mean score on to-be-treated verbs (7.43) was higher than on untreated verbs (5.0); this differential caused several of the effects reported below. However, despite the strong starting position, mean values for treated verbs improved across Sessions (7.43, 8.86, 9.43).

In addition there was a significant first order interaction between Function type and Treatment set, $F(1,6) = 41.78$, $MSe = 45.76$, $p < .001$. Post-hoc Newman-Keuls tests ($p < .05$) showed that treated verbs were better across Sessions than untreated verbs but that there was no significant difference between treated and untreated prepositions across Sessions. The verb block of the Real World Test improved significantly between sessions 1 and 2 when verbs were being treated, but not between session 2 and 3 while prepositions were being treated.

Performance on the preposition block did not improve significantly between sessions 1 and 2 during verb treatment, but showed a significant improvement at session 3, after preposition treatment (see Figure 16).

Morphology data. Table 37 shows the morphology scores for Group A over sessions 1, 2 and 3. The mean morphology scores were plotted with Real World performance in Figure 16. Analysis of variance with Sessions as the within-subjects factor showed no significant effect of sessions, $F(2,12) = 1.55$, $MSe = 2.05$, ns. There was therefore no change in morphology arising from the treatment of verbs and prepositions.

| MORPHOLOGY TEST | | | |
|----------------------------|------|-----|------|
| score (max=20) | | | |
| | s1 | s2 | s3 |
| P1 | 10 | 9 | 12 |
| P2 | 8 | 7 | 9 |
| P3 | 11 | 10 | 11 |
| P5 | 15 | 12 | 14 |
| P7 | 9 | 10 | 7 |
| P10 | 7 | 7 | 9 |
| P13 | 13 | 12 | 12 |
| mean | 10.4 | 9.6 | 10.6 |

Table 37. Morphology Test results for Group A.
s1, s2 and s3 denote the three test sessions.

4.1.2 ANALYSIS OF VARIANCE GROUP B (prepositions treated first)

Treatment data. The accuracy scores of Group B for the Verb Test and Preposition Test across the three test sessions are given in Table 38. The means for each sentence set across the three test sessions are plotted in Figure 17.

Analysis of variance showed a significant main effect of Sessions, $F(2,12) = 17.08$, $MSe = 55.19$, $p < .001$. The means for sessions 1, 2 and 3 collapsed across Function type and Treatment set were 9.2, 11.5 and 11.7 respectively (max=20). Post-hoc Newman-Keuls tests ($p < 0.5$) showed performance in session 1 to be significantly worse than in session 2, which did not differ from performance in session 3. The main effects of Function type ($F(1,6) = 0.05$, $MSe = 1.44$, ns) and

Treatment set ($F(1,6) = 0.86$, $MSe = 3.44$, ns) were not significant, and none of the interactions approached significance.

| | session | VERB TEST | | | PREPOSITION TEST | | |
|-----|---------|----------------|------------------|--------------|------------------|------------------|--------------|
| | | treated /20 | untreated /20 | total /40 | treated /20 | untreated /20 | total /40 |
| P4 | s1 | 12 | 13 | 25 | 9 | 8 | 17 |
| | s2 | 12 | 12 | 24 | 13 | 14 | 27 |
| | s3 | 12 | 16 | 28 | 16 | 14 | 30 |
| P6 | s1 | 4 | 4 | 8 | 3 | 5 | 8 |
| | s2 | 5 | 5 | 10 | 6 | 9 | 15 |
| | s3 | 8 | 9 | 17 | 6 | 7 | 13 |
| P8 | s1 | 15 | 13 | 28 | 15 | 14 | 29 |
| | s2 | 16 | 17 | 33 | 20 | 17 | 37 |
| | s3 | 19 | 12 | 31 | 19 | 18 | 37 |
| P9 | s1 | 6 | 7 | 13 | 7 | 9 | 16 |
| | s2 | 12 | 12 | 24 | 8 | 5 | 13 |
| | s3 | 13 | 10 | 23 | 1 | 6 | 7 |
| P11 | s1 | 5 | 5 | 10 | 5 | 7 | 12 |
| | s2 | 10 | 7 | 17 | 10 | 6 | 16 |
| | s3 | 9 | 11 | 20 | 8 | 6 | 14 |
| P12 | s1 | 11 | 14 | 25 | 18 | 18 | 36 |
| | s2 | 13 | 12 | 25 | 19 | 18 | 37 |
| | s3 | 17 | 13 | 30 | 19 | 19 | 38 |
| P14 | s1 | 12 | 8 | 20 | 3 | 7 | 10 |
| | s2 | 10 | 12 | 22 | 15 | 8 | 23 |
| | s3 | 14 | 12 | 26 | 7 | 6 | 13 |
| | mean s1 | 9.29 | 9.14 | 18.43 | 8.57 | 9.71 | 18.29 |
| | mean s2 | 11.15 | 11.00 | 22.14 | 13.00 | 11.00 | 24.00 |
| | mean s3 | 13.14 | 11.88 | 21.71 | 10.86 | 10.86 | 21.71 |

**Table 38. Verb and Preposition Test results for Group B.
(prepositions treated first)**

The separate analyses of each group's data indicated that performance across sessions on treated and untreated verbs and prepositions differed between the two groups. This suggestion was supported in a combined analysis of variance carried out on the data from both groups, which produced a significant third order interaction between Groups, Sessions, Function type and Treatment set, ($F(2,24) = 3.66$, $MSe = 14.54$, $p < .05$).

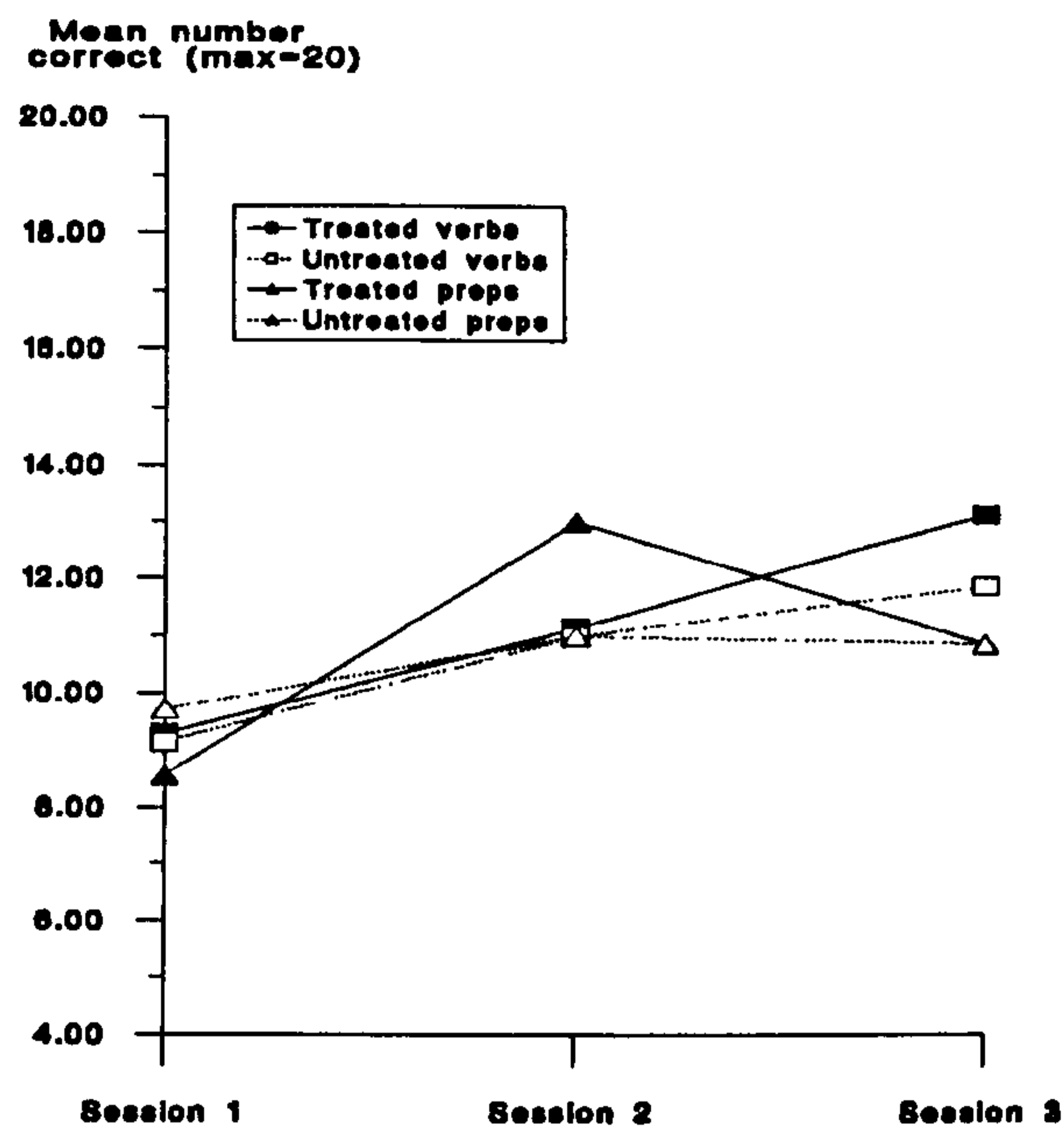


Figure 17. Verb and preposition treatment results for Group B.

Real World data. The performance of Group B on the Real World Test across the three test sessions is shown in Table 39 and the changes in mean performance on verb and preposition items over the three test sessions are illustrated in Figure 18.

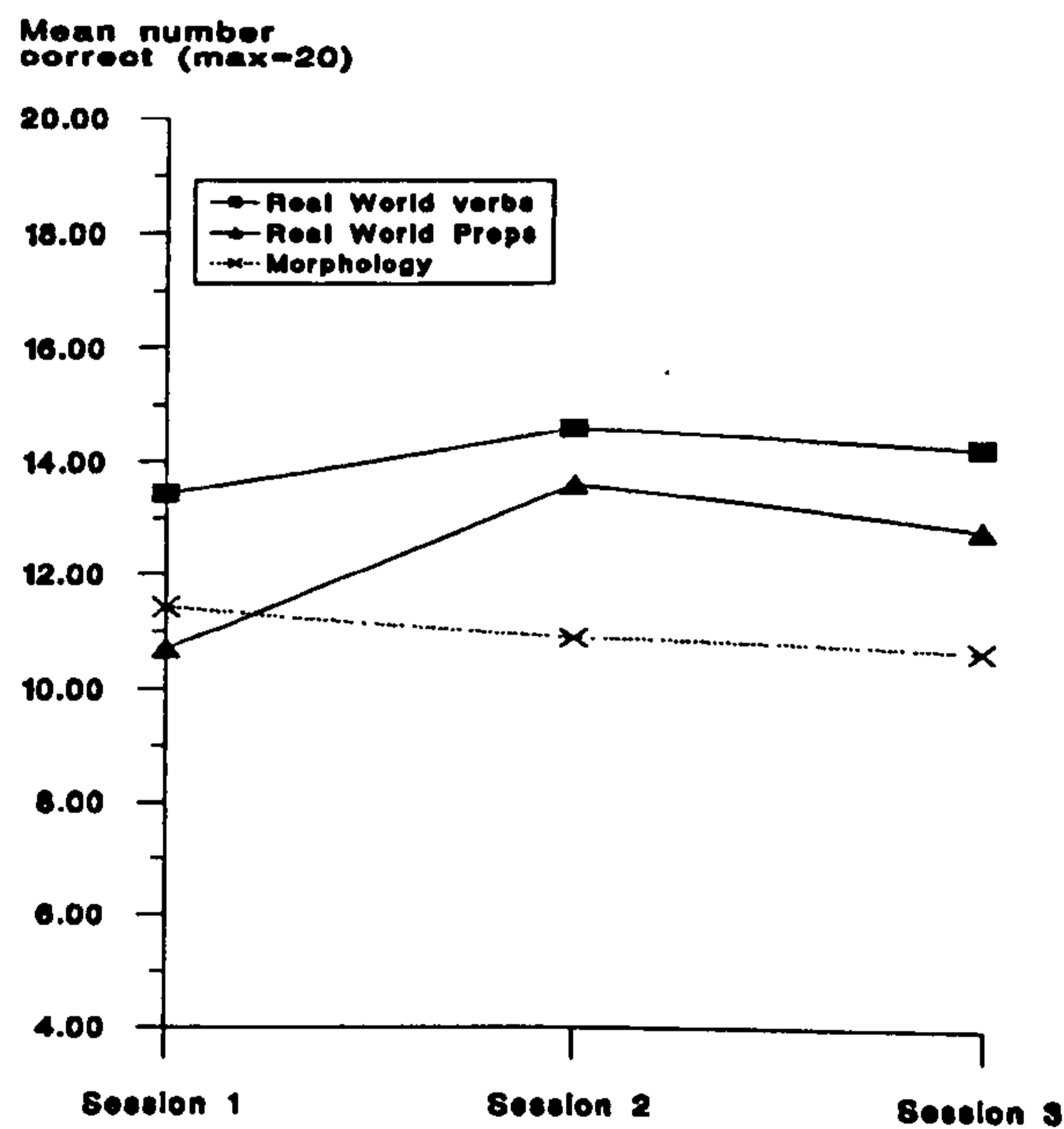


Figure 18. Morphology and Real World Test results for Group B.

| REAL WORLD TEST | | | | | | | |
|-----------------|---------|----------------|------------------|--------------|----------------|------------------|--------------|
| | | VERBS | | | PREPOSITIONS | | |
| | session | treated /10 | untreated /10 | total /20 | treated /10 | untreated /10 | total /20 |
| P4 | s1 | 9 | 8 | 17 | 6 | 8 | 14 |
| | s2 | 10 | 9 | 19 | 8 | 10 | 18 |
| | s3 | 8 | 9 | 17 | 8 | 9 | 17 |
| P6 | s1 | 8 | 7 | 15 | 5 | 3 | 8 |
| | s2 | 5 | 6 | 11 | 6 | 4 | 10 |
| | s3 | 8 | 4 | 12 | 6 | 6 | 12 |
| P8 | s1 | 9 | 6 | 15 | 9 | 9 | 18 |
| | s2 | 10 | 9 | 19 | 9 | 10 | 19 |
| | s3 | 9 | 8 | 17 | 7 | 9 | 16 |
| P9 | s1 | 5 | 5 | 10 | 3 | 7 | 10 |
| | s2 | 5 | 6 | 11 | 4 | 6 | 10 |
| | s3 | 6 | 6 | 12 | 7 | 6 | 13 |
| P11 | s1 | 1 | 8 | 10 | 2 | 3 | 5 |
| | s2 | 4 | 6 | 10 | 7 | 6 | 10 |
| | s3 | 3 | 7 | 10 | 4 | 4 | 8 |
| P12 | s1 | 9 | 8 | 17 | 6 | 7 | 13 |
| | s2 | 10 | 9 | 19 | 10 | 9 | 19 |
| | s3 | 7 | 8 | 15 | 8 | 8 | 16 |
| P14 | s1 | 6 | 4 | 10 | 3 | 4 | 7 |
| | s2 | 7 | 6 | 13 | 5 | 4 | 9 |
| | s3 | 8 | 8 | 16 | 4 | 3 | 7 |
| mean s1 | | 6.71 | 6.57 | 13.43 | 4.86 | 5.86 | 10.71 |
| mean s2 | | 7.29 | 7.29 | 14.57 | 7.00 | 6.57 | 13.57 |
| mean s3 | | 7.00 | 7.14 | 14.14 | 6.28 | 6.43 | 12.71 |

Table 39. Real World Test results for Group B.

All real world items were untreated. *Treated* and *untreated* columns refer to whether the verbs/prepositions concerned were treated in the microworld.

Analysis of variance showed a significant main effect of Sessions, $F(2,12) = 5.58$, $MSe = 7.87$, $p < .05$. The means for sessions 1, 2 and 3 collapsed across Function type and Treatment set were 6.0, 7.04 and 6.71 respectively (max=10). Post-hoc Newman-Keuls tests ($p < .05$) showed a significant improvement between sessions 1 and 2, but not between sessions 2 and 3.

The main effect of Function type approached significance, $F(1,6) = 5.0$, $MSe = 14.58$, $p = .07$, with verbs (mean = 7.0) tending overall to be easier than prepositions (mean = 6.71). There was no significant effect of Treatment set and none of the interactions approached significance.

Morphology data. Table 40 shows the morphology scores for Group B over sessions 1..3. The mean morphology scores were plotted with Real World performance in Figure 18. Analysis of variance with Sessions as the within-subjects factor showed no significant effect of sessions, $F(2,12) = 0.50$, $MSe = 1.33$, ns. This shows that, as with Group A, morphology performance remained static during treatment of both prepositions and verbs.

| MORPHOLOGY TEST | | | |
|----------------------------|------|------|------|
| score (max=20) | | | |
| | s1 | s2 | s3 |
| P4 | 13 | 14 | 13 |
| P6 | 9 | 11 | 7 |
| P8 | 13 | 12 | 12 |
| P9 | 14 | 12 | 14 |
| P11 | 4 | 5 | 6 |
| P12 | 18 | 12 | 13 |
| P14 | 9 | 10 | 9 |
| mean | 11.4 | 10.9 | 10.6 |

Table 40. Morphology Test results for Group B.
s1, s2 and s2 denote the three test sessions.

Combined analysis of Real World performance. An analysis of variance was carried out on the Real World Test data of Groups A and B combined; this showed no significant main effect of Groups.

There was a significant main effect of Sessions, $F(2,24) = 8.90$, $MSe = 25.2$, $p=.001$. The means for Sessions collapsed across other factors were 6.04, 6.95 and 7.34 respectively. Post-hoc Newman-Keuls tests ($p<.05$) showed that performance in session 1 was significantly worse than in session 2, but that improvement between sessions 2 and 3 was not significant. There was no significant main effect of Function type $F(1,12) = 3.61$, $MSe = 16.72$, ns. However, the main effect of Treatment set was significant $F(1,12) = 5.70$, $MSe = 14.29$, $p<.05$, with treated items (7.07) being better than untreated items (6.49).

A significant first order interaction was found between Groups and Treatment sets $F(1,12) = 8.27$, $MSe = 20.72$, $p=.01$. The anomaly in Group A (treated verbs being better than untreated verbs at session 1) has already been mentioned,

however, there was no significant difference for treated (6.52) and untreated items (6.64) in Group B.

There was also a significant first order interaction between Function type and Treatment set, $F(1,12) = 8.51$, $MSe = 26.72$, $p = .01$. The means collapsed across Groups and Sessions were; treated verbs (7.79), untreated verbs (6.40), treated prepositions (6.36), untreated prepositions (6.57). Post-hoc Newman-Keuls tests ($p < .05$) showed a significant difference between treated and untreated verbs, but not between treated and untreated prepositions.

Finally, there was a significant second order interaction between Groups, Function type and Treatment set, $F(1,12) = 6.16$, $MSe = 19.34$, $p < .05$. This arose because Group A showed a significant effect of treated items in the verb section of the Real World Test, but no significant difference between treated and untreated prepositions, while Group B showed no significant effect between treated and untreated items for either verbs or prepositions. As was noted in the report of Group A's results, this effect was present at session 1. However, as Group B's baseline results did not show to-be-treated 'real world' verb items to be easier than the untreated set (mean to-be-treated verbs = 6.71; untreated verbs = 6.57), there is insufficient evidence to suppose a flaw in the test materials.

Summary. The foregoing analysis of variance provides a condensed account of the main effects of treatment on each of the aphasic groups. The results show rather different outcomes for the two groups: Group A (verbs-treated-first) returned a classic cross-over pattern showing function-specific effects in both of the treated functions, with some generalisation both to untreated items and to real world items, but with (treated) item-specific gains dominant. Morphology results for Group A remained static throughout. On the other hand, Group B (which started off at slightly lower mean baselines, c.f. Figures 15 and 17) showed gains in verb performance after preposition treatment, this trend continuing through verb treatment. Group B's results were disappointing in two main respects, firstly that the difference between improvement on verbs and prepositions after preposition therapy (which is clearly evident in Figure 17⁶³) did

⁶³ The means for session 1 and session 2 in Table 38 indicate a strong effect of preposition treatment, but unfortunately almost all to treated items (an increase overall of 31 points on treated items and 9 on untreated items). This lack of generalisation, coupled with the smaller, but equally distributed improvement to treated and untreated verb items (an overall increase of 13 points on each), resulted in failure to achieve a significant interaction between Sessions and Function type.

not reach significance and secondly that the dramatic improvement in *treated* prepositions following preposition therapy, fell away sharply again once therapy was withdrawn. At session 3 the mean values for treated and untreated prepositions were identical. As with Group A, Group B's morphology results remained static throughout.

In Chapter 5, further aspects of the data are examined less formally, to gain some understanding of the effect of treatment on individuals, to find out how successful therapy was with respect to remediating the different sentence structures and to seek reasons for the dissimilar outcomes of the two groups.

4.2 ADDITIONAL POST-THERAPY TESTS

Section 2.6 reported the administration of three pre-therapy tests in addition to those based on the microworld and explained the rationale for including them. The Western Aphasia Battery (WAB) and the Test for Reception of Grammar (TROG) were repeated with all subjects as close as possible to the end of the treatment phase. The Digit-span Recall Test was repeated with 10 of the 14 aphasic subjects, between three and five months after cessation of the initial treatment phase of the research.

4.2.1 VISUAL DIGIT-SPAN RECALL TEST

The pre-therapy results of P1..P14 on the computer-based test of visual digit-span recall were presented in section 2.6.1. It was found that all the patients had impairments in this function, but that there appeared to be no consistent relationship between digit-span recall and either speed or accuracy over the three Syntax Screening Tests. The digit-span test was repeated in March 1991 with P4, P7 and P9 (who were all attending clinic for a second treatment phase reported in section 5.5) and in May 1991 with P1, P2, P3, P5, P8, P10, and P13 (who were recalled five months after the end of the treatment phase to assess the durability of treatment effects, reported in section 5.6). As there had been no connection between visual digit-span recall and severity of sentence processing deficit prior to therapy, it was not anticipated that this function would change as a result of treatment. The test was therefore repeated with the ten patients who were seen in connection with further evaluative work, but it was not considered necessary to

recall the remaining four patients for this purpose. The post-therapy digit-span recall results are shown in Table 41.

Comparison with Table 16 (p.103) shows that there was no change. Six subjects had the same digit-span pre- and post-therapy, three subjects showed an increase in capacity of one digit post-therapy and one subject showed a decrease in capacity of one digit. Thus, treating verb and preposition processing in these patients had no significant effect on their digit-span recalls which remained impaired - only two subjects (P1 and P10) were secure at the four digit level on re-testing. Improvements in sentence processing had occurred (and in some cases improvements in speed, see section 5.3) in spite of these limitations of temporary store (a similar result was reported by Byng (1988)).

| | DSR | | DSR |
|----|------|-----|------|
| P1 | 4[0] | P7 | 2[3] |
| P2 | 2[3] | P8 | 2[1] |
| P3 | 3[3] | P9 | 2[0] |
| P4 | 2[3] | P10 | 4[2] |
| P5 | 3[0] | P13 | 3[2] |

Table 41. The post-therapy visual digit-span recalls of ten of the aphasic subjects.
2[3] means accurate in at least 4/5 cases at a digit span of 1 and 2,
and in 3/5 cases at a digit span of 3

This was an interesting dissociation, in view of the two theories of STM involvement in sentence comprehension reviewed in section 2.6. One held that phonological STM is routinely involved in the parsing process, the other claimed that STM is not involved, unless there is a conflict to be resolved between syntactic or lexico-pragmatic interpretations. By the first sound-based account, most of P1..P14 would have experienced difficulties both with conversion to phonological form and with inner rehearsal. However, as the microworld minimised pragmatic preference for the correct interpretation over the reverse one (the sentence meanings being wholly recoverable from the lexical items and the rules of grammar), if the second theory were correct, then perhaps limitation of STM should not be important to sentence processing in the ball, box and star world.

The latter assumption turned out to be inaccurate, for while it may be true of the normal population who should find the microworld sentences unambiguous, it is,

of course, in the nature of agrammatics not to understand who is doing what to whom in reversible scenarios. They are therefore likely to be involved in a great deal of conflict resolution in trying to work this out. Thus, by either account of STM, P1..P14 should have shown an effect of temporary storage capacity on sentence processing performance and should not have been able to improve their sentence processing significantly without some parallel improvement in volatile memory span. It may then be the case that the principles behind the design of the remediation software (in terms of semantic partitioning to reduce the burden on STM and of 'packaging' the troublesome function words along with content words to form recognisable lexical patterns with readily recoverable meanings) were successful in allowing patients to improve their accuracy despite degraded, fixed-span STMs. Clearly, as the patients improved, the need for effortful resolution of thematic roles should have reduced (as was likely to have been the cause of reduced test times in many cases, see section 5.3). It nevertheless remained an observable feature of the behaviours of all the patients except P10 (who operated at normal speed).

4.2.2 WESTERN APHASIA BATTERY

The pre-therapy results of P1..P14 on the subset of the Western Aphasia Battery (WAB) required to calculate an aphasia quotient were presented in Table 17 (p.106). Early in January 1991, shortly after completion of the treatment phase this test was repeated. The results are shown in Table 42.

The two sets of performances were very static, indicating no change over the treatment period, (the mean aphasia quotient, was 71.73 pre-therapy and 72.69 post-therapy). Additionally, there was a very high positive correlation between the patients' aphasia quotients pre- and post-therapy ($r=0.95$) showing that the relative ordering of individual patients according to impairment of spoken output and auditory verbal input had not changed.

The lack of change on the WAB was a little disappointing, especially in view of the improvements in expressive language reported by most of the patients and their families (see section 6.2).

| | FL | CP | RP | NM | AQ |
|-----|----|------|------|-----|--------------------|
| P1 | 4 | 7.75 | 6.0 | 6.8 | 67.1 |
| P2 | 6 | 9.85 | 4.6 | 8.1 | 73.1 |
| P3 | 6 | 9.50 | 9.6 | 6.6 | 81.4 |
| P4 | 9 | 8.75 | 9.4 | 8.7 | 91.7 |
| P5 | 6 | 9.75 | 7.6 | 8.1 | 80.9 |
| P6 | 2 | 9.30 | 4.3 | 5.0 | 51.2 |
| P7 | 8 | 8.75 | 8.8 | 6.6 | 82.3 |
| P8 | 4 | 6.60 | 7.1 | 7.5 | 66.4 |
| P9 | 4 | 8.50 | 2.9 | 4.3 | 51.4 |
| P10 | 5 | 9.65 | 9.0 | 7.8 | 78.9 |
| P11 | 5 | 8.30 | 8.4 | 6.9 | 75.2 ⁶⁴ |
| P12 | 9 | 9.65 | 10.0 | 8.4 | 94.1 |
| P13 | 4 | 6.20 | 8.0 | 7.2 | 68.8 |
| P14 | 2 | 7.45 | 6.0 | 5.1 | 55.1 |

Table 42. Post-therapy WAB results for P1..P14.
The column headings are FL=fluency, CP=auditory verbal comprehension,
RP=repetition, NM=naming, AQ=aphasia quotient.

4.2.3 TEST FOR RECEPTION OF GRAMMAR

Table 18 (p.107) presented the pre-therapy Test for Reception of Grammar (TROG) results for P1..P14. This test was repeated during the first two weeks of January 1991, shortly after completion of the treatment phase and the results are shown in Table 43.

A comparison of the two sets of results showed no change (pre-therapy mean = 57.92; post-therapy mean = 59.85). The high degree of consistency between the two sets of results ($r=0.89$), obtained between three and five months apart, was remarkable in view of the reported variability of aphasics. P1's drop from 61 to 52 deserves a mention as he responded singularly well to microworld therapy. Discussing his post-therapy TROG with the administering clinician, I came to the conclusion that P1 had been trying to apply techniques developed in the microworld to sentence structures where they were not directly appropriate. P1 does have difficulty abstracting salient skills from one domain to another and having acquired a new skill, tends to apply it unselectively. As he was the patient

⁶⁴ P11 was the only patient whose aphasia subtype changed on post-test. On this result he would have been classified as Broca's whereas on first assessment he was classified as Anomic.

most responsive to the microworld, it was not entirely surprising that he should have over-rigidly tried to use what he had learned.

| | TROG max=80 |
|------|---------------------|
| P1 | 52 |
| P2 | 46 |
| P3 | 63 |
| P4 | 73 |
| P5 | 61 |
| P6 | 42 |
| P7 | 62 |
| P8 | 72 |
| P9 | 56 |
| P10 | 65 |
| P11 | 58 |
| P12 | 75 |
| P13 | 64 |
| P14 | 45 |
| Mean | 59.57 ⁶⁵ |

Table 43. A summary of the Post-therapy TROG results for P1..P14.

Since the vocabulary and sentence structures of the TROG are very diverse, and the therapy provided in this study was short and sharply focussed, generalisation on a large scale was not anticipated. However, clinical colleagues did spontaneously report a marked qualitative difference in the patients' tackling of the second TROG, which in comparison with the first was faster, much less effortful and with evidence of a more alert and systematic approach to the material.

⁶⁵ P9 was unfortunately neglected at the pre-therapy stage. Omitting his result the mean would have been 59.85.

CHAPTER 5

This chapter reports a number of supplementary and more descriptive analyses undertaken in response to the results of the analysis of variance (ANOVA) reported in Chapter 4. Section 5.1 considers the performance of individual subjects on the Verb Test, Preposition Test and Morphology Test to see how far the group results were representative of the profiles of their membership. It also examines changes in individual and group error patterns over the three test sessions. Section 5.2 looks at the treatment data by sentence structure, to see how performance on the various sentence types changed with the intervention applied. In section 5.3 the effects of treatment on group and individual speed profiles is examined. Section 5.4 discusses the clinical utility of a global indicator of treatment outcome and offers the basis for an index which takes into account both speed and accuracy. Section 5.5 reports the results of a second phase of treatment with P4, P7 and P9. Finally, section 5.6 presents follow-up data on seven of the subjects, who were recalled five months after the end of the treatment phase to assess the durability of treatment effects.

5.1 INDIVIDUAL PERFORMANCE PROFILES (ACCURACY)

The ANOVA results raised many interesting questions. This section, and the following two, address why the two treatment groups performed so differently. The data is explored from a number of angles to determine more about the nature of the differences and how they may have arisen.

GROUP A. Individual graphs showing the performance of patients in Group A (verbs treated first) on treated and untreated verbs and prepositions are shown in Figures 19a and 19b. From the graphs it can be seen that all the patients responded to verb treatment between sessions 1 and 2 (although P5's improvement was very marginal). By comparison, preposition performance was static as reported in section 4.1.1. However the individual graphs reveal that two patients, P7 and P10 showed improvements on the Preposition Test after verb therapy, responding as much to the to-be-treated function as to the treated one.

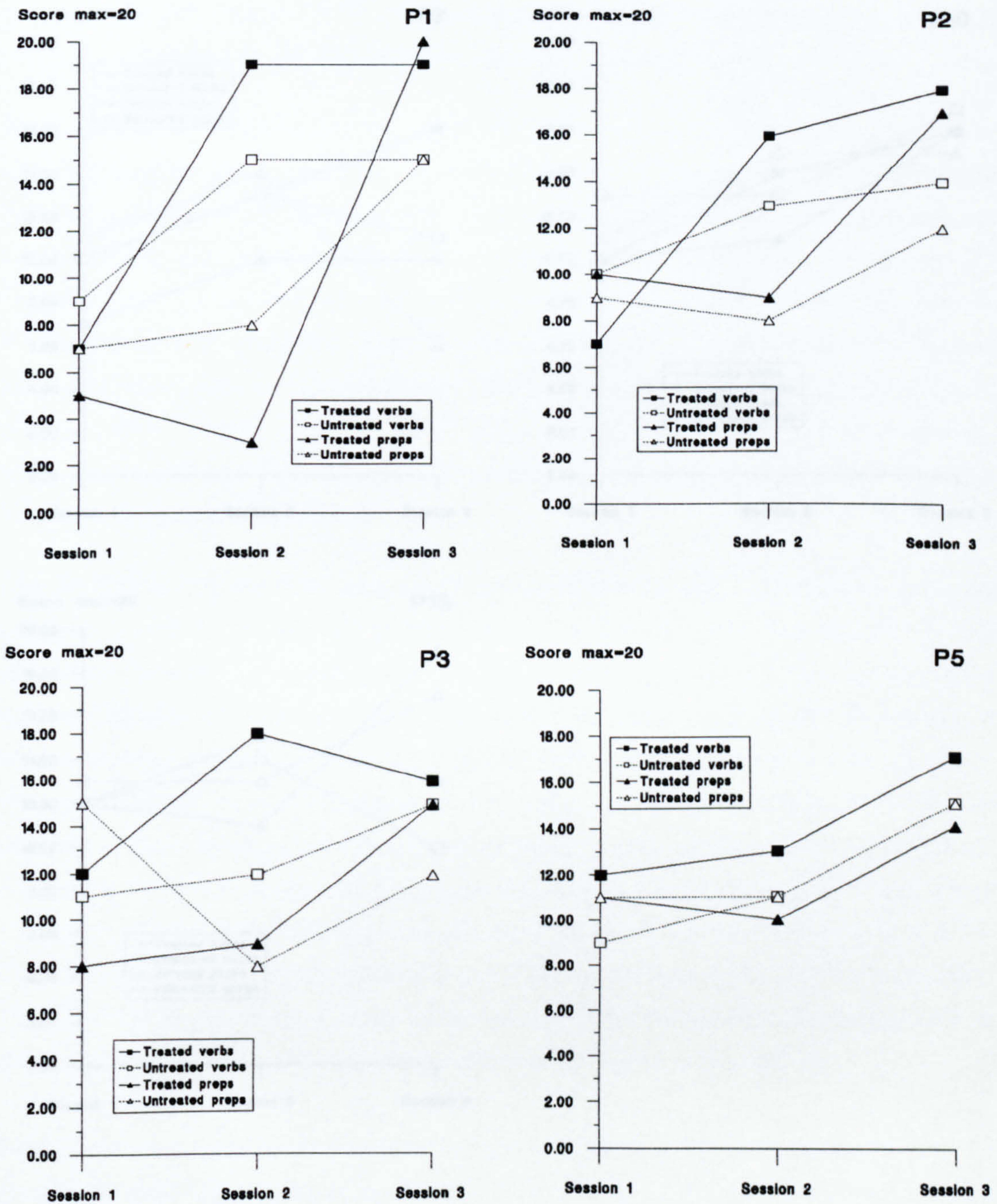


Figure 19a. Group A performance graphs for verbs and prepositions (accuracy).
 Session 1 = pre-therapy assessment, Session 2 = assessment after verb therapy
 and Session 3 = assessment after preposition therapy.

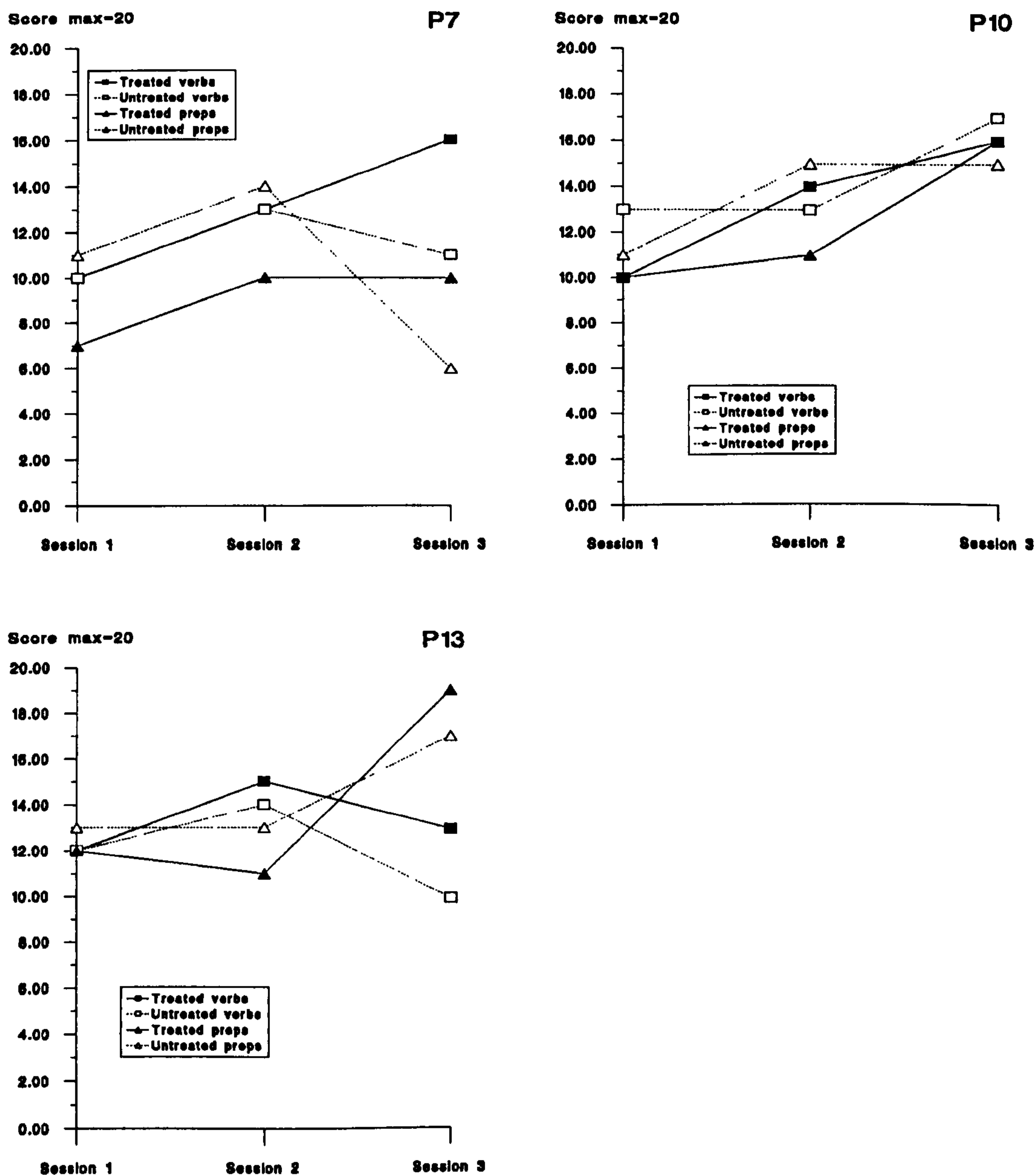


Figure 19b. Group A performance graphs for verbs and prepositions (accuracy).
 Session 1 = pre-therapy assessment, Session 2 = assessment after verb therapy
 and Session 3 = assessment after preposition therapy.

Between sessions 2 and 3, following verb therapy, all patients except P13 can be seen to have maintained or improved their performance on verbs (although P7's graph reveals that she declined towards her baseline performance in untreated verbs while continuing to improve on those items that had been treated). The graphs show that all patients except P7 responded to preposition therapy,

although, in the case of P10, who had responded to prepositions during verb therapy, there was no further improvement to untreated items.

While Group A's results overall were very pleasing, the individual graphs were useful in highlighting particular successes (P1, P2, P13 (preps)), disappointments (P7 (preps and untreated verbs), P13 (verbs)) and patterns other than the hoped-for cross-over profile. It seems, for example, from the verb results of P5 and P7 (treated items), that there is some evidence of a 'sleeper' effect, where full benefit is not necessarily apparent directly after treatment, but may require a longer period of assimilation. Interestingly, these two subjects made impressive gains directly after therapy in 'real world' verbs (see Figures 20a and 20b) showing, perhaps, that these subjects found the principles taught in therapy easier to apply in a less abstract environment.

The ANOVA showed that, overall, preposition scores had not changed between sessions 1 and 2 while verb treatment was underway (whereas, Group B had shown an increase in accuracy on verb items after preposition therapy that was not statistically differentiable from the larger increase on preposition items). It was of interest, therefore, to explore this further in case changes *had* taken place, but in preposition error *patterns* rather than in overall accuracy. Even if the number of correct responses remained constant, it was possible that an analysis of errors might reveal a simplification at session 2, for example that errors of types 3 and 4 were perhaps resolving towards predominantly reversal patterns (error 2). This possibility was investigated first of all by organising Group A's Preposition Test data by response type, as in Table 44, and examining what had happened to the mean number of each response type over the three test sessions.

Table 44 shows that the group results were remarkably stable in mean number of errors of each type comparing session 1 (baseline) with session 2 (after verb therapy). As noted from the individual graphs, P7 and P10 both improved in accuracy between sessions 1 and 2; Table 44 reveals more about the nature of this change. It is hard to understand why verb therapy should have helped P7 with error types 3 and 4 (e.g. all type 4 were lexical errors i.e. wrong prepositions); one suspects that these are random fluctuations, as P7 returned to baseline on these error types combined at session 3. However, P10's improvement in accuracy at session 2 can be seen to have been entirely due to a large decrease in reversal errors (session 1: 14 reversals, session 2: 5 reversals), a decrease that was maintained at session 3. Scrutiny of Tables F and J (Appendix 12) showed that verb therapy had a greater effect on the to-be-treated side than on the untreated

side of P10's Preposition Test - despite changes in accuracy suggesting the opposite. After verb therapy, 8 out of 10 reversal errors on the to-be-treated side had been corrected, but 3 formerly correct answers had been reversed. On the untreated side, 3 reversal errors had been corrected and no previously correct responses had been reversed. It seems possible, therefore, that some helpful component of verb therapy was at work here.

| | PREPOSITION TEST | | | | | | | | | | | |
|------|---------------------------|------|------|----------------------------|-----|-----|---------------------------------------|-----|-----|--|-----|-----|
| | response = 1 (correct) | | | response = 2 (reversal) | | | response = 3 (error) ⁶⁶ | | | response = 4 (wrong prep) ⁶⁷ | | |
| | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 |
| P1 | 12 | 11 | 35 | 21 | 20 | 3 | 4 | 3 | 1 | 3 | 6 | 1 |
| P2 | 19 | 17 | 29 | 7 | 6 | 2 | 9 | 11 | 4 | 5 | 6 | 5 |
| P3 | 23 | 17 | 27 | 10 | 8 | 10 | 3 | 9 | 1 | 4 | 6 | 2 |
| P5 | 22 | 21 | 29 | 7 | 11 | 7 | 8 | 5 | 2 | 3 | 3 | 2 |
| P7 | 18 | 24 | 16 | 10 | 12 | 13 | 5 | 2 | 4 | 7 | 2 | 7 |
| P10 | 21 | 26 | 31 | 14 | 5 | 6 | 3 | 6 | 2 | 2 | 3 | 1 |
| P13 | 25 | 24 | 36 | 5 | 6 | 1 | 5 | 3 | 1 | 5 | 7 | 2 |
| mean | 20.0 | 20.0 | 29.0 | 10.6 | 9.7 | 6.0 | 5.3 | 5.6 | 2.1 | 4.1 | 4.7 | 2.9 |

Table 44. Group A's Preposition Test results, analysis of error patterns.
(treated and untreated items, n=40 per subject per session)
(s1, s2 and s3 denote session 1, session 2 and session 3)

A full list of target sentences and distractors is in Appendix 6.

The full data set sentence by sentence is given in Appendix 12 (Tables F and J).

This raised the possibility that the to-be-treated side of Group A's Preposition Test data might show effects which were submerged in the complete data because it comprised fewer sentence structures than the untreated side, (structures 1 and 2 (e.g. *The ball is under the box*, *The ball is under the box and the star*) accounted for 14 out of 20 sentences and these, moreover, were sentence forms that could plausibly benefit from therapy on simple active declaratives (e.g. *The ball paints the box*)). In fact no such effect was found (the total number of errors made by Group A on to-be-treated preposition items was - session 1: 35 reversals, 15 other errors; session 2: 34 reversals, 16 other errors).

⁶⁶ In two-noun sentences the picture chosen illustrated an incorrect prepositional relationship, in more complex sentence structures a reversal around either the first or second preposition is generally entailed.

⁶⁷ This error type almost invariably indicates that the picture chosen showed an incorrect prepositional relationship, in two-preposition sentences one of the locatives was incorrect.

Apart from P10, P1 was the only individual who seemed to show a possible effect of verb therapy at session 2. On his structure 1 (to-be-treated) preposition sentences he returned a mixture of responses (1, 2 and 3) at session 1, but after verb therapy he chose the reverse role distractor (response =2) on every occasion (n=8). The probability of such a sequence of responses occurring by chance is obviously extremely small ($p=.000015$) and suggests that some element of verb therapy (possibly reinforcement of word order significance) exacerbated P1's tendency to reverse subject and object in simple locative sentences. The reason for P1's marked tendency to pick the reverse distractor (see Table 44) is discussed further in section 6.1.2.

For completeness, Table 45 shows Group A's Verb Test error patterns over the three test sessions. This table shows that verb therapy was successful in reducing all three error types and that the benefit in all was maintained after preposition therapy. However, in three cases, P3, P7 and P13, it can be seen that therapy failed to reliably reduce reverse role errors (response = 2).

| | VERB TEST | | | | | | | | | | | |
|------|---------------------------|------|------|----------------------------|-----|-----|---------------------------------------|-----|-----|---------------------------------------|-----|-----|
| | response = 1 (correct) | | | response = 2 (reversal) | | | response = 3 (error) ⁶⁸ | | | response = 4 (error) ⁶⁹ | | |
| | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 |
| P1 | 16 | 34 | 34 | 8 | 2 | 2 | 12 | 0 | 2 | 4 | 4 | 2 |
| P2 | 17 | 29 | 32 | 10 | 7 | 2 | 8 | 0 | 1 | 5 | 4 | 5 |
| P3 | 23 | 30 | 31 | 6 | 4 | 7 | 7 | 1 | 1 | 4 | 5 | 1 |
| P5 | 21 | 24 | 32 | 4 | 6 | 3 | 7 | 5 | 1 | 8 | 5 | 4 |
| P7 | 20 | 26 | 27 | 10 | 8 | 8 | 2 | 3 | 3 | 8 | 3 | 2 |
| P10 | 23 | 27 | 33 | 5 | 5 | 1 | 4 | 5 | 6 | 8 | 3 | 0 |
| P13 | 24 | 29 | 23 | 9 | 6 | 9 | 3 | 3 | 3 | 4 | 2 | 5 |
| mean | 20.6 | 28.4 | 30.3 | 7.4 | 5.4 | 4.6 | 6.1 | 2.4 | 2.4 | 5.9 | 3.7 | 2.7 |

Table 45. Group A's Verb Test results, analysis of error patterns.

(treated and untreated items, n=40 per subject per session)

(s1, s2 and s3 denote session 1, session 2 and session 3)

A full list of target sentences and distractors is in Appendix 4.

The full data set sentence by sentence is given in Appendix 12 (Tables H and L).

⁶⁸ In two-noun sentences the picture chosen contained a protagonist (either subject or object) not mentioned in the target sentence, in more complex sentence structures a reversal of object and indirect object is almost invariably indicated.

⁶⁹ In two-noun sentences the picture chosen illustrated an incorrect verb, in more complex sentence structures a reversal of subject and indirect object is most commonly indicated.

Group A's accuracy results on the Real World Test were presented in Table 36 (p. 161) and graphically in Figure 16 (p. 162). Individual performance graphs for members of Group A, showing changes in accuracy to 'real world' verb and preposition sentences and to the control function, morphology, are shown in Figures 20a and 20b.

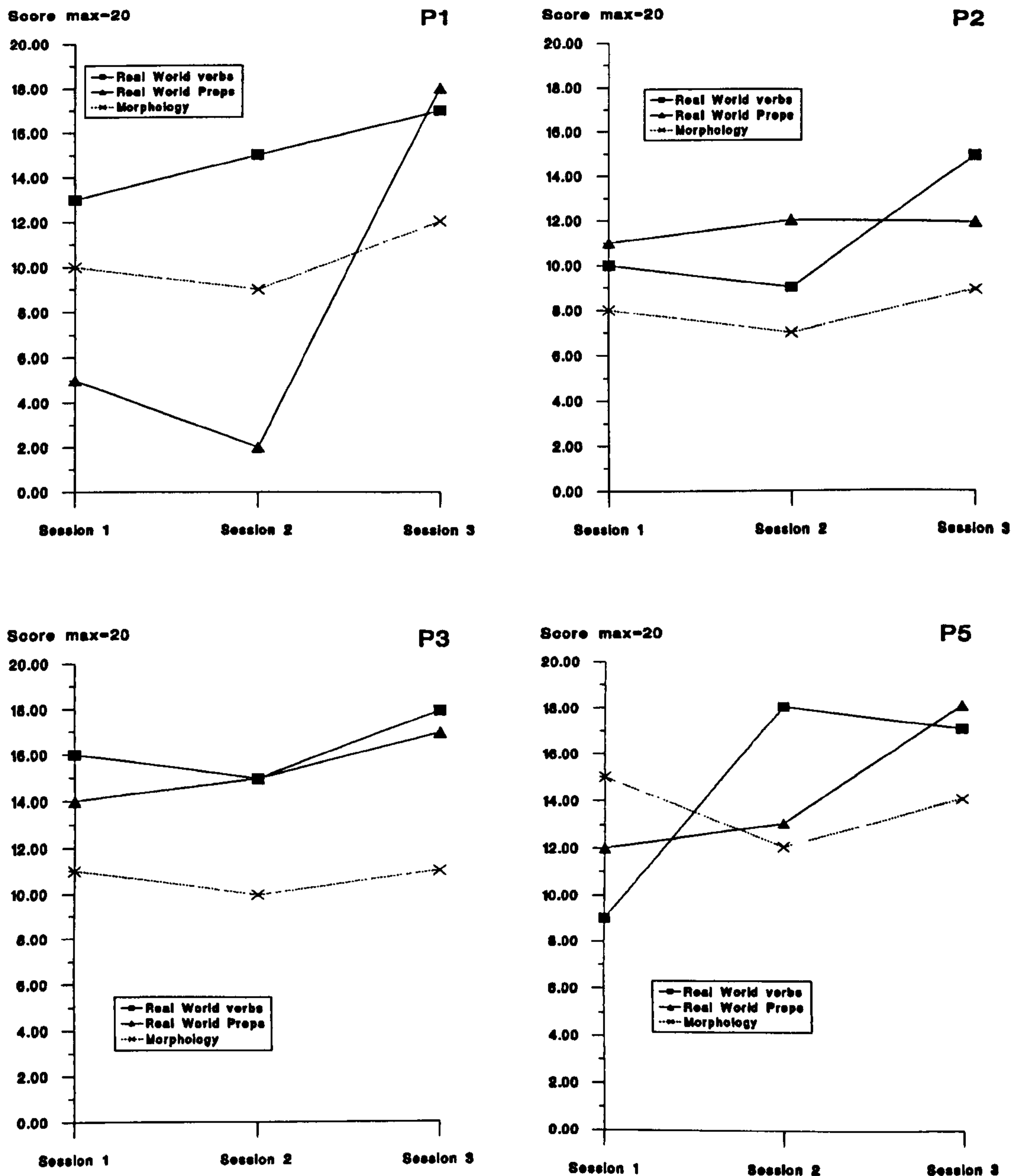
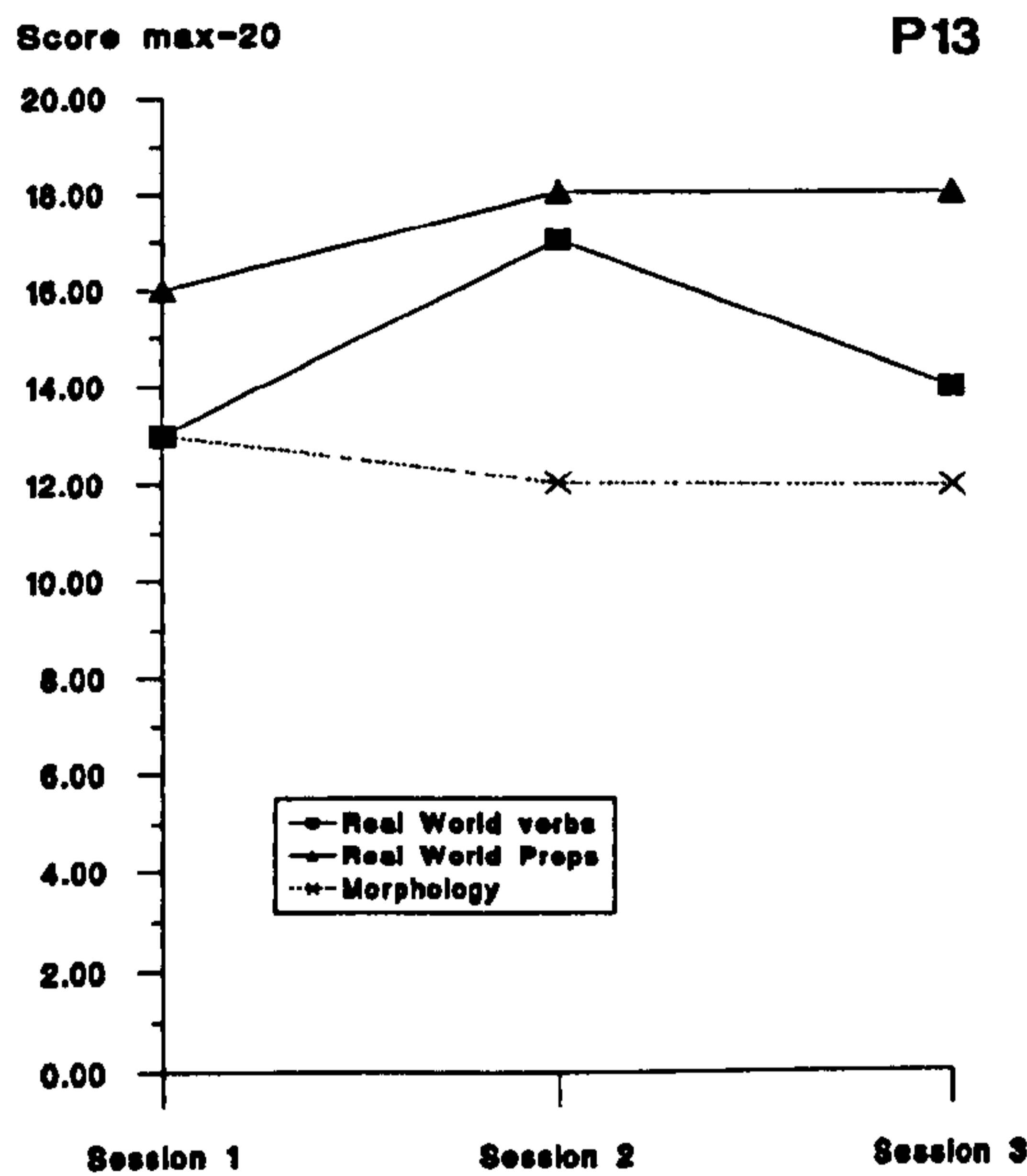
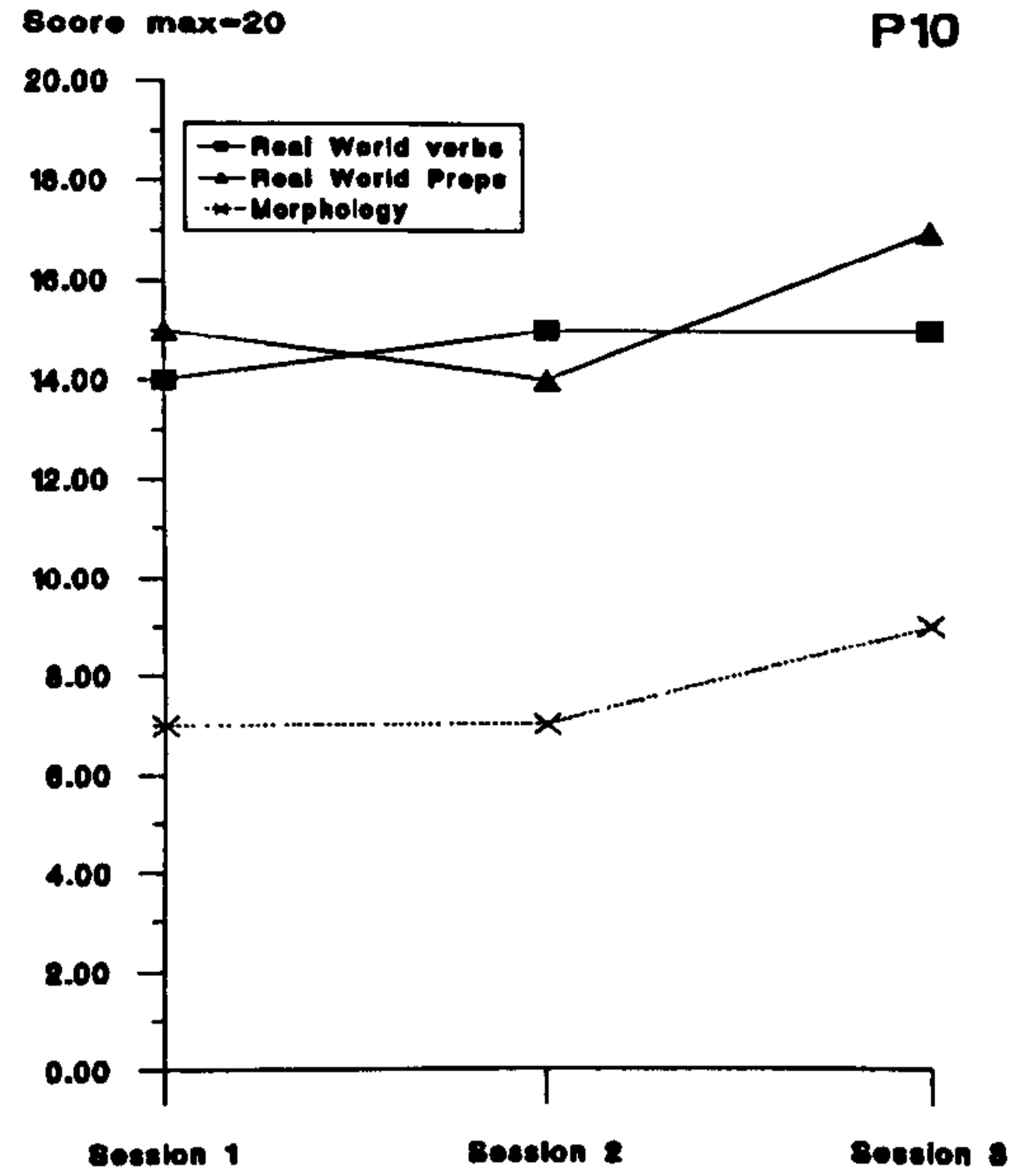
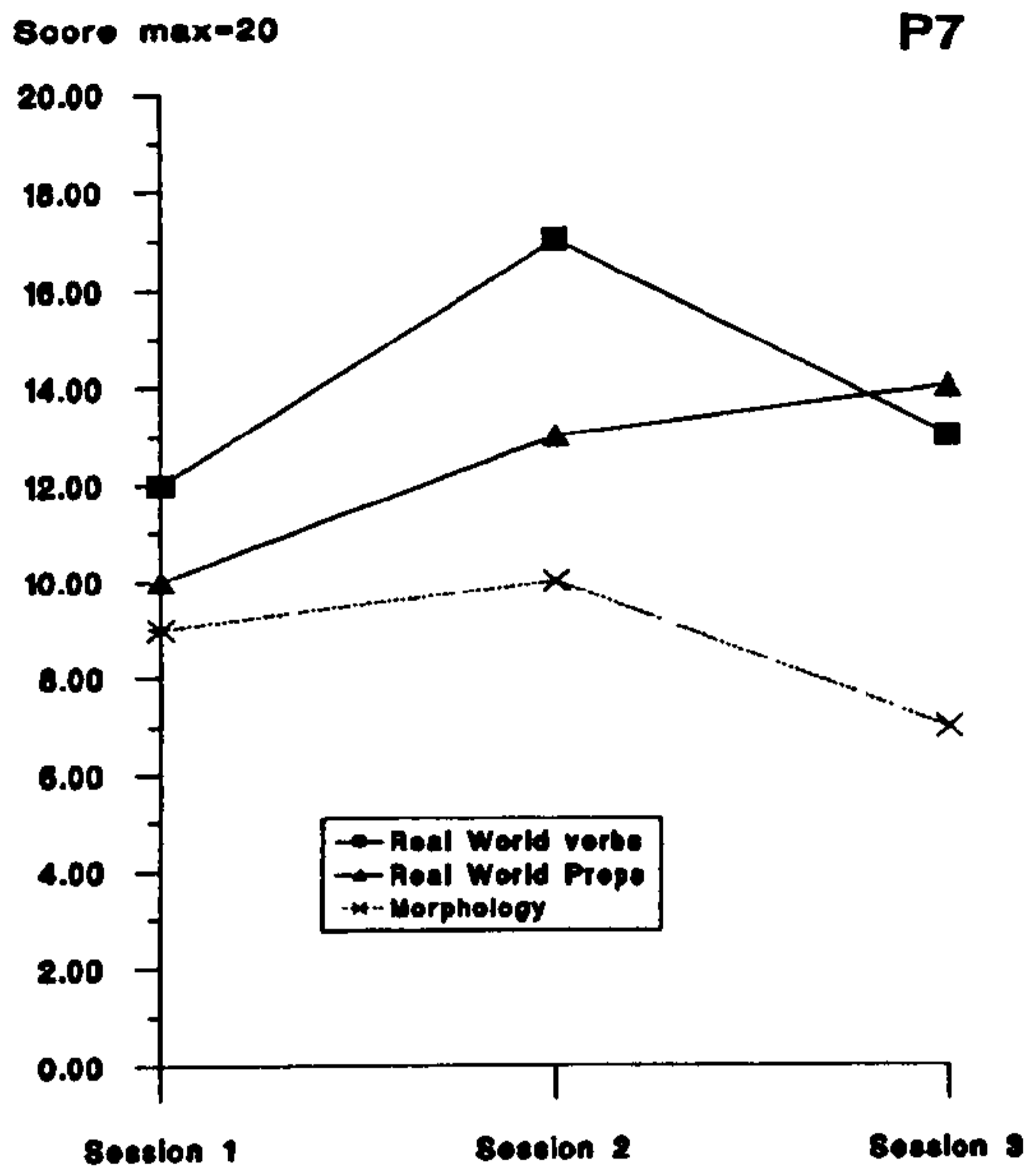


Figure 20a. Group A performance graphs for Real World Test (accuracy). Verbs were treated between sessions 1 and 2 and prepositions were treated between sessions 2 and 3.



**Figure 20b. Group A performance graphs for Real World Test (accuracy).
Verbs were treated between sessions 1 and 2 and prepositions
were treated between sessions 2 and 3.**

The Real World Test comprised 20 verb sentences and 20 preposition sentences, each set including sentence structures and verbs/prepositions which were to be treated, and other structures and lexical items from the untreated sides of the Verb Test and Preposition Test (see Table 23, p.120).

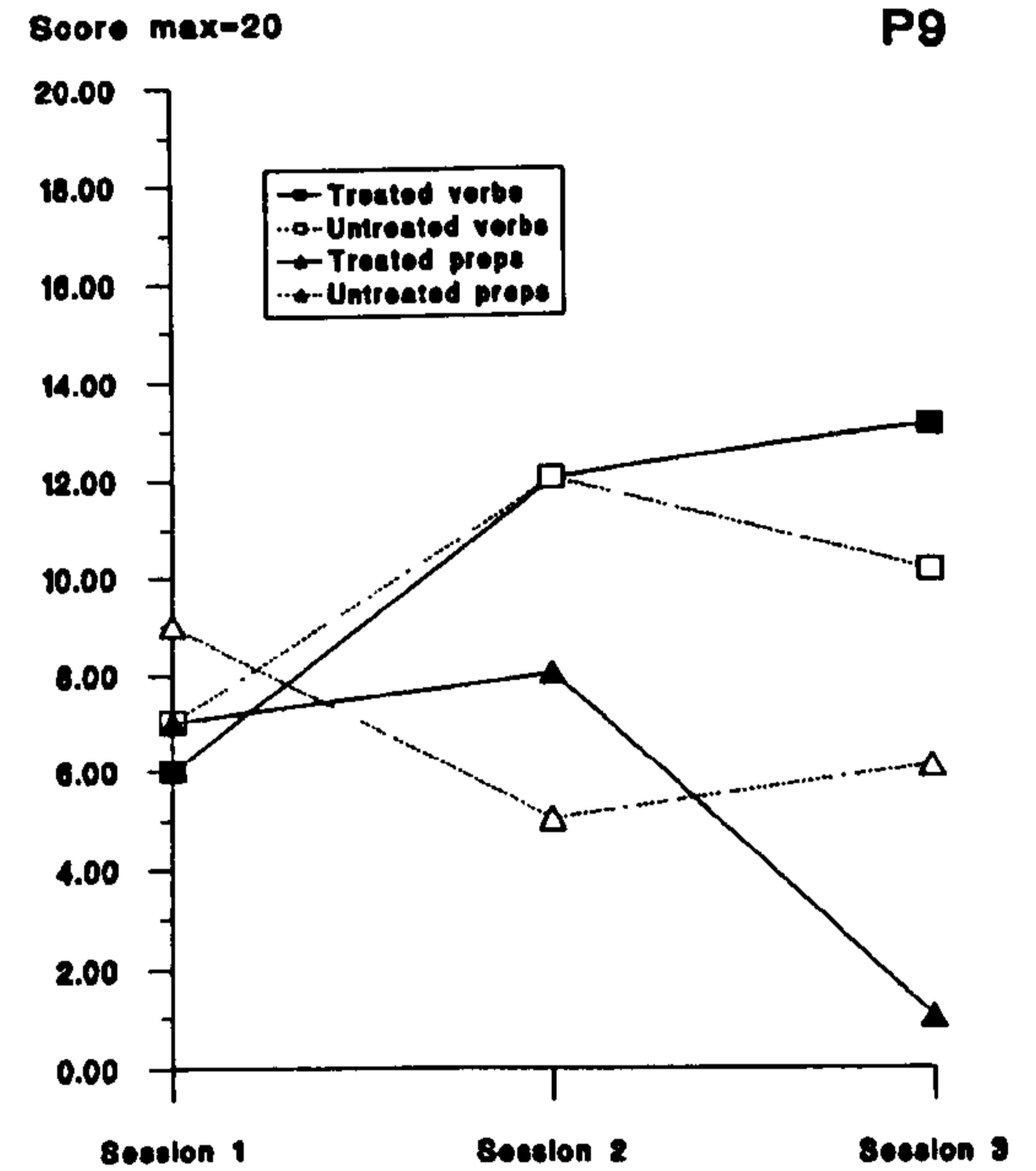
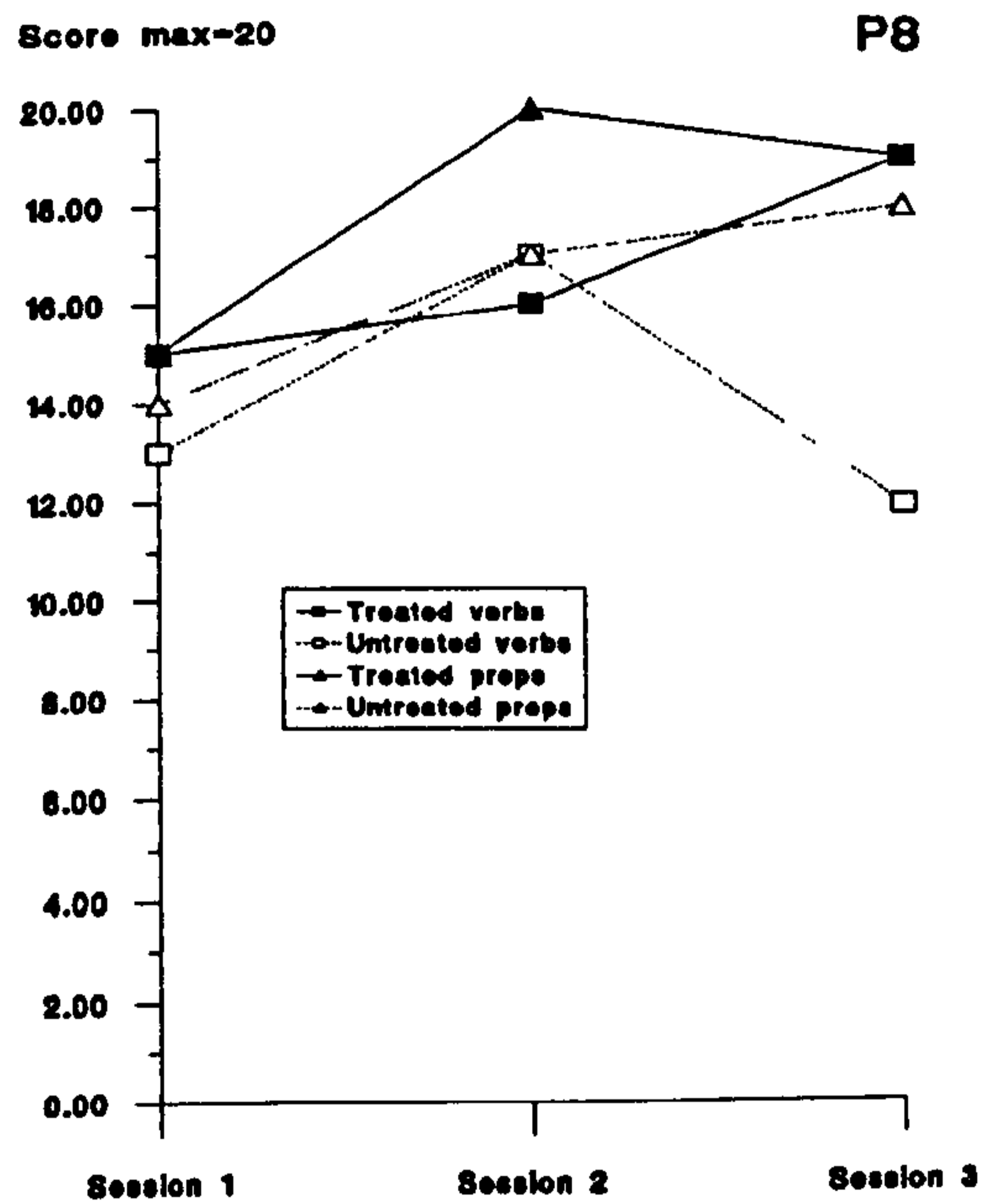
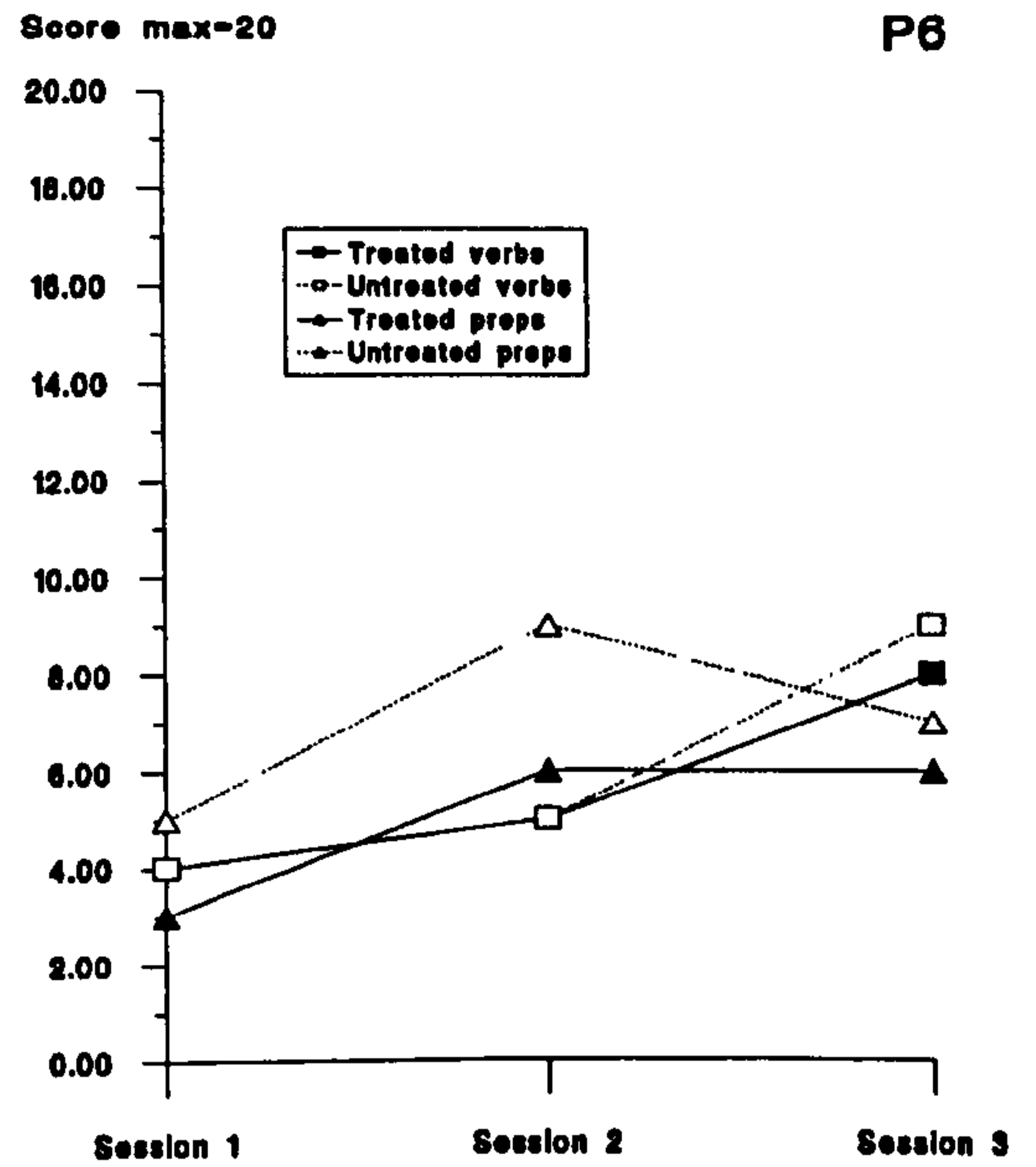
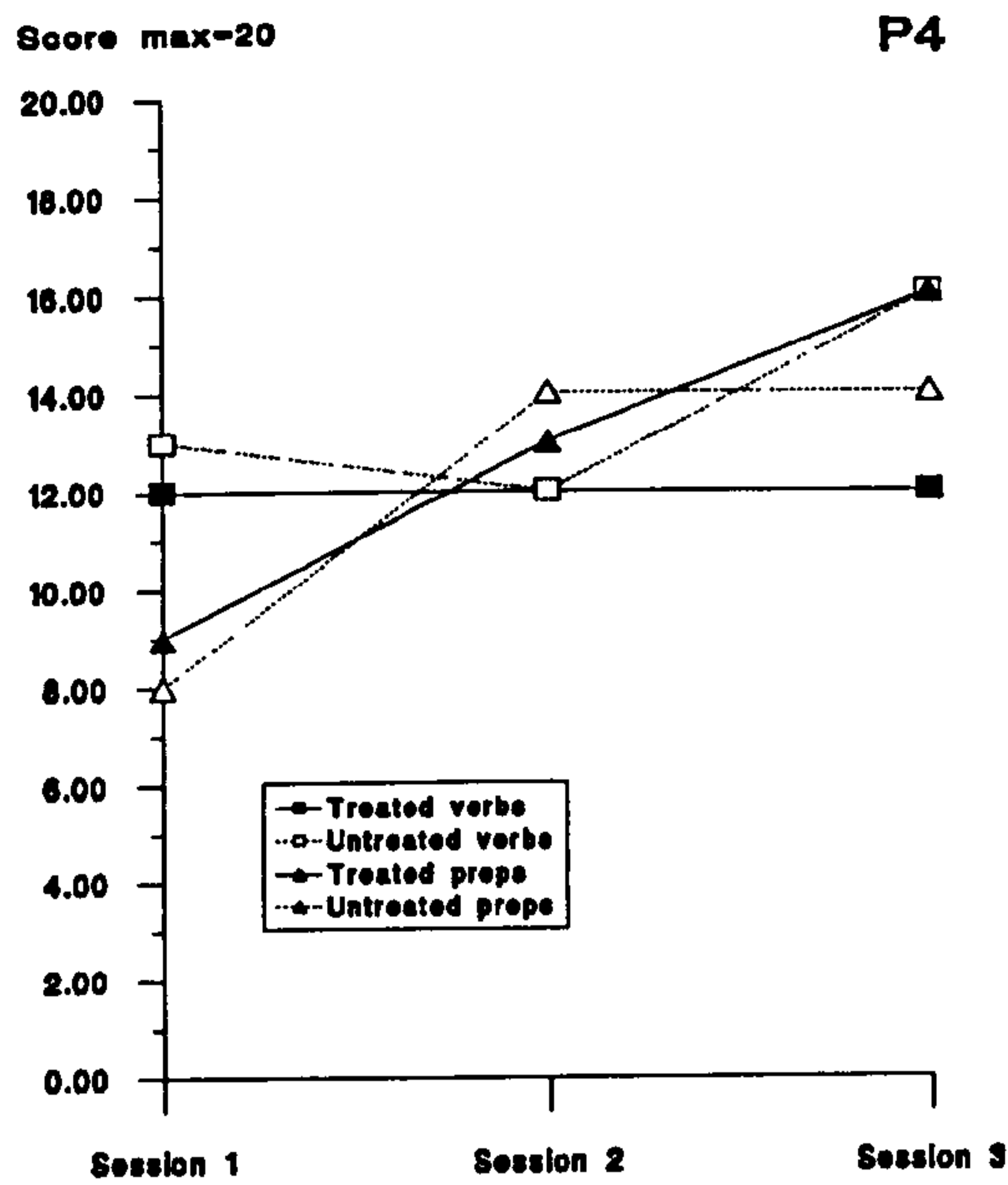
Since the Real World Test and microworld tests both consisted of fully reversible sentences which were plausible in either 'direction', and the single-word vocabularies for each were pre-checked for recognition, a consistent difference in accuracy between the two at baseline assessment was not anticipated. In fact, in spite of having been exposed to the microworld on three previous occasions (the Syntax Screening Tests) over a period of several weeks and in most cases several months prior to the treatment phase, Group A found the Real World Test easier at session 1 (Verb Test, mean/2 = 10.29;⁷⁰ Real World verb mean = 12.43). Only one patient (P5) performed slightly better in the microworld test at baseline. The vertical axes in Figures 19a, 19b, 20a and 20b are identical, for ease of comparison. From these, the tendency to higher baseline scores on the Real World Test is evident (e.g. P1 (verbs), and P13 (preps)).

The same trend was true of the Preposition Test compared with the matched preposition side of the Real World Test (Preposition Test mean/2 = 10.00; Real World preposition mean = 11.86) with P3, P10 and P13 showing the largest differences. Thus P3 and P10 were more accurate at session 1 on 'real world' items than on corresponding microworld items both on verbs and prepositions.

Figures 20a and 20b show some very elegant cross-over patterns, most notably those of P1 and P5. However, the individual graphs also highlight a falling off of 'real world' verb performance between sessions 2 and 3 in P7 and P13 (which mirrors their microworld profiles). P2's graph in Figure 20a shows that she demonstrated a marked 'sleeper effect' on 'real world' verbs and very little change on 'real world' prepositions, despite her improvement in microworld prepositions (c.f. Figure 19a).

GROUP B. The ANOVA reported in section 4.1.2 raised two main questions concerning the performance of Group B: why did verb items respond to preposition therapy and why was the effect of preposition therapy on preposition items lost after verb therapy? Individual performance profiles were examined to help answer these questions. Graphs showing the performance of patients in Group B (prepositions treated first) on treated and untreated verbs and prepositions are shown in Figures 21a and 21b.

⁷⁰ The mean has been halved for easier comparison with the Real World Test because the latter included 20 verb sentences, while the Verb Test comprised 40 items.



**Figure 21a. Group B performance graphs for verbs and prepositions (accuracy).
 Session 1 = pre-therapy assessment, Session 2 = assessment after preposition therapy
 and Session 3 = assessment after verb therapy.**

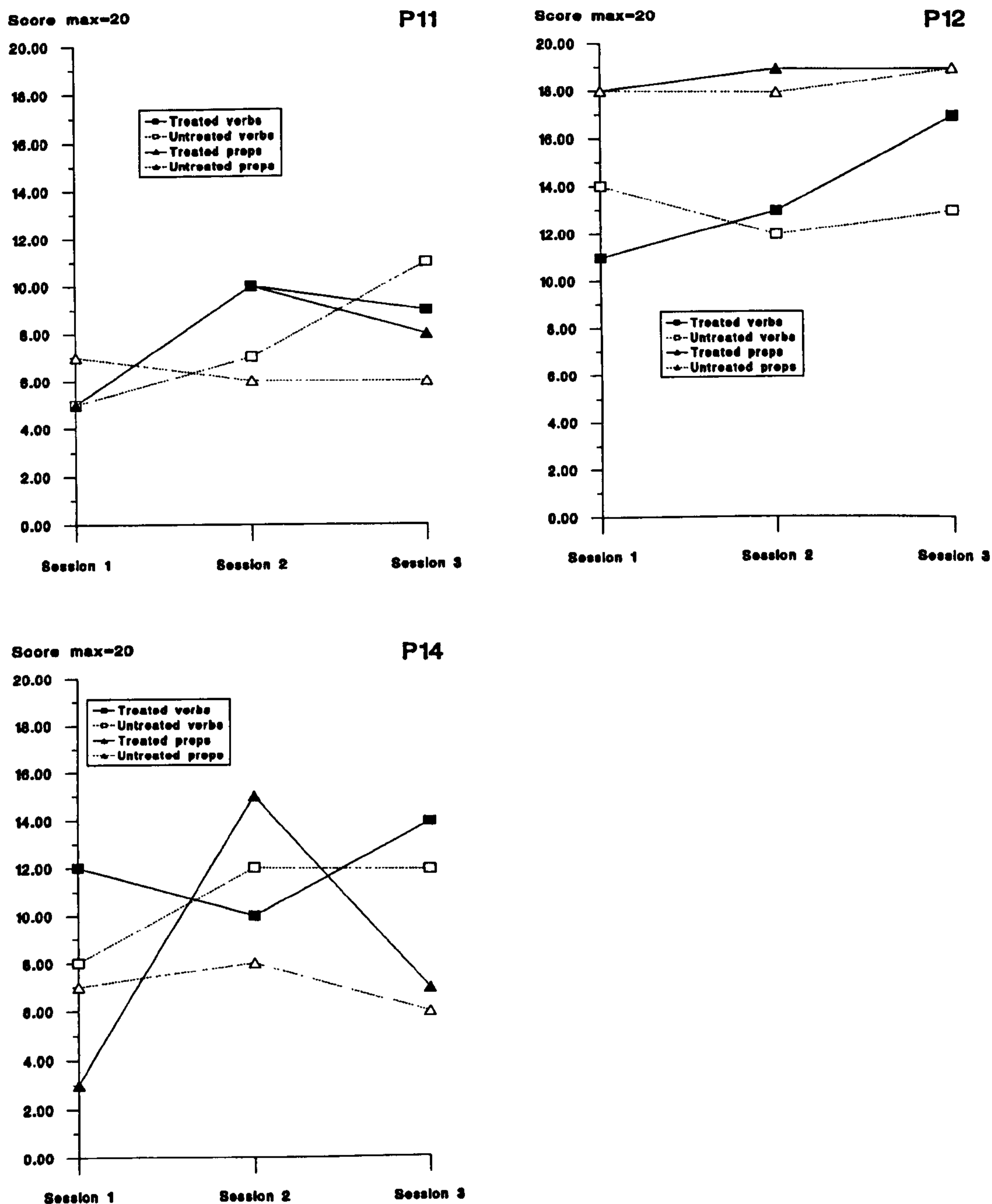


Figure 21b. Group B performance graphs for verbs and prepositions (accuracy).
 Session 1 = pre-therapy assessment, Session 2 = assessment after preposition therapy
 and Session 3 = assessment after verb therapy.

The graphs show that six out of seven patients improved on prepositions following preposition therapy, although in the cases of P11 and P14 this improvement was confined to treated items and P12 was very close to ceiling on this function pre-therapy, therefore having very little room for improvement on accuracy. P9 was

alone in declining on prepositions at session 2 (his graph shows that he regressed solely on untreated items which, oddly, had been better prior to therapy than any of the other categories tested, and remained almost static on the items treated).

Following preposition therapy (session 2 results), Group B also returned improved verb scores. Figures 21a and 21b show that 5 patients were involved in this overall improvement. Of these, two patients, P6 and P14, made marginal gains of two points each, but P8, P9 and P11 made gains of 5, 11 and 7 respectively. Thus P9 and P11 responded more to the as-yet-untreated function than to the treated one, P9 declining in prepositions after treatment, while improving substantially in verbs! In examining the extent to which improvements in preposition processing were maintained following verb therapy, the individual graphs revealed that two patients (P4 and P8) maintained their progress. P6 and P11 made small losses of two points each following verb therapy, but P9 and P14 made catastrophic losses (P9 who had not responded to preposition therapy declined even further to 1/20 on the treated items, and P14 lost most of his large improvement on treated items, see Figure 21b).

With respect to the effects of verb therapy on Group B's verb performance, Figures 21a and 21b show that five patients improved between sessions 2 and 3, although of these P4 and P11 did so only on untreated items and P14 only on treated items. P9 managed to maintain the progress he had made on treated verbs during preposition therapy (although his improvement on untreated verbs was less durable), however, P8 while continuing the improvement on treated verbs which had occurred following preposition therapy, declined markedly on untreated verbs after verb treatment, finishing the study slightly worse on these items than he had been at session 1.

From the foregoing it is clear that the disappointing results reported for Group B in section 4.1.2 were the product of several patients and not just one or two. Indeed, only three patients (P4, P6 and P12) returned the hoped-for cross-over profile (although P4 failed to respond to treated verbs, P6 was a very weak patient at the outset and the improvements he made still left him at a poor standard (17/40 verbs, 13/40 prepositions), and P12, as we have noted, was near ceiling on prepositions at the outset). P8, P11 and P14 returned partial elements of function-specific responses and P9 produced a bizarre pattern with respect both to the magnitude of his improvement on verbs at session 2 and to the magnitude of his regression on prepositions at session 3. Thus we find that P8, P9, P11 and P14 all contributed to the poor group result by either responding to

the function not being treated, failing to respond to the treated function, or losing previous improvements.

To probe the nature of these changes, Group B's responses over the three test sessions were examined, as for Group A. First the Verb Test results were investigated to find out how the errors made had altered after preposition therapy. The results are shown in Table 46.

| | VERB TEST | | | | | | | | | | | |
|------|---------------------------|------|------|----------------------------|-----|-----|---------------------------------------|-----|-----|---------------------------------------|-----|-----|
| | response = 1 (correct) | | | response = 2 (reversal) | | | response = 3 (error) ⁷¹ | | | response = 4 (error) ⁷² | | |
| | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 |
| P4 | 25 | 24 | 28 | 4 | 4 | 5 | 5 | 6 | 2 | 6 | 6 | 5 |
| P6 | 8 | 10 | 17 | 16 | 10 | 8 | 11 | 7 | 6 | 5 | 13 | 9 |
| P8 | 28 | 33 | 31 | 4 | 3 | 2 | 2 | 0 | 0 | 6 | 4 | 7 |
| P9 | 13 | 24 | 23 | 15 | 9 | 10 | 5 | 4 | 4 | 7 | 3 | 3 |
| P11 | 10 | 17 | 20 | 10 | 9 | 7 | 13 | 7 | 8 | 7 | 7 | 5 |
| P12 | 25 | 25 | 30 | 5 | 3 | 4 | 3 | 2 | 2 | 7 | 10 | 4 |
| P14 | 20 | 22 | 26 | 11 | 10 | 11 | 4 | 3 | 1 | 5 | 5 | 2 |
| mean | 18.4 | 22.1 | 25.0 | 9.3 | 6.9 | 6.7 | 6.1 | 4.1 | 3.3 | 6.1 | 6.9 | 5.0 |

Table 46. Group B's Verb Test results, analysis of error patterns.

(treated and untreated items, n=40 per subject per session)

(s1, s2 and s3 denote session 1, session 2 and session 3)

A full list of target sentences and distractors is in Appendix 4.

The full data set sentence by sentence is given in Appendix 12 (Tables I and M).

Table 46 confirms what was seen in the individual graphs, viz., that only P9 and P11 improved substantially in accuracy on verb items between sessions 1 and 2 (while prepositions were being treated), although this upward trend was reinforced by P6, P8 and P14 and not contradicted by 12. Table 46 shows that in the case of P11, the increase in accuracy was almost entirely due to the correction of type 3 errors. Reference to Tables I and M (Appendix 12), revealed that the said errors had occurred in structures 1 and 2 (where they indicate an incorrect lexical choice for one of the protagonists), and structure 3 (where they indicate a

⁷¹ The implication of this response type varies with sentence structures. In two-noun sentences the picture chosen contained a protagonist (either subject or object) not mentioned in the target sentence, in more complex sentence structures a reversal of object and indirect object is almost invariably indicated.

⁷² The implication of this response type varies with sentence structures. In two-noun sentences the picture chosen illustrated an incorrect verb, in more complex sentence structures a reversal of subject and indirect object is most commonly indicated.

reversal of the object and indirect object). It is plausible that practice in preposition mode should have sorted out lexical problems (e.g. *The box paints a ball => The box paints a star*), though why it should have helped with errors such as *The box gives a ball to the star => The box gives a star to the ball* is less clear.

Table 46 shows that P9 improved in accuracy on verbs at session 2, and suggests that this may have been the result of corrected reversal errors (which could plausibly have been ascribed to the word order significance aspect of preposition therapy). In fact, Tables I and M reveal that only four of these reversal errors were corrected, the rest were transformed into errors further from the target. However, five errors of type 4 in structure 1 sentences present at session 1 (e.g. *The ball paints the box => The ball holds the box*) had been resolved at session 2; this is surprising - it is hard to see how preposition therapy could have been responsible for an improvement in verb *meanings*.

There is very little evidence of preposition therapy affecting Group B's results in a consistent and plausible way. The rather large changes in accuracy of P9 and P11 discussed above were buttressed by small positive changes in three others (P6, P8 and P14) - of these, P6's contribution is suspect, since his responses were fairly uniformly distributed between the four response types and inconsistent between the first test and the second (indicating that his behaviour was random). A large part of the verb improvement was accounted for by resolution of lexical problems (*ball => box; paints => holds*); there is nothing *preposition-specific* which would explain this (*any* microworld exposure would have helped with the nouns (and with the verb meanings if they improved due to general semantic facilitation)). Of course, these errors should not have occurred in view of the Lexical Test that was used for screening! Clearly, had P9 and P11 not exhibited lexical problems at baseline, the results would have been different and the effects of preposition therapy on preposition items (an overall gain of 40 points, 31 of which were on treated items) might well have proved function-specific.

Turning to the Preposition Test results of Group B, the primary concern was why performance had fallen off after withdrawal of treatment. Table 47 summarises Group B's response types to preposition items over the three test sessions. Figures 21a and 21b showed that two patients (P9 and P14) suffered serious declines in treated prepositions during verb therapy. From Table 47 it can be seen that two other patients (P6 and P11) contributed small negative changes to the downward trend. Had the regressions of P9 and P14 been due to a

confounding aspect of verb therapy, one would have expected an increase in reversal errors (S-V-O reinforcement increasing the tendency to cast the first noun-phrase in the locative sentences in the 'dominant role' although the prepositions chosen for remediation (*in*, *under* and *behind*) always designated it subordinate). There was some evidence of this in the results of P9 (12 session 2 reversals remained reversed at session 3, in addition 8 responses correct at session 2 were reversed at session 3 (while 4 reversal errors at session 2 were corrected at session 3 and 3 responses correct at session 2 changed to errors 3 or 4 at session 3)). P9's data in Table G shows that at session 3, 7/8 of his responses to treated structure 1 preposition sentences were reversals; a pattern that is highly unlikely to occur by chance. P14's data, however, showed less consistency in the error patterns. Although 9 responses correct at session 2 were reversed at session 3, the distribution of those responses, plus the nature of other changes (7 responses correct at session 2 changed to errors 3 or 4 at session 3; 5 reversals at session 2 corrected at session 3) gives little support to the theory of verb therapy interference in this case.

| | PREPOSITION TEST | | | | | | | | | | | |
|------|---------------------------|------|------|----------------------------|------|-----|---------------------------------------|-----|-----|--|-----|-----|
| | response = 1 (correct) | | | response = 2 (reversal) | | | response = 3 (error) ⁷³ | | | response = 4 (wrong prep) ⁷⁴ | | |
| | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 | s1 | s2 | s3 |
| P4 | 17 | 27 | 30 | 11 | 9 | 6 | 5 | 3 | 0 | 7 | 1 | 4 |
| P6 | 8 | 15 | 13 | 12 | 10 | 12 | 12 | 10 | 11 | 8 | 5 | 4 |
| P8 | 29 | 37 | 37 | 5 | 3 | 2 | 4 | 0 | 0 | 2 | 0 | 1 |
| P9 | 16 | 13 | 7 | 11 | 19 | 21 | 9 | 5 | 6 | 4 | 3 | 6 |
| P11 | 12 | 16 | 14 | 8 | 18 | 15 | 13 | 2 | 6 | 7 | 4 | 5 |
| P12 | 36 | 37 | 38 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 1 |
| P14 | 10 | 23 | 13 | 10 | 10 | 12 | 14 | 5 | 7 | 6 | 2 | 8 |
| mean | 18.3 | 24.0 | 21.7 | 8.3 | 10.0 | 9.9 | 8.4 | 3.7 | 4.3 | 5.0 | 2.3 | 4.1 |

Table 47. Group B's Preposition Test results, analysis of error patterns.

(treated and untreated items, n=40 per subject per session)

(s1, s2 and s3 denote session 1, session 2 and session 3)

A full list of target sentences and distractors is in Appendix 6.

The full data set sentence by sentence is given in Appendix 12 (Tables G and K).

⁷³ The implication of this response type varies with sentence structures. In two-noun sentences the picture chosen illustrated an incorrect prepositional relationship, in more complex sentence structures a reversal around either the first or second preposition is generally entailed.

⁷⁴ This error type almost invariably indicates that the picture chosen showed an incorrect prepositional relationship, in two-preposition sentences one of the locatives was incorrect.

However, it is also clear from Table 47 that both P9 and P14 made more errors of type 4 at session 3 than they had done at session 2, showing an insecurity with preposition *meanings*. For example, P9 made four of these errors on treated structure 2 sentences (e.g. *The star is behind the ball and the box => The star is between the ball and the box*). Reference to Appendix 6 indicates the degree of confusion associated with choosing distractor 4 in all of sentences 11..14.

P9 had not responded to preposition therapy between sessions 1 and 2 (at least not on preposition items!) so in his case we are not seeking an explanation for loss of benefit after withdrawal of treatment. It turns out that P14 was the only subject who had suffered a significant decline at session 3 after responding to therapy. Studying his graphs in Figures 21b and 22b (below), it is tempting to conjecture that the failure of treatment effects to endure was predicted by the lack of generalisation evident at session 2, both in the microworld and in the Real World Test. Thus, P14's response was item-specific and short-lived, general principles had not been absorbed.

As with the Verb Test results of Group B, the Preposition Test results appear to have been spoiled by two individuals (removing the scores of P9 and P14, the number of correct responses at sessions 2 and 3 was identical). There is a little evidence that Group B's treatment ordering was disadvantageous, but more that the group results suffered through the chance allocation to it of individuals P9, P11 and P14. There seems every prospect, on the basis of the other subjects' results, that replication studies using the same protocol would obtain classical cross-over patterns in the prepositions-first condition.

Group B's accuracy results on the Real World Test were presented in Table 39 (p. 166) and graphically in Figure 18 (p. 165). Individual performance graphs for members of Group B showing changes in accuracy to 'real world' verb and preposition sentences and to the control function morphology, are given in Figures 22a and 22b.

A comparison of Group B's baseline scores for 'real world' and microworld verbs and prepositions confirms the findings reported for Group A, i.e. that on the whole the 'real world' items were found easier than the corresponding microworld items at session 1, (Verb Test mean/2 = 9.21, Real World verbs mean = 13.43; Preposition Test mean/2 = 9.14, Real World prepositions mean = 10.71)

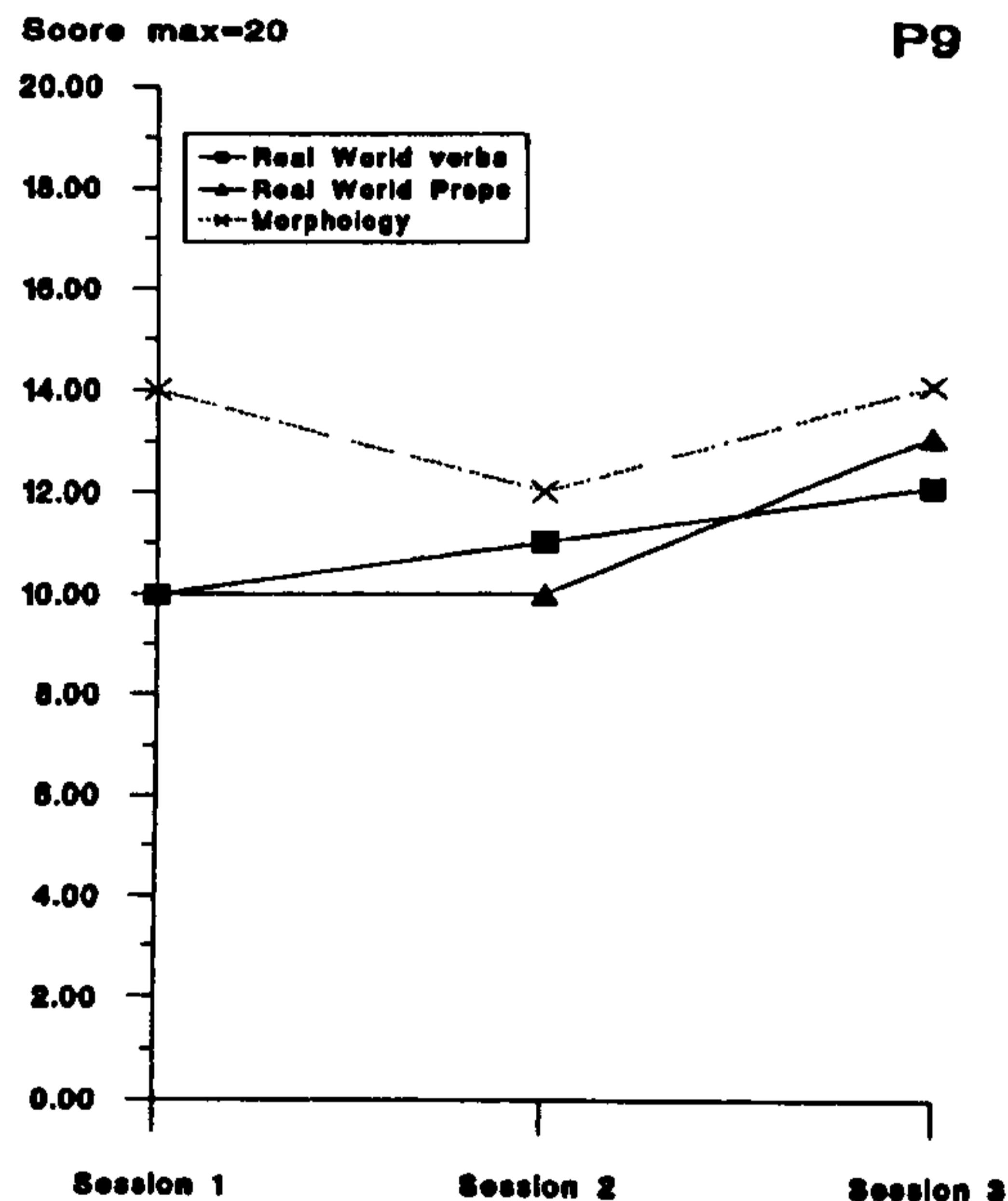
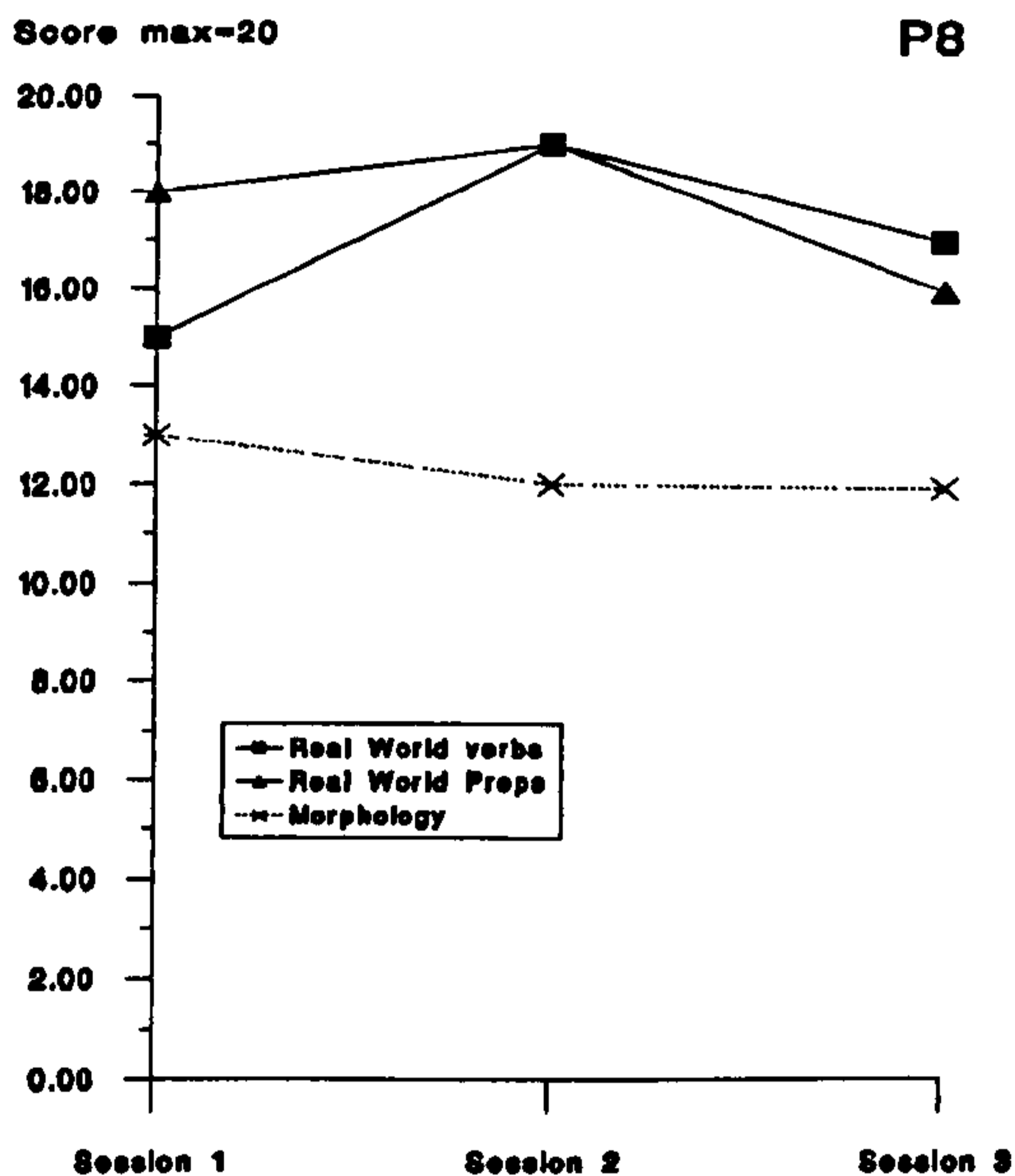
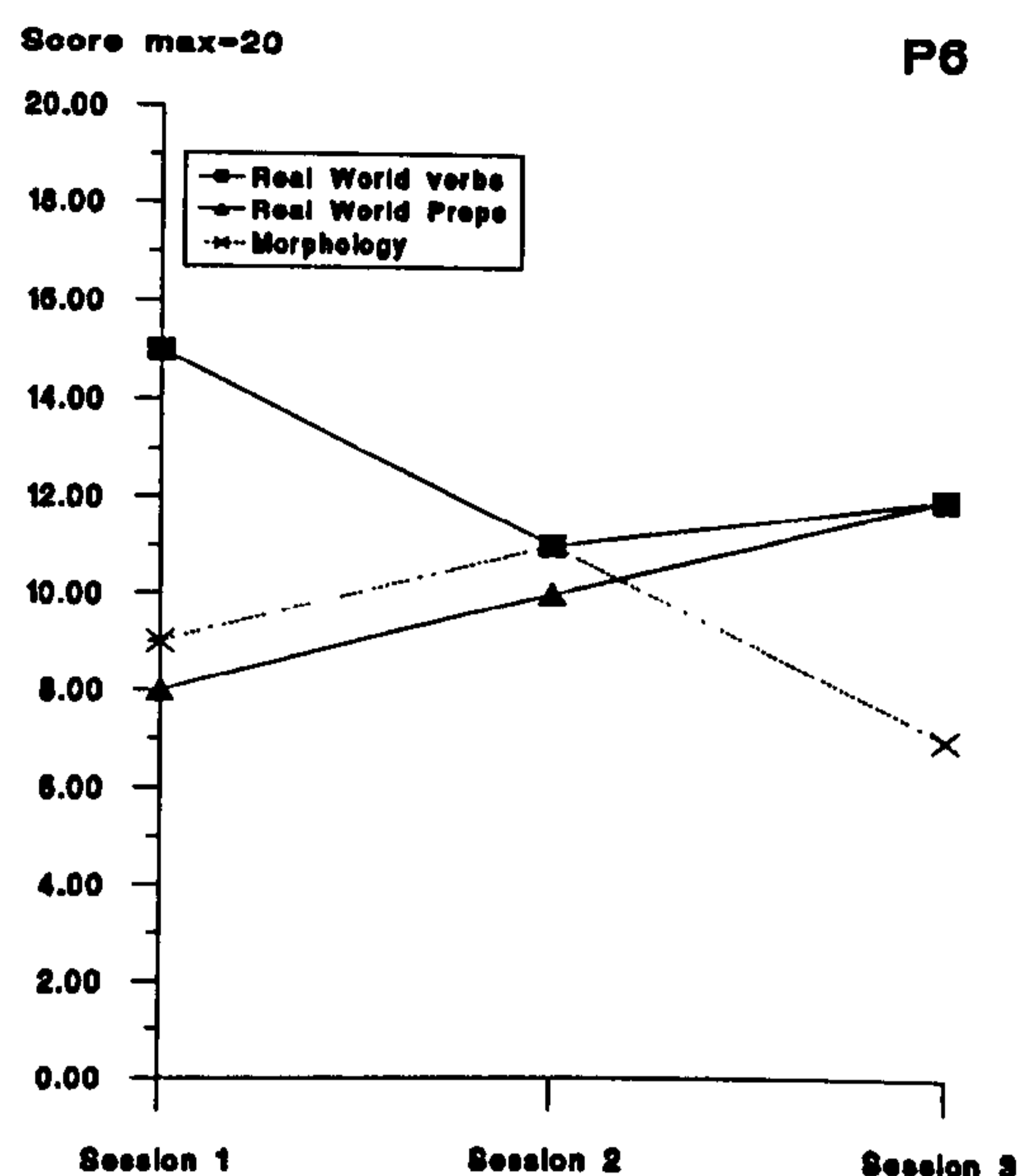
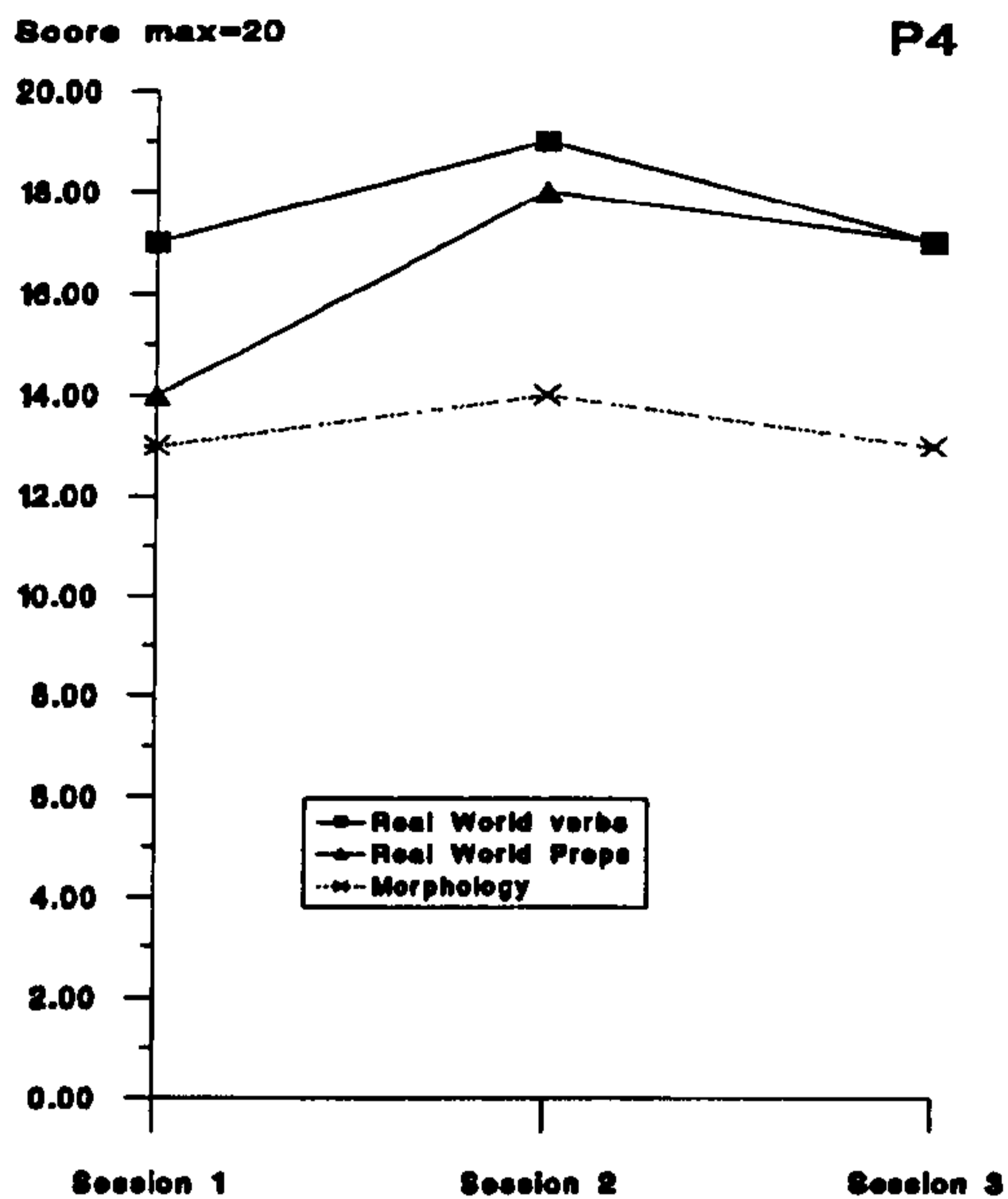


Figure 22a. Group B performance graphs for Real World Test (accuracy).
Prepositions were treated between sessions 1 and 2 and
verbs were treated between sessions 2 and 3.

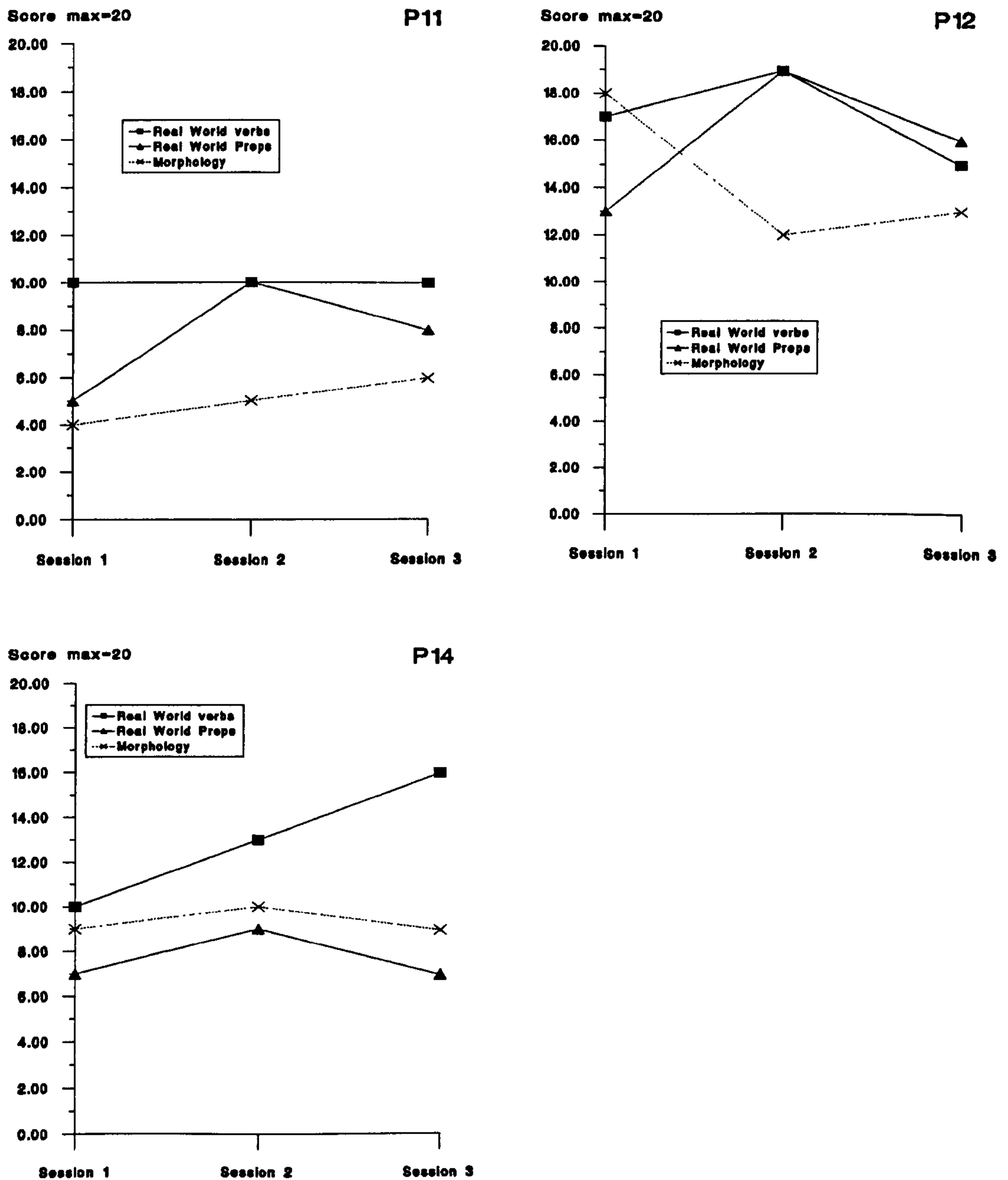


Figure 22b. Group B performance graphs for Real World Test (accuracy).
Prepositions were treated between sessions 1 and 2 and
verbs were treated between sessions 2 and 3.

The order of difference was the same for Group B's preposition results as for Group A's verbs and prepositions, but Group B's verb results showed a very much larger discrepancy. On investigation, it was found that five of the seven subjects exhibited a positive difference in favour of 'real world' items of 3.5 points or more

at the baseline test. However, the size of the overall skew was very largely attributable to P6, who scored 8/40 on the Verb Test and 15/20 on the verb items of the Real World Test (an extraordinary result for which the only explanation can be a compounding of the general trend found in other patients, with undue serendipity in this particular Real World Test. Indeed, P6 never attained this level again after therapy, as his graph in Figure 22a shows). Apart from P6, a comparison of Figures 21a, 21b, 22a and 22b shows that only one patient in Group B was strikingly more accurate on Real World Test items than on corresponding microworld items in both verbs and prepositions, this was P4 (25/40 Verb Test, 17/20 Real World verbs; 17/40 Preposition Test, 14/20 Real World prepositions).

The ANOVA reported in section 4.1.2 showed a significant main effect of treatment on 'real world' items (collapsed across verbs and prepositions) between sessions 1 and 2 after preposition therapy, but not between sessions 2 and 3 after verb therapy. The graphs in Figures 22a and 22b were helpful in exploding the individual contributions to that result. None of the subjects responded with the hoped for cross-over profile. However, the potential for satisfactory verb results was spoiled for this group by the high baseline verb scores, which in many cases improved further after preposition therapy. Three subjects, P4, P8 and P12 had already attained 19/20 on 'real world' verb items prior to verb therapy, this 'ceiling effect' made small losses on re-testing quite likely.

There were two additional dimensions of performance to consider in order to attain a fuller appreciation of the efficacy results. The first of these was an analysis by sentence structure (see section 5.2) since the pre-therapy test results reported in section 3.4.1 suggested that the different sentence structures would probably not be uniformly responsive to treatment. I also wanted to look more closely at items within the untreated sides of the Verb Test and Preposition Test to determine whether any noteworthy patterns had emerged in generalisation to untreated items and structures. Secondly, to complete the analysis of treatment results it was necessary to scrutinise the timing data to find out what had happened to patients' processing speeds as a result of therapy. The crucial question was whether increased accuracy had been accompanied by decreased speed, or whether gains in accuracy had been achieved at the expense of even slower response rates. Timing data is presented in section 5.3.

5.2 ANALYSIS OF PERFORMANCE BY SENTENCE STRUCTURE

There were two main reasons for examining the performance data by sentence structure. The first was that the assessment tests comprised small blocks of homogeneous sentence structures and it was of interest to see how these had responded to treatment. The second reason was that the ANOVA reported in Chapter 4 had shown different outcomes for Groups A and B and it was possible that an investigation at the sentence structure level would reveal more about how the two groups had responded to therapy. As explained in section 3.4.1, because the number of observations for each sentence type, for each subject, was so small, it was not feasible to submit the structure-level data to formal statistical analysis. This has not been a major hinderance as many of the response patterns worthy of mention are quite obviously significant in the clinical sense and the ANOVA on the accuracy data has shown that the grouped results are also significant in the statistical sense. However, the inability to test significance has inevitably led to a very cautious approach in the interpretation of smaller changes. (In section 6.3 the problems of test composition and size in the assessment of complex cognitive tasks is discussed further in the context of recommendations for future work).

In section 3.4.1 Tables 30 and 34 (p. 150 and p. 154) summarised the pre-therapy performances of both groups of aphasic subjects on the treated items of the Preposition Test and Verb Test, giving the results in terms of percentage accuracy for each to-be-treated structure. Similar calculations were done on the responses obtained after the first and second treatment blocks, and these, together with the baseline measures, form the basis for the report below. The Verb Test is considered first and a breakdown is presented of the performances of Groups A and B on treated items, followed by an analysis of the untreated side of the Verb Test for both groups. Data for the Preposition Test follows in similar format.

VERB TEST. Figure 23 is a histogram showing the session 1, 2 and 3 Verb Test results for Group A by sentence structure. This group received verb therapy first. The corresponding results for Group B are shown in Figure 24. Throughout this section, to aid interpretation of the histograms, the pre-therapy bars have a horizontal fill-pattern, the bars representing scores obtained directly after therapy for the function in question are cross-hatched and the bars representing treatment of the other function are filled with diagonals. Thus, for example, in Figure 23, as verb therapy was administered first to Group A and is the subject of

the histogram, the middle bar in each set is cross-hatched, whereas because Group B received verb therapy second, the final bar in each set is cross-hatched in Figure 24.

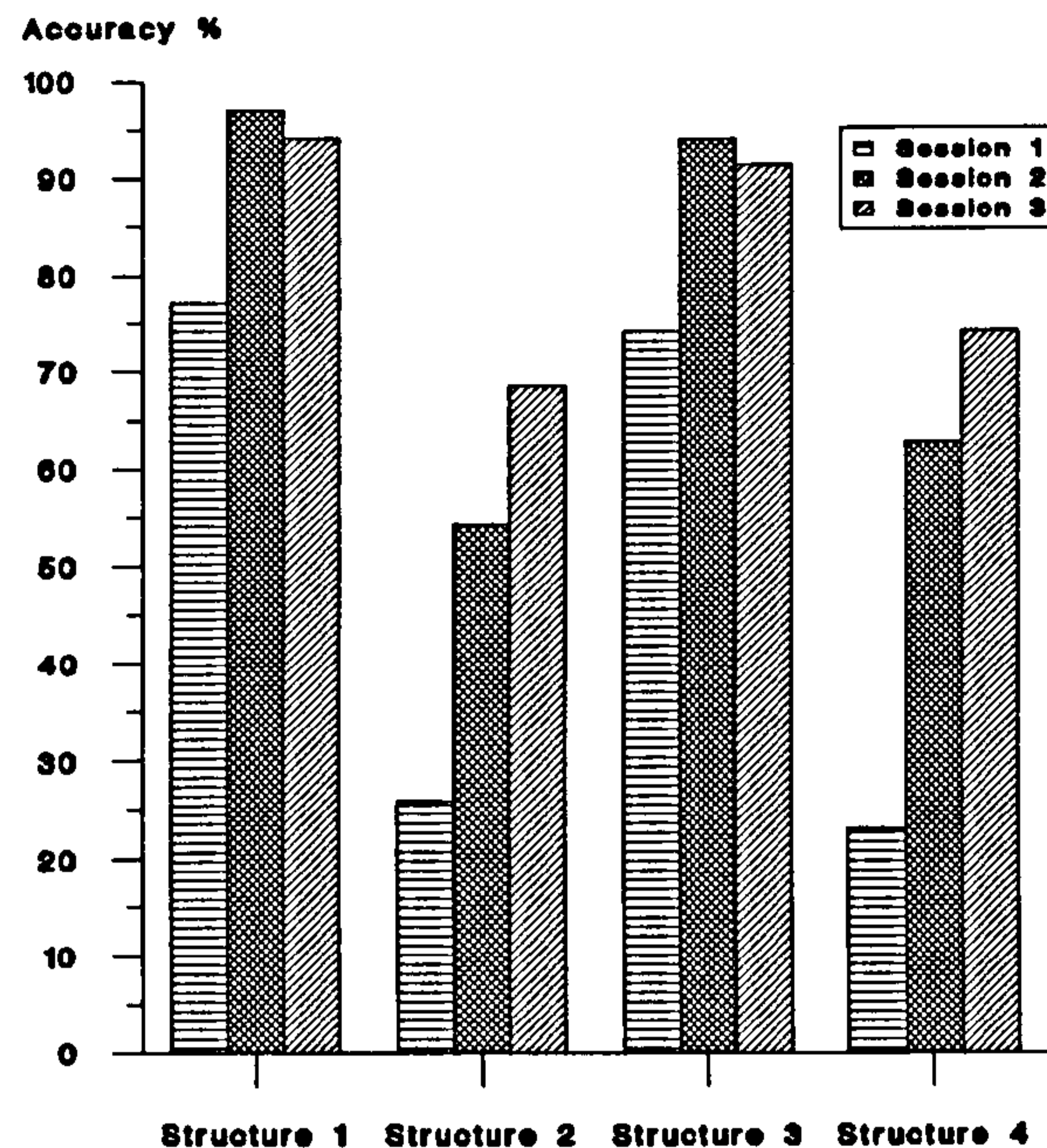


Figure 23. Treatment effects by sentence structure Group A Verb Test.
(treated items, $n=35$ per session for each structure).

Figure 23 shows that **Group A** responded to all four treated structures. (The composition of the Verb Test was given in Table 19, p. 111). After verb therapy performance on structures 1 and 3 had increased from 77.14% and 74.29% accuracy respectively, to 97.14% and 94.29% respectively and the benefits of therapy were maintained through to session 3.⁷⁵ Performance on structures 2 and 4 which had been very weak at the outset (25.71% and 22.86% respectively) improved to 54.29% and 62.86% respectively following verb therapy and on repeat testing after preposition therapy were found to have increased further to 68.57% and 74.29% respectively.⁷⁶ The magnitude of these total gains on the two

⁷⁵ Statements of this sort are, in the absence of statistical support, personal judgements as to the clinical implications of change.

⁷⁶ The baseline performance on passives (structure 2) 25.71% accuracy, was much worse than chance (50% if the subject is choosing between the target and reverse pictures, as Group A clearly were - 24 of the 26 errors made were reversals, i.e. passives interpreted as actives). This result supports my contention in section 6.1.2 that the passive construction was not recognised by these subjects. Group B made 65.21% reversal errors showing that in this group there were additional weaknesses that led to lexical errors being made. The combined accuracy of P1..P14 on to-be-

harder structures was remarkable (42.86% in structure 2 (passives) and 51.43% in structure 4 (two-verb sentences)).

Group B's Verb Test results yielded a rather different picture. While there was an upward change in accuracy between sessions 1 and 3 in all four structures, the amount of improvement made was in all cases except structure 1, less than had occurred in Group A. This point is illustrated by comparing Figures 23 and 24 with respect to the width of the band obtained by drawing conceptual parallel lines across the histogram at the height of the lowest session 1 bar and the lowest session 3 bar. Group A's minima were, session 1: 23%, session 3: 69%, whereas Group B's minima were session 1: 29%, but session 3 only 49%. This difference of 20% in the minimum accuracy level at session 3 is indicative of a much poorer response to treatment on the part of Group B.

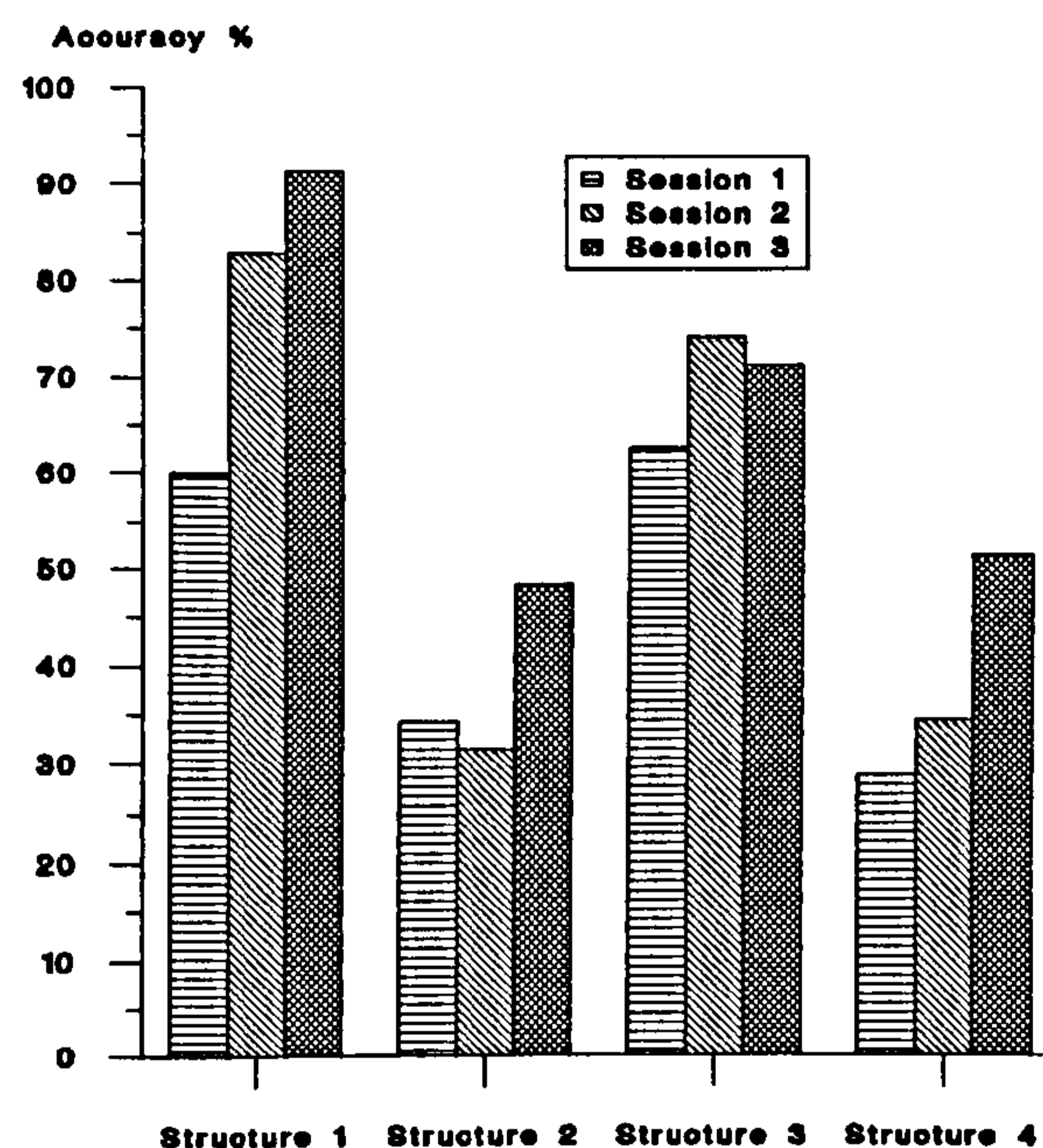


Figure 24. Treatment effects by sentence structure Group B Verb Test.
(treated items)
n=35 per session for each structure.

Perhaps the most striking aspect of the two sets of results was that Group B's structures 2 and 4 (which, if anything, had been a little more accurate than the

treated passives (30%) was far lower than the worst individual performances recorded by Sherman and Schweikert (1989) (50% obtained on non-reversible improbable passives). The present study offers little support for the claim of preserved syntactic ability for this construction.

same structures in Group A pre-therapy) responded much less to treatment, finishing with percentages 20% and nearly 23% lower than Group A had achieved. The hypothesis that the word order significance reinforcement common to both therapies was responsible for the effect of preposition therapy on Group B's verb structures 1 and 3 goes some way towards explaining the gains made on those items between sessions 1 and 2, however there are a few responses in Table I (Appendix 12) which cannot be accounted for in that way. The most obvious of these are P9's three lexical errors (type 4) in structure 1 (*paints => holds* (2) and *holds => paints*). One cannot plausibly ascribe resolution of these errors to preposition therapy.

The performances of the two aphasic groups on *untreated* verb sentences is considered next, starting with Group A. The ANOVA presented in section 4.1.1 showed that some generalisation to untreated items had taken place. However, it will be recalled from Table 19 (p. 111) that the untreated side of the Verb Test was composed of both treated and untreated sentence structures and within each of these, sentences incorporating treated and untreated verbs. A complete list of responses by Group A to the untreated Verb Test items appears in Table L (Appendix 12). An analysis was carried out to discover how therapy affected the treated and untreated sentence structures and to determine how the untreated verbs (*draws, puts, thinks*) had fared compared with the treated ones (*gives, paints, holds*). Figure 25 is a histogram showing the changes in *untreated items* by sentence structure over the three test sessions. Treated and untreated-verb items were collapsed for this analysis and the three untreated structures (which if taken separately would only have yielded 14 observations per session) were amalgamated.⁷⁷

From Figure 25 it is clear that generalisation occurred to some degree across all the sentence structures and that progress was maintained or continued in every case during the period when preposition therapy was administered. However, the histogram shows that least generalisation occurred on the untreated structures (structures 5..7) (i.e. those where the sentence forms had not been seen in therapy).

A comparison of Figures 23 and 25 reveals that at session 3 the untreated items in structures 1 and 3 had attained the level of the treated items, from similar

⁷⁷ Thus there were 28 observations per session for structures 1 and 4, 21 observations per session for structures 2 and 3, and 42 observations per session for structures 5-7.

baseline scores. However, untreated items in structure 2 (passives) and structure 4 (two-verb sentences) improved less than their treated counterparts, despite, oddly, being about 12% and 20% respectively more accurate at session 1. Thus, less generalisation occurred in the structures which all the patients found hardest. Overall these results are very encouraging, indicating that the capacity for the transfer of learning, particularly to untreated instances of treated structures, was found to be present in this group of long-term aphasic subjects.

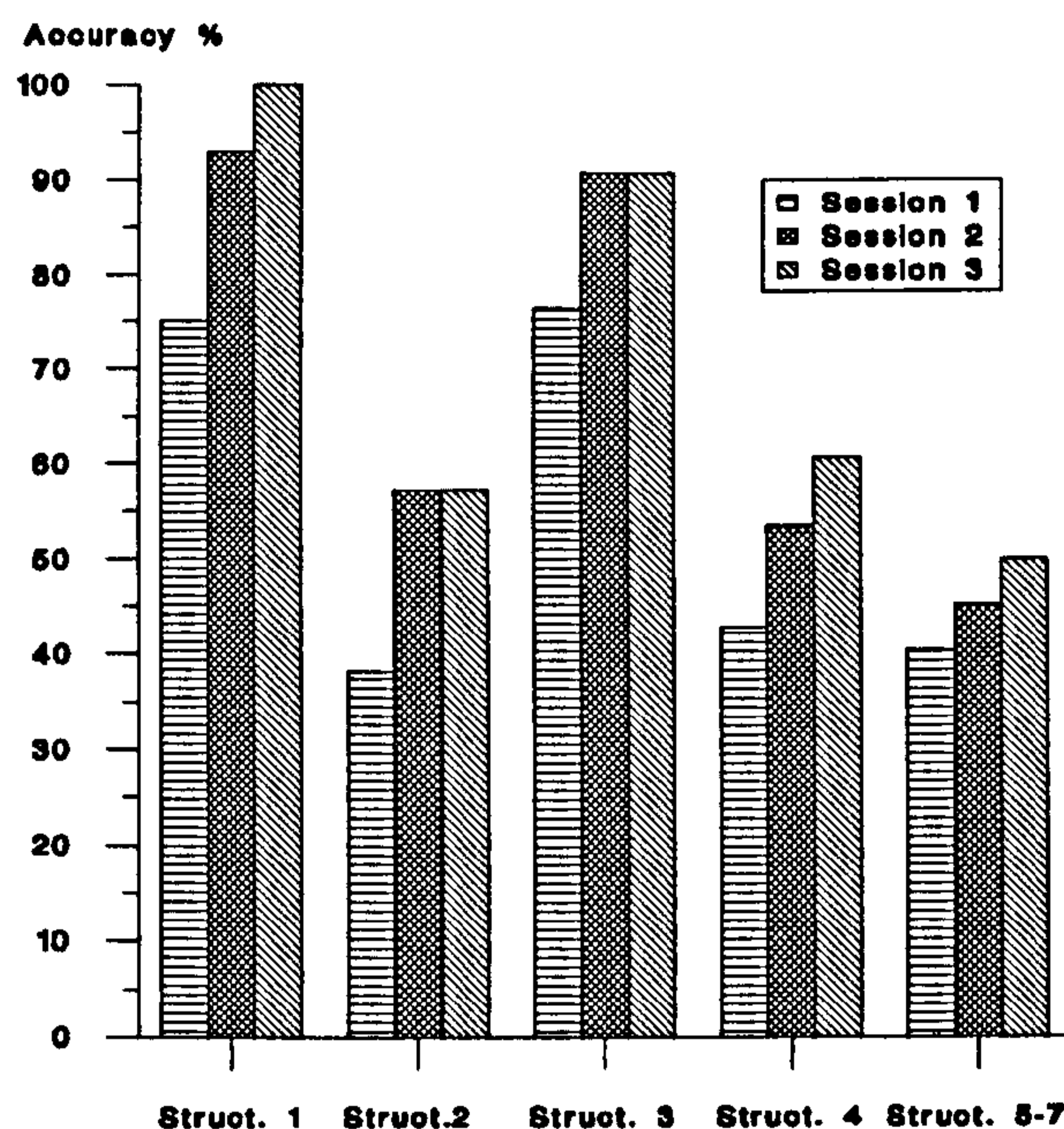


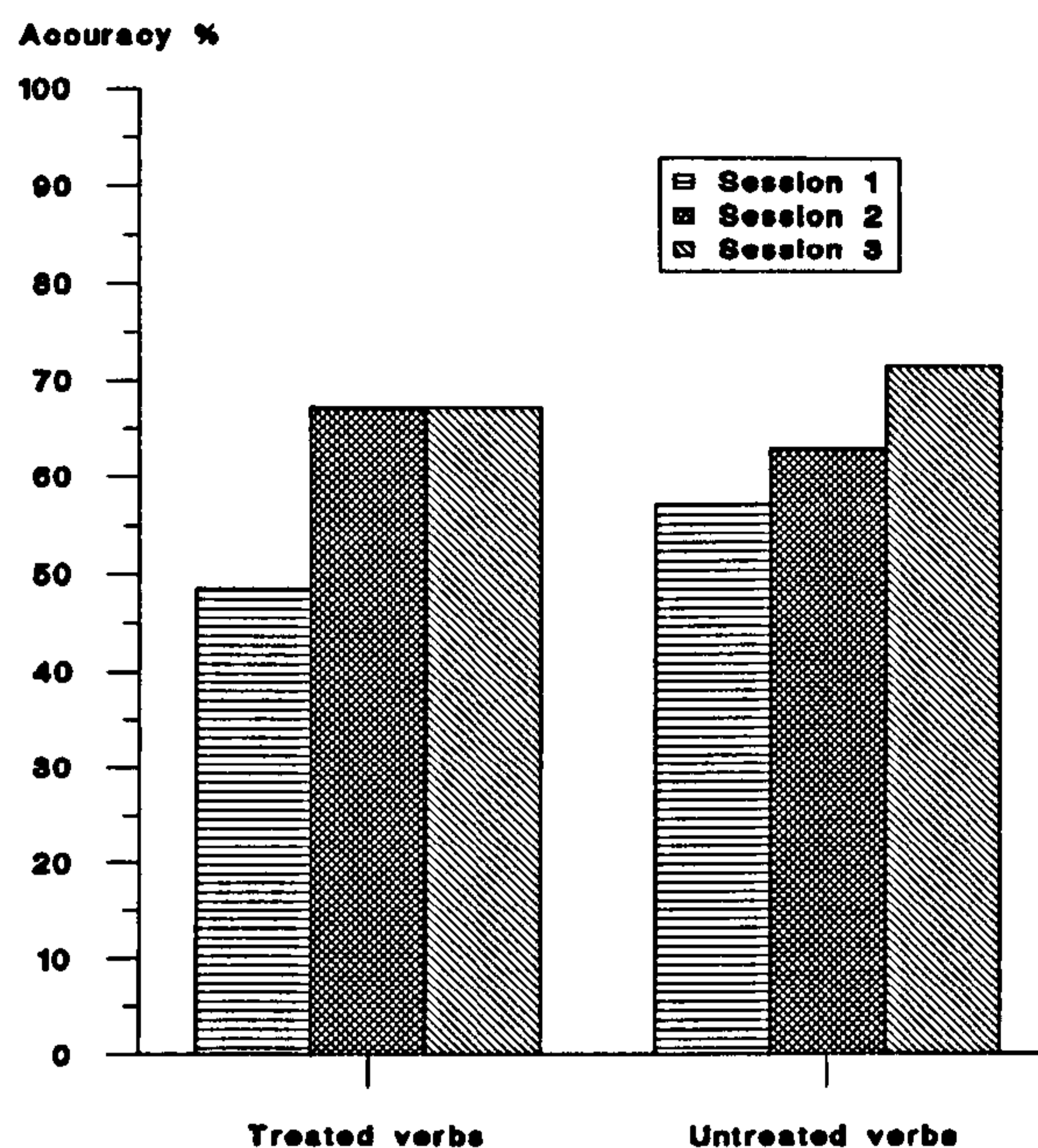
Figure 25. Untreated items by sentence structure Group A Verb Test.

n=28 per session structures 1 and 4

n=21 per session structures 2 and 3

n=42 per session structures 5-7

Further to this point, it was of interest to know whether in the untreated side of the Verb Test, there had been any difference between the untreated and the treated-verb sentences in terms of the progress made. To determine this, an analysis of accuracy for treated and untreated-verb items was carried out, disregarding sentence structures. As the untreated side of the Verb Test comprised 10 treated-verb and 10 untreated-verb sentences (see Table 19, p. 111 and Table L, Appendix 12), and there were 7 patients in the group, there were 70 observations per session to consider for each of the two categories. The results of this analysis are shown in Figure 26.



**Figure 26. Treated and untreated-verb sentences Group A
(untreated items)
n=70 treated-verb items and 70 untreated-verb items**

Figure 26 shows that Group A performed better on untreated items containing untreated verbs than on those containing to-be-treated verbs at session 1 (pre-therapy). However, the effect of therapy was much more marked on the treated-verb sentences at session 2. A 'sleeper effect' was evident on the untreated side, indicating perhaps that the untreated verbs benefited from a further assimilation period.

The *untreated* side of the Verb Test was analysed for Group B patients as for Group A. A full list of Group B's responses to the untreated side of the Verb Test appears in Table M (Appendix 12). Figure 17 (p. 165) showed that Group B achieved some generalisation to untreated verb items and it was of interest to discover whether this pattern was common across sentences structures or was perhaps more selective. As for Group A, treated and untreated-verb sentences were amalgamated for this comparison and responses to structures 5, 6 and 7 were collapsed. The results of this analysis are shown in Figure 27, where again the three bars in each set represent results at sessions 1, 2 and 3 respectively and the results obtained directly after verb therapy are cross-hatched.

Figure 27 shows that there were considerable differences in the extent to which the different untreated instances of the treated sentence structures (structures

1..4) responded to therapy. Structure 2 (passives) remained unchanged throughout at 47.62%; Group B were better on untreated than on treated passives at session 1 (c.f. Figure 24) and this score is very close to their session 3 result on treated passives (48.57%). Of the other structures, all improved to some degree, structure 3 showing the greatest improvement (a gain of 38%), most of which was made following preposition therapy. Likewise, performance on structure 4 increased more after preposition therapy than after verb therapy and performance on structure 1 showed improvements equally stepped between sessions 1 and 2 and sessions 2 and 3. There was also some generalisation to untreated structures (structures 5..7) although all of this took place before verb therapy.

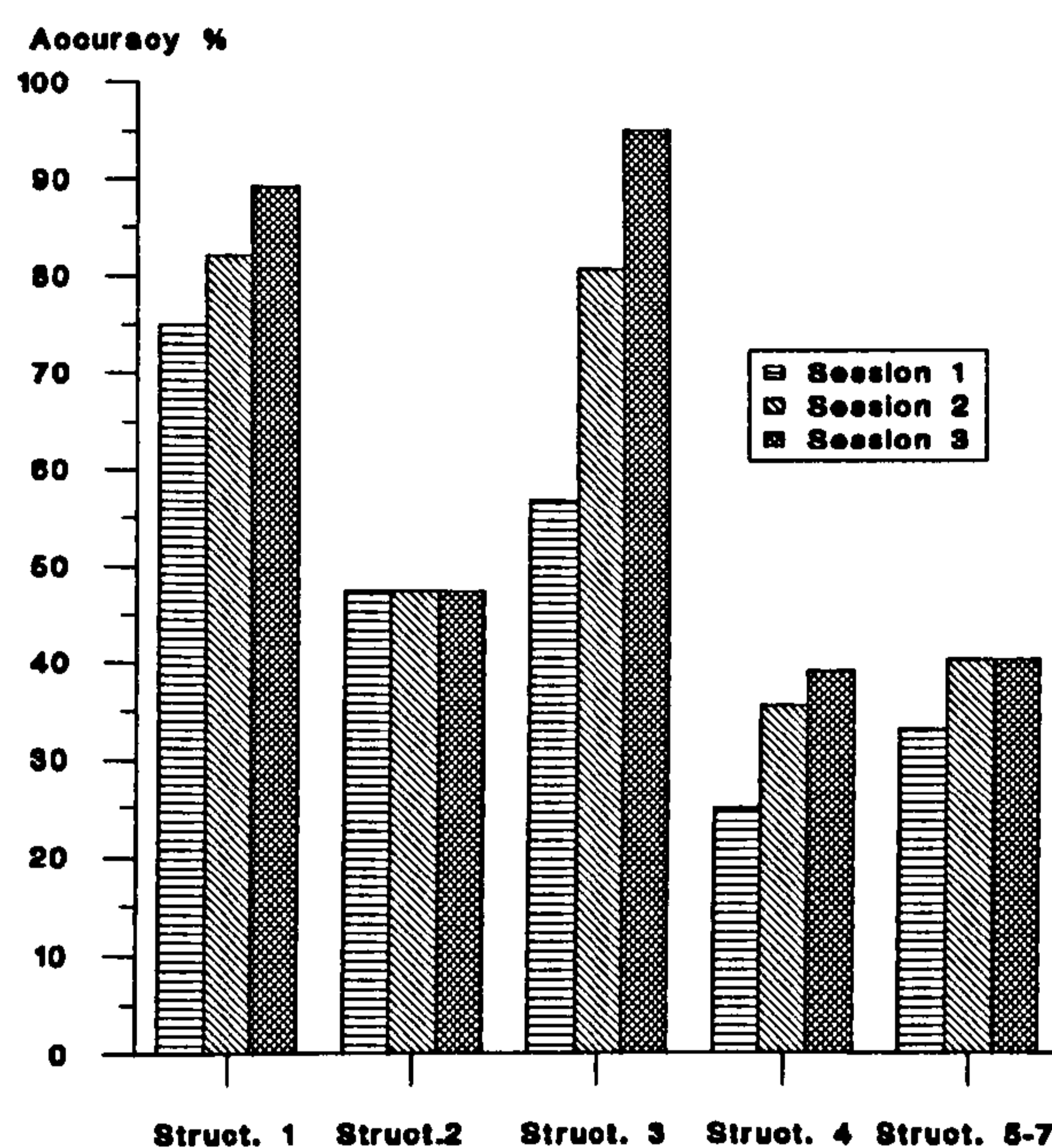


Figure 27. Untreated Items by sentence structure Group B Verb Test.

n=28 per session structures 1 and 4

n=21 per session structures 2 and 3

n=42 per session structures 5-7

It was a disappointment that there was no effect on structures 2 and 5..7 and very little on structure 4 between sessions 2 and 3 when verb therapy was administered. Also, given the high pre-therapy accuracy on structure 1 sentences a larger improvement there might have been hoped for. Again, the weaker

performance of Group B is evident in that three structures on the untreated side of the Verb Test failed to reach 50% accuracy at session 3, whereas in Group A, even the untreated structures (5..7) managed to attain the 50% level.

As for Group A, Group B's responses to the untreated side of the Verb Test were examined to discover how successful therapy had been in improving performance on sentences incorporating untreated verbs. As before, this analysis was collapsed across sentence structures, yielding 70 observations per session each for treated and untreated-verb sentences. The results are shown in Figure 28.

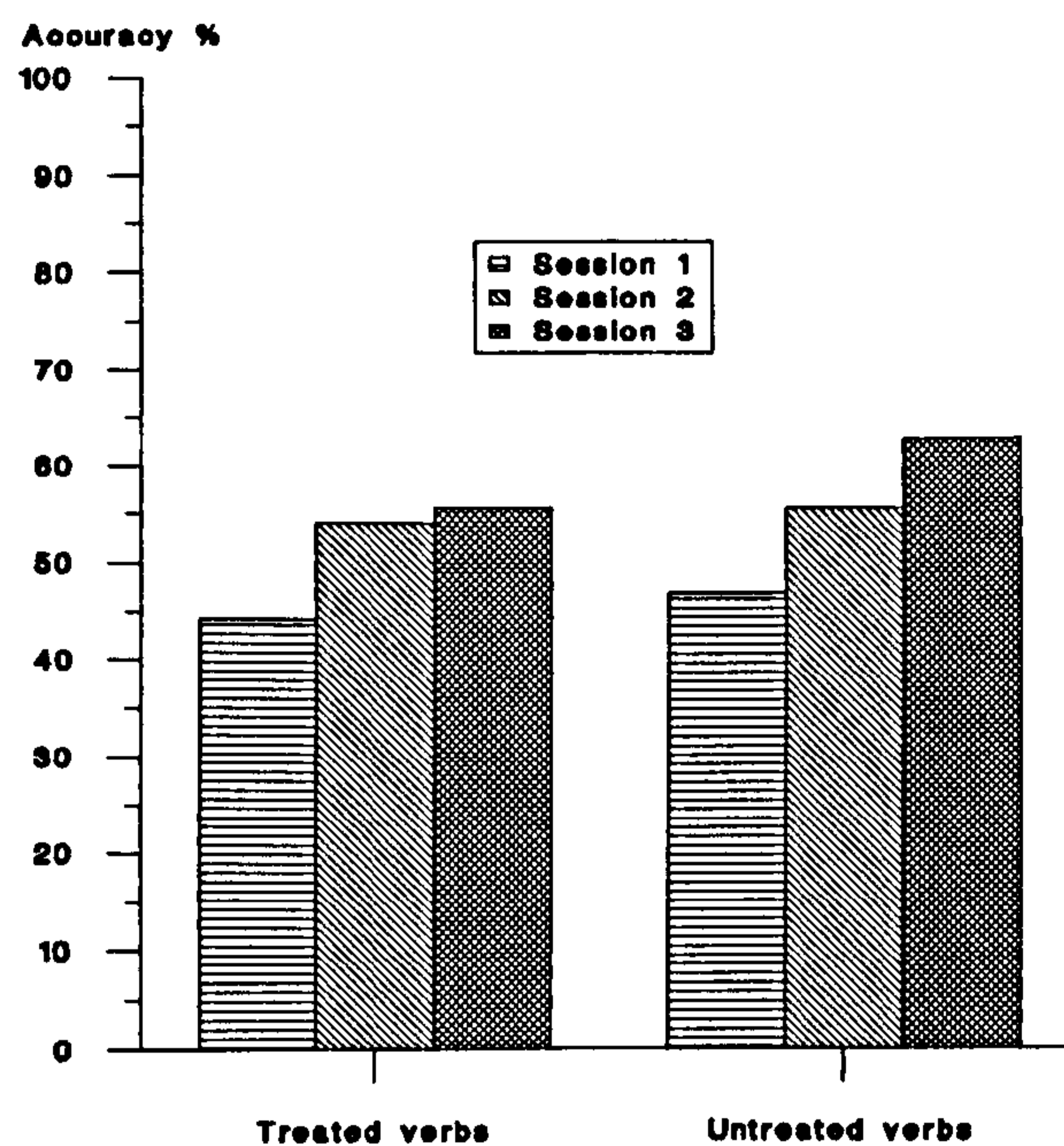


Figure 28. Treated and untreated-verb sentences Group B (untreated items)

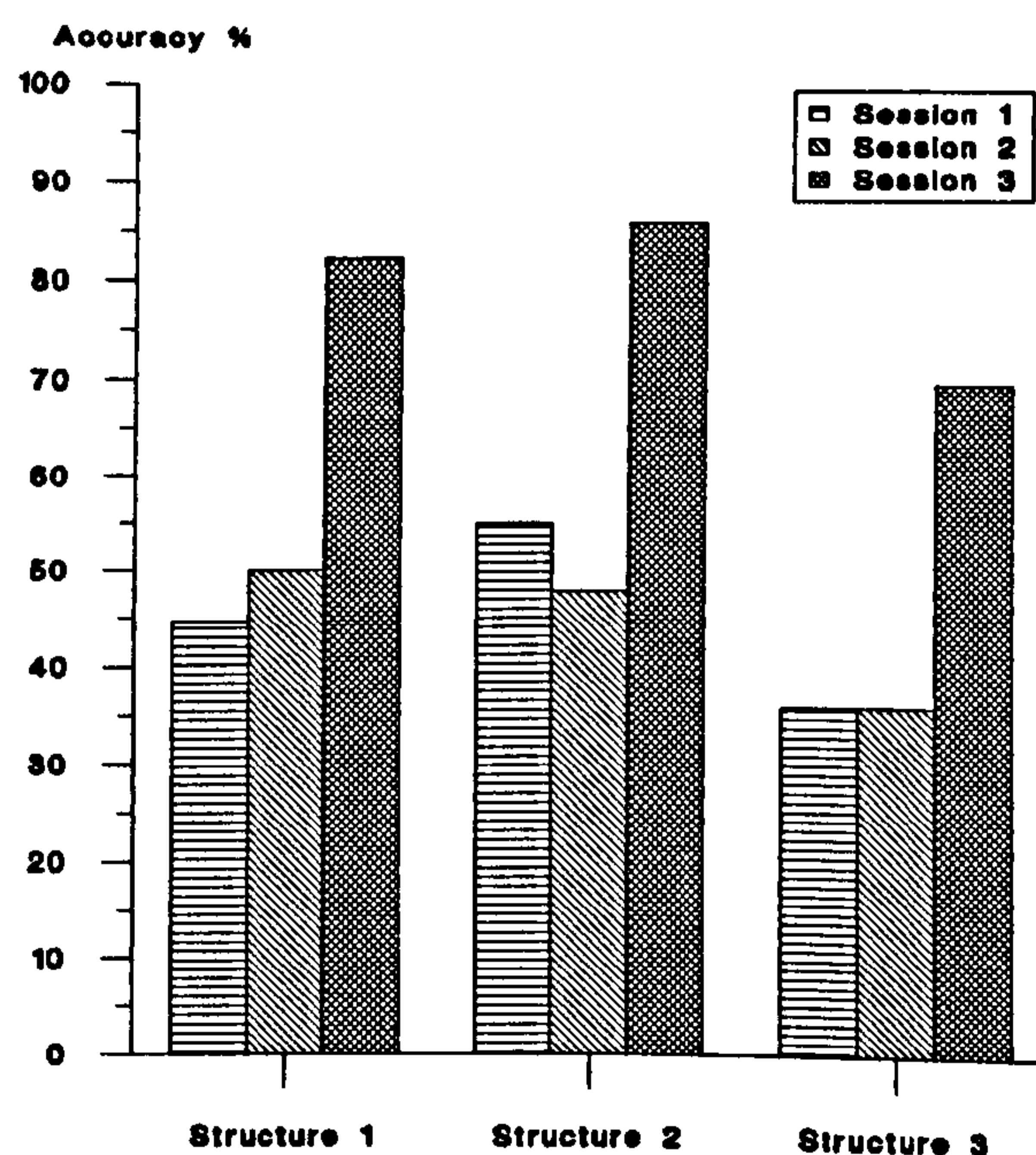
n=70 treated-verb items and 70 untreated-verb items

Figure 28 is interesting in that, although Group B's results are depressed compared with Group A's (c.f. Figure 26) and the greater part of their improvement was made before commencement of verb therapy, Group B improved more on untreated sentences containing untreated verbs than on those containing treated verbs. This indicates that although these patients seem to have been weaker overall than the subjects in Group A, they nevertheless exhibited a capacity to generalise their learning within the grammatical category treated. So although Group B's overall verb processing results were weaker after therapy

than might have been hoped (especially on the untreated side), still the analysis presented gives cause for optimism regarding the possibility of achieving some improvement in the performance of severely disordered individuals on what are, for aphasic subjects, very complex cognitive tasks.

PREPOSITION TEST. The second part of this section subjects the Preposition Test results to similar scrutiny. (The composition of the Preposition Test was given in Table 20, p. 114). Figure 15 (p. 160) showed considerable success in treating this function with **Group A** and it was therefore of interest to find out how the improvement had been distributed across the treated sentence structures and the extent of generalisation to untreated structures and to sentences containing untreated prepositions. An analysis of the treated side of the Preposition Test pre-therapy (see Table 30, p. 150) had shown that overall, Group A was more accurate in structure 2 than in structure 1 and as was expected, found structure 3 the hardest. Below I examine what happened to these performances after verb therapy (which was administered first) and again after preposition therapy.

Figure 29 shows the mean accuracy for each of the treated preposition structures obtained at sessions 1, 2 and 3.



**Figure 29. Treatment effects by sentence structure Group A
Preposition Test. (treated items)**
n=56 per session structure 1
n=42 per session structures 2 and 3

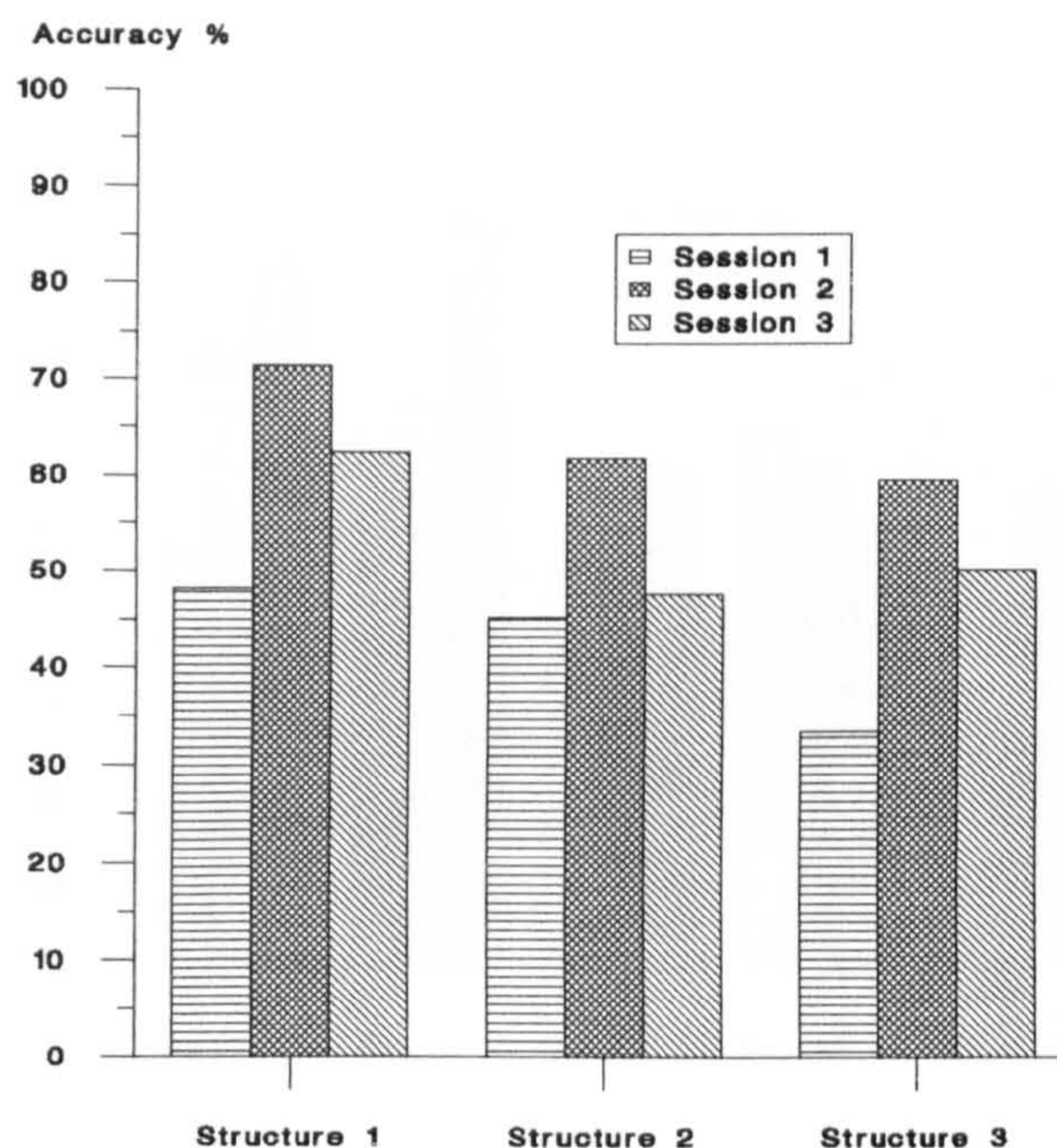
The histogram fill-patterns are maintained, viz. that horizontal lines denote pre-therapy status, cross-hatching is used for results obtained after therapy for the treated function (prepositions for the remainder of this section) and diagonal lines indicate that the results were obtained after therapy for the other function (hereafter verbs).

Figure 29 confirms that there was very little change in preposition performance as a result of treating verbs (slight gains in structure 1 were offset by small losses in structure 2 and structure 3 (the two-preposition sentences) was static). The histogram shows that positive effects of preposition therapy were evident in all treated structures, with structure 3 items responding as readily as those in structure 1. The magnitude of the gains between sessions 2 and 3 were 32.14%, 38.09% and 33.34% for structures 1..3 respectively. From a comparison of Figures 23 and 29, it can be seen that although Group A presented initially with very much poorer scores in (to-be-treated) Preposition items than in (to-be-treated) verb items (particularly preposition structures 1 and 2 compared with verb structures 1 and 3), preposition therapy was successful in substantially reducing the differential.

Turning to **Group B**, we have already observed from the group graph (Figure 17, p. 165) and the subsequent analysis of individual performances, that Group B lost much of the improvement made to treated preposition items after withdrawal of therapy. It was therefore of concern to determine how the three treated sentence structures had responded across the three test sessions. Group B's results for the treated side of the Preposition Test are shown in Figure 30.

Figure 30 shows that all three treated sentence structures did respond to preposition therapy, structures 1..3 gaining 23.22%, 16.66% and 26.19% respectively. So while Group B did not respond as much to therapy as Group A (despite very similar pre-preposition-therapy performances) the progress made was evident across all treated items, with the greatest gains being to the more complex items. However, on re-testing following verb therapy, Figure 30 shows that Group B declined in all treated structures (-8.93%, -14.28% and -9.52% on structures 1, 2 and 3 respectively). These decreases left structure 2 at baseline level, while structures 1 and 3 can be seen to have finished stronger than they started (gains between sessions 1 and 3 of 14.29% and 16.67% respectively). The pattern is suggestive of some aspect of verb therapy having had a general, detrimental effect. The overall failure to improve performance on structure 2

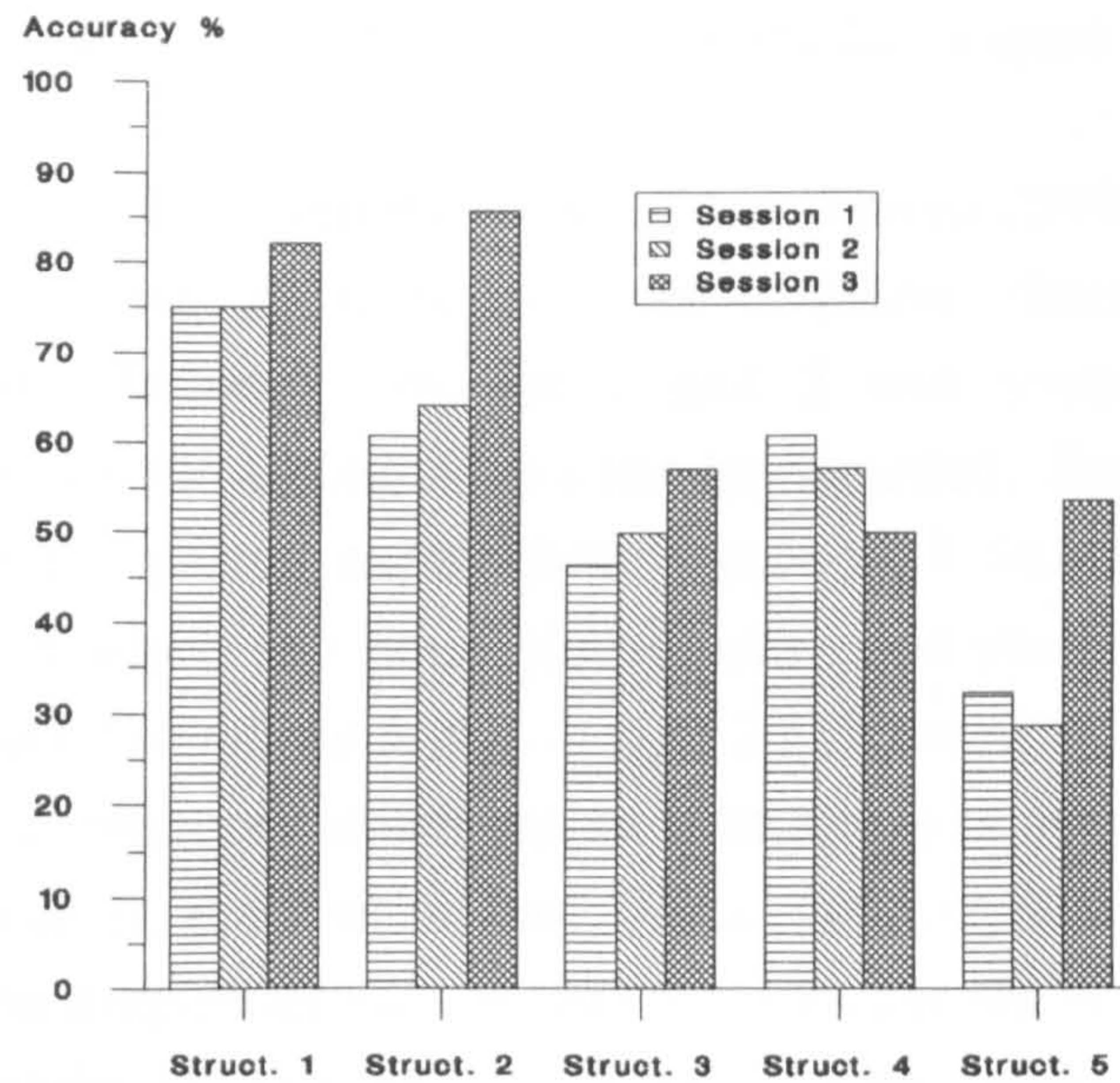
sentences (*The A is <prep> the B and the C*) was particularly disappointing, especially in view of the progress made by Group A on these items.



**Figure 30. Treatment effects by sentence structure Group B
Preposition Test (treated items).**
n=56 per session structure 1
n=42 per session structures 2 and 3

The performances of the two aphasic groups on *untreated* preposition sentences is considered next, starting with **Group A**. The results presented in Figure 15 (p. 160) showed that generalisation to untreated items had taken place. However, it will be recalled from Table 20 (p. 114) that the untreated side of the Preposition Test was composed of both treated and untreated sentence structures and within each of these, sentences incorporating treated and untreated prepositions. A complete list of responses by Group A to the untreated Preposition Test items appears in Table J (Appendix 12). An analysis was carried out to discover how therapy affected the treated and untreated sentence structures and to determine how the untreated prepositions (*above, between, beside*) had responded compared with the treated ones (*in, under, behind*). Figure 31 is a histogram showing the changes in untreated items by sentence structure over the three test sessions. Treated and untreated-preposition items were collapsed for this analysis, however, it was unnecessary to amalgamate the untreated structures as was done

for the Verb Test. There were thus three treated structures (structures 1, 2 and 3) and two untreated structures (structures 4 and 5) each yielding 28 observations per session.



**Figure 31. Untreated items by sentence structure Group A
Preposition Test.**
n=28 per session all structures

It was observed in section 4.1.1 that Group A's performance on untreated prepositions was better than on to-be-treated prepositions at session 1. Comparison of structures 1..3 in Figures 29 and 31 shows that this was true of all three structures, but that whereas the differences in structures 2 and 3 were small (5.95% and 10.72% respectively), untreated items in structure 1 were 30.36% more accurate than corresponding items on the to-be-treated side. It seems likely that part of the reason for the large discrepancy was the presence on the untreated side of the Preposition Test, of prepositions (*above, beside, between*) which tended not to subordinate the first noun phrase as the treated prepositions (*in, under, behind*) did, and which therefore did not elicit as many reversal errors. (This phenomenon is discussed further in section 6.1.2). However the gap was larger than could be accounted for by this reason alone. A further possibility was that *beside* and *between* caused less confusion because they are not members of common antonym pairs such as *under/above* and *behind/in front of*.

Figure 31 shows that there was little, if any, effect of verb therapy on the untreated Preposition Test items. Preposition therapy can be seen to have been

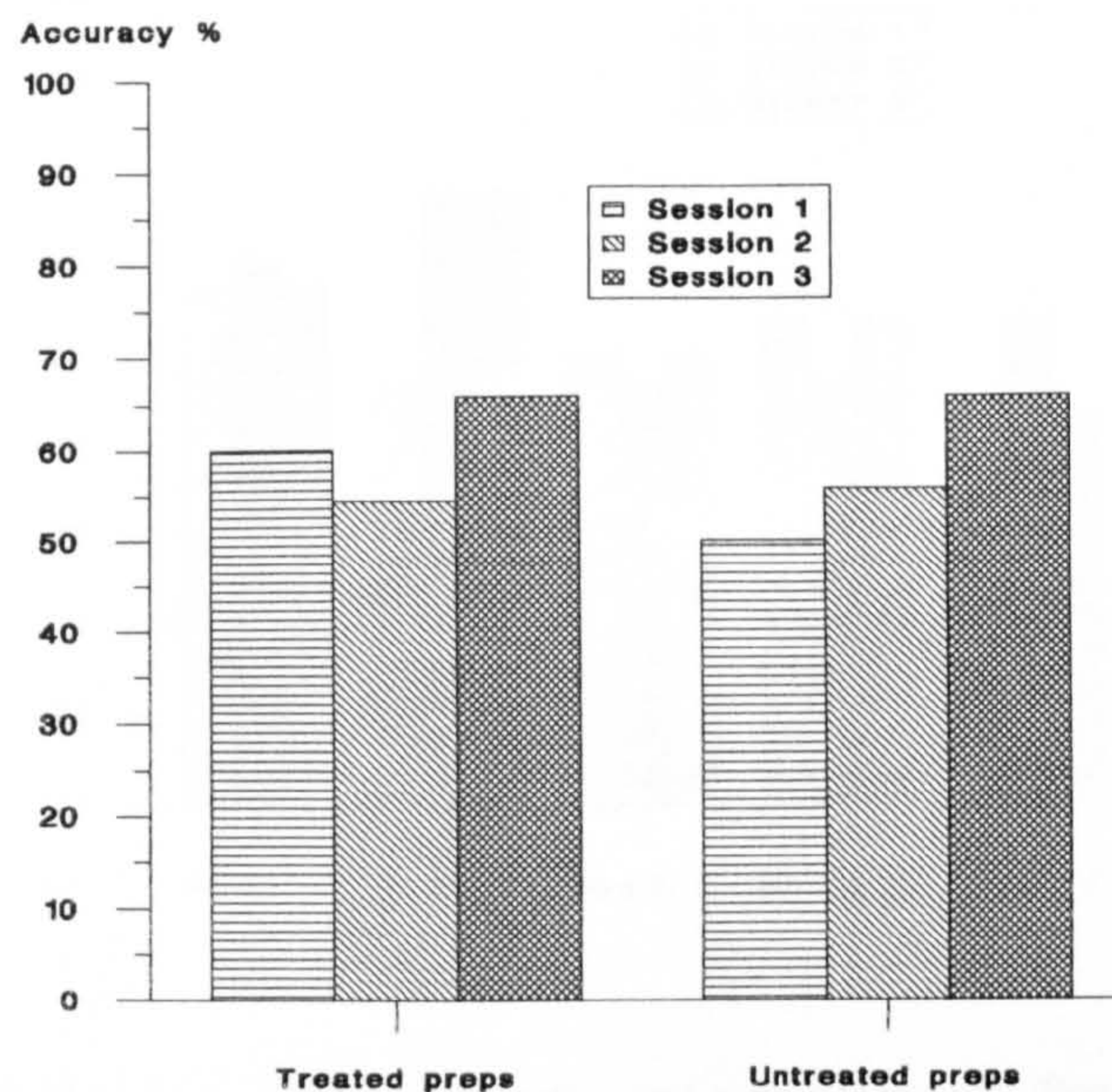
successful in improving performance between sessions 2 and 3 on four out of five structures, with the increases to structures 2 and 5 being much larger than those to structures 1 and 4. Despite Group A's very strong pre-therapy performance in untreated structure 1 sentences, after therapy performance on treated and untreated items in structures 1 and 2 was identical (c.f. Figure 29).

The improvement made in (untreated) structure 5 items (25% between sessions 2 and 3) was very pleasing, however, the negative changes to structure 4 performances both between sessions 1 and 2 *and* sessions 2 and 3 were disappointing and unique among all the results recorded. Inspection of Table 20 (p. 114) suggested a partial explanation: structure 4 was the only one in the Preposition Test in which two noun phrases preceded the preposition (e.g. *The ball and the star are behind the box.*). Figure 31 shows that Group A responded well to structure 2 sentences which varied from those in structure 4 only by the relative positions of the preposition and conjunction (e.g. *The ball is under the box and the star.*). The preponderance of reversal errors in the responses to structure 4 (Table J, Appendix 12) indicate that either the two noun phrases were being assigned a dominant position in the spatial relationship, or that the preposition was being applied to the noun phrase following it. As many of the reversals occurred in response to the more salient, untreated prepositions, the latter interpretation seems the more likely. It is not possible to be more than tentative in these speculations because the number of observations was relatively small and behaviour in response to untreated structures was, by the nature of the experiment, not studied during treatment.

As for the Verb Test data, an analysis was performed to compare Group A's performance on untreated sentences incorporating treated prepositions, with that on sentences containing untreated prepositions. As before, the data was collapsed across sentence structures for this comparison, giving 70 observations per session for each of the two categories. The results are shown in Figure 32.

A comparison of Figures 26 and 32 shows that Group A made less progress on untreated items containing treated prepositions than untreated items containing treated verbs (though the former were more accurate to start with), but that at session 3 accuracy on the untreated sides of the Verb Test and Preposition Test was very similar for this Group. Figure 32 shows that overall, verb therapy had little effect on untreated preposition items (the treated-preposition sentences declining a little and the untreated-preposition sentences improving by a similar

amount). After preposition therapy both sets of sentences can be seen to have improved somewhat, although the benefit to the untreated side is the more convincing. Following preposition therapy there was no difference between Group A's performance on (untreated) treated-preposition and untreated-preposition sentences (65.71% in both cases) suggesting that generalisation had taken place as much, if not more, to the unseen prepositions as to those encountered during therapy.



**Figure 32. Treated and untreated-preposition sentences Group A
(untreated items)**

n = 70 treated-preposition items and 70 untreated-preposition items per session

The comparative performance of **Group B** on untreated preposition sentences is illustrated in Figure 33. Figure 17 (p. 165) had shown that there was a very small positive change to Group B's untreated preposition items after therapy; Figure 33 details the changes to individual sentence structures after preposition therapy and again after verb therapy. Structures 1..3 were the treated structures and structures 4 and 5 were untreated structures.

Figure 33 shows a singular lack of success in affecting Group B's performance on structures 1, 3 and 4; in each of these cases session 1 and session 3 results were identical. By contrast there was an increase in accuracy of 21.43% on structure 2

items, which was maintained after verb therapy and an increase in performance on structure 5 items of 17.86%, but unfortunately more than half of this was lost by session 3. A comparison of Figures 27 and 33 shows a much smaller range of minimum and maximum performance values in the untreated preposition items than in the untreated verb items.

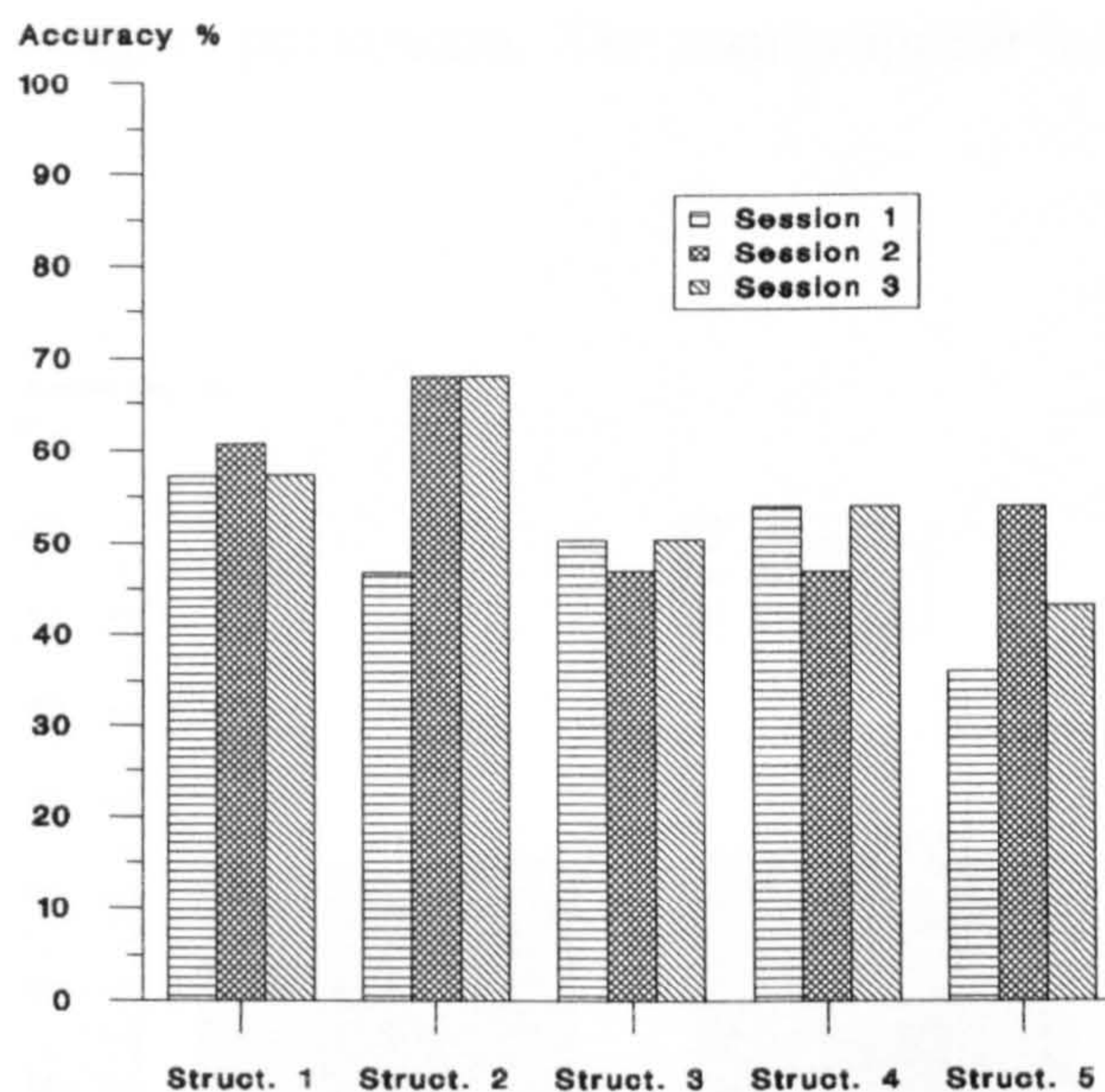


Figure 33. Treatment effects on untreated items Group B Preposition Test.
n=28 per session all structures

Group B's preposition results (treated and untreated items) present a confusing set of data. It is unclear, for example, why preposition therapy should seem to have failed to affect, and if anything worsened, performance on untreated items in structures 3 and 4 (Figure 33) and that pre-therapy performance should have been restored by verb therapy. Small changes like this may, of course, be nothing more than random fluctuations. However, it is strange to find treated structures 1, 2 and 3 all responding well to preposition therapy (see Figure 30), while untreated instances of structures 1 and 3 (combined) were unchanged. Moreover, it is curious that improvement on all the treated items reversed once preposition therapy was withdrawn - the gain in structure 2 items being all but eradicated, while the improvement on untreated structure 2 items (see Figure 33) was

maintained. Possible reasons for Group B's response patterns are discussed further in section 6.1.1.

Finally, Group B's responses to the *untreated items* in the Preposition Test were examined with respect to changes in sentences containing treated prepositions (*in, under, behind*) compared with changes in the matched sentences containing untreated prepositions (*above, between, beside*). As for Group A, the data was collapsed across sentence structures for this analysis thereby yielding 70 observations per category per session. The results appear in Figure 34.

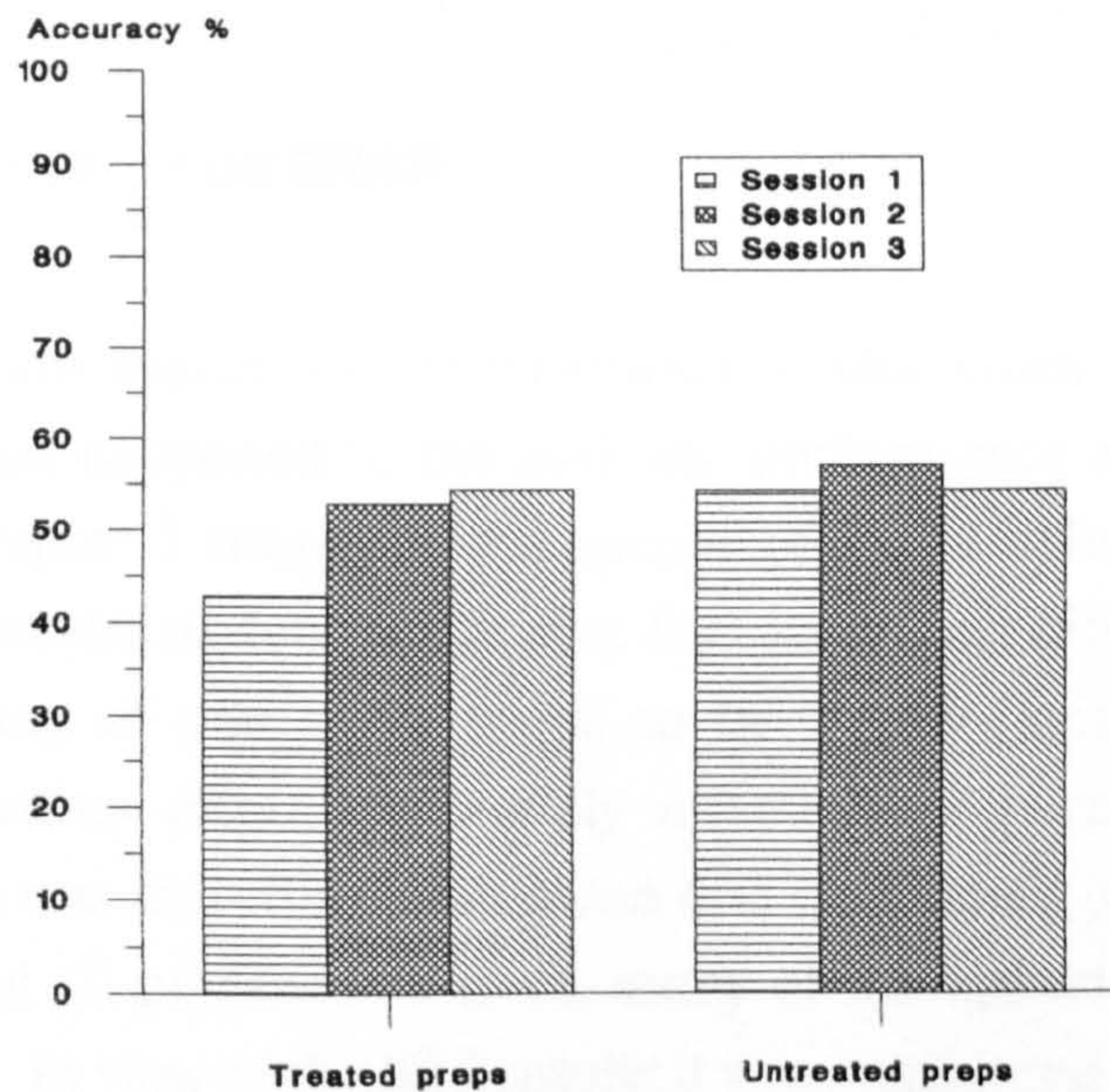


Figure 34. Treated and untreated-preposition sentences Group B (untreated items)

n = 70 treated-preposition items and 70 untreated-preposition items per session

Figure 34 shows that contrary to what was found for Group A (see Figure 32), untreated prepositions were more accurate pre-therapy than to-be-treated prepositions. However, preposition therapy can be seen to have improved accuracy on treated preposition items by 10% and a further small increase measured after verb therapy brought treated items up to the pre- and post-therapy level of the untreated items. There was a disappointing lack of success in improving performance on untreated-preposition items (on which Group A had shown a 15% increase, see Figure 32) compared both with treated-preposition

items and with untreated-verb sentences (on which Group B had achieved an increase in accuracy of 15.72% (see Figure 28)).

In conclusion of this section, the structure-by-structure analysis was important in determining how the overall treatment effects reported in sections 4.1.1 and 4.1.2 were distributed across the different treated sentence sets. Additionally, within the untreated sides of the Verb Test and Preposition Test, it enabled a comparison of changes both to treated and untreated structures and to sentences containing treated versus untreated lexical items. Moreover, this analysis was helpful in achieving a fuller appreciation of the constituent results which contributed to such different overall performance profiles for Groups A and B.

5.3 TREATMENT EFFECTS ON SPEED

A further important aspect of the treatment results which has so far not been mentioned is what happened to the patients' performance speeds as a result of intervention. Chapter 2 compared the speeds of the 14 aphasic subjects with 45 normal subjects on the six-function Syntax Screening Test (SST) and the aphasics (with the exception of one) were found to be grossly impaired in speed, with preposition sentences disproportionately affected compared with the normal performances. It was therefore anticipated that confronted with tests comprising 40 verb items and 40 preposition items, many of the aphasic subjects would be very slow indeed. In view of the SST results it was considered that accuracy apart, most of the aphasic subjects were seriously functionally impaired by virtue of not being able to operate at anything approaching normal speed. As was briefly mentioned in section 3.4.1, close attention was paid to the pre-therapy timing results of P1..P14 in formulating clinical goals for each patient. Where the total time taken for an assessment test exceeded about forty minutes it was considered particularly important to try to reduce it (and large increases in speed accompanying increases in accuracy after therapy were regarded as detrimental to the overall outcome, see section 5.4).

Timing data is infrequently reported in aphasiological literature and time is only a minor factor (where it is considered at all) in existing aphasia assessments. This is not surprising because reaction times are difficult to obtain manually, but it is a pity because speed data should be indispensable in assessing the severity of language processing disorders and in evaluating their susceptibility to treatment.

The Verb Test and Preposition Test software recorded the reaction times of the patients to each of the target sentences (accurate to 1/100 sec.), calculated the mean⁷⁸ reaction time for each patient to the treated and untreated items in the tests and provided details of the total time taken (including pauses) for test completion. In this section an overview is presented first of the changes in total time taken by the two aphasic groups, for both functions treated, between sessions 1 and 2 and sessions 2 and 3. This is followed by an examination of individual patient's performances, comparing changes in accuracy with total time taken for the tests. Next a comparison of mean reaction times to treated and untreated items is undertaken to determine whether there was any discernible difference between them in response to therapy. Finally, timing data from the Real World Test is considered to discover whether the improvements in accuracy on this test previously reported were accompanied by a decrease in time taken.

An ANOVA was carried out on the total test completion times (in minutes) for the Verb Test and Preposition Test of Group A, Group B and both aphasic groups combined. The group analyses were performed with two within-subjects factors; Sessions (3 levels: session 1, session 2 and session 3) and Function type (2 levels: verbs and prepositions), and no between-groups factors. The combined analysis used the same within-subjects factors and one between-groups factor; Groups (2 levels: Group A and Group B).

No significant main effects were found.⁷⁹ The mean test completion times for Group A collapsed across Function type were 30.36, 23.86 and 28.43 minutes for sessions 1, 2 and 3 respectively, and for Group B the corresponding values were 35.50, 34.28 and 33.14 minutes. None of the interactions approached significance with the exception of Group B's first order interaction between Sessions and Function type, $F(2,12) = 3.20$, $MSe = 27.60$, $p = .08$. Examination of the mean

⁷⁸ Mean rather than median reaction times were used because the composition of the tests was not homogeneous (they comprised blocks of sentence structures of varying complexity). The resulting reaction data therefore showed large ranges, with the faster values being quite densely clustered and the slower ones being distributed across a much wider range. Median values would have been misleading and would not have captured any improvement in speed to the more complex test items.

⁷⁹ Group A: Sessions $F(2,12) = 1.48$, $MSe = 156.02$, ns.
 Function type $F(1,6) = .32$, $MSe = 17.36$, ns.
 Group B: Sessions $F(2,12) = .22$, $MSe = 19.45$, ns.
 Function type $F(1,6) = .54$, $MSe = 126.88$, ns.
 Combined: Groups $F(1,12) = 1.25$, $MSe = 960.19$, ns.
 Sessions $F(2,24) = 1.08$, $MSe = 104.57$, ns.
 Function type $F(1,12) = .83$, $MSe = 119.05$, ns.

test completion times for verbs and prepositions across the three test sessions⁸⁰ showed a trend towards a greater difference between verbs and prepositions in session 1 than in sessions 2 and 3.

The ANOVA showed that considering the patient data overall, or by treatment group, therapy had not had a significant effect on the speed of processing of the microworld items (although significant effects were found for real world items as reported later in this section). This outcome was not unexpected in view of the very large variability in test completion times and in speed/accuracy relationships at initial assessment. For example, the baseline Verb Test produced a maximum test completion time of 84 mins (P2) and a minimum test completion time of 6 mins (P10). P10 functioned at normal speed but was inaccurate, while P12 was accurate on prepositions but slow (39 minutes) and less accurate on verbs and even slower (73 minutes), P14 was very inaccurate (20/40 verbs, 10/40 prepositions) but fairly fast by aphasic standards (26 minutes verbs, 21 minutes prepositions). With such a range of starting positions, it was predictable that the patients should exhibit different treatment effects with respect to time taken. Moreover, it was necessary in any event to scrutinise their data on an individual basis to determine how far therapeutic goals (which for the slower patients specifically targeted speed) had been met. Similarly, in considering patients who had maintained improvements in accuracy on the first-treated function throughout therapy in the second function, it was important to examine corresponding changes to speed for an understanding of the quality of the treatment effects.

In view of the huge range of values in the timing data, and wishing therefore to avoid the calculation of means, the timing data for Groups A and B (Verb Test and Preposition Test) was examined to determine the cumulative changes that had taken place in total time taken for test completions between sessions 1 and 2 and sessions 2 and 3. The method used was (for each test taken) to sum the total time taken by each member of a group for each test session and then to subtract the session 2 total from the session 1 total to obtain a measure of change after the first function treated, and to subtract the session 3 total from the session 2 total to do the same for the second function treated. This yielded the nett change in minutes for the group as a whole. The results for Group A are shown in Figure 35 and the corresponding results for Group B are given in Figure 36. The pre-

⁸⁰ Group B: session 1 - verbs 38.86, preps 32.14; session 2 - verbs 35.28, preps 33.28; session 3: verbs 34.0, preps 32.28. (All times in minutes).

therapy status of each function treated is plotted with an origin of zero, so positive changes indicate increases in time taken and negative changes indicate decreases in time taken. Hence in these graphs and the individual ones that follow, negative slopes are desirable. Additionally, throughout this section the graphs are annotated with a plus sign where the associated accuracy increased, if accuracy remained constant this is indicated by a zero and if accuracy declined this is indicated by a minus sign. Thus the optimum combination is a negative slope with a plus sign beside it, as in the Verb Test results between sessions 1 and 2 plotted in Figure 35.

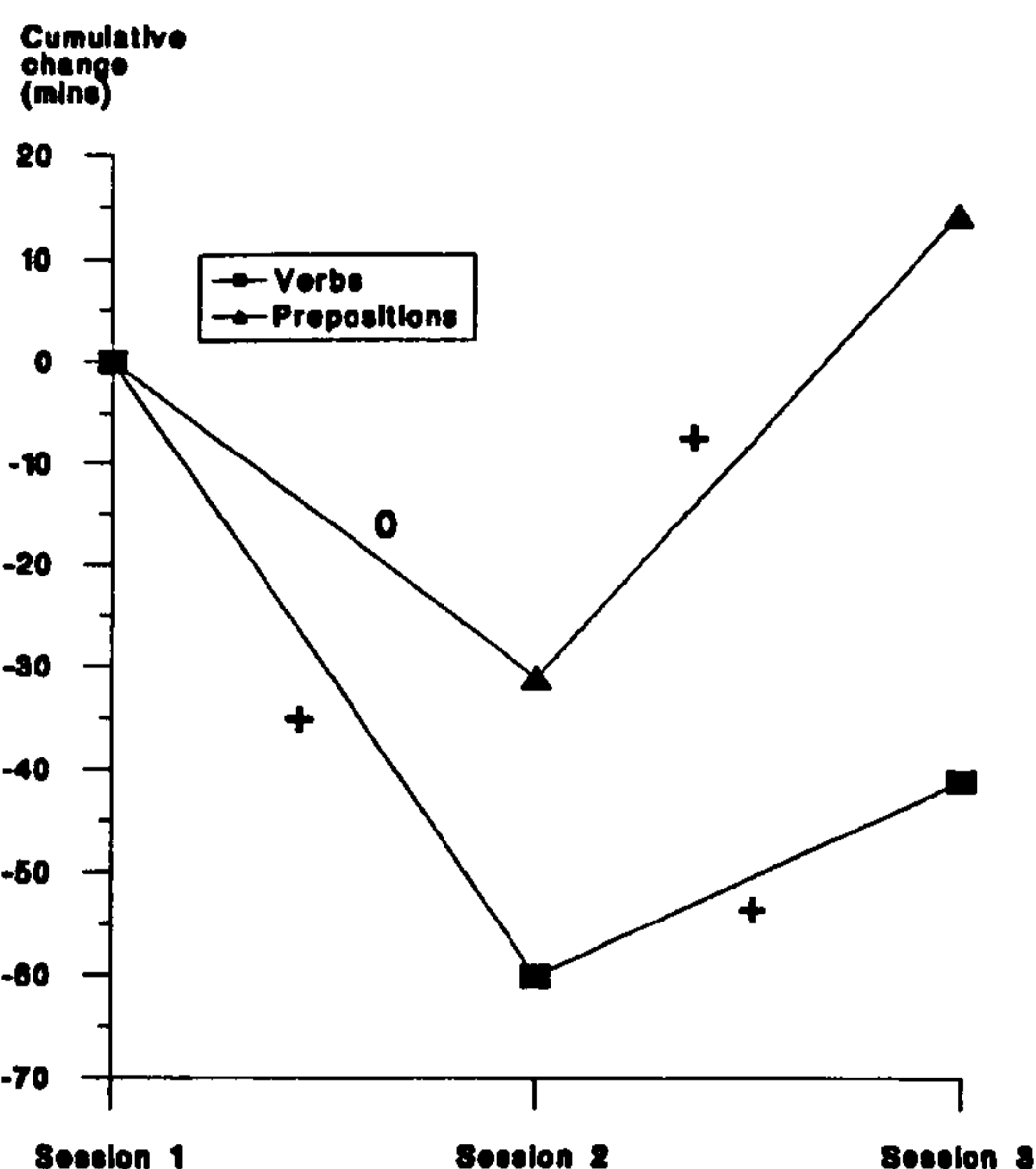


Figure 35. Treatment effects on total time taken Group A.
(verbs treated first)

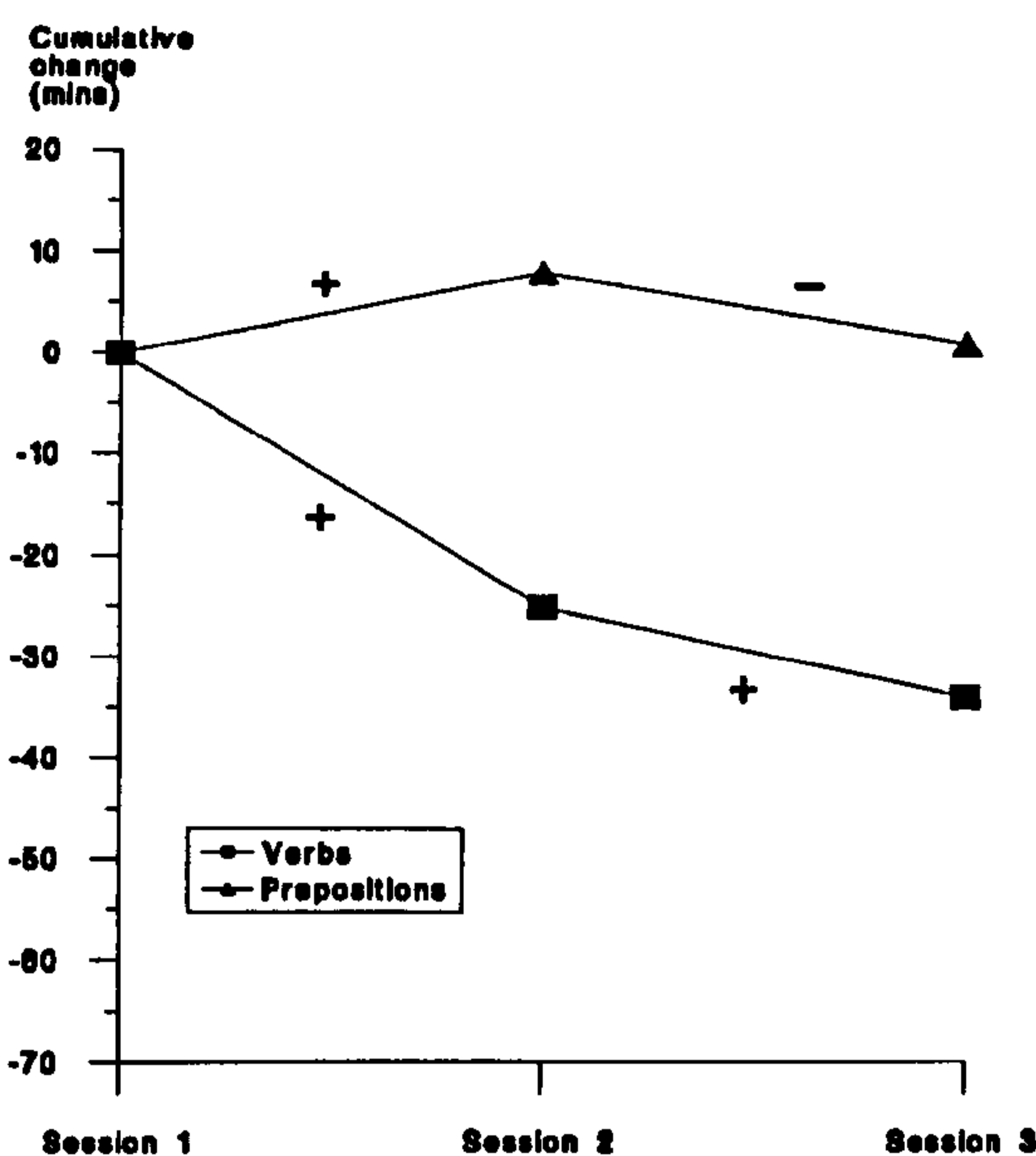
Figure 35 highlights the interesting result that therapy was conspicuously more successful in reducing Group A's overall time for completing the Verb Test (where the nett change for the group between sessions 1 and 3 was 41 minutes)⁸¹ than for completing the Preposition Test (where an overall increase of 14 minutes between sessions 1 and 3 was observed). Another noteworthy feature of this data is the extra information it furnishes about the effects of verb therapy on the Preposition Test (i.e. that there was an overall reduction of about 30 minutes in Group A's cumulative time taken to complete this test). The annotation on the preposition line-segment between sessions 1 and 2 in Figure 35 is a reminder that

⁸¹ However, from the individual graphs, Figure 37a, it will be seen that P2 was responsible for 41 minutes of the Group's overall improvement of 60 minutes between sessions 1 and 2).

accuracy on preposition items remained unchanged following verb therapy. This is an interesting finding that modifies the impression gained from accuracy data alone, i.e. that there had been no change in Group A's Preposition Test performances as a result of verb therapy. Figure 35 also shows that verb items took slightly longer after preposition therapy than directly after verb therapy, so while accuracy continued to increase there is evidence of the tasks being a little more effortful after a lapse of five weeks (this may have been due to their not having been practiced recently, or to some interference from preposition therapy). Finally, it is clear from Figure 35 that Group A's excellent preposition results were not obtained without some loss of speed. Interestingly, following verb therapy the group saved 31 minutes on prepositions without loss of accuracy, but following preposition therapy lost 45 minutes on their improved speeds in attaining the results summarised in Figure 15 (p. 160). This observation gives some insight into the effort expended, even by the better group, in achieving the results reported here.

The corresponding results for Group B are shown in Figure 36. Their pattern of performance is quite different. Overall, in marked contrast to Group A, there was barely any change at all in the time taken to complete preposition items (although individuals, of course, contradict this). Thus, the significant improvement in performance on prepositions (and for that matter on verbs!) between sessions 1 and 2, demonstrated by the accuracy ANOVA (section 4.1.2), was achieved without a time penalty. In addition, the decline in preposition performance between sessions 2 and 3 was not accompanied by an overall decrease in speed (there were exceptions e.g. P11, see Figure 38b). However, the heaviest losses to preposition accuracy after verb treatment were suffered by P9 and P14 - their graphs in Figures 38a and 38b tend to suggest that if verb therapy had undermined their grasp of prepositions, it certainly had done so at a level which caused them no conscious dilemma.

Group B's results show that the increases in performance on verb items after preposition therapy and after verb therapy were both accompanied by decreases in overall time taken, with the larger gains being apparent after preposition therapy. The differential between changes to verb processing time and preposition processing time between sessions 1 and 3 was not as great as for Group A, but nevertheless the two groups showed the same trend with Verb Test times much reduced compared with Preposition Test times.



**Figure 36. Treatment effects on total time taken Group B.
(prepositions treated first)**

The presentation of individual patients' results which follows has also been based on the total time taken for completion of the Verb Test and Preposition Test recorded at sessions 1, 2 and 3 (rather than mean response latencies). This was found to be a useful global measure for practical purposes (e.g. for communicating a tangible measure of progress to patients and their relatives and for planning appointments and transportation) as it yields one readily assimilable value for each test, allowing patients to be easily compared and the changes both over sessions and between the two treated functions to be easily appreciated. In addition, the total time taken includes any pause time (whereas the mean reaction times reported later do not), thus it captures improvements due to increased concentration span. The test completion times for members of Group A are summarised in the graphs comprising Figures 37a and 37b and similar data for Group B is shown in Figures 38a and 38b. As in Figures 35 and 36 the line segments of the single-case graphs are annotated with either '+', '0' or '-' to indicate whether the accuracy score associated with that particular test increased, remained static or declined.⁸² It was not possible to use the same vertical axis scaling for all graphs because of the huge ranges involved. The graphs of P2, P10

⁸² The actual scores for each subject were shown in Table 35 (p. 159) and Table 38 (p. 164).

and P12 are different from the others in this respect and care should be taken in making direct comparisons.

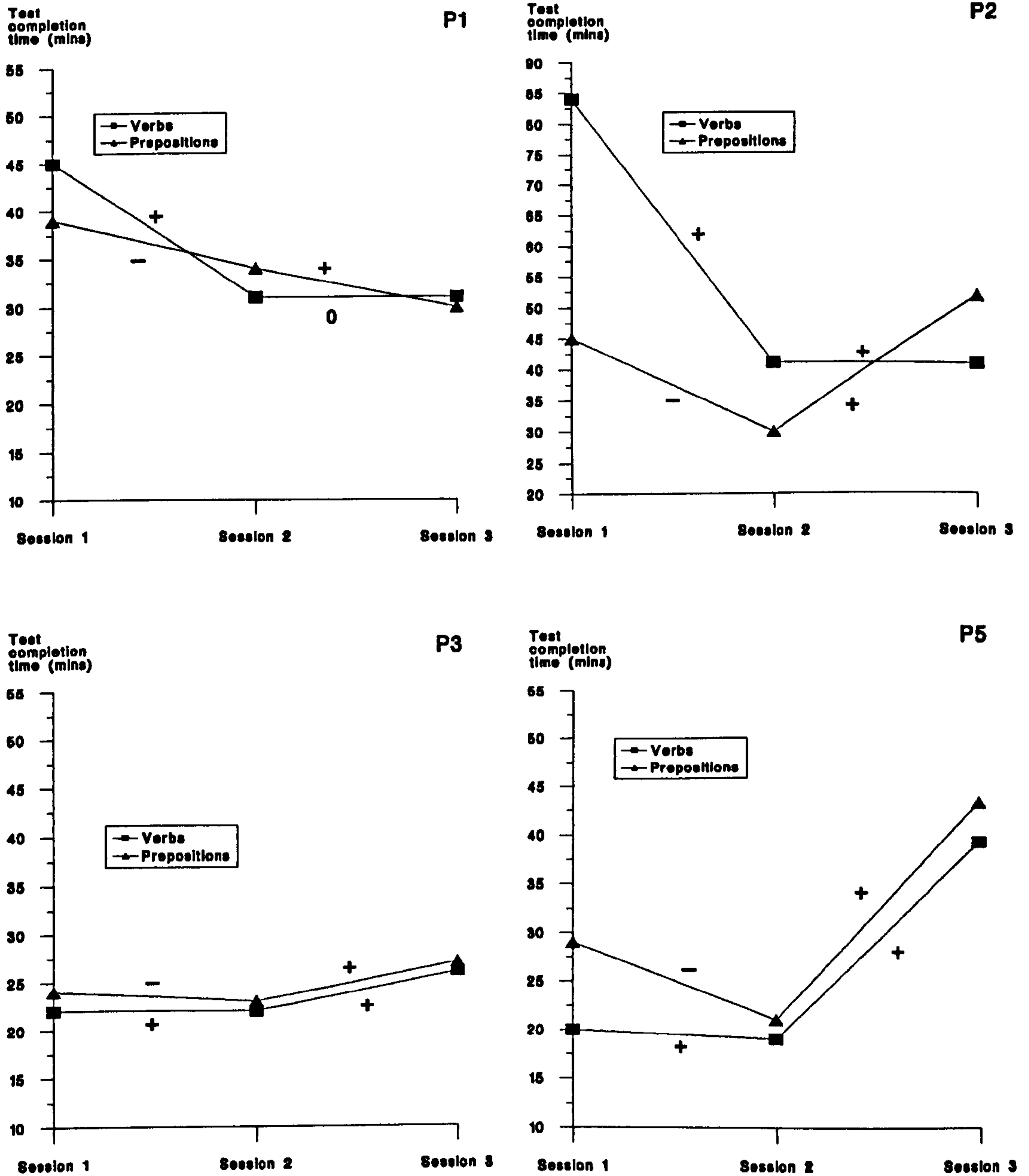


Figure 37a. Group A treatment effects (speed).
 Verbs were treated between sessions 1 and 2 and prepositions were treated between sessions 2 and 3.

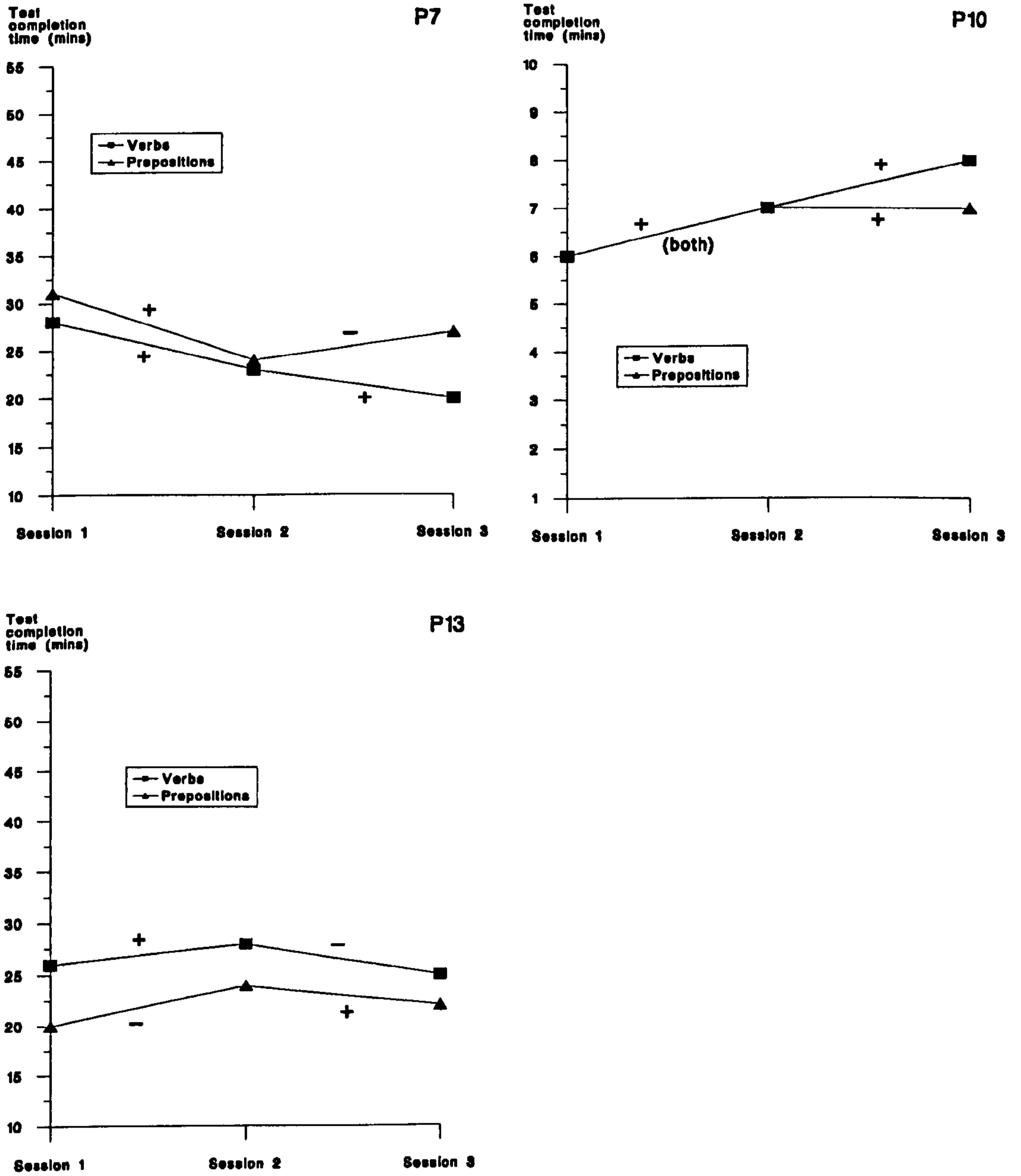


Figure 37b. Group A treatment effects (speed). Verbs were treated between sessions 1 and 2 and prepositions were treated between sessions 2 and 3.

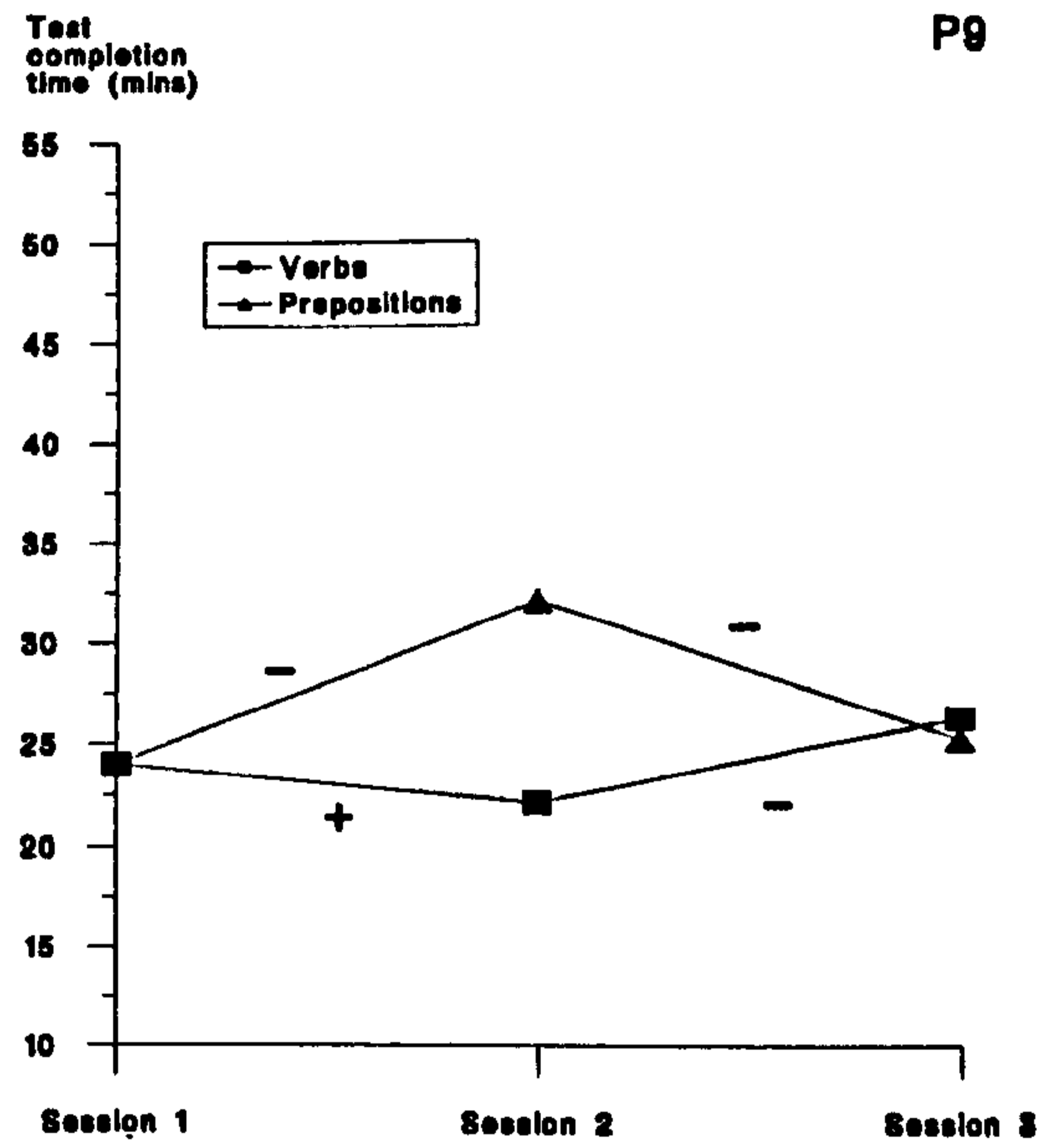
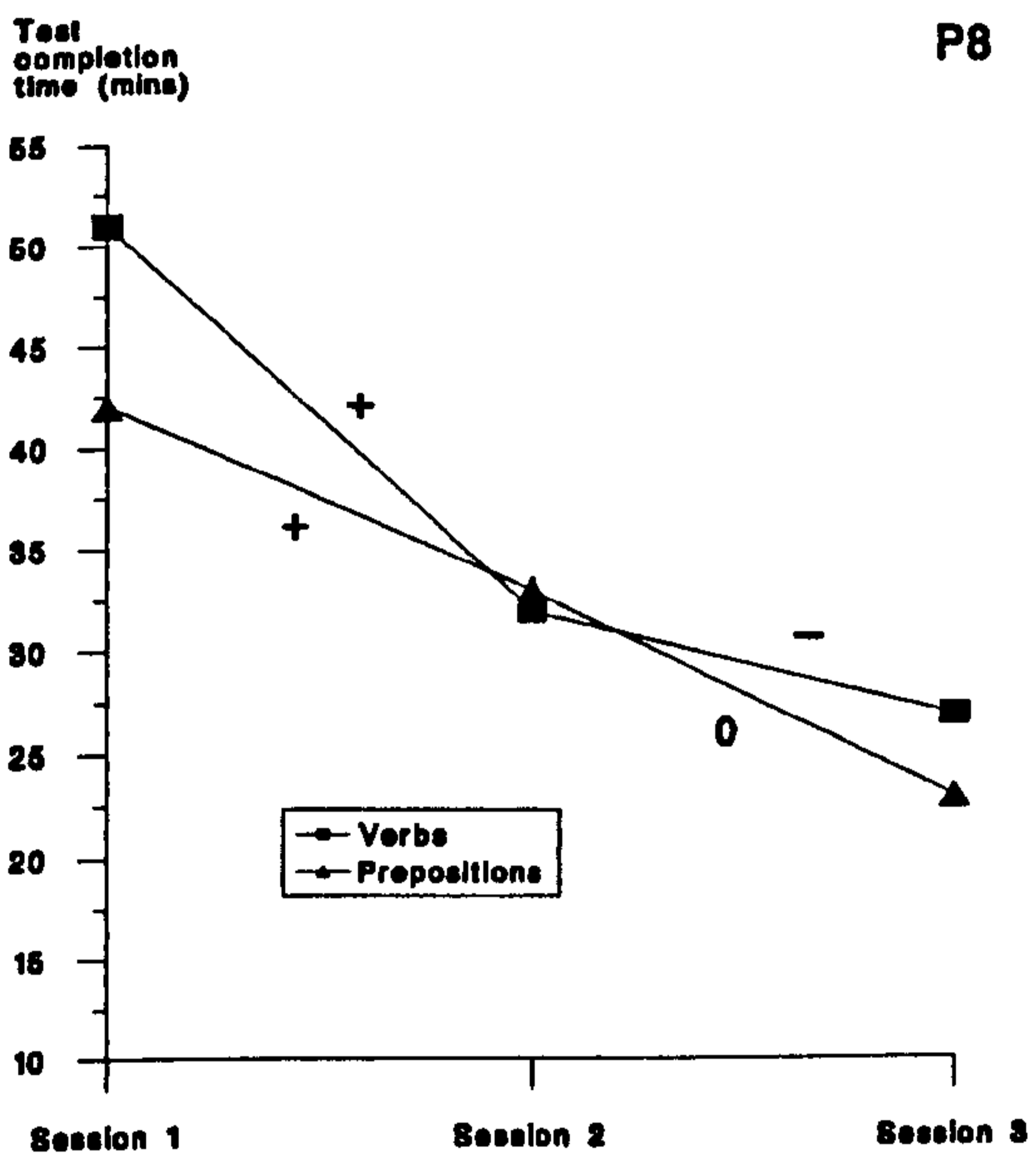
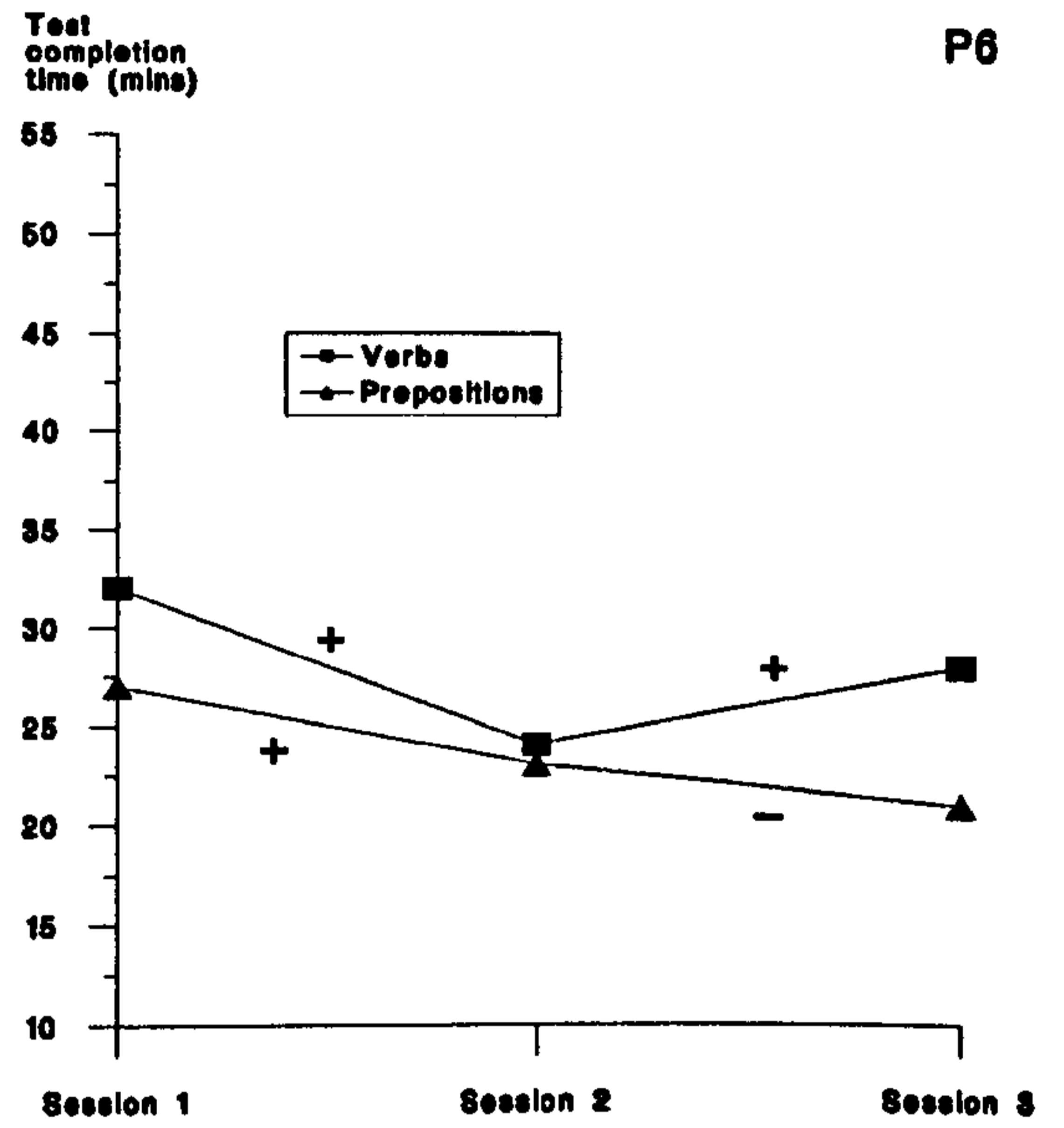
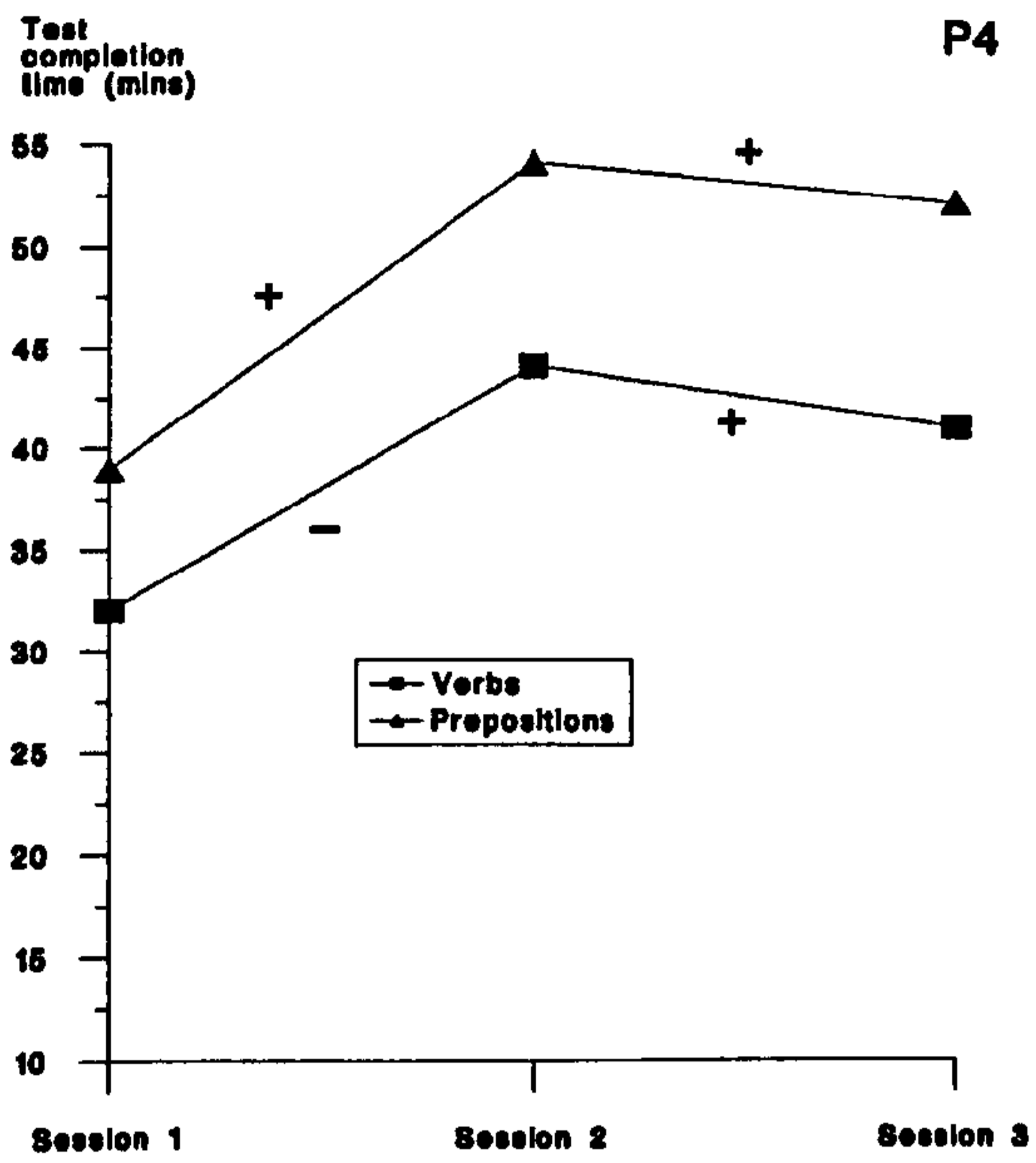


Figure 38a. Group B treatment effects (speed).
 Prepositions were treated between sessions 1 and 2 and
 verbs were treated between sessions 2 and 3.

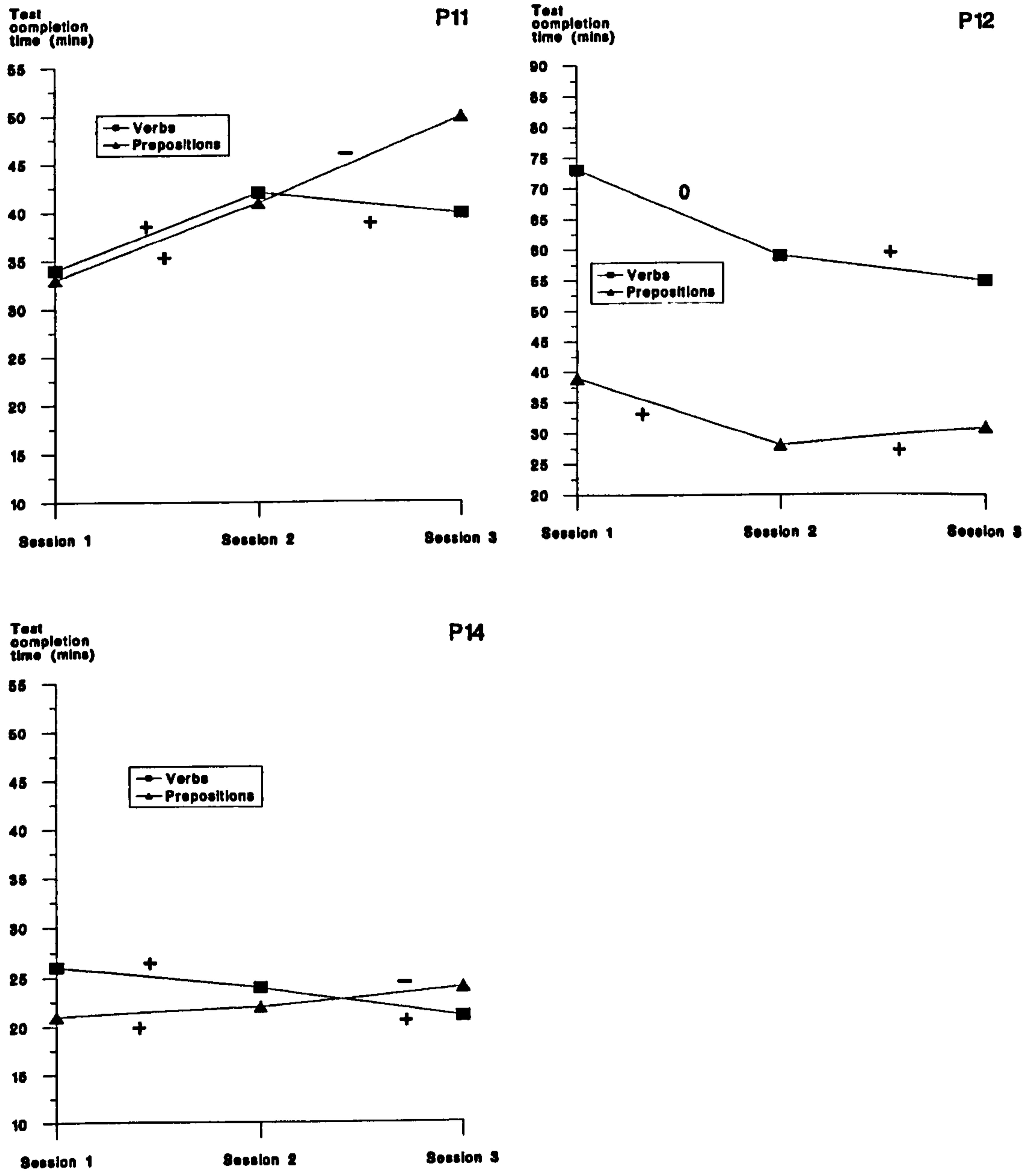


Figure 38b. Group B treatment effects (speed).
 Prepositions were treated between sessions 1 and 2 and
 verbs were treated between sessions 2 and 3.

The individual performance graphs were very informative in a number of ways, facilitating a speed-related overview of the whole data set, a comparison of intra-group results and detailed observations on single cases. Figures 37a, 37b, 38a

and 38b show that the majority of subjects took longer to complete the Verb Test at session 1 than to complete the Preposition Test (8 subjects took longer on the Verb Test, 4 subjects took longer on the Preposition Test and two subjects took equal times for both). Interestingly, three of these subjects (P2, P11 and P14) who initially took longer to complete the Verb Test than the Preposition Test returned quite noticeably longer preposition times at session 3. The opposite change (prepositions taking longer at session 1 but being faster than verbs at session 3) did not occur, thus in this set of subjects, if prepositions were slower than verbs at session 1 (P3, P4, P5, P7) therapy never reversed that pattern.

A pictorial representation of relative timings is useful in identifying subjects with, for example, an unusually large discrepancy between the time taken for one test and the other. P2 and P12 stood apart from the other subjects at session 1 in displaying very large differences between their completion times for the Verb Test and the Preposition Test (both taking of the order of twice as long to complete the verb items as to complete the preposition items). One can see from their graphs that the outcome of therapy was different in each case. The initial pattern was reversed in the case of P2 who responded well (time-wise) to verb therapy, but showed an increase in the time taken to complete preposition items after preposition therapy. P12, on the other hand, managed to decrease the time taken for both treated functions, more so in verbs than in prepositions, but at session 3 still showed a striking difference in the time taken to complete the two tests (verbs 55 mins; preps 31 mins). (Interestingly, P4's graph shows the opposite pattern of performance, i.e. a consistent and large difference in time between the two tests, with prepositions taking longer). From this single example it is obvious that accuracy data alone furnishes a very incomplete picture of cognitive performance. Indeed, the contrast between the timing data of P4 and P12 indicates that it may prove worthwhile to detect and explore dissociations of speed as routinely as those of accuracy in analysing pathological performances. A profile such as P12's in Figure 38b is suggestive of a residual disorder for some aspect particular to the verb processing tasks, despite a reduction in time taken from 73 minutes to 55 minutes and an increase in accuracy from 25/40 to 30/40. In fact P12's difficulty was one of visual interpretation (this is discussed in section 6.1.2). P12 was worse in the microworld, where he often found the salient aspects of the Verb Test pictures hard to identify (this was discovered during remediation sessions), but his Real World Test performance also showed a smaller but still constant difference between the time taken to process verb items and to process preposition items (see Table 50 below).

With respect to the overall timing results and the extent to which therapy was successful in increasing processing speeds, inspection of the individual graphs shows that the most dramatic improvements were made in cases where the pre-therapy speeds were very slow (i.e. 40 minutes or longer). Particularly successful instances included P1 (verbs: 45 minutes at session 1, 31 minutes at sessions 2 and 3), P2 (verbs: 84 minutes at session 1, 41 minutes at sessions 2 and 3) and P8 (verbs: 51 minutes at session 1, 27 minutes at session 3; prepositions: 42 minutes at session 1, 23 minutes at session 3). Where times taken initially were between 20 and 40 minutes, large improvements seemed much more difficult to make. The largest improvement recorded in this band was made by P1 (prepositions: 39 minutes at session 1, 30 minutes at session 3) and many patients in this middle range became considerably slower after therapy (e.g. P4, P5, P11). In no case was therapy successful in reducing the time taken for either of the assessment tests below 20 minutes. P10 continued to be an exception (as he had been on the Syntax Screening Test reported in section 2.5.2) taking between 6 and 8 minutes to complete his verb and preposition tests. He showed distinct improvements in accuracy between sessions 1 and 3, achieving final scores of 33/40 (Verb Test) and 31/40 (Preposition Test). These results could not have been obtained by chance, hence we can be confident that P10 was completing the sentence processing tasks and doing so well within a normal time span.

So far treatment effects on the total times taken for test completion have been examined. In addition to these values, the assessment software recorded reaction times to each target sentence (i.e. the latency between onset of screen display and selection of picture choice) and calculated the mean response time to items in the treated and the untreated set. From these figures it was possible to determine whether there was any specific effect of treated items on the improvements in speed obtained, or whether increases of speed were evenly distributed across treated and untreated items. It will be recalled from Tables 19 and 20 (p. 111 and p. 114) that the composition of the treated and untreated sides of the assessment tests was different, the untreated sides containing structures not present on the treated sides. In both tests the untreated set had fewer simple sentences than the treated set to accommodate the inclusion of untreated structures, which in both cases were of more complex types. Hence one would not be surprised to find the untreated items on average taking a little longer than the treated items. This in no way impedes an investigation of the treatment effects on each set, since it is primarily the changes from baseline that are of interest.

Table 48 gives the mean response times of members of Group A to the treated and untreated sets of the Verb and Preposition Tests. The three rows for each subject show measurements taken pre-therapy, after verb therapy and finally after preposition therapy. While there was a great deal of inter-subject variation in Group A, both in initial processing speed and in the effects of therapy on speed, one can see very striking effects of the treated set in many of the results. The overall trends are easier to appreciate in graphical form. Figure 39 plots the mean reaction times of Group A to the treated and untreated sides of the Verb Test and Preposition Test. Again, the annotations on the line segments indicate whether accuracy increased (+), decreased (-) or was unchanged (0).

| | | Verb Test | | Preposition Test | |
|-----|----|-------------------|---------------------|-------------------|---------------------|
| | | treated (secs) | untreated (secs) | treated (secs) | untreated (secs) |
| P1 | s1 | 51.0 | 67.6 | 45.7 | 57.7 |
| | s2 | 31.2 | 55.4 | 45.2 | 49.0 |
| | s3 | 31.3 | 54.9 | 36.6 | 48.9 |
| P2 | s1 | 108.6 | 125.5 | 65.2 | 61.6 |
| | s2 | 51.3 | 64.1 | 44.1 | 35.4 |
| | s3 | 50.1 | 63.9 | 68.7 | 71.5 |
| P3 | s1 | 26.5 | 34.6 | 33.4 | 33.8 |
| | s2 | 26.7 | 33.6 | 28.8 | 35.2 |
| | s3 | 32.2 | 37.3 | 39.7 | 35.2 |
| P5 | s1 | 20.0 | 27.3 | 29.7 | 39.5 |
| | s2 | 19.7 | 31.5 | 27.1 | 29.3 |
| | s3 | 41.5 | 65.9 | 49.3 | 71.4 |
| P7 | s1 | 34.2 | 31.5 | 32.4 | 36.3 |
| | s2 | 24.9 | 37.6 | 36.0 | 29.4 |
| | s3 | 20.6 | 30.5 | 30.2 | 28.8 |
| P10 | s1 | 7.5 | 7.0 | 6.7 | 6.4 |
| | s2 | 8.1 | 7.7 | 7.2 | 8.5 |
| | s3 | 9.4 | 10.2 | 8.0 | 8.8 |
| P13 | s1 | 24.2 | 29.3 | 29.9 | 26.1 |
| | s2 | 27.6 | 45.9 | 32.7 | 34.2 |
| | s3 | 32.1 | 36.3 | 29.9 | 29.1 |

Table 48. Mean response times to treated and untreated items Group A.
s1, s2 and s3 denote test sessions 1, 2 and 3 respectively,
verbs were treated between sessions 1 and 2
prepositions were treated between sessions 2 and 3.

Figure 39 shows specific effects of verb therapy both in accuracy *and* speed, with item-specific effects suggested by the tendency for treated verb items to have improved in speed more than untreated verb items. That untreated preposition items should have improved in speed more than to-be-treated preposition items after verb therapy seemed a little odd, however inspection of the individual data (Table 48) revealed an explanation for most of this divergence. Two subjects (P1 and P5) showed large differences between mean response times to untreated and to-be-treated preposition items at session 1. Following verb treatment these differences had been largely eliminated, suggesting that reinforcement of some common element(s) of the two processing tasks (possibly word order significance and handling of relative clauses) had perhaps rendered the harder items in the untreated side of the preposition test more accessible to these patients.

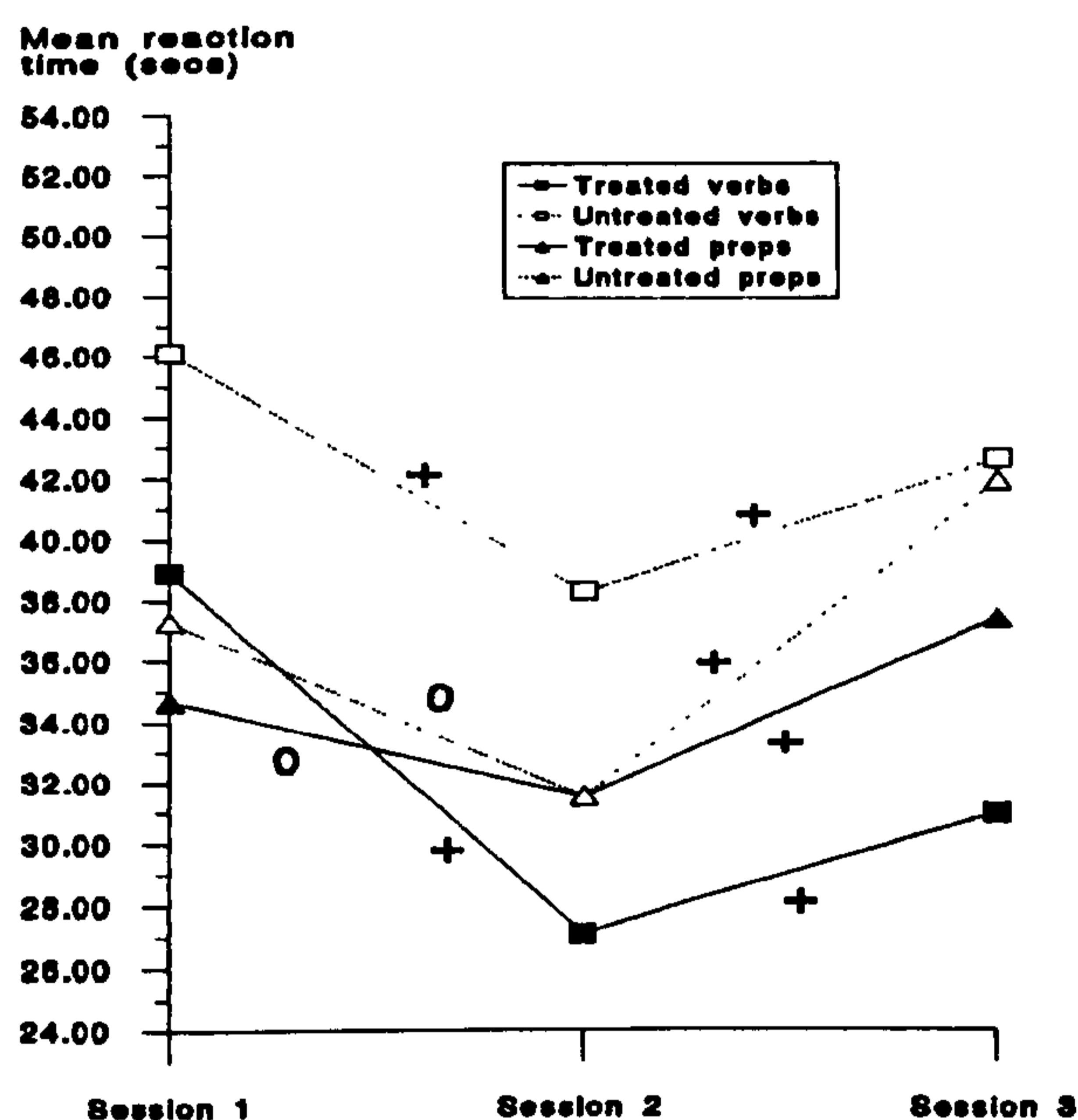


Figure 39. Treatment effects on treated and untreated verbs and prepositions Group A (speed)

After preposition treatment all four sentence sets showed increases in mean reaction time, although accuracy increased in every case. Treated and untreated verb items responded in parallel, the treated items maintaining the time differential established at session 2⁸³. The effect of preposition treatment was to

⁸³ As mentioned earlier, it is impossible to be sure whether the increase in time observed for verb items after preposition therapy was due to the interval intervening since they had last been seen (5 weeks) or to some interference arising from the specifics of locative treatment.

increase the time taken to process preposition items in comparison with verb items. However, the overall increase in mean response times to untreated preposition items was much greater than to treated preposition items, suggesting an effect of treated set on response latencies. As mentioned above, the increase in time taken to process preposition items after therapy gives an indication of how difficult locative items proved to be for these aphasic subjects.

The corresponding data for Group B showing the treatment effects on treated and untreated sentence sets is given in Table 49. Group B was treated on prepositions first, so the three data rows for each patient in Table 49 show results pre-therapy, after preposition therapy and after verb therapy respectively. Figure 40 shows the cumulative changes in mean response latencies for Group B between sessions 1 and 2 and between sessions 2 and 3.

| | | Verb Test | | Preposition Test | |
|-----|----|----------------|------------------|------------------|------------------|
| | | treated (secs) | untreated (secs) | treated (secs) | untreated (secs) |
| P4 | s1 | 33.0 | 41.2 | 38.9 | 41.0 |
| | s2 | 52.2 | 60.0 | 65.8 | 68.3 |
| | s3 | 53.5 | 54.8 | 65.3 | 70.3 |
| P6 | s1 | 41.4 | 40.0 | 37.4 | 33.2 |
| | s2 | 27.7 | 26.3 | 29.4 | 35.5 |
| | s3 | 37.1 | 39.8 | 25.9 | 31.8 |
| P8 | s1 | 67.4 | 75.1 | 56.1 | 55.8 |
| | s2 | 36.4 | 54.0 | 47.4 | 44.6 |
| | s3 | 32.0 | 43.1 | 34.0 | 30.6 |
| P9 | s1 | 33.2 | 34.0 | 30.5 | 36.6 |
| | s2 | 26.9 | 43.1 | 41.6 | 49.5 |
| | s3 | 33.8 | 40.3 | 33.9 | 35.5 |
| P11 | s1 | 39.6 | 41.5 | 39.9 | 42.2 |
| | s2 | 56.4 | 58.0 | 49.1 | 51.9 |
| | s3 | 47.5 | 51.3 | 58.3 | 67.8 |
| P12 | s1 | 117.3 | 92.3 | 56.1 | 42.8 |
| | s2 | 87.1 | 83.6 | 39.9 | 35.5 |
| | s3 | 75.7 | 80.5 | 46.6 | 41.1 |
| P14 | s1 | 33.4 | 39.2 | 28.2 | 28.5 |
| | s2 | 28.8 | 36.6 | 22.0 | 37.8 |
| | s3 | 19.4 | 39.2 | 34.7 | 31.7 |

Table 49. Mean response times to treated and untreated items Group B.
s1, s2 and s3 denote test sessions 1, 2 and 3 respectively,
prepositions were treated between sessions 1 and 2
verbs were treated between sessions 2 and 3.

The changes to mean reaction times illustrated in Figure 40 are difficult to interpret. It has already been observed that the *accuracy* of Group B on verb items improved after preposition therapy, that the improvement was not as large as for preposition items and that the gain to verbs was equally distributed between untreated and to-be-treated sets. Figure 40 suggests an effect of treatment set on response times to preposition items, the untreated items showing much greater increases from the baseline reaction times than the treated items after therapy. However, the effect of preposition therapy on to-be-treated verb items compared with untreated verb items is puzzling. Unlike Group A's prepositions (for which the case was made for some equalisation of response times to treated and untreated items occurring after verb therapy), Group B's mean reaction times to to-be-treated and untreated verbs were almost identical at session 1, one would therefore not have expected such a marked difference in speed between these two sentence sets after preposition therapy. Examination of Table 49 revealed that two patients (P8 and P12) were responsible for most of the imbalance.

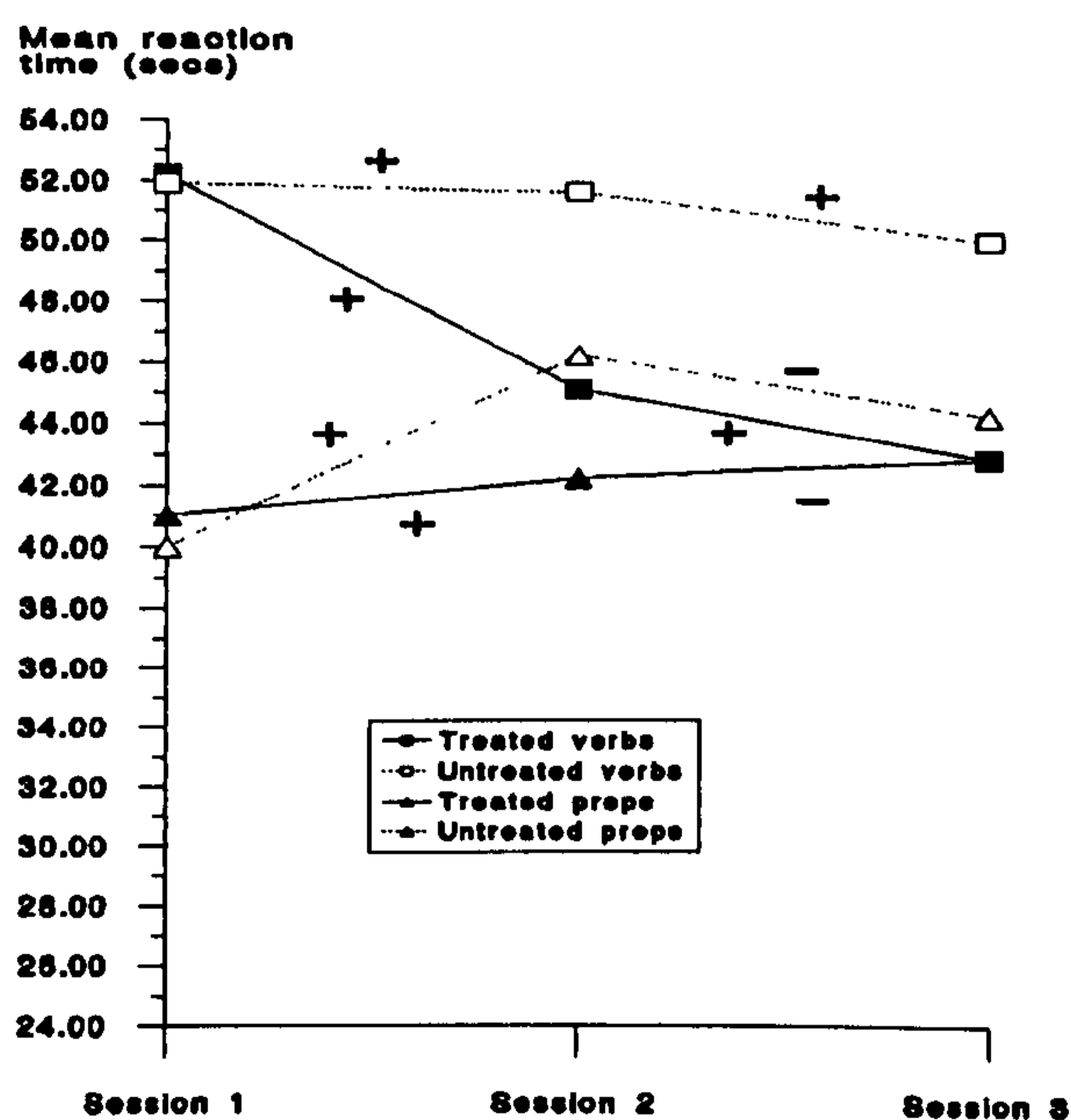


Figure 40. Treatment effects on treated and untreated verbs and prepositions Group B (speed)

P12 began the programme much slower on the to-be-treated verb items (mean reaction time 117.3 seconds) than on the untreated items (92.3 seconds), his

massive improvement in speed on the to-be-treated items after preposition therapy resulting in near equalisation (87.1 secs / 83.6 secs). Since I have argued that, if anything, the *untreated* items should take slightly longer, it was of interest to explore P12's response data to individual target sentences (not included here) to find out what the source of the discrepancies had been at session 1. P12 took 73 minutes without a pause to complete his first verb test. Inspection of his response times to to-be-treated items revealed three responses that were abnormally long in comparison with other responses to identical sentence types. He returned a response latency of 319.5 seconds to sentence 3 (when the mean for the remaining four structure 1 sentences was 60.75 seconds), 135.78 seconds to sentence 13 (the mean for the remaining structure 3 sentences was 66.07 seconds) and 422.87 seconds to sentence 17 (the mean for the other structure 4 sentences was 178.23 seconds). Ignoring these three sentences, P12's mean response time to to-be-treated verb items was 86.39 seconds, which is in line with his performance on the untreated set (92.3 secs). These observations suggest that the effect of preposition treatment on P12's verb processing was a general one resulting in a reduction of about 10 seconds to both sides of the Verb Test, whereas the apparent differential between to-be-treated and untreated verb items on first assessment was spurious, being due to three lapses of concentration, all falling on to-be-treated items.

P8, on the other hand, returned more plausible session 1 results (see Table 49). However, his individual responses to treated and to-be-treated verb items were also examined to seek an explanation for his startling decrease in mean reaction time to to-be-treated verb items following preposition therapy. In this case the differential in improvement (the mean reaction time to to-be-treated items improved by 31 seconds and the mean reaction time to untreated items by 10.2 seconds) appeared to be genuine. At session 2, P8 was found to have improved his reaction times to 18 out of 20 to-be-treated verb sentences and to 14 out of 20 items on the untreated side. Thus his improvements were unquestionably widespread and happened to be more numerous on the to-be-treated side. This profile is consistent with general improvement as a result of some helpful component of preposition therapy.

Returning to Figure 40, it can be seen that following verb therapy, Group B showed an improvement in accuracy on treated and untreated verb items, accompanied by a small decrease in mean reaction times to both. After verb treatment preposition items suffered declines in accuracy on both sides (all losses

bar one being confined to the treated side which had responded much more to therapy), however, Figure 40 shows that untreated prepositions improved a little in speed between sessions 2 and 3, recovering about one third of the heavy increase to the mean response time incurred between sessions 1 and 2.

Comparing the two groups in their mean reaction times to treated and untreated verb and preposition items over the three test sessions (Figures 39 and 40), one is struck principally by the much longer mean latencies of Group B. This group started and finished the study with longer mean reaction times to all four sentences sets. However, Group A's results were influenced by the abnormally fast response times of P10. Eliminating these, there was still a difference of 8.2 seconds between the mean response times on to-be-treated verb items at baseline,⁸⁴ but the difference in mean response times to to-be-treated prepositions diminished to an insignificant 1.6 seconds.⁸⁵

The **Real World Test** performances of P1..P14 were also examined to find out whether microworld therapy had affected speed of response. The Real World Test was paper-based and manually administered, therefore it was not practicable to collect response times to individual items. Instead the total time taken for each half of the test (i.e. for the 20 verb sentences and the 20 preposition sentences) was recorded. The timing data for individuals is summarised in Table 50 and may be compared with the accuracy data which was given in Tables 36 (p. 161) and 39 (p. 166).

The patients on the left of Table 50 are members of Group A, who had verb treatment first, those on the right are Group B who had preposition treatment first. The overall results for Group A and Group B are shown in Figures 41 and 42 respectively, in a format that can be readily compared with the effects of treatment on microworld items, summarised in Figures 35 and 36. It should be remembered that there were only 20 verb sentences and 20 preposition sentences in the Real World Test (mentally doubling the figures in Table 50 will give an idea of how long real world assessments took compared with microworld

⁸⁴ This is reinforced by the observation that the fastest mean response time in Group B was 33.0 seconds, whereas four subjects in Group A returned values under 27.0 seconds

⁸⁵ I considered using median values instead of means for the study of treatment effects on reaction time, but concluded that this would be even less satisfactory because of the uneven spread of values, the huge range and the very small sample size. The mean better represents the average change to members of the groups.

| REAL WORLD TEST | | | | | | | |
|-----------------|----|-----------------|-----------------|-----|----|----|----|
| | | verbs (mins) | preps (mins) | | | | |
| P1 | s1 | 23 | 22 | P4 | s1 | 15 | 16 |
| | s2 | 14 | 18 | | s2 | 16 | 16 |
| | s3 | 16 | 13 | | s3 | 10 | 12 |
| P2 | s1 | 28 | 30 | P6 | s1 | 12 | 15 |
| | s2 | 12 | 15 | | s2 | 9 | 13 |
| | s3 | 11 | 14 | | s3 | 10 | 11 |
| P3 | s1 | 14 | 11 | P8 | s1 | 14 | 13 |
| | s2 | 11 | 10 | | s2 | 19 | 6 |
| | s3 | 8 | 8 | | s3 | 11 | 6 |
| P5 | s1 | 11 | 15 | P9 | s1 | 10 | 10 |
| | s2 | 9 | 9 | | s2 | 6 | 12 |
| | s3 | 8 | 9 | | s3 | 13 | 13 |
| P7 | s1 | 11 | 13 | P11 | s1 | 14 | 16 |
| | s2 | 11 | 14 | | s2 | 15 | 15 |
| | s3 | 9 | 10 | | s3 | 13 | 18 |
| P10 | s1 | 4 | 4 | P12 | s1 | 25 | 20 |
| | s2 | 4 | 4 | | s2 | 17 | 12 |
| | s3 | 4 | 4 | | s3 | 19 | 15 |
| P13 | s1 | 13 | 17 | P14 | s1 | 16 | 19 |
| | s2 | 12 | 12 | | s2 | 14 | 13 |
| | s3 | 11 | 7 | | s3 | 8 | 11 |

Table 50. Real World Test results for P1..P14 (speed)
s1, s2 and s3 denote test sessions 1, 2 and 3 respectively

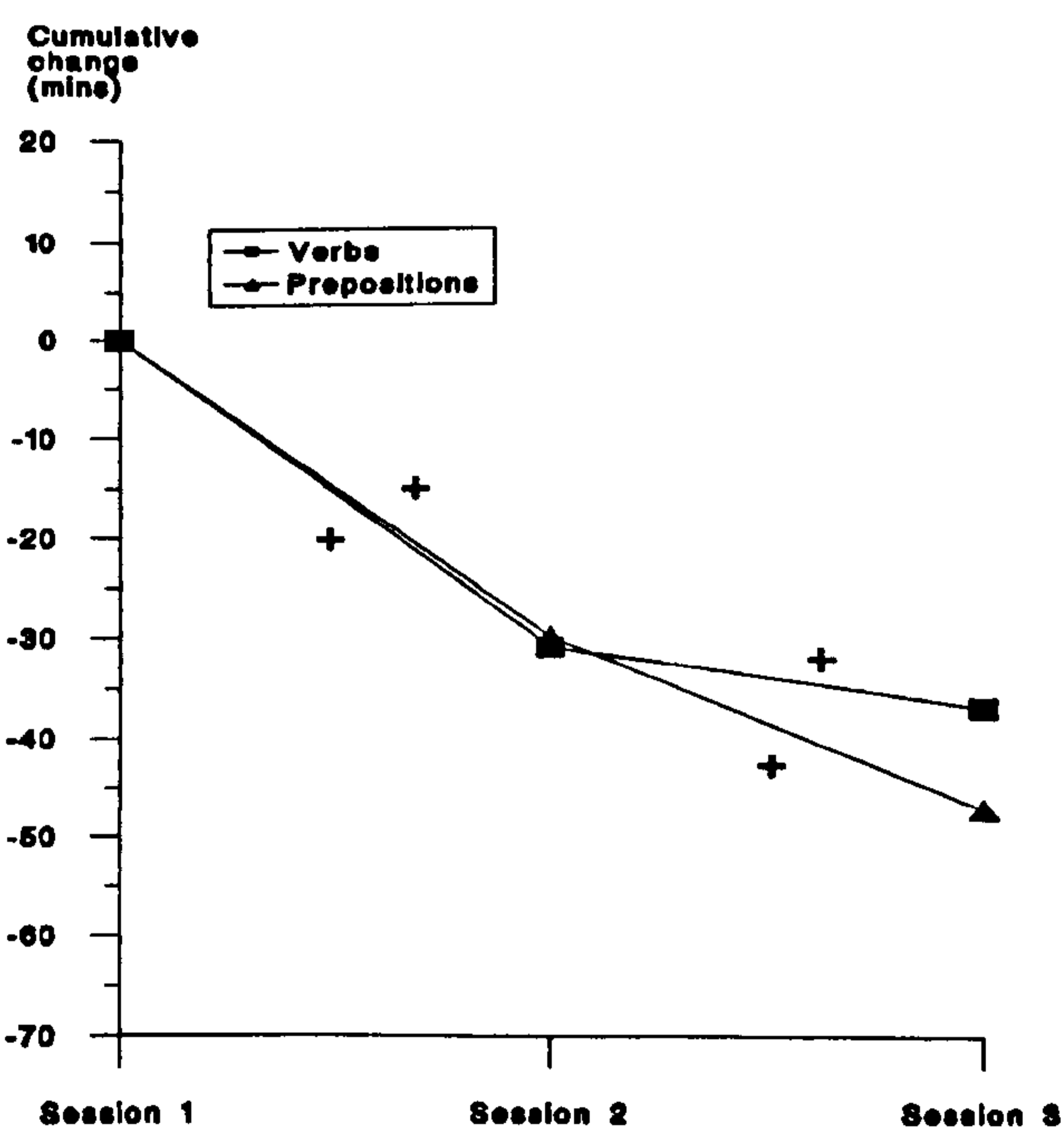


Figure 41. Treatment effects on Real World Test (speed)
Group A.

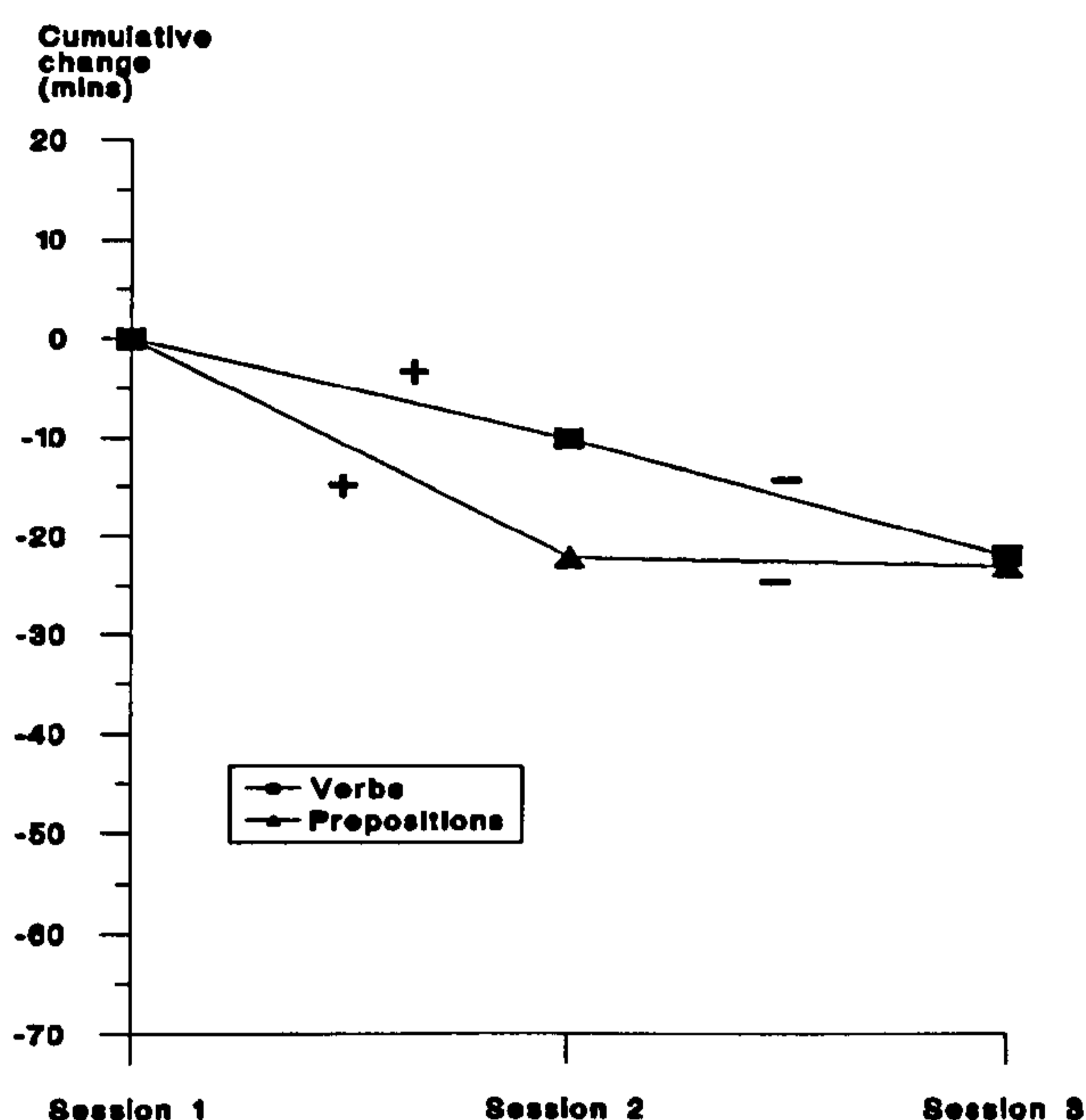


Figure 42. Treatment effects on Real World Test (speed) Group B.

equivalents, similarly, the time changes represented in Figures 41 and 42 could be doubled for rough comparison with Figures 35 and 36).

An ANOVA was performed on the test completion times for the Real World Test for Groups A and B separately and for both groups combined. The individual group data was analysed with two within-subjects factors and no between-groups factors. The within-subjects factors were Sessions (3 levels: session 1, session 2 and session 3) and Function type (2 levels: verbs and prepositions).

The data of Group A showed a significant main effect of Sessions, $F(2,12) = 6.55$, $MSe = 132.07$, $p = .01$. The means for sessions 1, 2 and 3 collapsed across Function type were 15.36, 11.00 and 9.43 minutes respectively. Post-hoc Newman-Keuls tests ($P < .05$) showed speed in session 2 to be significantly faster than speed in session 1, but there was no significant difference between speeds in sessions 2 and 3.

The main effect of Function type was not significant ($F(1,6) = 1.20$, $MSe = 4.02$, ns) and neither was the first order interaction between Sessions and Function type

($F(2,12) = 0.79$, $MSe = 2.17$, ns), showing no significant difference between speeds on verb and preposition items overall, or as a result of the therapy applied.

The data of Group B showed a main effect of Sessions which approached significance, $F(2,12) = 3.27$, $MSe = 38.31$, $p=.07$. The means for sessions 1, 2 and 3 collapsed across Function type were 15.36, 13.07 and 12.14 minutes respectively, showing a trend towards faster times in the later sessions. As for Group A, the main effect of Function type was not significant ($F(1,6) = .02$, $MSe = .38$, ns) and neither was the first order interaction between Sessions and Function type ($F(2,12) = 0.65$, $MSe = 3.17$, ns), showing no significant difference between performances on verb and preposition items overall, or with Sessions.

The Real World Test completion times for the two groups combined were analysed using the same within-subjects factors as the individual analyses and one between-groups factor, Groups (2 levels: Group A and Group B). There was a significant main effect of Sessions, $F(2,24) = 9.81$, $MSe = 156.30$, $p<.001$. The means for sessions 1, 2 and 3 collapsed across Function type were 15.36, 12.04 and 10.79 minutes respectively. Post-hoc Newman-Keuls tests ($P<.05$) showed speed in session 1 to be significantly slower than speed in session 2, but there was no significant difference between speeds in sessions 2 and 3.

The main effect of Groups was not significant ($F(1,12) = .57$, $MSe = 53.44$, ns) and neither was the main effect of Function type ($F(1,12) = .08$, $MSe = .96$, ns). In addition, none of the interactions approached significance.

Figures 41 and 42 show that speed of performance increased for both groups although Group A made larger gains as indicated by the ANOVA. (The pre-therapy status of the two groups was almost identical: Group A - mean time taken, verbs 14.9 minutes, prepositions 16 minutes; Group B verbs, 15.1 minutes, prepositions 15.6 minutes). An important finding was that real world items showed greater improvements in speed than microworld items (the savings shown in Figures 41 and 42 were on 20 item tests, whereas there were 40 items tested in the computer-based verb and preposition tests represented in Figures 35 and 36). Therapy was therefore successful in improving the speed as well as the accuracy of the real world sentences. It is also interesting to note that the upturns in speed shown by Group A in microworld verbs and prepositions between sessions 2 and 3 (see Figure 35) did not occur in the Real World Test (where both groups showed improvements in speed in both functions at each test session).

5.4 OVERALL TREATMENT OUTCOME

The foregoing sections of this Chapter have presented a wide-ranging analysis of the performances of P1..P14, examining both accuracy and speed data for verb and preposition items across the three test sessions. Group performances were considered, the profiles of individual subjects, the relative responsiveness of the different sentence structures to treatment, the effects of treated and untreated lexical items on treatment outcome and the extent to which treatment effects generalised to the more naturalistic Real World Test. The data set was a complex and rich one. In exploring it a balance was sought between on the one hand, swamping the reader with indigestible amounts of minutiae, and on the other, overlooking important observations facilitated by the output of the assessment software. The timing data was found to add an essential, though often neglected, dimension to the treatment results, without which, it was argued, accuracy data provides an incomplete and potentially misleading picture.

In attempting a summary of the results of this efficacy study three related issues emerged which are at the forefront of current clinical debate. The first, and central one, is the notion of overall *treatment outcome*; finding some global measure of treatment effect by which an individual's progress can be gauged and by which the outcomes of different subjects can be compared. The other two issues depend on amassing a database of treatment outcomes together with a method of analysing them. One concerns the ability to formalise, study, rationalise and debate the bases for decisions regarding ongoing patient management, the other is the complementary process of selecting the most appropriate candidates for therapy programmes in the first place, based on previous treatment histories (they both hinge on being able to derive useful prognoses). Clearly, as this is the first study of its type, there were no previous cases with which to compare P1..P14, so at the patient selection stage there was no basis for predicting outcome. These 14 cases constitute the first records in a clinical database which it is hoped will be expanded by the replication and extension of this work in other centres. That being the case, it was felt useful to provide in addition to the details of performance herein, a measure of treatment outcome for each patient, an indication of whether any factor or combination of factors could be identified which would have predicted treatment outcome, and finally, based on the experience of this clinical trial, what the recommendations for P1..P14 would have been were therapy to have continued, and why.

Table 51 summarises the changes to accuracy and speed of P1..P14 in verbs and prepositions and for both functions combined. The subjects are presented in descending order of overall treatment outcome according to a formula outlined below. Negative results do not necessarily imply that patients got worse, but show that when speed *as well as* accuracy was taken into account these outcomes were judged to be, on balance, negative. Negative treatment outcomes are not synonymous with unsuccessful treatment (the accuracy of the four subjects at the bottom of Table 51, on verbs and prepositions, had improved in 7 out of 8 cases), on inspection they may indicate a strong case for further treatment, possibly of revised complexity. All the data in Table 51 are based on changes in performance between sessions 1 and 3 (i.e. the difference between pre-therapy status and performance after completion of the second treatment block). The accuracy entries in Table 51 have been calculated by subtracting the score at session 1 (expressed as a percentage of 40) from the score at session 3 (expressed as a percentage of 40). Thus for every improvement of 1 point on an assessment test a patient was deemed to have improved by 2.5%, irrespective of his baseline score. The speed entries were calculated slightly differently, there not being a fixed target. For these, the changes were based on the subject's test completion time at session 1. For example, P1 took 45 minutes to complete the Verb Test pre-therapy and 31 minutes at session 3, so his speed datum is -31.11% $((45-31)/45) \times 100$, an improvement of just under one third. Where a patient's pre-therapy time was less than 30 minutes (a threshold explained below) and his session 3 time exceeded 30 minutes, only the increase beyond 30 minutes was considered in calculating the speed component (P5 was the only patient to whom this rule applied).

In calculating the overall outcome for each treated function (the columns headed P.I., an abbreviation for *performance indicator*) the signs preceding the speed data were reversed (because a negative change to speed constitutes an improvement). Increases in time taken were ignored (scored as zero in the calculation of the P.I.) where the test completion time at session 3 was under 30 minutes⁸⁶ *and* there had been an increase in accuracy (e.g. P3 Verb Test), in all other cases the speed and

⁸⁶ This was to avoid small increases in time taken negating or diminishing increases in accuracy, where the final operating speed was still very acceptable (P3, P9, P10, P13 and P14 were involved). P4 and P10 provide data to clarify this principle. Both subjects showed increases of 33.33% in time taken to complete assessments (P4 preps, P10 verbs) however P4's time taken increased from 39 minutes to 52 minutes whereas P10's increased from 6 to just 8 minutes. These are extreme examples, but show that when considering the implications of increased response times, it is necessary also to bear in mind the absolute time taken and whether the increase represents a functional handicap.

accuracy changes were summed and divided by two.⁸⁷ Similarly the final column, marked 'overall treatment outcome', was obtained by summing the two performance indicators and dividing the result by two.

| TREATMENT OUTCOME | | | | | | | |
|-------------------|-----------|--------|--------|------------------|--------|--------|---------------------------|
| | VERB TEST | | | PREPOSITION TEST | | | Overall treatment outcome |
| | Accuracy | Speed | P.I. | Accuracy | Speed | P.I. | |
| P1 | +45.00 | -31.11 | +38.06 | +57.50 | -23.08 | +40.29 | +39.18 |
| P8 | +7.50 | -47.06 | +27.28 | +20.00 | -45.24 | +32.62 | +29.95 |
| P2 | +37.50 | -51.19 | +44.35 | +25.00 | +15.56 | +4.72 | +24.54 |
| P6 | +22.50 | -12.50 | +17.50 | +12.50 | -22.22 | +17.36 | +17.43 |
| P12 | +12.50 | -24.66 | +18.58 | +5.00 | -20.51 | +12.76 | +15.67 |
| P7 | +17.50 | -28.57 | +23.04 | -5.00 | -12.90 | +3.95 | +13.50 |
| P10 | +25.00 | +33.33 | +12.50 | +25.00 | +16.67 | +12.50 | +12.50 |
| P14 | +15.00 | -19.23 | +17.12 | +7.50 | +14.29 | +3.75 | +10.44 |
| P3 | +20.00 | +18.18 | +10.00 | +10.00 | +12.50 | +5.00 | +7.50 |
| P13 | -2.50 | -3.85 | +0.68 | +27.50 | +10.00 | +13.75 | +7.22 |
| P9 | +25.00 | +8.33 | +12.50 | -22.50 | +4.17 | -13.34 | -0.42 |
| P4 | +7.50 | +28.13 | -10.32 | +32.50 | +33.33 | -0.42 | -5.37 |
| P11 | +25.00 | +17.65 | +3.68 | +5.00 | +51.52 | -23.26 | -9.79 |
| P5 | +27.50 | +45.00 | -8.75 | +17.50 | +44.83 | -13.67 | -11.21 |

Table 51. Indicators of treatment outcome P1..P14.
(P.I. is an abbreviation for performance indicator)

Thirty minutes was chosen as the functional speed threshold for the calculations in Table 51 based on the performance characteristics of P1..P14. The rationale for this was as follows: It was felt that the patients fell into three categories; P10 was a singleton, being the only subject to operate in the normal speed range. Secondly there was a set of subjects such as P3, P7, P13 and P14 who operated in the 20..30 minute range in both functions before and after therapy. Thirdly, there was a set of patients with excessively long response times, e.g. P1, P2, P4 and P12, and/or who declined in speed following treatment to overly long times, e.g. P5 and P11. In no case was therapy successful in reducing total time taken below 20 minutes and on the whole the patients in the 20..30 minute band remained fairly static. Thus on the basis of this small sample of patients and this small input of

⁸⁷ Notice, for example, that a large improvement in speed without an improvement in accuracy would result in a halving of the impact of the speed increase, because in that case the accuracy component would be zero. The same is true of an accuracy increase without a speed increase (subject to the '30 minute rule').

therapy, there is little cause for optimism in seeking to substantially reduce the processing speed of patients into the vast range between P10's speeds of 6.8 minutes and P7's next best time of 20 minutes. On the other hand, there was considerable success in reducing the very long processing speeds down towards the 30 minute mark, e.g. P1. Thus 30 minutes was selected as a functional cut-off point; a realistic target speed for slower patients, and for faster patients a speed below which increases in accuracy were considered to outweigh increases in time taken.

It must be stressed that Table 51 *is a guide only* as to how the quantitative results of treatment may be used to calculate and rank outcomes. Having produced such a preliminary model, it becomes much easier to formulate relevant questions as to appropriate weightings and whether, for example the introduction of functional thresholds (or performance bands) would be better than applying the same rules no matter what the pre-therapy/post-therapy level of impairment. For example, it may be felt that the method used above places too high a weighting on speed compared with accuracy and that a patient such as P5, who improved on both functions (verbs 21/40 -> 32/40; preps 22/40 -> 29/40) though showing large speed increases (verbs 20 mins -> 39 mins; preps 29 mins -> 43 mins) still merits a positive overall treatment outcome. (As explained above, an effort has been made to ameliorate the effect of a speed increase where the patient was still operating at a good (aphasic) functional level (30 minutes or less)). On the other hand, P12's performance indicator for the Preposition Test is possibly lower than his achievement merits because he was at ceiling on accuracy and his increase in speed had been diluted by a very small positive change in accuracy. In most cases, of course, objectives will be to improve both speed and accuracy, but this example highlights the need for flexibility in building evaluative systems so that exceptional objectives can be accommodated. Appropriate threshold levels are clearly a matter for debate and much more work needs to be done on treating sentence processing deficits to establish recovery patterns and thus be able to set realistic therapeutic goals and make informed judgements as to efficacy.

Given the range of performances evident in this small patient cohort, it is unlikely that the development of any evaluative algorithm, no matter how sophisticated, would satisfy all aphasic cases equally well. It is certainly not suggested that automation should supplant human clinical judgement, but that it provides the basis for objective decision-making (the premises of which are open to scrutiny) and for shareable clinical databases. What is clear from this study is that speed

must be an important parameter in the evaluation of sentence-level therapy, because of the very long response latencies that typically arise and the potentially serious functional consequences of unduly prolonging them. Moreover, in assessing treatment outcome it is important to be able to distinguish cases where increases in time taken constitute increases in handicap (irrespective of accuracy, e.g. P4), and conversely, for instance, to be able to credit improvements in speed independent of changes in accuracy (e.g. to P12 who was near ceiling on prepositions prior to therapy, but was slow).

There is no such thing a definitive formula and certainly a realistic clinical model would want to take a number of variables into account, perhaps favouring one version over another for different purposes. However, Table 51 does produce a principled ranking of P1..P14 suitable as the core of an equation that could be fine-tuned for increased sensitivity and to which additional factors could quite easily be added. It was pleasing to see that even by this rather stringent measure of treatment outcome, only four patients gave concern that the overall treatment effects had been other than resoundingly positive. An examination of the two accuracy columns shows that between sessions 1 and 3, all patients except P13 made progress on verbs and all patients with the exception of P7 and P9 made progress on prepositions. Therefore, of the 14 subjects treated, 11 showed improvements in accuracy on both verbs and prepositions, the remaining three improved on one function and declined on the other (only one of these latter patients, P9, failed to respond to therapy on the function that was weaker at session 3 than at baseline, P7 and P13 both improved after treatment and then regressed). However, it is also clear from Table 51 that response time suffered in many cases; 6 patients took longer to complete the Verb Test at session 3 than at the baseline test and 9 of the 14 patients took longer to complete the Preposition Test. Hence, response time was adversely affected in many cases, a few of which resulted in serious degradations of 'performance' as shown by the performance indicators (Table 51). Since the amount of therapy given was very short (six hours in each function), it is possible that extending the treatment period might have shown greater benefits to time taken, and perhaps even larger improvements to accuracy.

The method used to calculate the treatment outcomes in Table 51, while advocated as giving a more comprehensive account of responses to therapy than an accuracy-alone ranking, does produce a very different impression of the patients' performances than would have been obtained by considering only

changes in accuracy. To explore the degree of difference between the method used above and the more usual score-based evaluations, the two accuracy entries in Table 51 were summed for each patient and the rank ordering, shown in Table 52, was compared with the ordering given in Table 51. The correlation between the two was found to be low ($r=0.2$). For this reason, although the discussion which follows is based primarily around the preferred composite treatment outcomes shown in Table 51, reference is made to parallel calculations which were performed on the rankings in Table 52 to ensure that no important observations were missed.

| | | | | | | | | | | | | | | |
|----------------|----|----|-----|----|----|----|----|-----|----|-----|-----|-----|----|----|
| Rank | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Subject | P1 | P2 | P10 | P5 | P4 | P6 | P3 | P11 | P8 | P13 | P14 | P12 | P7 | P9 |

**Table 52. Ranking of P1..P14 by overall improvement in accuracy only.
(verbs and prepositions)**

Next, in the light of the treatment results, the issue of 'backcasting' is considered to see whether there were any factors that seem to have been predictive of responsiveness or otherwise to therapy. There are two interlinked aspects to consider; the performance of the two groups and the performance of individual subjects. Throughout this chapter the poorer performance of Group B has been evident. To what can this be attributed? Was it the effect of the ordering of the treatment blocks, could the administering clinician have been a factor or were the results due to Group B containing patients who were on average more impaired than those in Group A and who proved less able to benefit from the short amount of treatment given?

During the course of the treatment analyses there was cause to speculate that experiencing preposition therapy first may have been disadvantageous to Group B. As a result of treating verbs first with Group A it was discovered that there is an extra layer of specificity involved in processing locative prepositional sentences, over and above understanding the lexical items in isolation and knowing the significance of word order (this is discussed further in section 6.1.2). This was demonstrated by the fact that Group A improved in speed on preposition sentences as a result of verb therapy, but their accuracy remained absolutely static. It can therefore be argued that mastering S-V-O structures is a helpful pre-condition, if not a prerequisite, to successfully tackling locatives. If

this is so, Group B may have been doubly disadvantaged by their treatment ordering, firstly by confronting locatives before simple active declaratives had been secured, and secondly by having their fragile grasp of locatives undermined by the swift change to the more general verb items. As mentioned earlier, the fact that the prepositions chosen for therapy all happened to cast the first object mentioned in a subordinate position to the second, may well have provoked a conflict with the application of the 'first noun-phrase is dominant' rule reinforced by the verb therapy. Hence the effect of verb therapy for those with a weak grasp of locatives may have been to 'overwrite' the particulars of locative treatment with the more general S-V-O mechanism. Group B's response data provided some evidence to support this explanation, both in their lack of generalisation to untreated items after preposition therapy and in an increase in reversal errors after verb therapy (especially P9), however among the errors elicited at session 3 were a number related to preposition meanings which should not have been undermined by verb therapy.

Apart from the issue of a natural sequence and the suggestion that verb sentences should be introduced first on account of their commonality with locatives, but their greater generality, there may also be a case for arguing that functions should be tackled in increasing order of complexity as evidenced by the results of a patient or patient group. The point being that functions may be differentially impaired and perhaps rather than basing the sequence of therapy either on indicators of complexity in normals, or on linguistically-based criteria, it may be more productive simply to start with the function which seems to be least disordered in the individual(s) (building outwards from what can be done best). If Group B could be shown to have been significantly poorer on preposition items than on verb items at session 1, starting with preposition therapy may have been contra-indicated for this group irrespective of the validity of the previous arguments. In fact only very weak evidence was found for there being any difference between the two functions at the outset, so there was no insight to be gained here. (The mean scores at session 1 were verbs 18.43, preps 18.29. Five subjects took longer on the Verb Test and five subjects had slightly lower scores on the Verb Test (pointing perhaps to verbs being marginally harder) against which the median score for prepositions was a little lower (16) than for verbs (20). Incidentally, Group A showed absolute equality between the two functions at the outset in these respects).

The possibility of the administering clinician being a contributory factor to the inter-group variation was raised above. While it cannot be discounted (as I treated all of the subjects in Group A and P6 and P12 in Group B, while a colleague treated the five other members of Group B), the characteristics of Group B's performance make it unlikely to have been the major cause. Preposition therapy clearly was effective for Group B. That verb accuracy improved too, though less, for this group, whereas preposition accuracy did not improve in Group A while verbs were being treated, seems more likely to have been related to the treatment orderings (given the very structured nature of the tasks) than to the administering clinicians. Similarly, the fact that Group B declined on prepositions after withdrawal of therapy is less convincingly attributed to ineffective therapy than failure to make any progress in the first place. One would expect inter-clinician effects, if present, to influence the degree of progress made, but not to alter outcome profiles as fundamentally as witnessed here. A further point which would tend to argue against a strong clinician factor, is that during an extended phase of treatment reported in section 5.5, I shared the treatment of P9 who had previously been unsuccessfully treated by my colleague. The outcome was typical of the poorer Group B results, i.e. dramatic item-specific benefits of treatment, but no generalisation and equally dramatic loss of accuracy on treatment withdrawal.

The third possibility introduced above was that the composition of Group B may offer a large part of the explanation. It may simply have been, that although there was no way of foretelling this, several patients in Group B turned out to be less responsive to therapy than their counterparts in Group A, independent of, or perhaps in addition to the conjectured disadvantage of the treatment ordering. During the course of the present chapter it was observed that the poorer results of Group B were not just confined to the effects of one or two patients. The combined effects of several subjects conspired to produce the disappointing profile illustrated in Figure 17 (p. 165), by either not showing function-specific effects of treatment appropriately, not improving on untreated items after therapy or not maintaining improvement in treated items after withdrawal of therapy. The question is, were the poorer results due to the characteristics of the Group members themselves or to the treatment conditions they experienced?

A retrospective examination of the Syntax Screening Test (SST) results, by group, showed that the median score (collapsing the data across the three test sessions) was slightly lower for Group B (Group A, median = 24.0; Group B median =

21.33) and that Group B had a larger range (Group A range = 7.33; Group B range = 15.34). Likewise with the pre-therapy Western Aphasia Battery (WAB) results (Group A median = 74.9, range = 18.3; Group B median = 72.3, range = 48.6). These observations indicated considerably more variability among the members of Group B than Group A. Group B members P9, P11 and P14 were particularly weak patients on initial assessment with the SST (see Table 13, p. 93). Ranking the 14 subjects by total score over their three assessments with this test, P9, P11 and P14 came 11th, joint 12th and 13th respectively. (On the pre-therapy Western Aphasia Battery they ranked 13th, 6th and 12th respectively). These patients were major contributors to the poorer results returned by Group B (especially P9 who yielded an inexplicably large increase in verb accuracy after preposition therapy and an even more bizarre score of 1/20 on treated preposition items after preposition therapy, and P14 who lost almost all of his large gain on treated prepositions after withdrawal of therapy). The magnitude of these changes was very significant in shaping the overall group results. While there was no way of foreknowing that P9 and P11 would continue to be weak subjects (whereas P2 (in Group A) and P6 (in Group B) who were also very weak initially, would make impressive progress) they, and P14, were nevertheless all assigned to Group B. It seems unlikely that the performance of these subjects was group-dependent and more probable that Group B's results suffered by the chance allocation to it of these patients.

Group B also contained P12, who while he was a successful patient in achieving his therapy goals, was very close to ceiling on preposition accuracy at the outset, requiring therapy in this function for speed only, thus he brought to Group B very little potential for improvement in preposition accuracy.

Another point that emerged during analysis and appears to have prejudiced the Real World Test results of Group B (which were also inferior to those of Group A, c.f. Figure 16 (p. 162) and Figure 18 (p. 165)) was that, oddly, Group B were very much better at 'real world' verb items than at matched microworld verb items at first assessment. After preposition therapy 'real world' verbs had improved further, such that three subjects had attained 19/20 *prior* to verb treatment. This allowed almost no room for generalisation to occur and in fact all three 'bounced off this ceiling' on the final assessment, with small declines that contributed to a disappointing result between sessions 2 and 3.

From the foregoing it may be concluded that there is no simple explanation for the inter-group variation observed in the treatment results. The answer is likely to lie in a combination of the factors discussed. There is evidence that Group B contained a less homogeneous set of patients with respect to their pre-therapy status; this greater variability may have been responsible for Group B's more chaotic result profiles. While I have argued that there *may* have been an inherent disadvantage to the treatment ordering experienced by Group B, the treatment results of P4, P6 and P12 indicate that the 'prepositions first' treatment condition does not inevitably yield a muddled cross-over pattern, and suggests that with a different set of patients, a complementary outcome to that of Group A might have been obtained. Further replication studies are required to determine whether there is in fact an advantage to treating verbs first.

Finally, considering the subjects as individuals, I wondered whether it was possible to identify a factor or factors that might have been predictive of treatment outcome. In fact, Table 51 indicates that treatment was beneficial to some degree in all patients, and that it certainly changed the behaviours of all of them, so in looking for predictive factors we were seeking indicators of particular receptivity, and not of response versus non-response. In looking for prognostic factors, three domains were considered - the microworld, the additional pre-therapy assessments and factors external to the assessments that may have been salient. Within the microworld the SST results were examined, and the session 1 Verb Test and Preposition Test results (accuracy and timing). The additional assessments were those described in section 2.6; the WAB, the TROG and the test of digit-span recall (DSR). The 'external factors' considered were age, sex, interval post-onset, nature of neurological damage, motivation, previous occupation/intellectual level, domiciliary situation, density of hemiparesis and any relevant medical or social factors affecting the treatment period. All mentions of treatment outcome below refer to outcome as shown in Table 51 unless otherwise stated.

The 'external factors' were unenlightening. There was no relationship between age and treatment outcome rank order ($r=-0.23$) or number of months post-onset and treatment outcome rank order ($r=0.26$). There were only two female patients in the cohort and they were not distinguished from the males in outcome. Premorbid intellectual level or occupation does not seem to have been a factor (e.g. P11 and P4 would have been well-matched with P1 in this respect yet their outcomes were very different, whereas P8, P2 and P6 had much poorer

educational backgrounds and occupations, but all responded well to treatment). All the subjects were motivated enough to take part in this voluntary and exacting research programme and therefore deserve to be rated 'highly motivated', yet knowing them well it was possible to make subtle distinctions. However, there was no evident relationship between strength of desire to succeed and treatment outcome. Likewise domiciliary situation proved irrelevant; subjects alone in long-term care or sheltered accommodation (P6, P8, P9) were not distinguished from the others who were in family environments. By the same token, patients who suffered minor incidents such as falls (P6, P7) or fits (P8, P14) or underwent surgery (P3) performed at least as well as patients who did not. P1's wife and P4's family both mentioned independently and spontaneously that a change of anti-convulsive medication just prior to the treatment phase of the research had stabilised both subjects greatly, increasing confidence; yet their overall outcomes were quite different. P6 suffered a deep emotional upset coinciding with the onset of the treatment phase, yet still managed to make progress. So none of these factors appears to have been significant.

The only two 'external factors' that could not confidently be rejected as at least partial predictors of outcome were the related ones of nature of neurological damage and density of hemiparesis. Unfortunately the superficial details of the neurological damage sustained by P1..14 available from their speech therapy cases notes and supplied by referring therapists were inadequate to be able to undertake a detailed comparison of site and extent of brain damage with treatment effects. A question mark must therefore hang over whether such a study would have been fruitful. There is *perhaps* a suggestion in the ranking of patients in Table 51 that degree of paralysis may be negatively correlated with size of treatment outcome. P4, P6, P11 and P14 were the most severely affected in this respect and three of these appear in the bottom half of the Table.⁸⁸ (P4 and P14 were known to have had particularly massive CVAs). However, one can find counter-evidence - P3 (who had no hemiparesis) and P9 who was mildly affected are also both in the bottom half of Table 51.

Comparison of the patients' pre-therapy WAB, TROG and DSR performances with their treatment outcomes also yielded little of predictive value. Patients were not sufficiently well differentiated by the DSR for it to be very useful. However, it was noticeable that P1 and P2 had respectively the best and worst digit-span recalls and P11 and P12 had identical ones, so clearly digit-span had not

⁸⁸ Though P4 performed much better by accuracy alone (see Table 52).

been critical to treatment outcome. The treatment outcome rank order of P1..P14 was compared with their pre-therapy aphasia quotients ($r=0.24$) and with their pre-therapy TROG scores ($r=0$) and the degree of correlation was found to be low in the first case and zero in the second.⁸⁹

Finally, P1..P14's pre-therapy performances on microworld assessments were examined to see whether there was any indication of future responsiveness to treatment. The rank ordering of the patients by score over the three Syntax Screening Tests (SST1..SST3) was compared with that in Table 51 and the correlation between the two was found to be zero.⁹⁰ The patients' session 1 scores out of 40 and total times taken for test completion (Verb Test and Preposition Test separately) were compared to see whether there was any relationship on initial assessment between accuracy and time taken (as had been found in aphasics and normals in the SST results reported in Chapter 2). The correlation approached zero in both cases, indicating no correspondence (Verb Test $r=0.04$; Preposition Test $r=0.16$).

The patients' speeds for test completion at session 1 and their speed outcomes as shown in Table 51 were then compared for both tests. There was only a very low negative correlation for prepositions ($r=-0.25$) but the result for verbs ($r=-0.73$) confirmed that there was an inverse relationship between length of time taken initially to complete the Verb Test and the size of the reduction recorded at session 3. Essentially, the slower patients had been initially, the larger their speed increases had been. The inconsistent pattern for prepositions reflects the greater difficulty patients seemed to experience with locatives; long completion times were almost as likely to increase (P4) as to decrease (P8).

A further comparison was done to explore the predictive value of accuracy results obtained at session 1. The initial accuracy scores out of 40 were compared with the accuracy outcomes shown in Table 51 for each test separately. The results for verbs and prepositions were once again different, tending to reinforce the results reported in the previous paragraph. No relationship was found between initial accuracy in prepositions and the overall change to accuracy shown in Table 51 ($r=-0.04$), but a moderate degree of negative correspondence was present in the

⁸⁹ Similar correlations were obtained using the patients' accuracy-alone rankings and comparing them with their ranking on the pre-therapy WAB ($r=0.02$) and with pre-therapy TROG scores ($r=0.13$).

⁹⁰ This was almost the same as comparing rank by SST1..SST3 with rank by accuracy gains only ($r=0.05$).

verb results ($r=-0.5$). The latter shows some tendency for patients with the weakest initial scores to have made the largest improvements in accuracy.

In view of there being a zero correlation between patients' initial accuracy in prepositions and the change in preposition accuracy recorded at session 3, P1's result was particularly striking. His Preposition Test results were the most successful in the entire study and the improvement was maintained (see section 5.6). The reason for this was that I was able to discover *the reason* for his very consistent role reversal errors and therefore help where a number of previous therapies had failed. This is discussed further in section 6.1.2. The point to be made here is that increased diagnostic precision enables better-targeted therapy, which in turn has better chances of success. I attribute much of the success of this treatment study to the diagnostic edge afforded by both assessment and remediation software coupled with the heavily analytical approach taken in their use. If the nature of the problem is consistent and conscious application of an inappropriate rule (rather than of cognitive degradation seriously degrading ability to complete a parsing task) and this rule can be discerned, the prospects of remediation are extremely good.

To summarise; the search for factors predictive of patients' outcomes to treatment yielded nothing compelling. There was insufficient consistency in the data set to be able to establish anything other than a good prospect of substantially increasing accuracy and reducing time taken in patients impaired in verb processing, presenting with slow initial speeds and poor initial accuracy. However, this is perhaps hardly surprising. The number of patients studied was small and they exhibited a very broad spread of abilities both in speed and accuracy at session 1. In spite of this, therapy was successful in improving aspects of the performance of all of them (and we shall see in section 6.2 that the benefits perceived by the patients, and sometimes the clinicians, often exceeded the purely quantitative ones reported so far). Had treatment been unequivocally beneficial in some cases and totally ineffective in others the chances of identifying predictive factors might have been higher. In fact, this short amount of treatment changed the behaviours of the patients in different ways, some improving in speed and accuracy, others in speed at the expense of accuracy and so forth, producing a complex data set that cannot be satisfactorily reduced to one or more simple input/output relationships.

However, the lack of a prognostic indicator that would account for the degree of benefit observed in P1..P14 is not seen as a major disadvantage. The value of prognostic information obviously increases with the cost of the treatment, (in resources, wasted effort in administering inappropriate treatment, lack of opportunity for treatment of suitable patients or delay in treatment of patients who would benefit, by misselection of others, etc.). If the improvements reported had been obtained after hundreds or even tens of hours of therapy, extending over many months, it would have been more important to be able to say who improved most and why. In fact they were obtained in only six hours per function administered in twice weekly sessions. Moreover the assessment used to select the patients for treatment (SST) took only one session to administer. The results of this study support offering microworld treatment to any patient who qualifies on initial assessment. Only by experience with much larger numbers of patients and with longer periods of treatment will it be possible to discover for whom and in what circumstances the benefits are greatest and most enduring, and what the limits are to the recoveries that can be made.

Three issues were raised at the beginning of this section; the formulation of a global measure of treatment outcome, the feasibility of predicting the outcome of future cases on the basis of the performances of P1..P14 and the implications of the performances of P1..P14 for ongoing treatment recommendations. I have discussed the formulation of a global measure of treatment outcome and used it and its components in the subsequent search for a prognostic indicator. The last issue to address is how one might proceed with P1..P14 if treatment were to continue.

Clinical decision-making is both hard to do and difficult to justify. Increasingly, practitioners are becoming aware of the benefits of collating and codifying expertise which is at present unavailable as a unified body of knowledge and of subjecting their intuitions to more formal appraisal (Lendrem and Leach, 1988), for example using decision analysis techniques (Weinstein and Fineberg, 1980). It was therefore of interest to find some way of rationalising a set of ongoing treatment recommendations for P1..P14 and then to explore the suitability of these by offering a second phase of treatment to a small number of subjects and studying the outcomes.

As with the generation of a global measure of treatment outcome, any algorithm to assist in making clinical recommendations will be found to throw up anomalous

cases, or cases who have only just failed to reach some designated threshold. However, having such a formula at all provides an objective framework whereby such individuals can be identified and discussed, and can lead, as with all adaptive systems, to the refinement and improvement of the formula itself over time. On the basis of the performances of P1..P14 and the insights gained into for example, average test completion times and what one might consider to be reasonable accuracy levels compared with accuracy levels that would indicate the need to simplify treatment materials, a computer program was written to generate tentative recommendations for ongoing management. The object of the exercise was to begin to identify the factors that might guide decision-making and to see whether subsequent therapy sessions would confirm or deny these intuitions.

The program was based on summarising the potential speed/accuracy combinations between sessions 1 and 3 as four mutually exclusive outcome conditions shown in Table 53.

| Condition | Accuracy improved | Speed improved or was static |
|-----------|-------------------|------------------------------|
| 1 | yes | yes |
| 2 | yes | no |
| 3 | no | yes |
| 4 | no | no |

Table 53. Treatment outcome combinations.

These were considered in conjunction with just four constants which were compared with session 3 outcomes; 'functional speed' which was set at 30 minutes and denoted the speed at or below which response time was not considered to warrant treatment, 'acceptable speed' which was set at 40 minutes, this was used as an indicator that complexity should be reduced or in combination with unacceptable accuracy (defined below), was an indicator that therapy should be discontinued as unsuccessful. The other two parameters were 'functional accuracy', set at 32/40, the level of attainment at or above which further therapy for accuracy was not recommended, and 'acceptable accuracy', which was set at 20/40 - below this complexity should be reduced or if speed was also unacceptable, then therapy should be abandoned. It would be premature to include the detail of the algorithm since the utility of any such decision aid can

only be established through verification with a large number of cases. To give a single example; setting functional speed at 30 minutes caused P1 to be recommended for further verb treatment for speed and P12 to be recommended for further preposition treatment for speed (they both took 31 minutes). If future experience of longer duration therapy shows that the chances of improving speed below 30 minutes is very small, then clearly the algorithm should be modified accordingly, for re-treating P1 and P12 would not be an efficient recommendation.

Out of interest, the treatment recommendations generated for P1..P14 are reproduced in Table 54. Fulfilling the objectives of this efficacy study precluded inviting P1..P14 to continue with treatment as recommended in Table 54, since it was important to ascertain whether the benefits of therapy they had shown thus far would endure after treatment had ceased. The cross-over design had permitted re-assessment of the first functions treated after an interval of 5 weeks, but there had been no such durability measure for the second functions treated. It was decided to re-test some of the subjects after an interval (with no further treatment) of 5 months; the results obtained are reported in section 5.6.

However, three patients whose responses to therapy had been disappointing in contrasting ways were invited to undertake a second phase of treatment. They were P4, P7 and P9. P4 had suffered serious degradations in speed and the recommendation for him was to simplify the treatment material, both for verbs and for prepositions. If he did not improve in speed after a second similar treatment input this recommendation would have been supported, however, if a second treatment period improved his speed, it would be an indication that the initial treatment was not too complex, but too short. P9 had plummeted catastrophically in his final preposition assessment, and I was naturally eager to explore why. His session 3 preposition responses were reminiscent of P1's at session 1 in the preponderance of reversal errors, it was therefore possible that his difficulty was similar. P7 was chosen as a contrasting case. She was not of great concern speed-wise, but had failed to maintain her progress in prepositions and had considerable room for improvement both in verbs and prepositions. The recommendation in Table 54 had been to reduce the complexity of her preposition treatment. Again, I wanted to test this, as with P4, by offering her 'more of the same'. P4, P7 and P9 were all keen to undertake a second treatment phase. Their results are presented in section 5.5.

| | VERBS | PREPOSITIONS |
|-----|--------------------------------|--------------------------------|
| P1 | re-treat (speed) | discharge successful |
| P2 | re-treat (speed) | reduce complexity and re-treat |
| P3 | re-treat (accuracy) | re-treat (accuracy) |
| P4 | reduce complexity and re-treat | reduce complexity and re-treat |
| P5 | re-treat (speed) | reduce complexity and re-treat |
| P6 | re-treat (accuracy) | re-treat (accuracy) |
| P7 | re-treat (accuracy) | reduce complexity and re-treat |
| P8 | re-treat (accuracy) | discharge successful |
| P9 | re-treat (accuracy) | re-treat (accuracy) |
| P10 | discharge successful | re-treat (accuracy) |
| P11 | re-treat (speed) (accuracy) | reduce complexity and re-treat |
| P12 | re-treat (speed) (accuracy) | re-treat (speed) |
| P13 | re-treat (accuracy) | discharge successful |
| P14 | re-treat (accuracy) | re-treat (accuracy) |

Table 54. Suggested ongoing treatment recommendations for P1..P14.

5.5 A TREATMENT EXTENSION PHASE WITH THREE SUBJECTS

The efficacy results reported in section 5.4 showed positive benefits of treatment in most of the subjects, taking both accuracy and speed into account. Since the duration of the therapy given had been short and the experimental design had not afforded an opportunity to test the durability of treatment effects in the second functions treated, it was decided to extend evaluation of this new treatment approach in two ways. The first was to select a small number of subjects who in different ways had produced disappointing results in the first phase of treatment, and to offer them a repeat. The object of this was to have a further opportunity to study their problems and to find out whether the initial six one-hour treatments had simply been too short to be maximally effective.

P4, P7 and P9 were the subjects selected for repeated microworld therapy and all three proved eager to take part. P4 and P9 had been members of Group B, who received preposition therapy first and P7 had been in Group A and therefore had received verb therapy first. For the second phase of treatment it was decided to repeat the cross-over design treating all three subjects on prepositions first. The potential for inter-clinician effects was reduced in this second phase by, instead of allocating each patient to only one clinician, sharing each patient between me

(MAC), my colleague Elizabeth Dean (ECD) and a small number of student therapists (ST) as shown in Table 55.

| | | MAC | ECD | ST |
|----|-------|-----|-----|----|
| P4 | verbs | 0 | 0 | 7 |
| | preps | 1 | 3 | 3 |
| P7 | verbs | 4 | 0 | 3 |
| | preps | 3 | 2 | 2 |
| P9 | verbs | 4 | 1 | 2 |
| | preps | 3 | 2 | 2 |

Table 55. Distribution of treatment hours among clinicians, phase two.

To counter the possible 'diluting' effects of the students' involvement and of non-continuous association with the same clinician, it was decided to give the patients seven one-hour sessions of treatment in each function (instead of six as previously). As before, the patients attended twice weekly. Therapy goals for each subject were based on their session 3 performances. The programme was therefore seven sessions of preposition therapy, followed by assessments (the Preposition Test, Verb Test and Real World Test⁹¹), followed by seven sessions of verb therapy and finally a repeat of the three assessments. The last assessments of the first phase of treatment took place on December 21 1990 and P4, P7 and P9 had no further contact with the clinic until the beginning of the second phase of treatment, in the second week of January 1991. The patients are presented as single cases below, with P4 and P9, for whom the sequence of therapy repeated their earlier treatment ordering, preceding P7 for whom the pattern was reversed.

P4 had been selected for extended treatment mostly on account of his very slow post-therapy speeds. On accuracy measures alone he had a good treatment outcome, especially for prepositions (see Figure 43 below), but when speed was taken into account he appeared towards the bottom of the patient cohort in rank ordering (c.f. Table 51, p.232 and Table 52, p.235). Figure 44, below, shows that P4's time taken had increased in both functions quite substantially from baseline (verbs, 32 -> 41 mins; preps 39 -> 52 mins), the length of time recorded at session 3 for prepositions being alarming, despite his impressive improvement in accuracy (17/40 -> 30/40). A second aspect of P4's performance which had been

⁹¹ It was decided that there was no need to continue testing morphology as it had proved, in both groups, to be unaffected by verb and preposition treatment.

disappointing was his failure to respond at all to treated verb items (see Figure 43).

Table 54 (p. 246) shows that according to the criteria discussed in section 5.4 the recommendation for P4 would have been to reduce the complexity of the remediation materials in both functions. By not following this advice, and giving him more treatment at the same level, I wanted to find out whether P4 would respond as desired (showing that he had the capacity to do so but that the initial treatment duration was too short) or whether he would continue to exhibit excessive response times, indicating that the recommendations generated were appropriate. The results of P4's second treatment phase are shown in Figures 43, 44 and 45. In interpreting the three graphs below, it is important to keep in mind both the temporal details of the test sessions and the sequence of therapies administered between them. Preposition therapy was given between sessions 1 and 2 and between sessions 3 and 4, verb therapy occupied the other two blocks.

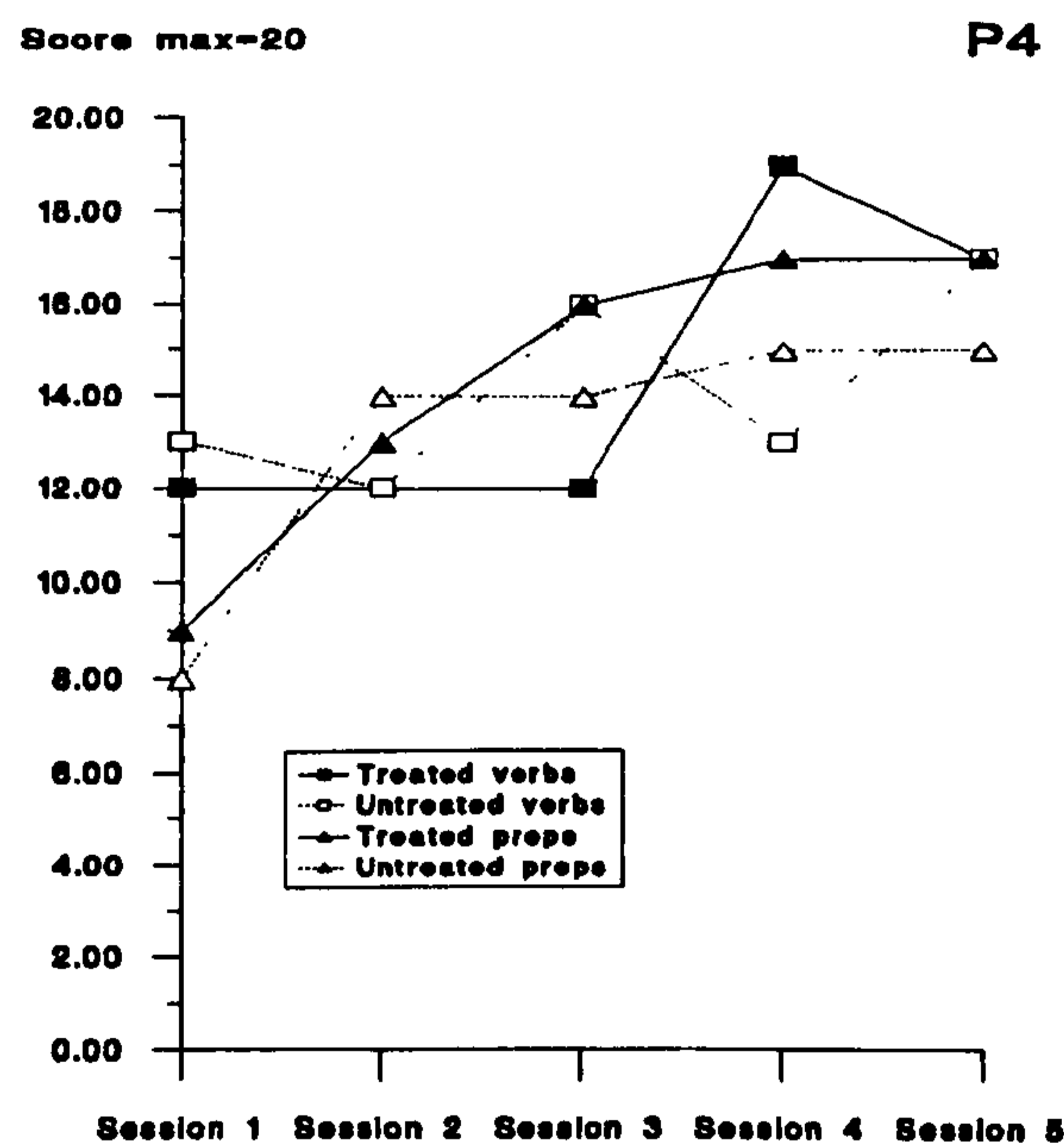


Figure 43. P4's performance profile (accuracy).

Preposition therapy was given between sessions 1 and 2, and between sessions 3 and 4.

Verb therapy was given between sessions 2 and 3 and between sessions 4 and 5.

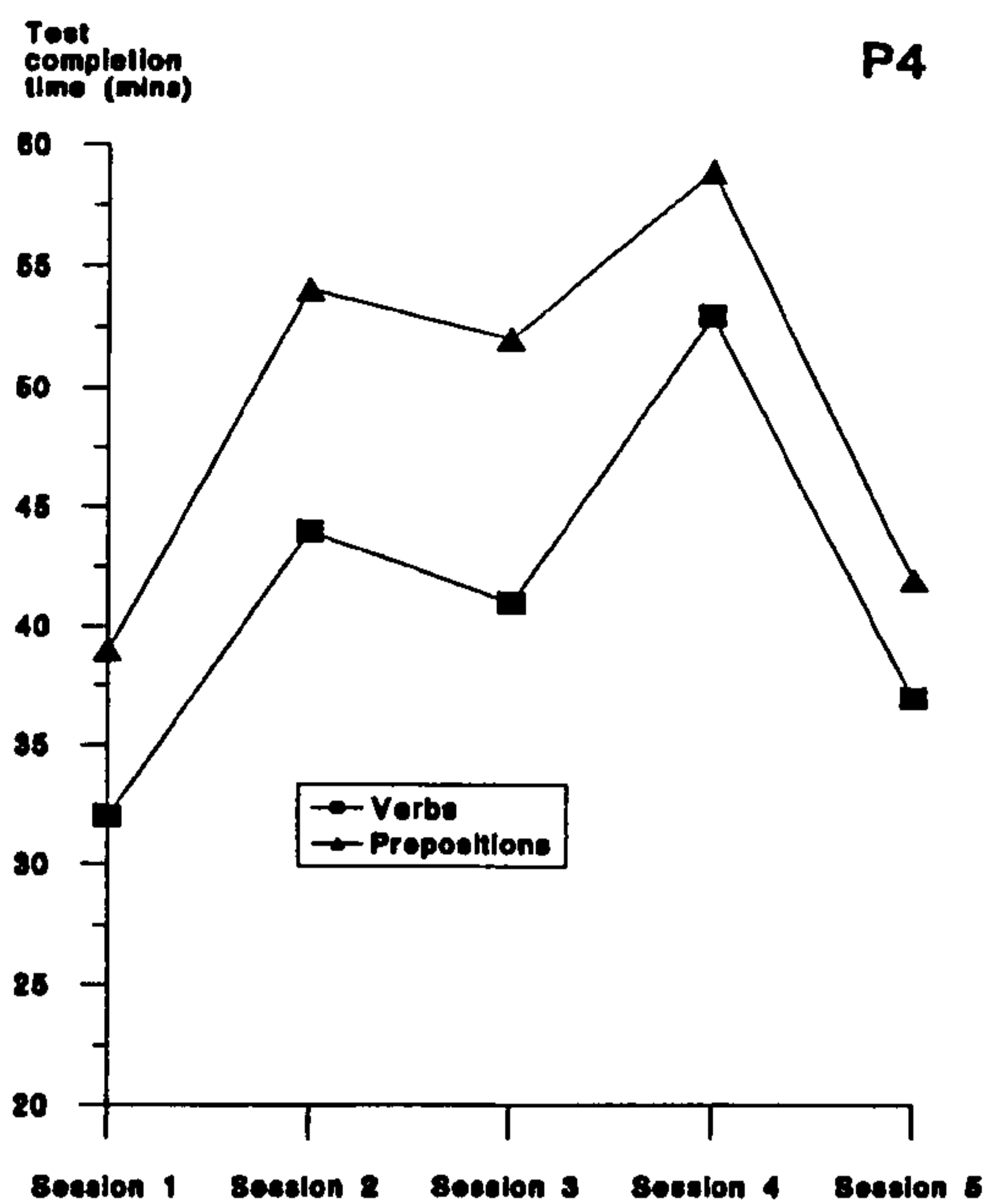


Figure 44. P4's performance profile (speed).
 Preposition therapy was given between sessions 1 and 2, and between sessions 3 and 4.
 Verb therapy was given between sessions 2 and 3 and between sessions 4 and 5.

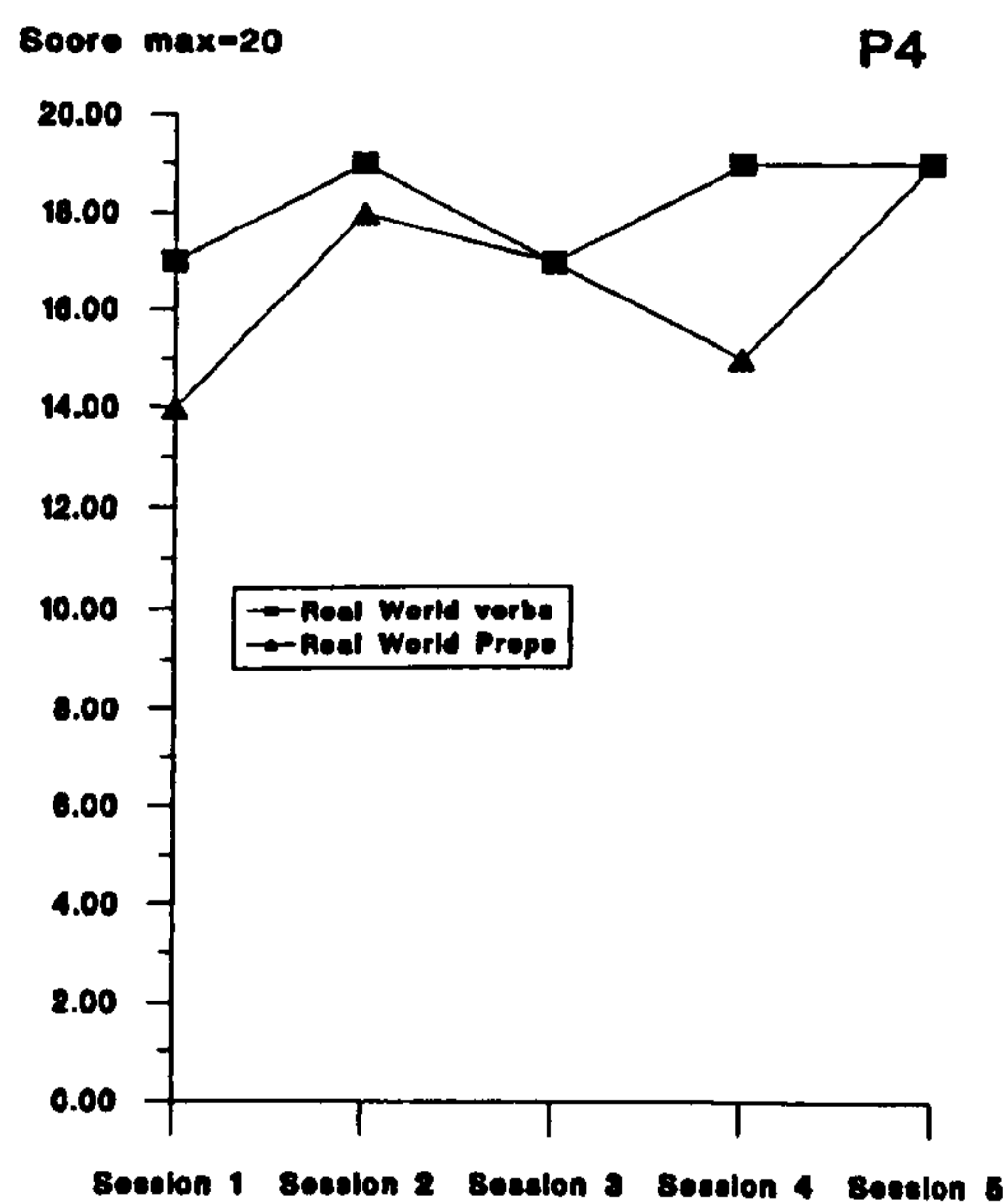


Figure 45. P4's Real World Test performances.
 Preposition therapy was given between sessions 1 and 2, and between sessions 3 and 4.
 Verb therapy was given between sessions 2 and 3 and between sessions 4 and 5.

Figures 43 and 44 show that at session 4, after preposition therapy, P4's prepositions had improved just two points to 32/40, however, his time taken had worsened to 59 minutes. His Verb Test results showed a marked improvement to the treated side (12/20 -> 19/20) and an overall improvement of 4 points to 32/40 despite the fact that it was 10 weeks since P4 had last had verb treatment. Unfortunately, this further improvement in accuracy was accompanied by a serious further degradation in speed. Although at session 4, P4 had achieved 80% accuracy in both treated functions, he was taking close to one hour for each test. The Real World test, on which P4 was close to ceiling at session 3 stayed static at 34/40, but the time taken increased from 22 minutes at session 3 to 33 minutes at session 4. At the midway point of P4's second treatment phase it seemed that the recommendation to simplify the treatment materials had been correct. P4 appeared to be at his cognitive limit, and the increase in time taken more than negated the small gain in overall accuracy.

However, the changes recorded at test session 5 gave considerable cause for optimism. Following this second block of verb therapy P4 achieved 34/40 on the Verb Test (17/20 on either side), taking only 37 minutes. (The mean response time to treated items declined much more than to untreated items) He maintained his previous Preposition Test results exactly, but reduced his time taken to 42 minutes (again the mean response time to treated items declined more than to untreated items). Finally, he increased his accuracy on the Real World Test to 38/40 and reduced the time taken to do this test from 33 minutes to 23 minutes.

P4's second treatment input was indeed beneficial, without any reduction in the complexity of the items treated and tested. From this subject's performance it seems that we cannot expect improvements in speed and accuracy to necessarily co-occur, there may be two phases of learning; the first where accuracy is increased but with a trade-off in speed and the second where the degradation in speed is reversed. In this case, the recommendation to simplify the treatment materials seems to have been premature. As found with some Group A subjects between their sessions 2 and 3, P4 exhibited a 'sleeper effect' on verbs, showing an improvement on the items that had been treated, not directly after therapy, but after a further period of assimilation. At session 5 both P4's test completion times were longer than they had been at session 1 but not worryingly so. Although the total therapy input had not managed to improve his speed, his session 5 results were markedly more accurate than those at session 3. An interesting feature

highlighted by Figure 44 was the parallel movement that occurred in P4's timing data in the face of the alternating treatment conditions applied, prepositions taking longer throughout.

Table 56 shows P4's re-calculated performance indicators (P.I.) for both treated functions and his overall treatment outcome based on changes between session 1 and 5. These were calculated in the same way as described for the entries in Table 51 (p. 232).

| | VERB TEST | | | PREPOSITION TEST | | | Overall treatment outcome |
|----|-----------|--------|-------|------------------|-------|--------|---------------------------|
| | Accuracy | Speed | P.I. | Accuracy | Speed | P.I. | |
| P4 | +22.50 | +15.63 | +3.44 | +37.5 | +7.69 | +14.91 | +9.18 |

Table 56. P4's Treatment outcome after extended therapy.

Table 56 shows that after a second phase of treatment P4 had improved on his pre-therapy status to the extent that his revised treatment outcome would have ranked him in 9th place in Table 51, instead of in 12th place. We must conclude from this that the initial duration of therapy was not long enough to allow P4 to benefit to his capacity. The results reported in this section indicate that the patient may have had further progress to make. They also suggest that a period of rest between treatment inputs may be more efficacious than simply extending the length of the treatment blocks.

P9 had been selected for extended treatment on account of his perplexing phase one results. His Verb Test accuracy had almost doubled at session 2 after preposition therapy, but then remained static after verb therapy. His Preposition Test accuracy declined slightly after preposition therapy and at session 3, after verb therapy, had dropped to 7/40 (1/20 on treated items). Figure 21a (p. 183) shows that P9 was a relatively weak subject at the outset in accuracy, but Figure 38a (p. 217) shows that he operated at a good (aphasic) speed. Not having had the opportunity to see this patient during the first phase of remediation, I was keen to explore his difficulties further. In the light P1's progress, and the fact that P9 had made 7 reversal errors (n=8) on structure 1 (treated) preposition sentences at session 3 (c.f. P1 (Table F) and P9 (Table G) (Appendix 12)) there seemed at least a prospect that P9 might now be poised to respond to treatment.

P9's performances across the five test sessions are summarised in Figures 46, 47 and 48.

P9's session 4 results were encouraging. His Verb Test results were static although it was 10 weeks since he had last been treated on these and test completion time had dropped from 26 minutes at session 3 to only 18 minutes at session 4. The Preposition Test results showed a clear effect of treated items, his previous score of 1/20 had risen to 15/20, however, there was no generalisation at all to untreated items in the microworld and the time taken to complete the Preposition test increased quite steeply. Disappointingly, 'real world' items declined between sessions 3 and 4 in both functions (see Figure 48) although the time taken dropped sharply to only 17 minutes.

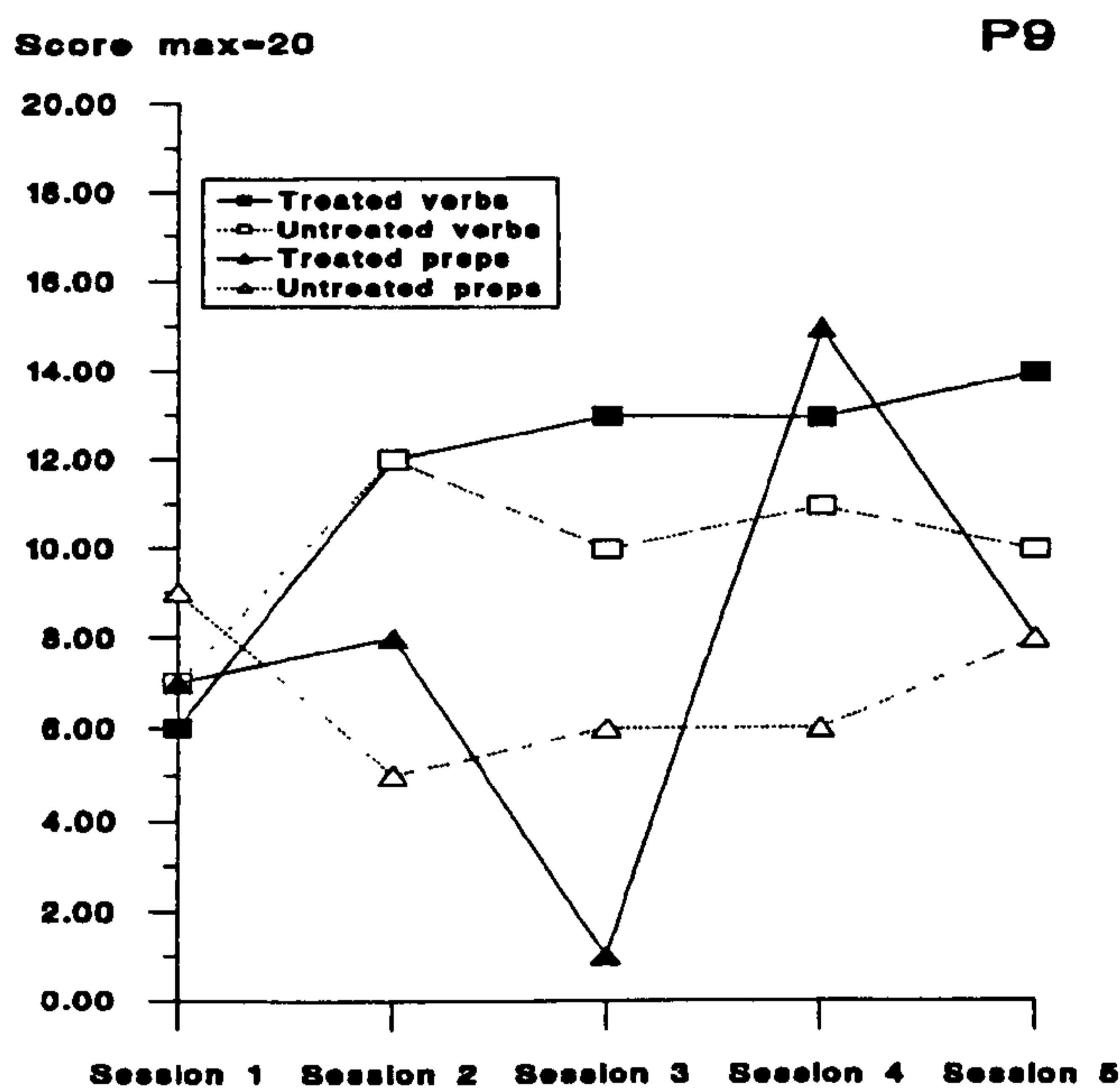


Figure 46. P9's performance profile (accuracy).

Preposition therapy was given between sessions 1 and 2, and between sessions 3 and 4.

Verb therapy was given between sessions 2 and 3 and between sessions 4 and 5.

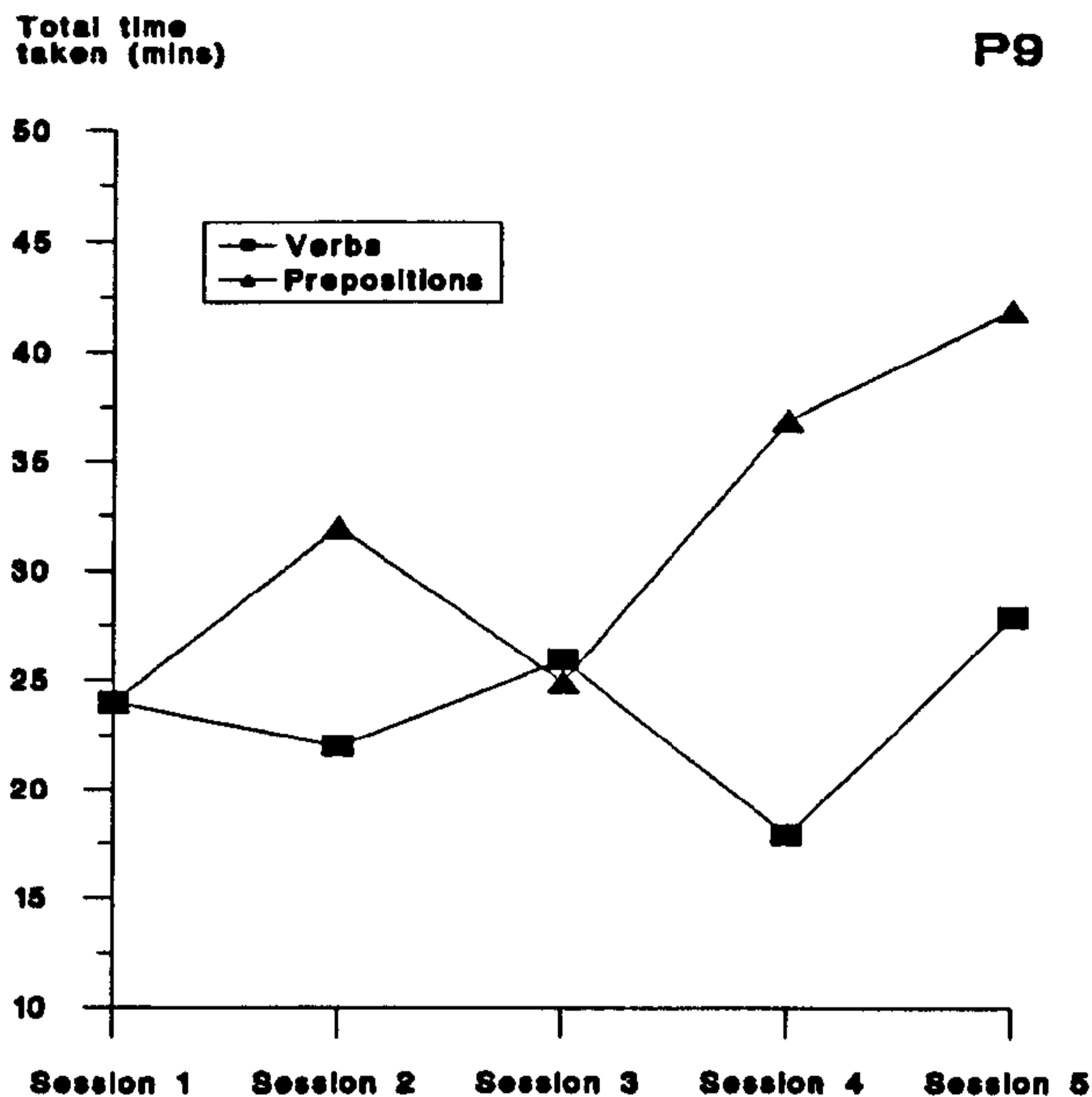


Figure 47. P9's performance profile (speed).
 Preposition therapy was given between sessions 1 and 2, and between sessions 3 and 4.
 Verb therapy was given between sessions 2 and 3 and between sessions 4 and 5.

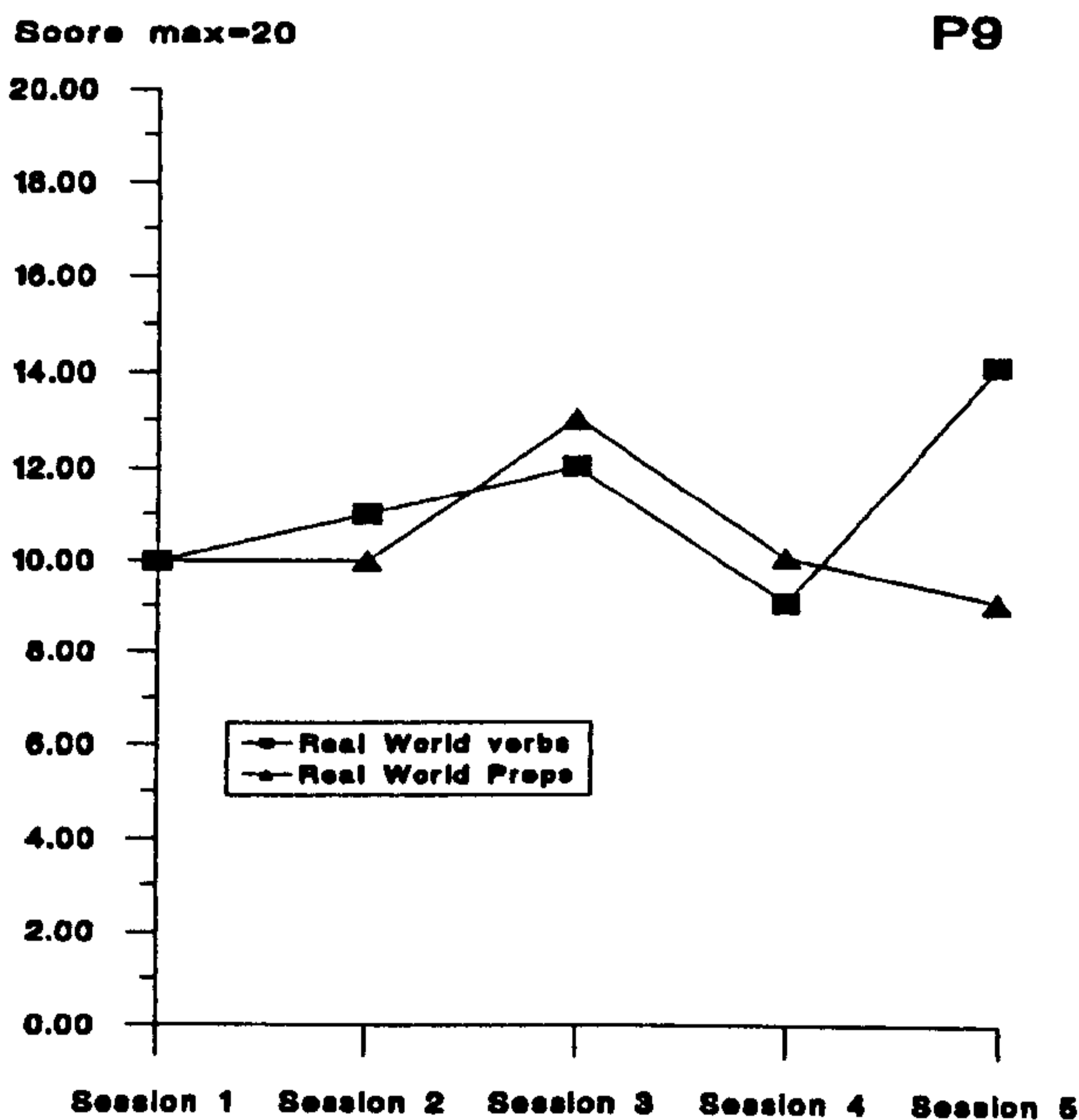


Figure 48. P9's Real World Test performances.
 Preposition therapy was given between sessions 1 and 2, and between sessions 3 and 4.
 Verb therapy was given between sessions 2 and 3 and between sessions 4 and 5.

At session 5, following the second block of verb therapy, P9 showed no improvement in accuracy on verb items (which had now been static since session 2) and his test completion time had increased to its maximum. The dramatic improvement in treated prepositions at session 4 had disappeared at session 5, leaving P9 at his pre-therapy (session 1) accuracy, but now seriously impaired in speed. His 'real world' verb items had responded to verb therapy, but the time taken had also risen, making his overall result in this test little different from at session 1.

It would appear that microworld therapy was of little benefit to P9. There were glimmers of hope in his Verb Test speed at session 4 and his response to treated prepositions in session 4, but overall we were not successful in raising the accuracy of this patient to a satisfactory level and in prepositions his outcome was negative. P9 had almost no verbal output, so it was difficult to explore his problems in the same way as with P1 (who had a little expressive language). He made remarkable progress during remediation sessions, reaching the point where he was faultless in repairing incorrect sentences generated by me to target pictures, fixing incorrect prepositions, noun-phrase reversals, indeed any combination of incorrect lexical components. That he could make this progress at all and demonstrate it in the subsequent picture-matching test does show that he had some capacity to re-acquire sentence understanding strategies, but very little ability to generalise his learning or to preserve it after withdrawal of therapy. In this respect his performance pattern (timing excepted) was very similar to that of P14 (see Figure 21b, p. 184).

Table 57 shows P9's overall treatment outcome between sessions 1 and 5. There had been a very small positive change in the Verb Test performance indicator since session 3 (+12.50) (note that the increase in time taken at session 5 was ignored under the '30 minute rule') but not enough to justify the extra treatment. Prepositions were unchanged from session 1 in accuracy and very much slower, producing a high negative outcome.⁹² P9's overall treatment outcome after extended therapy was substantially worse than at session 3. In fact, it would have ranked him at the bottom of Table 51.

⁹² Because P9 did not improve on accuracy between sessions 1 and 5, he incurred the full time penalty, i.e. the '30 minute rule' did not apply.

The ongoing treatment recommendations for this patient, according to the algorithm outlined in section 5.4 (see Table 54, p. 246), would have been to terminate preposition therapy as unsuccessful and to persist with verb therapy on the grounds that speed was 'functional' and accuracy was 'acceptable'. The algorithm was deliberately designed to be conservative in its recommendations (i.e. it gives the patient the benefit of the doubt) the idea being that while clinical experience with the system was slender, patients would tend to be recommended for extended therapy if they showed any promise at all. The criteria could then be systematically refined as knowledge increased. P9's outcome highlights the need to introduce a limit to the number of times therapy is offered to a subject who fails to make progress, but also fails to drop below 'acceptable' level. P9's profile on verbs across sessions 2 to 5 is a pattern that probably should not merit further treatment (of this type, at this time).

| | VERB TEST | | | PREPOSITION TEST | | | Overall treatment outcome |
|----|-----------|--------|--------|------------------|--------|--------|---------------------------|
| | Accuracy | Speed | P.I. | Accuracy | Speed | P.I. | |
| P9 | +27.5 | +16.67 | +13.75 | 0.00 | +75.00 | -37.50 | -11.88 |

Table 57. P9's Treatment outcome after extended therapy.

The third and final patient who was involved in the extended treatment phase was P7. She was offered a second treatment period because her Preposition Test results at session 3 were not improved over session 1 and her Verb Test results at session 3 showed no generalisation to untreated items. In interpreting P7's changes in performance over the five test sessions shown in Figures 49, 50 and 51, it is important to remember that (unlike the alternating pattern of treatments given to P4 and P9) she received verb therapy between sessions 1 and 2 and between sessions 4 and 5, and preposition therapy between sessions 2 and 3 and between sessions 3 and 4.

Figure 49 indicates that P7 showed function specific effects at session 4 after her second block of preposition treatment, with gains in both treated and untreated preposition items while performance on the Verb Test did not improve. However, at session 5, after a second block of verb therapy, P7's preposition performance had dropped sharply on both treated and untreated items to her lowest score over the five sessions (14/40). The Real World Test showed no benefit of preposition treatment at session 4.

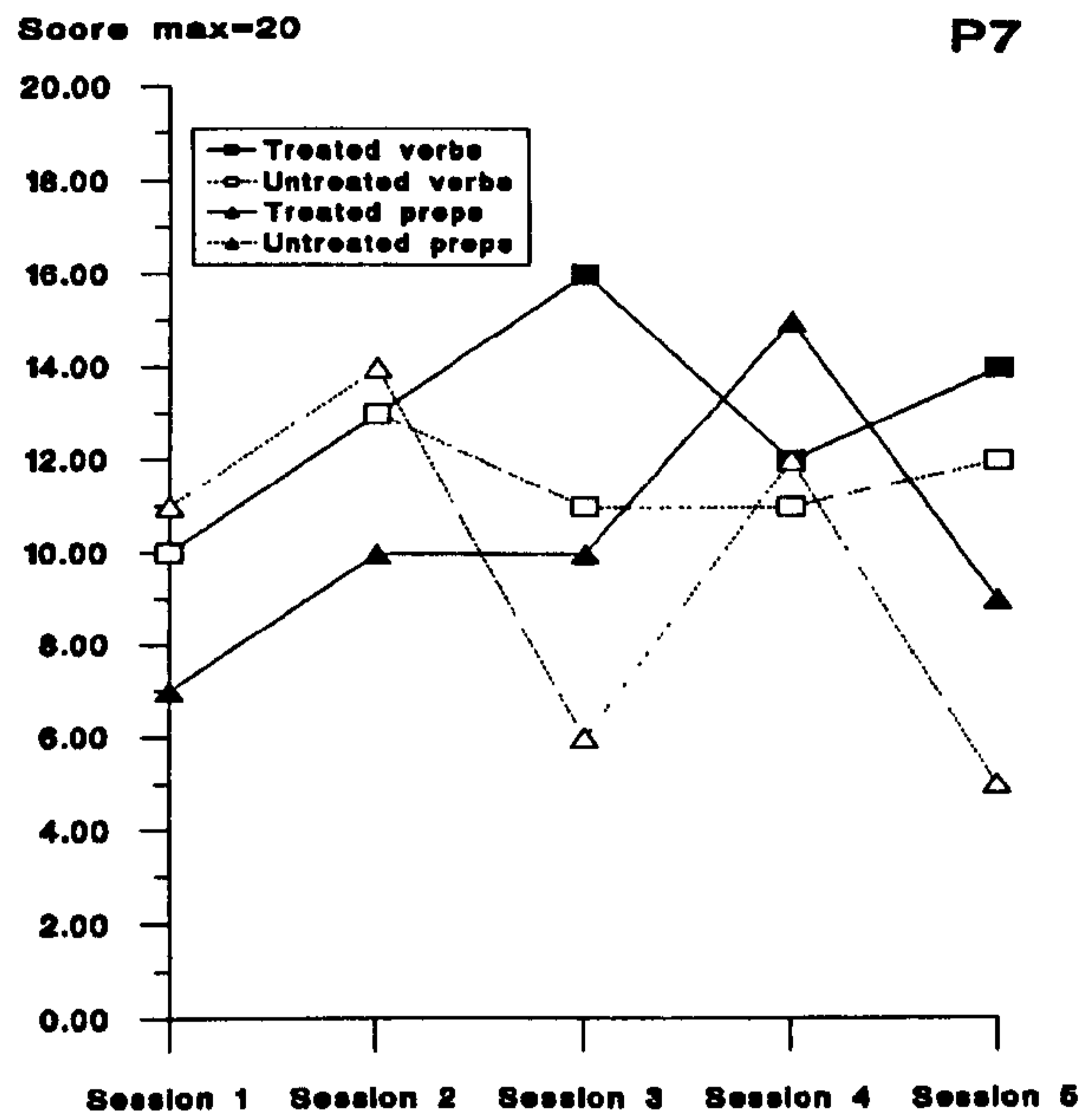


Figure 49. P7's performance profile (accuracy).

Verb therapy was given between sessions 1 and 2, and between sessions 4 and 5. Preposition therapy was given between sessions 2 and 3 and between sessions 3 and 4.

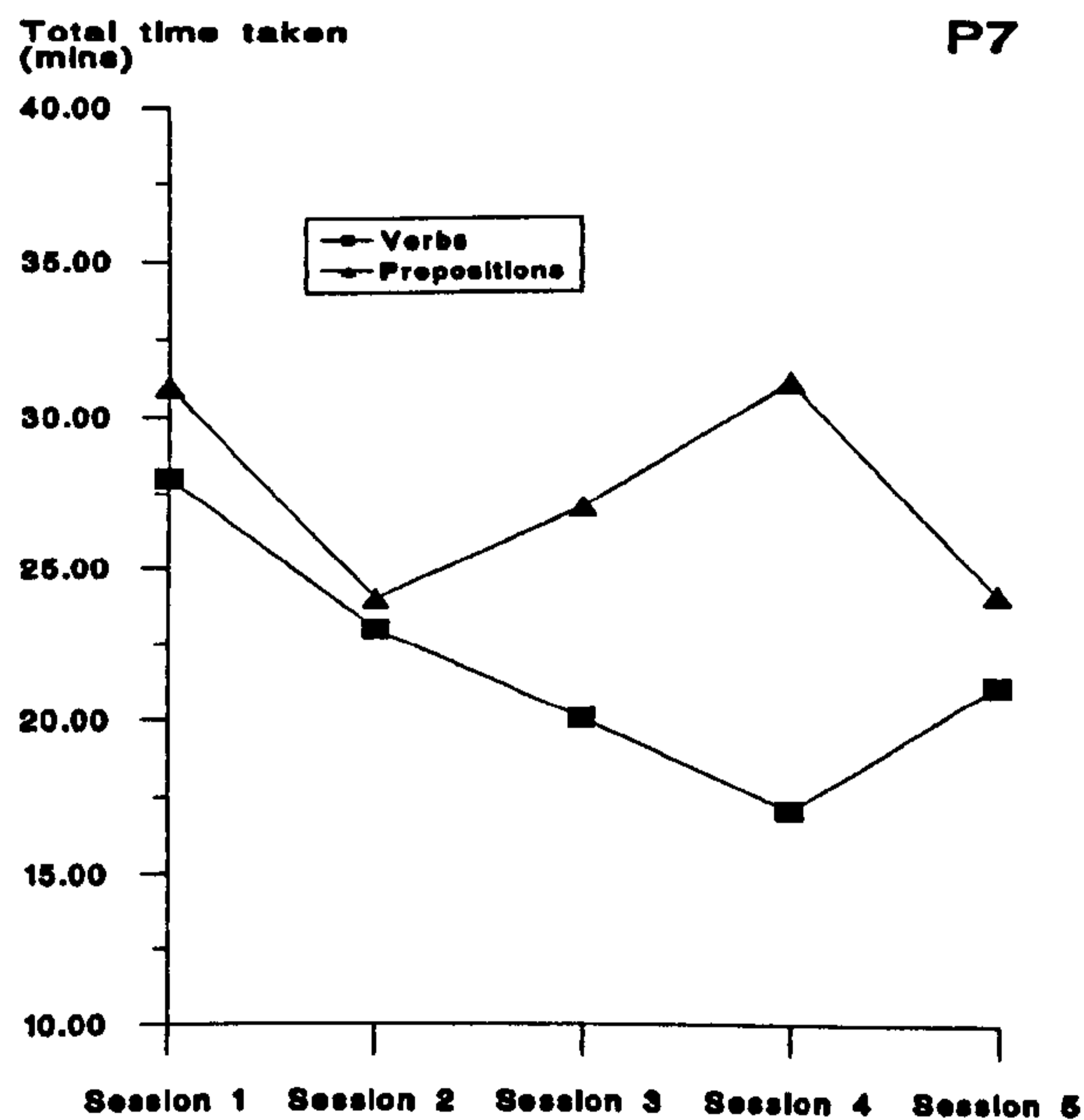


Figure 50. P7's performance profile (speed).

Verb therapy was given between sessions 1 and 2, and between sessions 4 and 5. Preposition therapy was given between sessions 2 and 3 and between sessions 3 and 4.

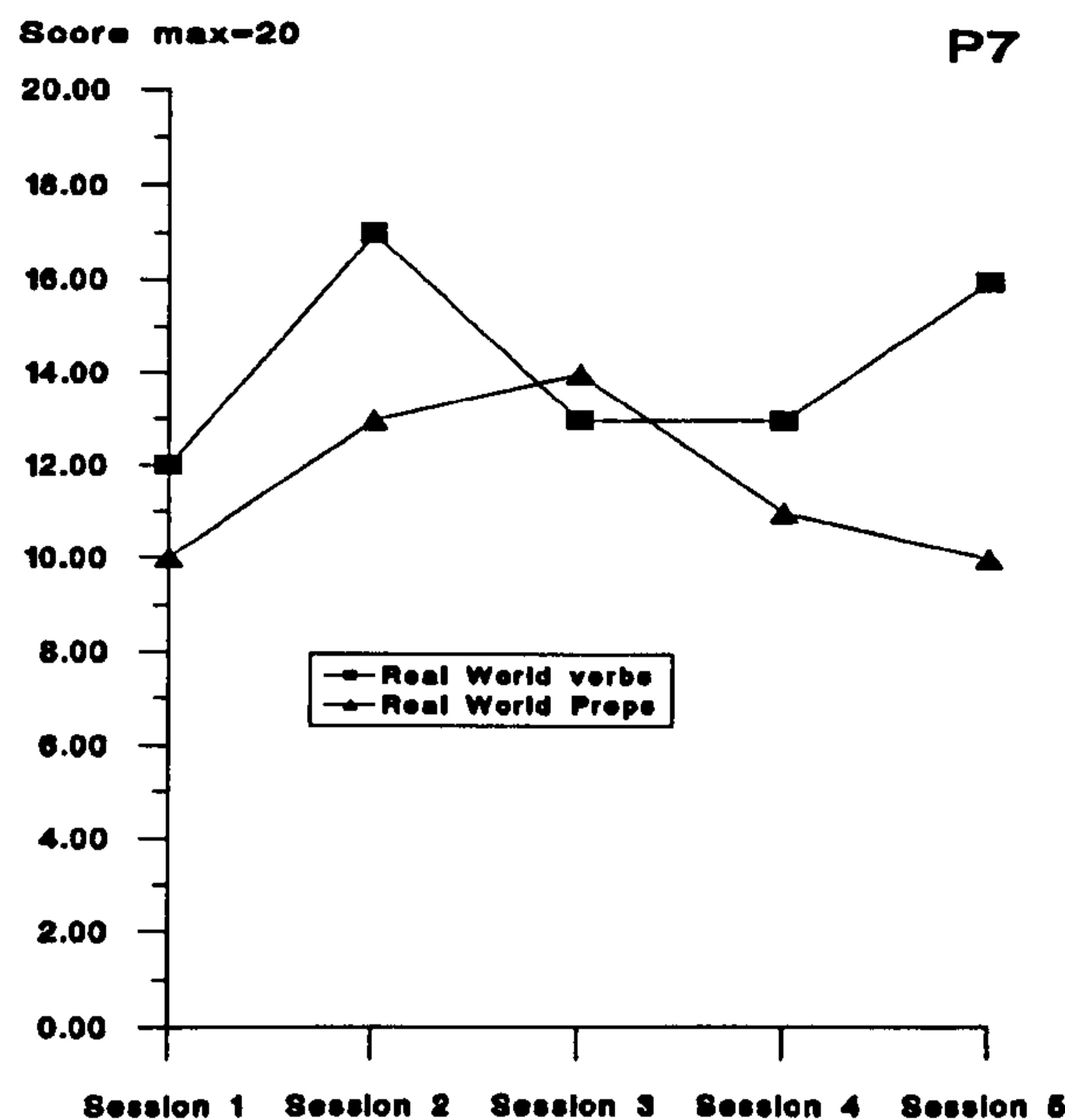


Figure 51. P7's Real World Test performances.

Verb therapy was given between sessions 1 and 2, and between sessions 4 and 5.
Preposition therapy was given between sessions 2 and 3 and between sessions 3 and 4.

There was a small positive effect of verb therapy on the Verb Test at session 5, however, P7 was still performing no more accurately than at session 2 (after the first block of verb therapy had been given). The same was true of 'real world' verbs, which had been close to ceiling at session 2 (17/20).

P7 showed some impressive decrements in time taken, especially on verb items where the trend was more stable. However, despite operating at very acceptable speeds, she proved unable to sustain progress in accuracy (as her very erratic pattern, especially in prepositions, shows). P7's overall treatment outcome was re-calculated on the basis of change from session 1 to session 5, the results are shown in Table 58.

| | VERB TEST | | | PREPOSITION TEST | | | Overall treatment outcome |
|----|-----------|--------|--------|------------------|--------|-------|---------------------------|
| | Accuracy | Speed | P.I. | Accuracy | Speed | P.I. | |
| P7 | +15.00 | -25.00 | +20.00 | -10.00 | -22.58 | +6.29 | +13.15 |

Table 58. P7's Treatment outcome after extended therapy.

A comparison of Table 58 with P7's entry in Table 51 confirms that there was no quantitative benefit of the second treatment phase. P4 was therefore the only patient of the three for whom extra treatment raised performance beyond the level attained after the first treatment phase.

5.6 THE DURABILITY OF TREATMENT EFFECTS

Seven of the aphasic subjects who had taken part in the efficacy study were recalled after a no-treatment period of approximately five months to assess the durability of the treatment effects.⁹³ It was decided only to recall subjects who had been relatively successful: there was no point looking at durability in those who had not made progress or who were not at a reasonable functional level after therapy. Additionally, P12 and P14 did not wish any further assessment. P4, P7 and P9 were not available for durability tests, having had extended therapy. The subjects re-assessed after five months were P1, P2, P3, P5, P8, P10 and P13; of these, all except P8 had belonged to Group A. For convenience, this subset of patients will be referred to hereafter as the 'durability group'. There were three durability tests; the Verb Test, Preposition Test and Real World Test. The conditions under which the durability results were obtained were exactly as described for the efficacy study proper, i.e. the computer-based tests were operated by the patients with no participation by the observing clinician (myself in all cases).

The purpose of this section is to compare the performance of the durability group over test sessions 1, 3 and 4 (i.e. at baseline, at the end of the treatment phase (when both verbs and prepositions had been treated) and after a further no-treatment period of five months). Since all subjects, irrespective of previous group membership, had received treatment for both verbs and prepositions by session 3, the seven subjects were considered together in conducting an analysis of variance (ANOVA) on the session 1, session 3 and session 4 results.

The nomenclature used in this section is the same as in Chapter 4 - *Function type* referring to verbs and prepositions and *Treatment set* to treated and untreated items. ANOVA was carried out on the data for the durability group as before,

⁹³ The latest date on which any of these subjects had treatment (which was on the second function treated) was 7.12.1990. The durability tests took place between 6.5.1991 and 24.5.1991.

with 3 within-subjects factors - Sessions (3 levels: session 1, session 3 and session 4), Function type (2 levels: verbs and prepositions) and Treatment set (2 levels: treated and untreated). The results of the treatment data are presented first, followed by the results of the Real World Test.

Treatment data. The accuracy scores of the durability group for the Verb Test and Preposition Test across the three test sessions are given in Table 59. The summary rows in Table 59 are shown graphically in Figure 52, from which the maintenance of treatment effects is clearly evident.

| | session | VERB TEST | | | PREPOSITION TEST | | |
|---------|---------|----------------|------------------|--------------|------------------|------------------|--------------|
| | | treated /20 | untreated /20 | total /40 | treated /20 | untreated /20 | total /40 |
| P1 | s1 | 7 | 9 | 16 | 5 | 7 | 12 |
| | s3 | 19 | 15 | 34 | 20 | 15 | 35 |
| | s4 | 20 | 17 | 37 | 20 | 16 | 36 |
| P2 | s1 | 7 | 10 | 17 | 10 | 9 | 19 |
| | s3 | 18 | 14 | 32 | 17 | 12 | 29 |
| | s4 | 18 | 17 | 35 | 17 | 18 | 35 |
| P3 | s1 | 12 | 11 | 23 | 8 | 15 | 23 |
| | s3 | 16 | 15 | 31 | 15 | 12 | 27 |
| | s4 | 14 | 13 | 27 | 11 | 12 | 23 |
| P5 | s1 | 12 | 9 | 21 | 11 | 11 | 22 |
| | s3 | 17 | 15 | 32 | 14 | 15 | 29 |
| | s4 | 17 | 15 | 32 | 16 | 13 | 29 |
| P8 | s1 | 15 | 13 | 28 | 15 | 14 | 29 |
| | s3 | 19 | 12 | 31 | 19 | 18 | 37 |
| | s4 | 18 | 16 | 34 | 16 | 17 | 33 |
| P10 | s1 | 10 | 13 | 23 | 10 | 11 | 21 |
| | s3 | 16 | 17 | 33 | 16 | 15 | 31 |
| | s4 | 13 | 13 | 26 | 11 | 17 | 28 |
| P13 | s1 | 12 | 12 | 24 | 12 | 13 | 25 |
| | s3 | 13 | 10 | 23 | 19 | 17 | 36 |
| | s4 | 16 | 11 | 27 | 17 | 19 | 36 |
| mean s1 | | 10.71 | 11.00 | 21.71 | 10.14 | 11.43 | 21.57 |
| mean s3 | | 16.86 | 14.00 | 30.86 | 17.14 | 14.86 | 32.00 |
| mean s4 | | 16.57 | 14.57 | 31.14 | 15.43 | 16.00 | 31.43 |

Table 59. Verb and Preposition Test results for the durability group.

There was a significant main effect of Sessions, $F(2,12) = 11.75$, $MSe = 198.14$, $p = .001$. The means for sessions 1, 3 and 4 collapsed across Function type and Treatment set were 11.1, 15.7 and 15.6 respectively (max=20). Post-hoc Newman-

Keuls tests ($p < .05$) showed performance in session 1 to be significantly worse than in session 3 but showed no significant change between sessions 3 and 4. There was no significant main effect of Function type ($F(1,6) = .004$, $MSe = .05$, ns) or of Treatment set ($F(1,6) = 3.06$, $MSe = 21.0$, ns) showing that overall, no significant difference was found between verbs and prepositions or between treated and untreated items.

The first order interaction between Sessions and Treatment set approached significance, $F(2,12) = 3.47$, $MSe = 14.71$, $p = .06$, suggesting a difference between treated and untreated items across sessions. Figure 52 shows the tendency for performance on treated and untreated items to be more similar at session 4 (5 months post-treatment) than at session 3 (immediately post-treatment).

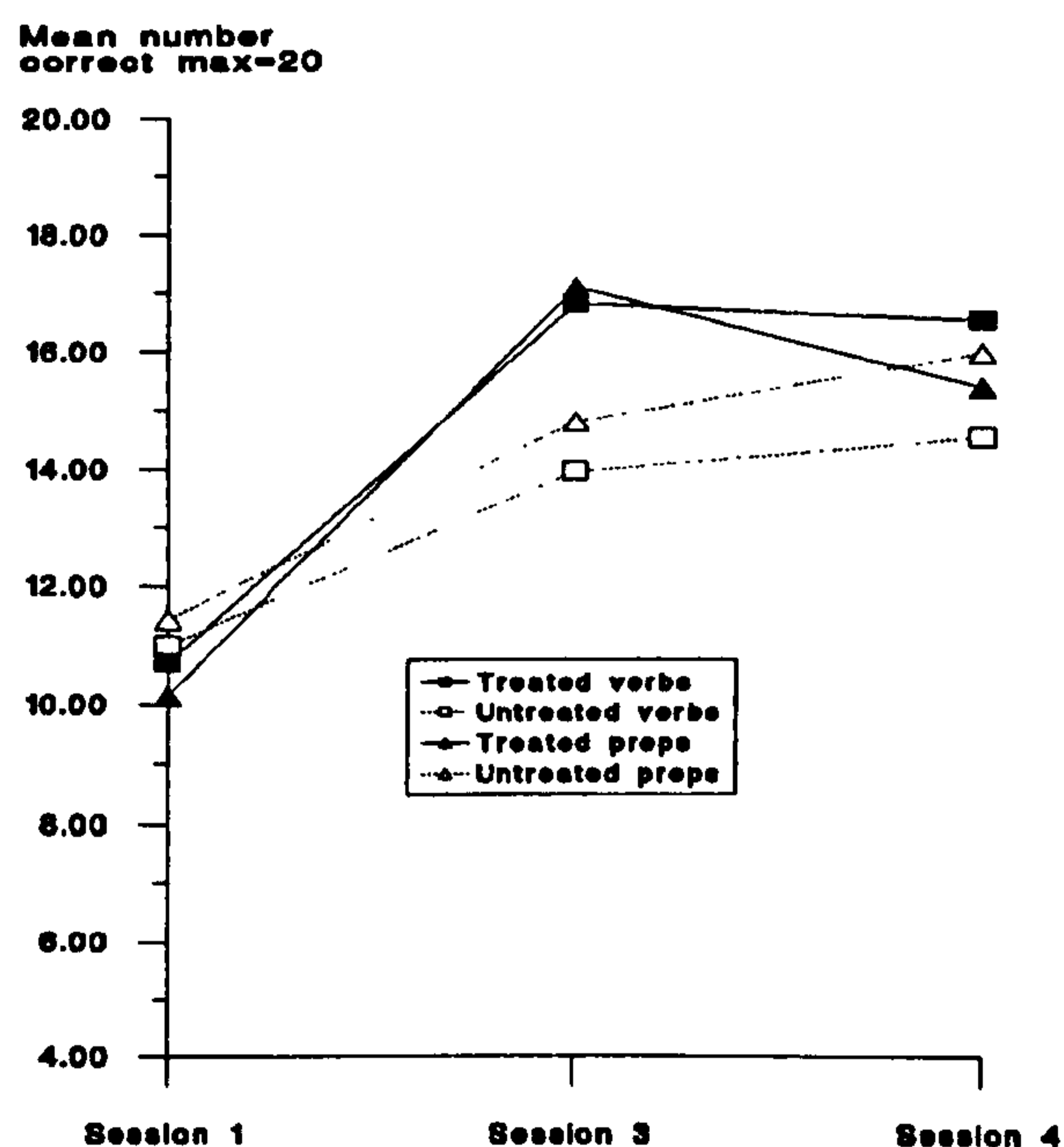


Figure 52. Verb and preposition durability results.

The first order interaction between Function type and Treatment set also approached significance, $F(1,6) = 5.03$, $MSe = 15.43$, $p = .07$. Collapsed across sessions, treated verbs tended to be better than untreated verbs, whereas the mean values for treated and untreated prepositions was almost identical. The difference in accuracy between treated and untreated verb items was not present

at session 1 (treated verbs, mean = 10.71; untreated verbs, mean = 11.0). Figure 52 shows that generalisation to untreated preposition items tended to be more successful than to untreated verb items. This suggestion is strengthened by evidence from the Real World Test presented below, where the interaction between Function type and Treatment set was found to be significant and to follow the same pattern.

Real World Data. The performance of the durability group on the Real World Test across test sessions 1, 3 and 4 is shown in Table 60. The means for the verb and preposition items are plotted in Figure 53.

| REAL WORLD TEST | | | | | | | |
|-----------------|---------|----------------|------------------|--------------|----------------|------------------|--------------|
| | | VERBS | | | PREPOSITIONS | | |
| | session | treated /10 | untreated /10 | total /20 | treated /10 | untreated /10 | total /20 |
| P1 | s1 | 8 | 5 | 13 | 2 | 3 | 5 |
| | s3 | 10 | 7 | 17 | 9 | 9 | 18 |
| | s4 | 10 | 9 | 19 | 10 | 10 | 20 |
| P2 | s1 | 6 | 4 | 10 | 7 | 4 | 11 |
| | s3 | 10 | 5 | 15 | 7 | 5 | 12 |
| | s4 | 10 | 6 | 16 | 9 | 7 | 16 |
| P3 | s1 | 9 | 7 | 16 | 4 | 10 | 14 |
| | s3 | 10 | 8 | 18 | 9 | 8 | 17 |
| | s4 | 9 | 7 | 16 | 7 | 8 | 15 |
| P5 | s1 | 6 | 3 | 9 | 7 | 5 | 12 |
| | s3 | 10 | 7 | 17 | 8 | 10 | 18 |
| | s4 | 10 | 5 | 15 | 9 | 5 | 14 |
| P8 | s1 | 9 | 6 | 15 | 9 | 9 | 18 |
| | s3 | 9 | 8 | 17 | 7 | 9 | 16 |
| | s4 | 9 | 10 | 19 | 9 | 10 | 19 |
| P10 | s1 | 9 | 5 | 14 | 7 | 8 | 15 |
| | s3 | 9 | 6 | 15 | 7 | 10 | 17 |
| | s4 | 9 | 8 | 17 | 8 | 10 | 18 |
| P13 | s1 | 8 | 5 | 13 | 8 | 8 | 16 |
| | s3 | 10 | 4 | 14 | 10 | 8 | 18 |
| | s4 | 10 | 6 | 16 | 10 | 9 | 19 |
| mean s1 | | 7.86 | 5.00 | 12.86 | 6.29 | 6.71 | 13.00 |
| mean s3 | | 9.71 | 6.43 | 16.14 | 8.14 | 8.43 | 16.57 |
| mean s4 | | 9.57 | 7.29 | 16.86 | 8.86 | 8.43 | 17.29 |

Table 60. Real World Test results for the durability group.
All real world items were untreated. *Treated* and *untreated* columns refer to whether the verbs/prepositions concerned were treated in the microworld.

ANOVA showed a significant main effect of Sessions, $F(2,12) = 8.24$, $MSe = 34.33$, $p < .01$. The means for sessions 1, 3 and 4 collapsed across Function type and Treatment set were 6.5, 8.2 and 8.5 respectively (max=10). Post-hoc Newman-Keuls tests ($p < .05$) showed performance in session 1 to be significantly worse than in session 3, but there was no significant difference between performance at sessions 3 and 4, indicating that the improvement had been maintained.

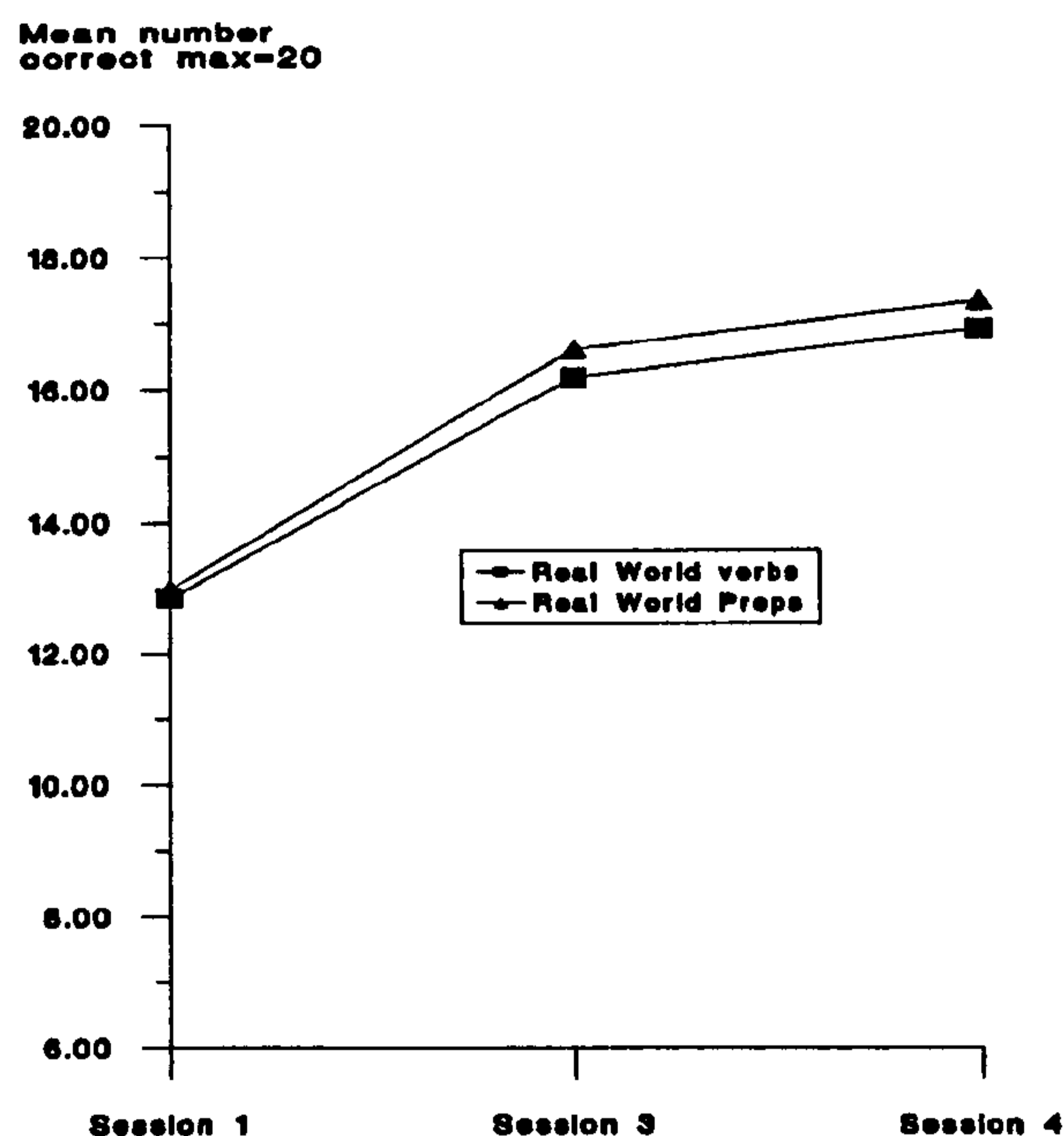


Figure 53. Real World durability results.

The main effect of Function type was not significant, $F(1,6) = 0.24$, $MSe = 0.58$, ns, showing that verbs and prepositions did not differ in the extent to which they benefited. However, there was a significant main effect of Treatment set, $F(1,6) = 7.31$, $MSe = 38.68$, $p < .05$, with 'real world' sentences containing verbs/prepositions that had been treated in the microworld (mean = 8.4) showing overall better performance than those containing untreated verbs/prepositions (mean = 7.0)

There was no significant interaction between Sessions and Treatment set ($F(2,12) = 0.07$, $MSe = 0.14$, ns) or between Sessions and Function type ($F(2,12) = 0.03$, $MSe = 0.05$, ns), but the first order interaction between Function type and Treatment set was found to be significant, $F(1,6) = 43.45$, $MSe = 44.30$, $p < .001$.

Post-hoc Newman-Keuls tests ($p < .05$) showed that overall there was a significant difference between performance on treated compared with untreated verb items, but not between treated and untreated preposition items. Unfortunately, as reported in section 4.1.1, this effect was present at session 1 in Group A. The durability group differed from Group A only in the substitution of P8 for P7, and he in fact exacerbated the trend slightly (treated verbs, mean = 7.86; untreated verbs, mean = 5.0). However, despite this imbalance at session 1, the combined evidence from the microworld tests and Real World Test reported in this section and the earlier results of Group A over test sessions 1, 2 and 3 tends to suggest that there was a little less generalisation from treated to untreated verb items than there was from treated to untreated preposition items.

The results of the ANOVA, both on the treatment data and on the 'real world' data of this subgroup of aphasic patients, confirmed that the improvement they had made during the treatment phase of the research had been maintained over the following five months. It is worth noting that not only had the language skills been preserved, but the patients were able to operate the computer equipment after an interval of five months, without the need for re-familiarisation.

Although the durability group as a whole returned very pleasing results, it was of interest to look at the individual performance profiles of the seven subjects to see whether anyone had not maintained progress. It was also important in forming an impression of the quality of the durability data, to find out what had happened to patients' test completion times at session 4. Table 61 summarises the Verb Test and Preposition Test completion times of these subjects over sessions 1, 3 and 4. The important point that emerges from Table 61 is that, overall, neither the increase in accuracy between sessions 1 and 3 nor the maintenance of progress at session 4 was accompanied by a decrease in speed. In other words, the significant improvements in performance had not been the result of a speed-accuracy trade-off.

| | SESSION 1 | | SESSION 3 | | SESSION 4 | |
|------------------------|------------------|-----------|------------------|-----------|------------------|-----------|
| | Verb Test | Prep Test | Verb Test | Prep Test | Verb Test | Prep Test |
| Mean time taken (mins) | 36.29 (28.33) | 29.29 | 28.14 (26.00) | 29.14 | 28.86 (25.50) | 26.29 |

Table 61. Mean test completion times for the durability group.
The values in parentheses under Verb Test are the mean test completion times disregarding P2, who initially took 84 minutes to complete this test.

To permit the performances of individual subjects to be scrutinised more easily, graphs were prepared showing accuracy in the microworld Verb Test and Preposition Test, time taken to complete those two tests, and accuracy on 'real world' verb and preposition items. Figures 54a to 54d present a set of three graphs for each patient summarising performance over all four test sessions. On the sheets where there are six graphs per page the top graphs show performances on the treated and untreated sides of the Verb Test and Preposition Test, the middle graphs show total test completion times for those tests and the bottom graphs show performance on the verb and preposition items of the Real World Test. In considering these, it should be remembered that all the subjects except P8 received verb therapy between sessions 1 and 2 and preposition therapy between sessions 2 and 3; P8 underwent treatment in the reverse order.

The results of P1 and P2, shown in Figure 54a, were particularly gratifying. They had been weak subjects at session 1 but made substantial improvements both in verbs and in prepositions and showed generalisation to untreated items within the microworld and on the Real World Test. This improvement was maintained after five months. Encouraging aspects of P2's profiles were the generalisation to untreated microworld items (especially prepositions) between sessions 3 and 4 and the accompanying decrease in time taken for the Preposition Test between sessions 3 and 4. While P1's results were excellent, I had hoped to see a decrease in time taken between sessions 3 and 4, but this did not occur.

Figure 54b shows that P3's overall results were disappointing. He regressed in accuracy between sessions 3 and 4, so that after five months he was not better than at baseline (collapsing the two tests his scores were: session 1, 46/80; session 3, 58/80; session 4 50/80). Although he was more accurate on the Real World Test than in the microworld at baseline, he failed to make much progress on the former where his session 3 to 4 trend was also downwards. P5, on the other hand, did maintain his improvement in accuracy on the microworld tests. A pleasing result at session 4 was that his response speeds, which had become exceedingly slow at session 3, were much reduced, especially in prepositions. P5's Real World Test results were a little disappointing, showing that generalisation effects were not as strong at session 4 as they had been directly after therapy.

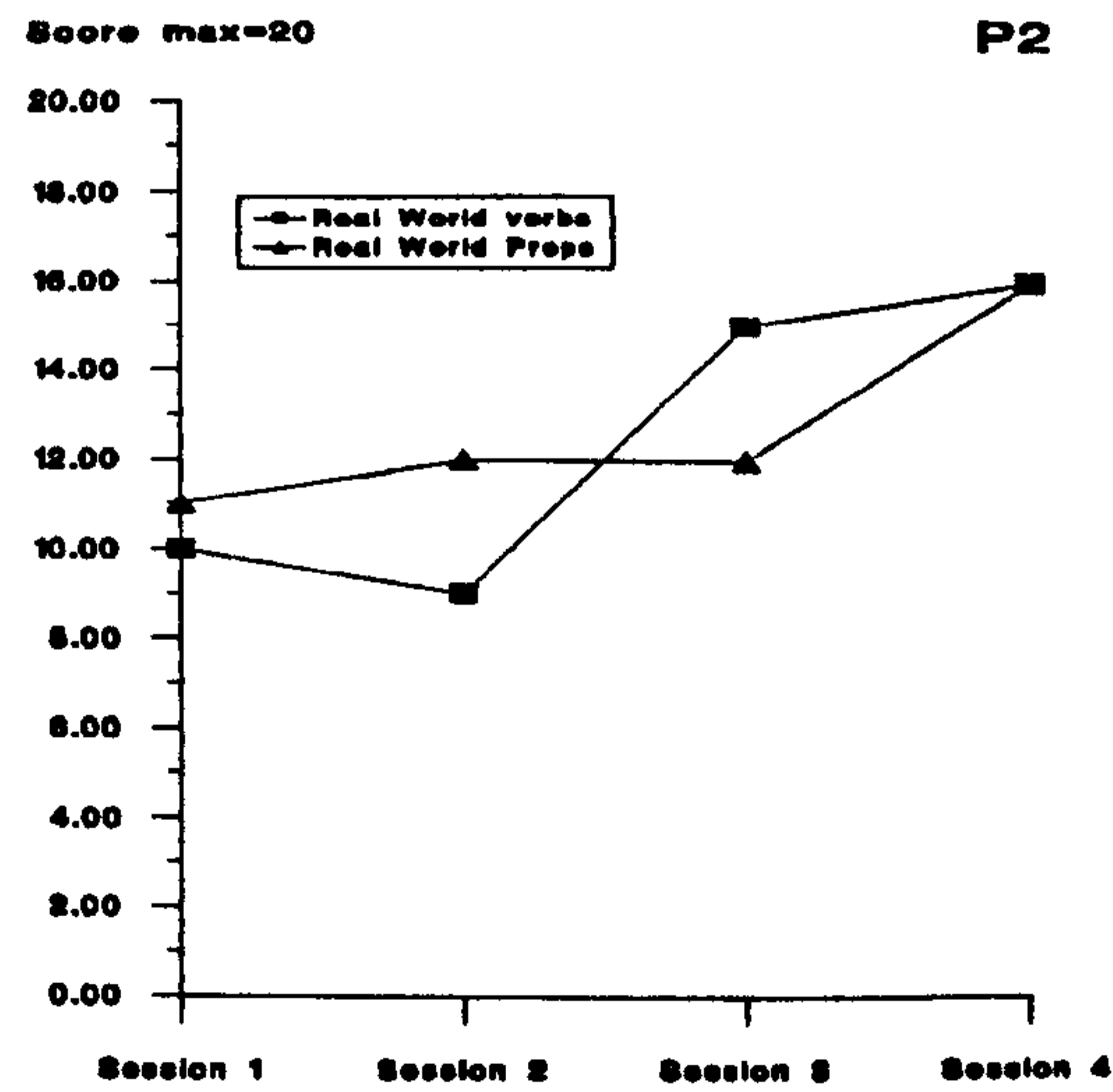
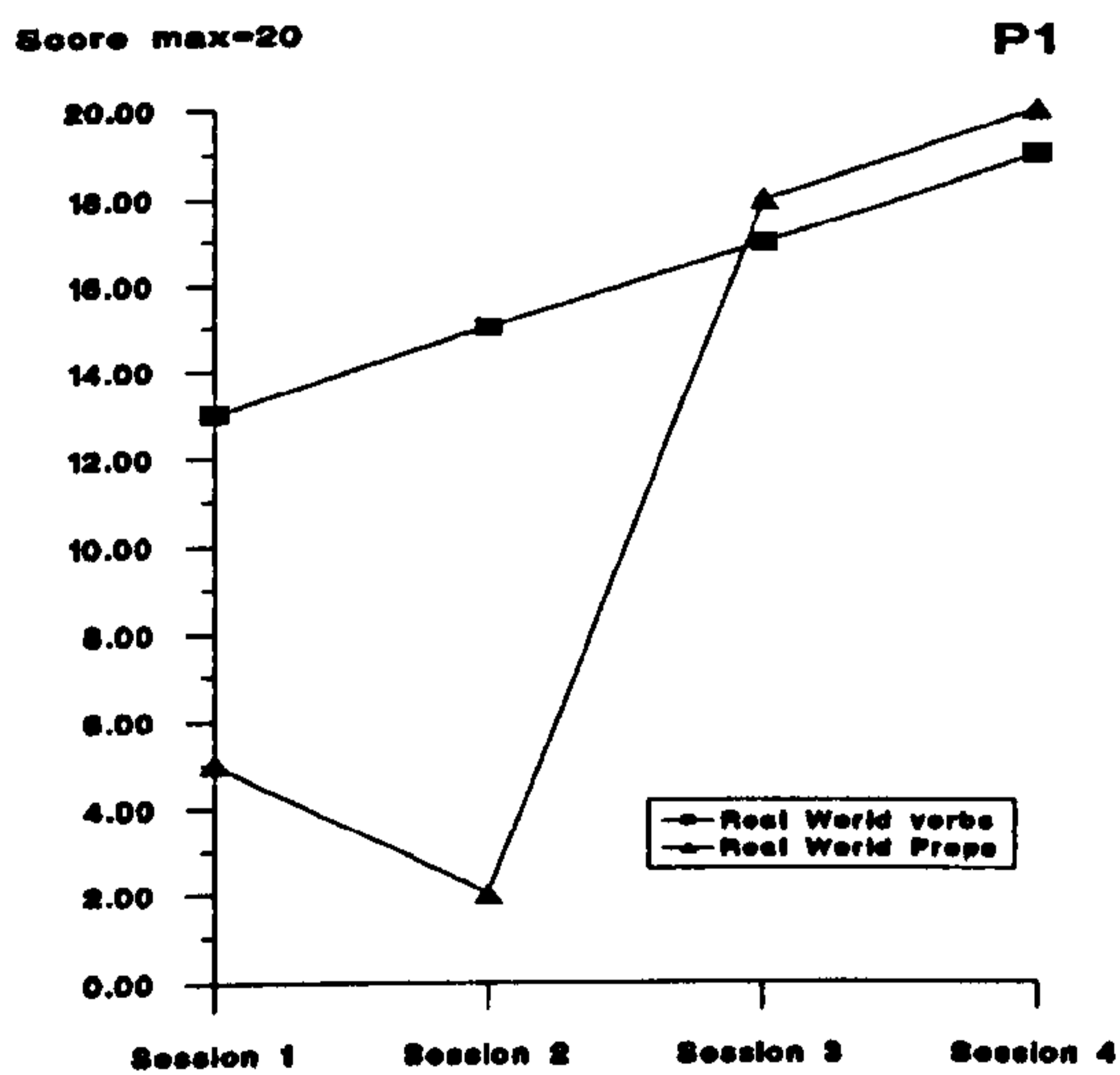
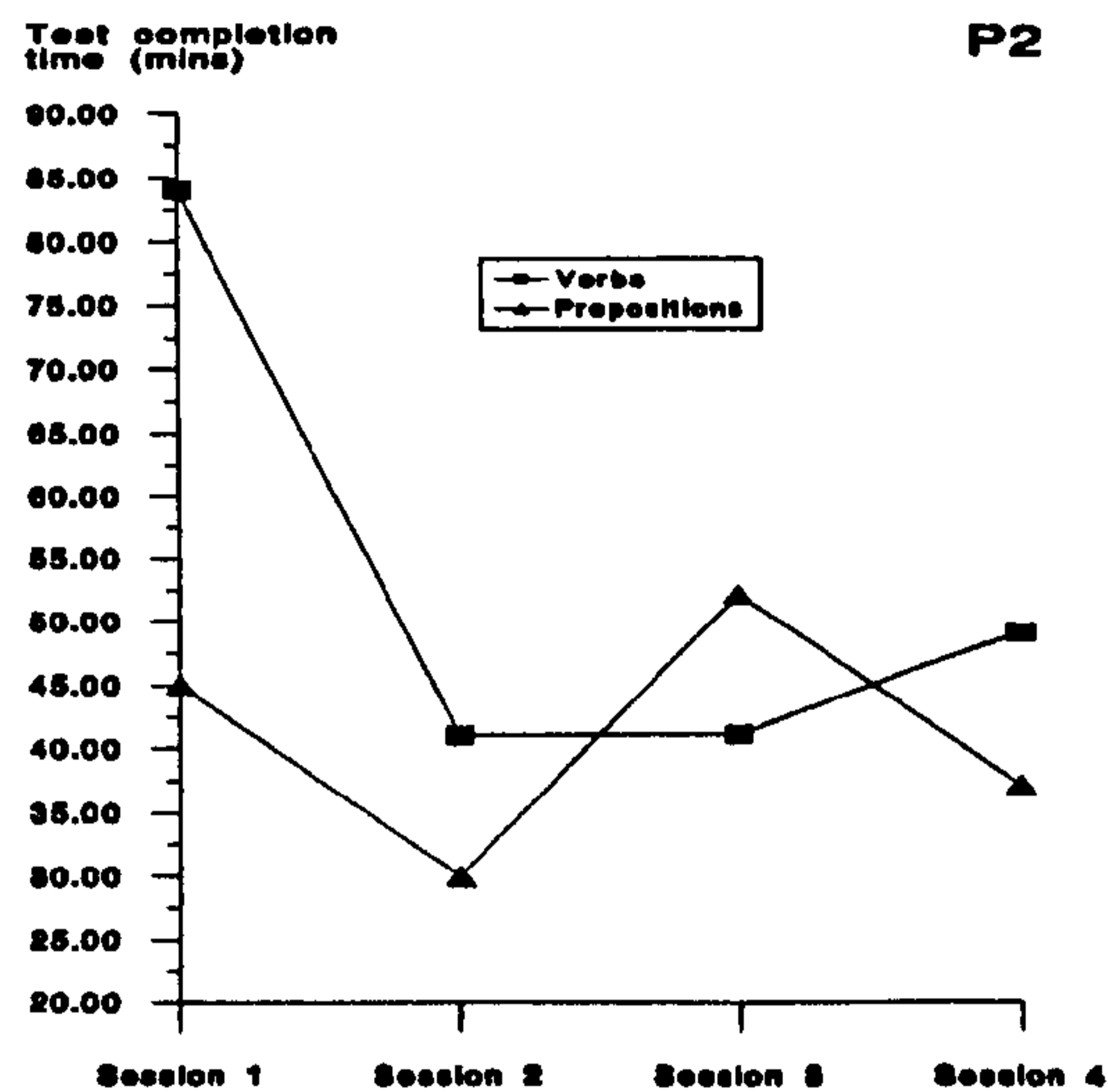
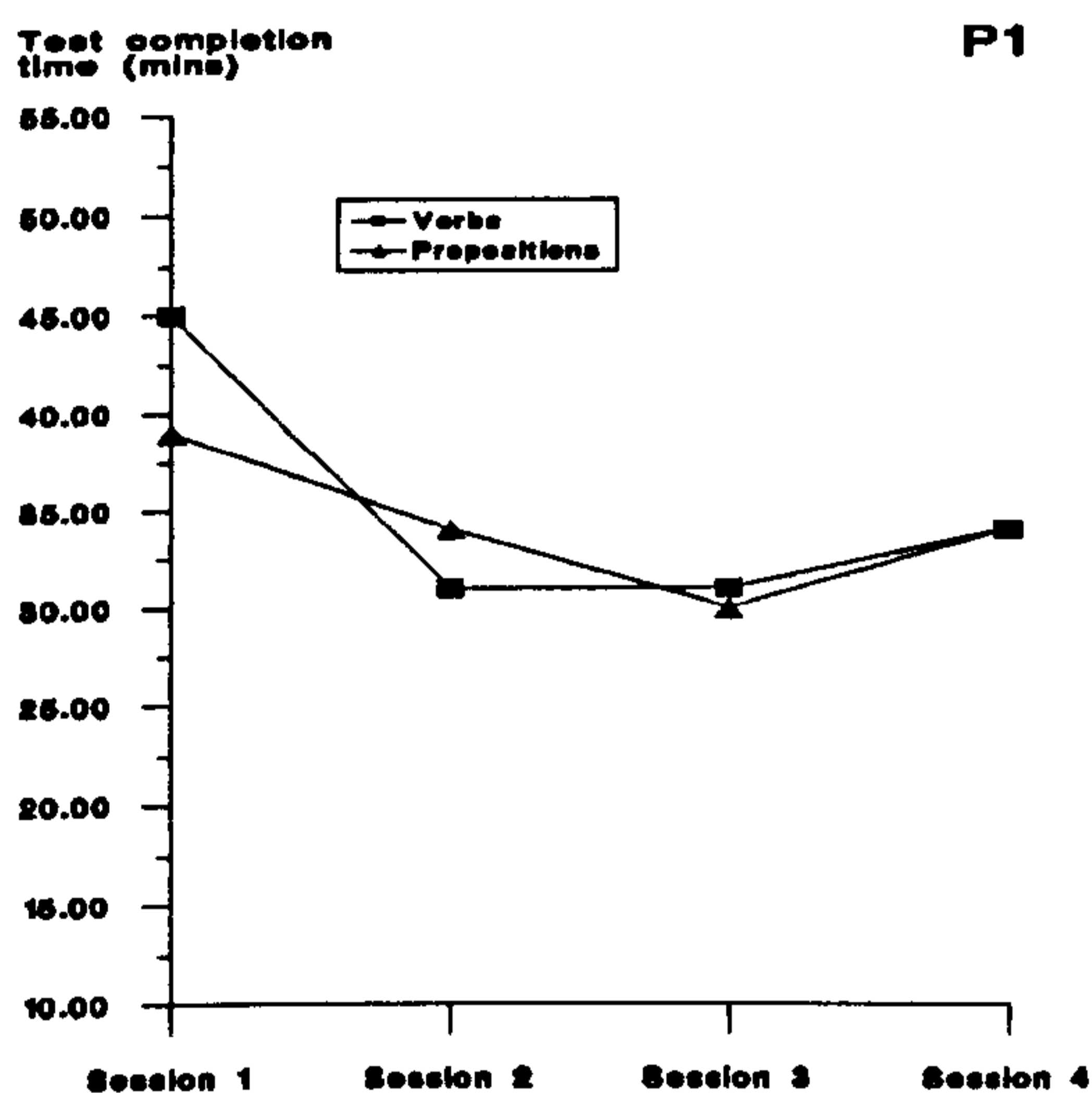
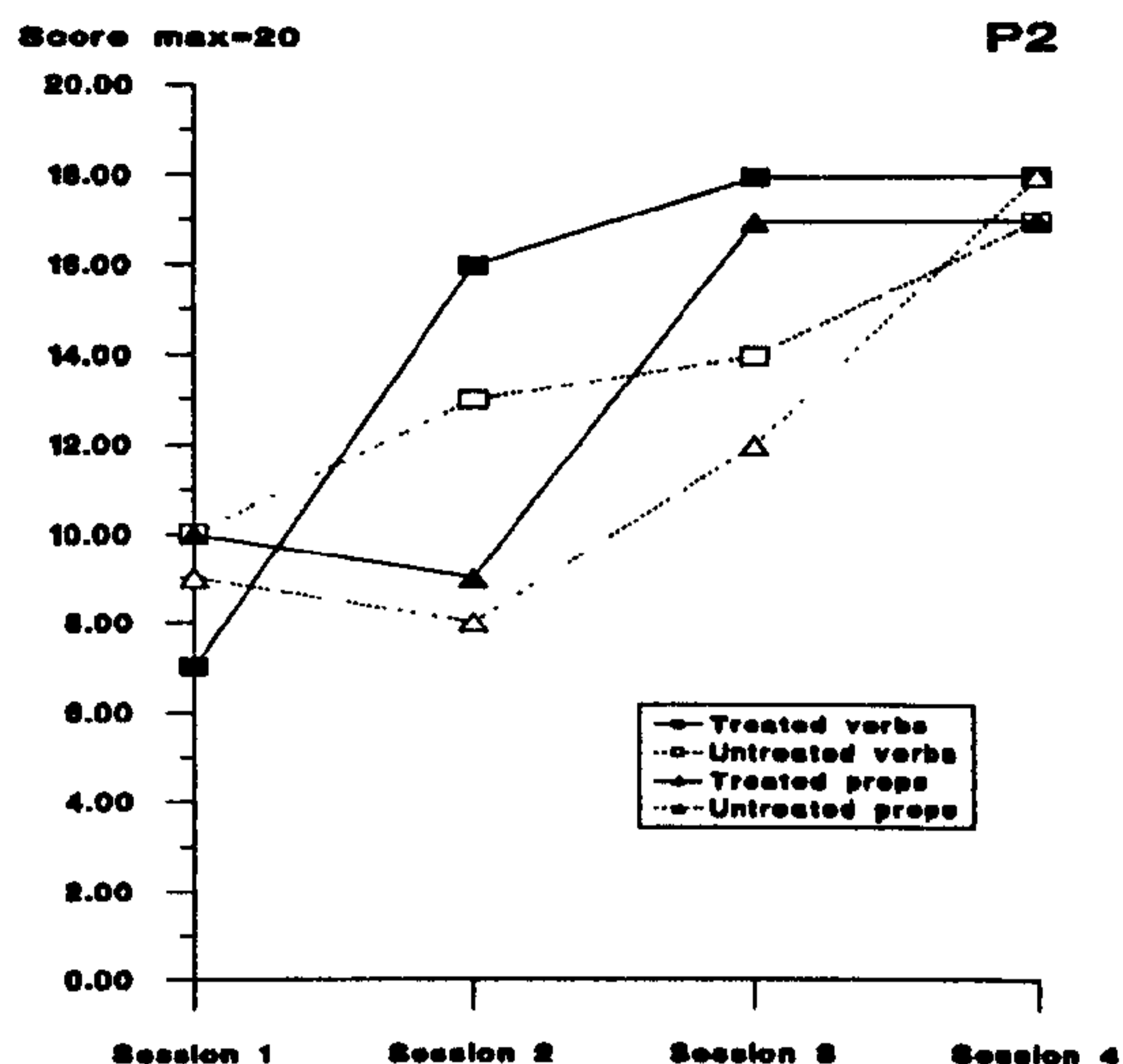
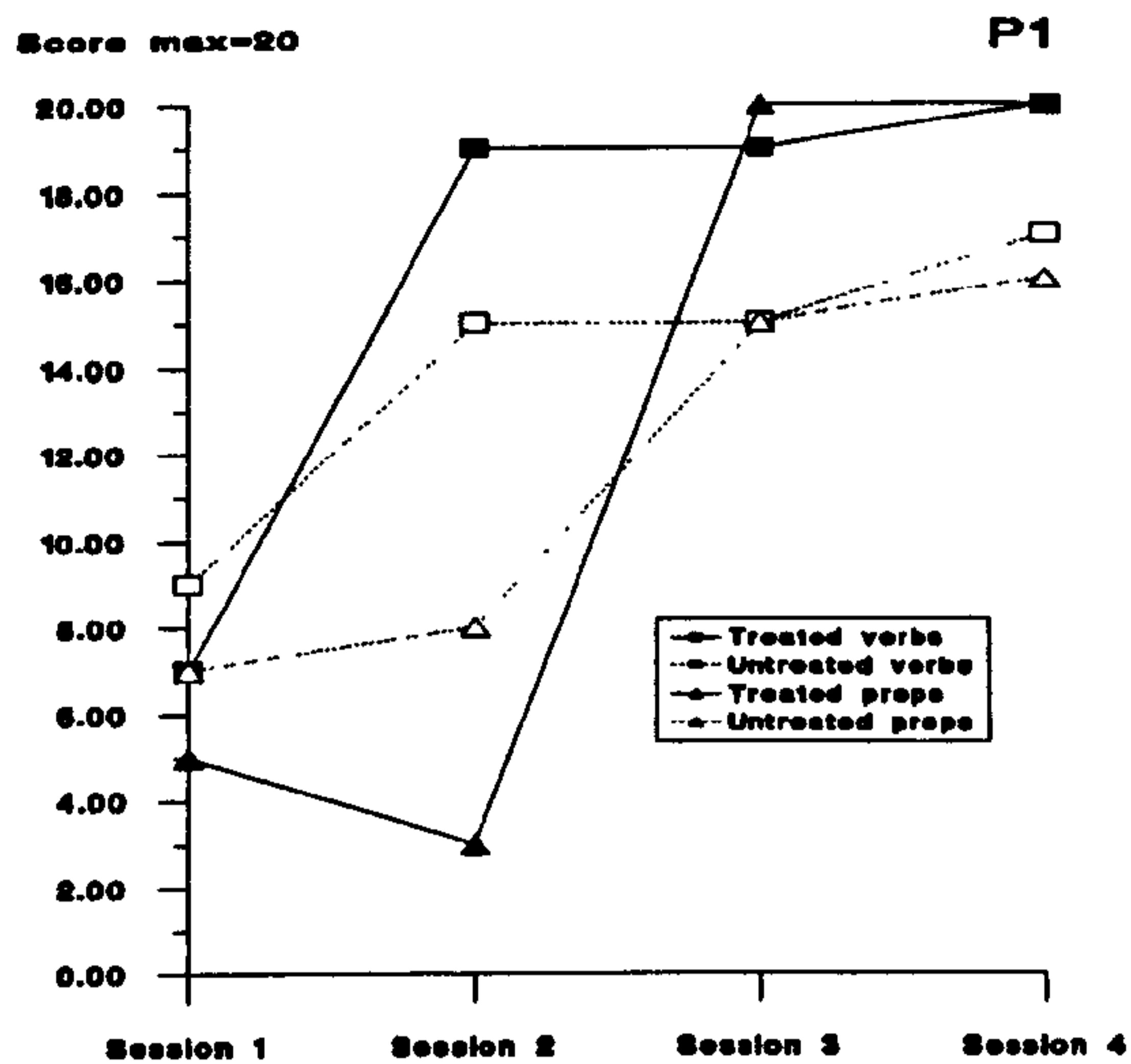


Figure 54a. Durability group individual accuracy and speed graphs.

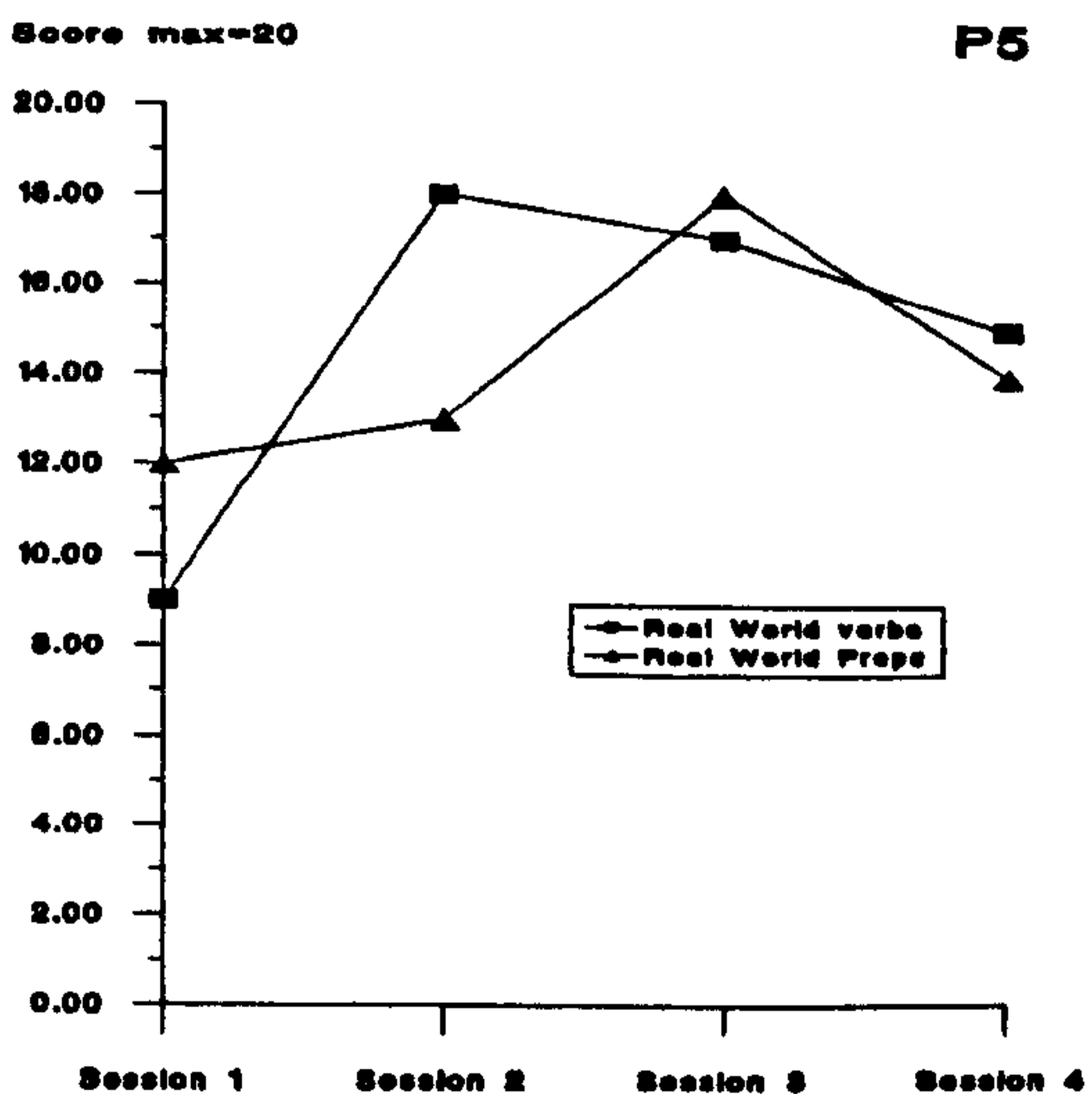
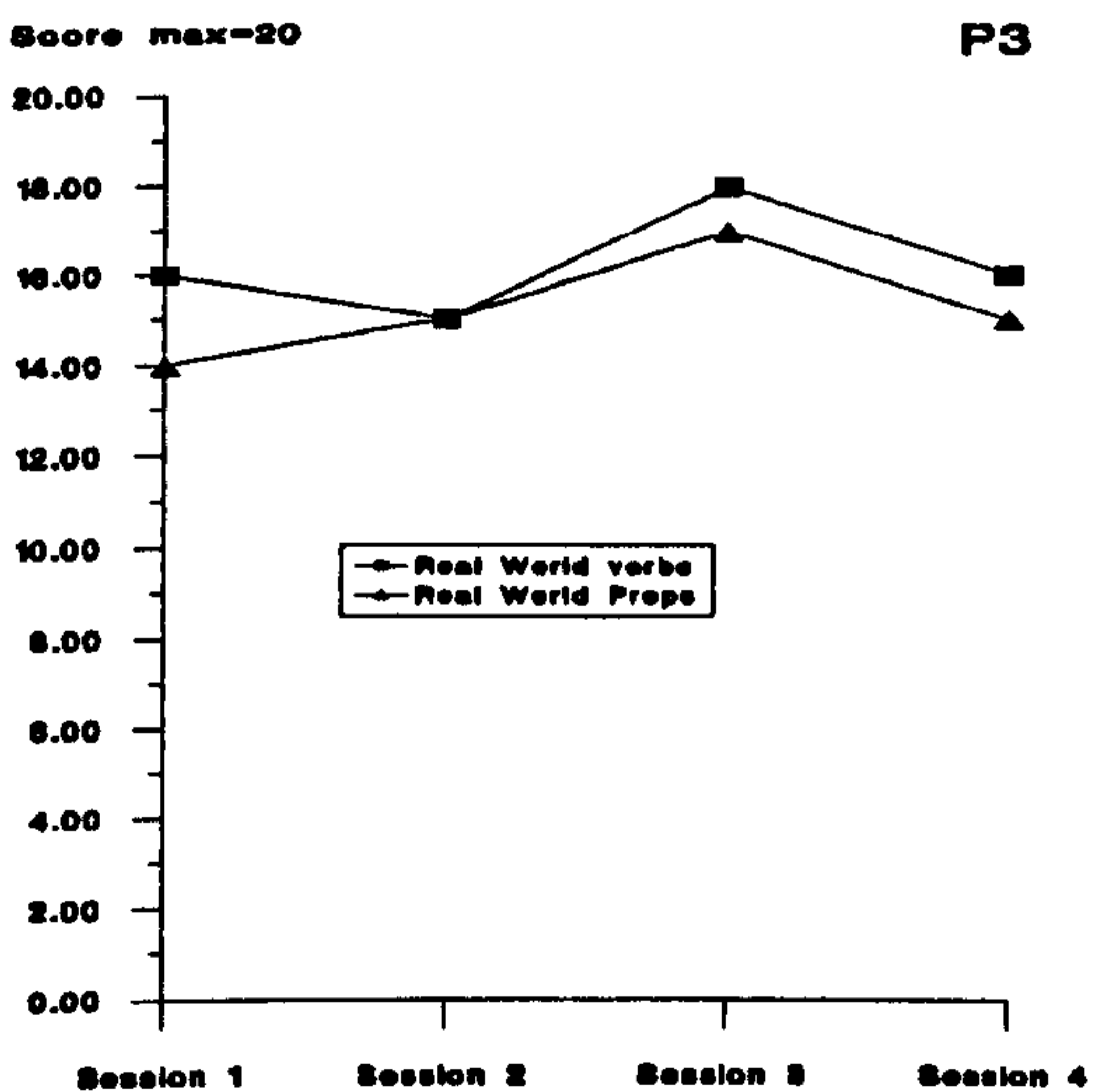
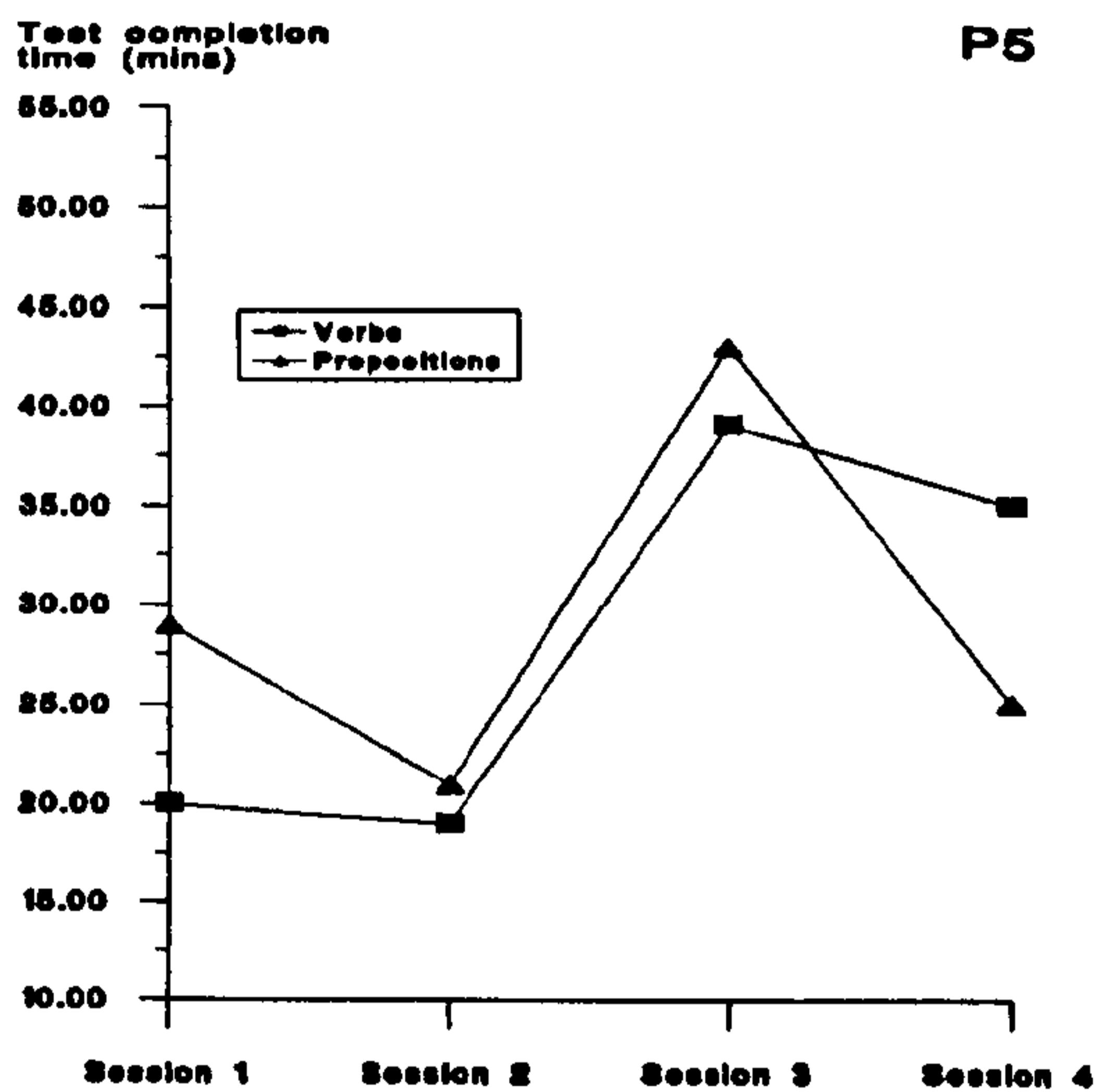
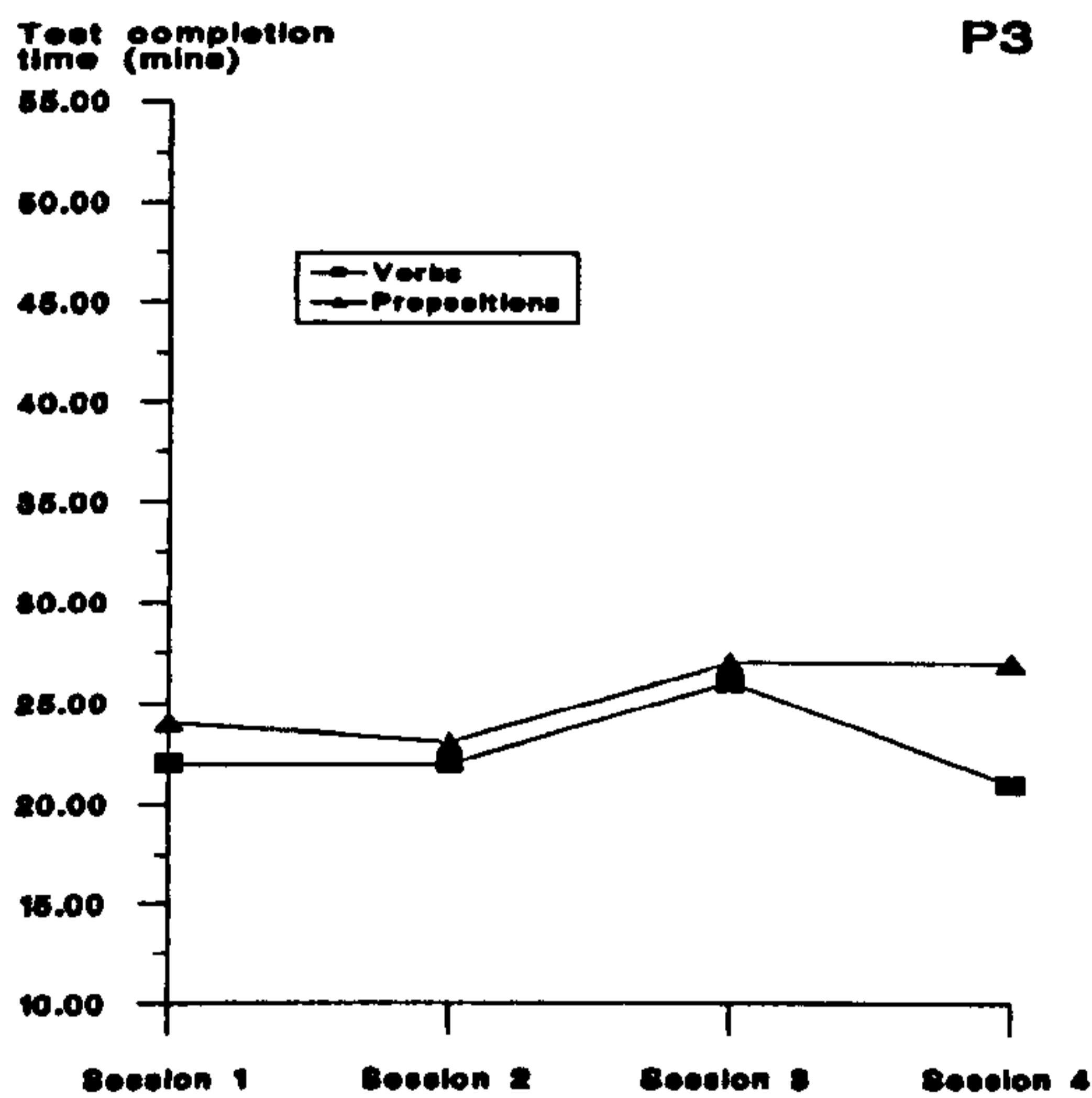
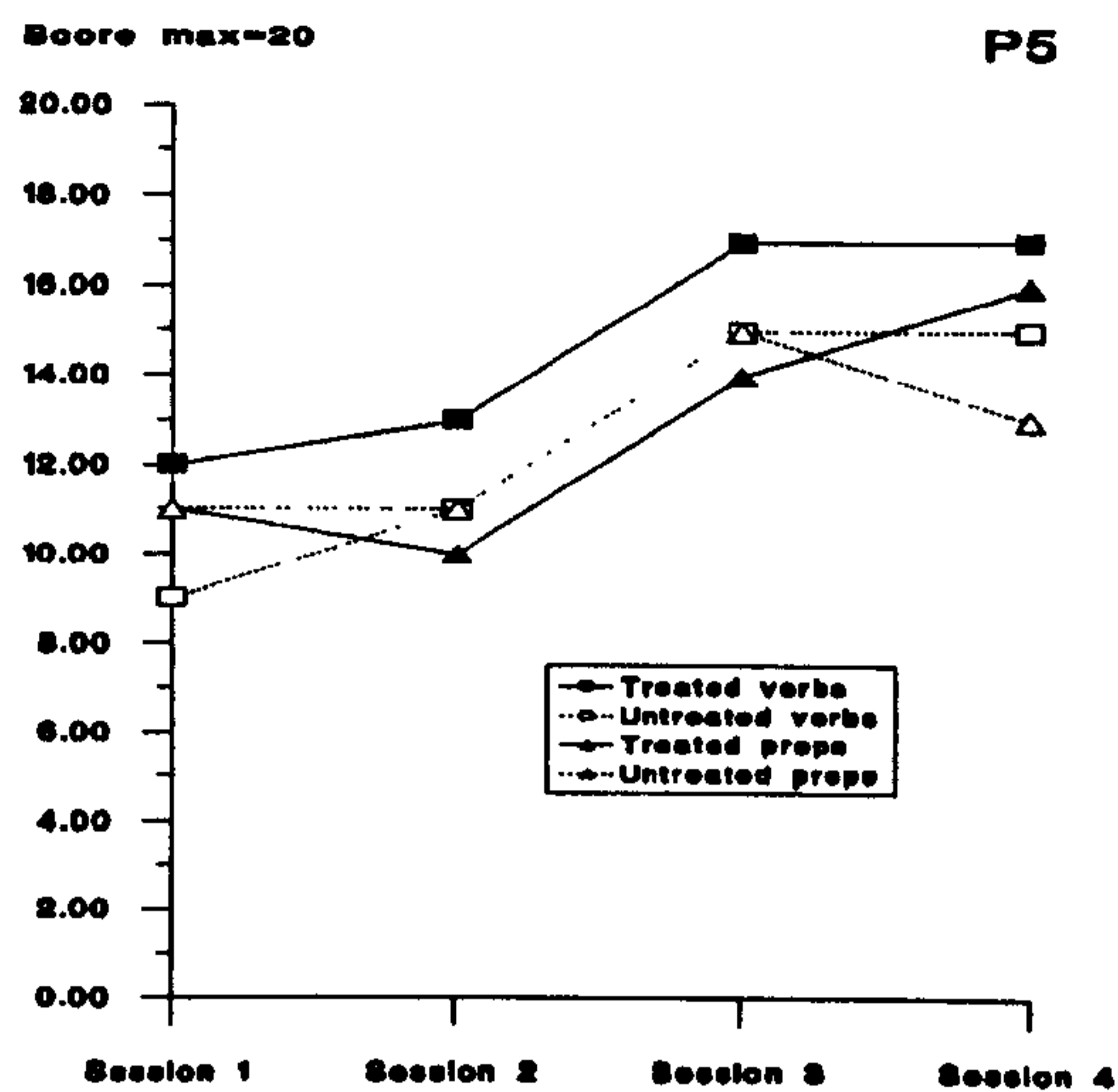
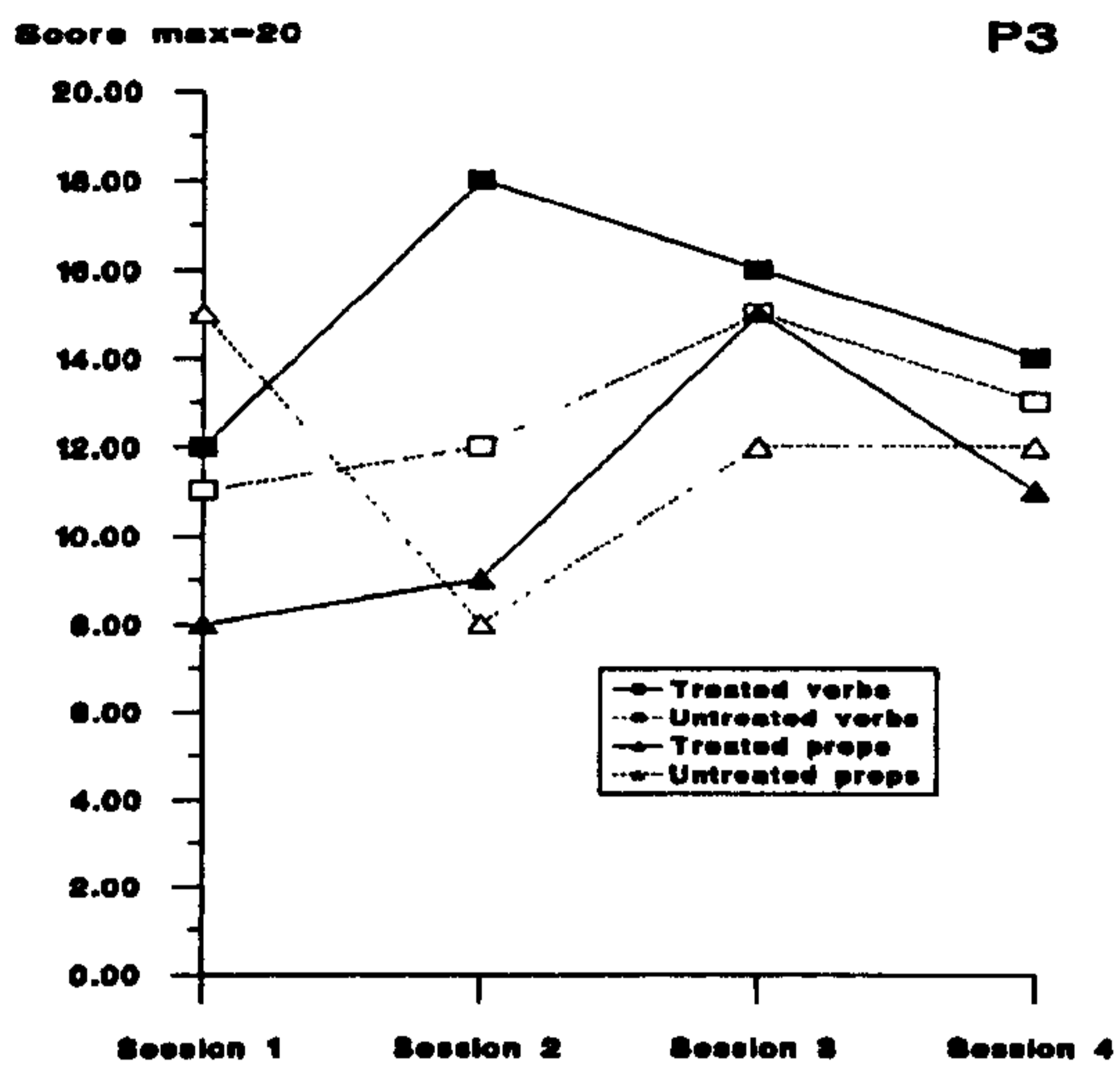


Figure 54b. Durability group individual accuracy and speed graphs.

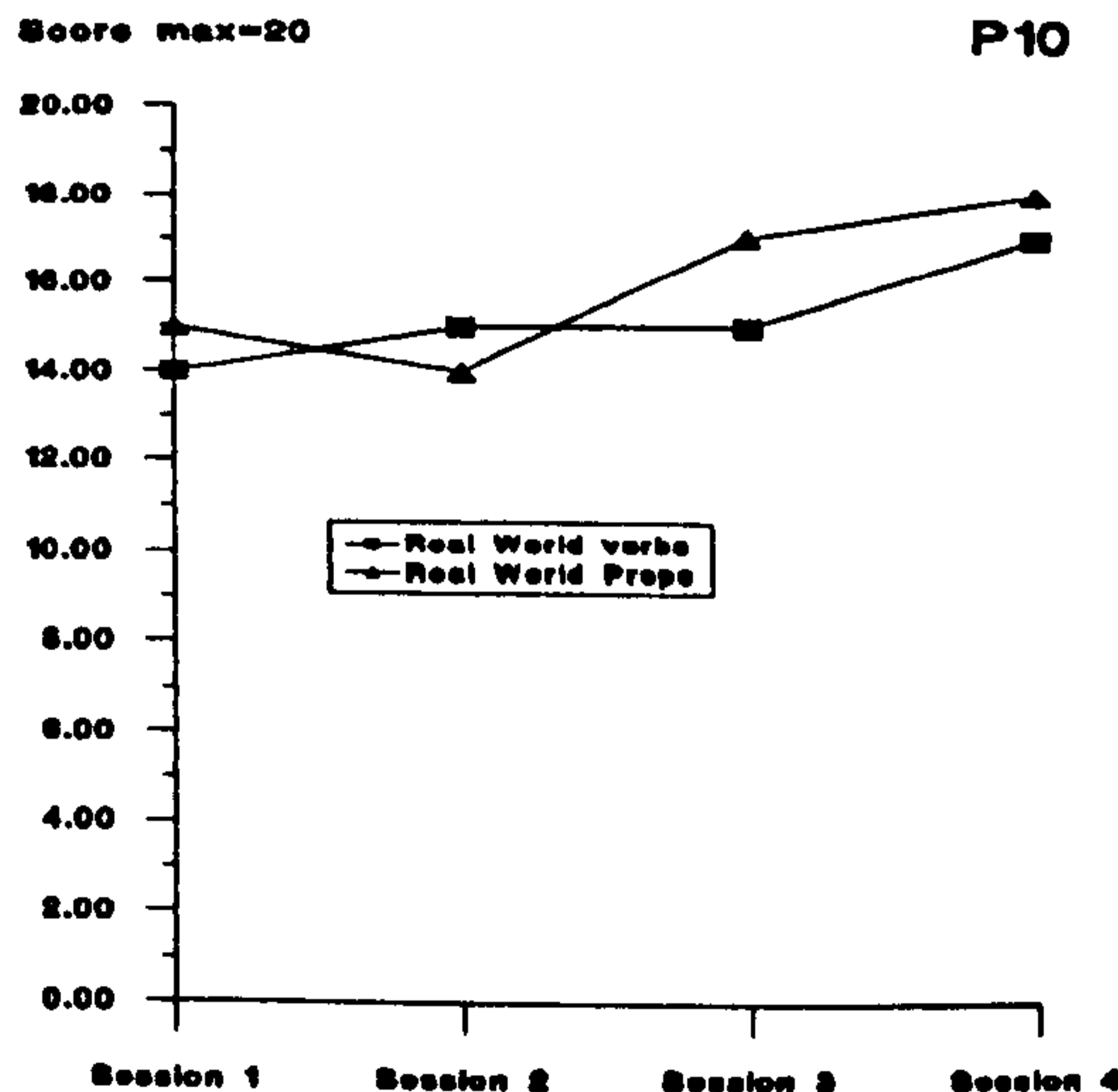
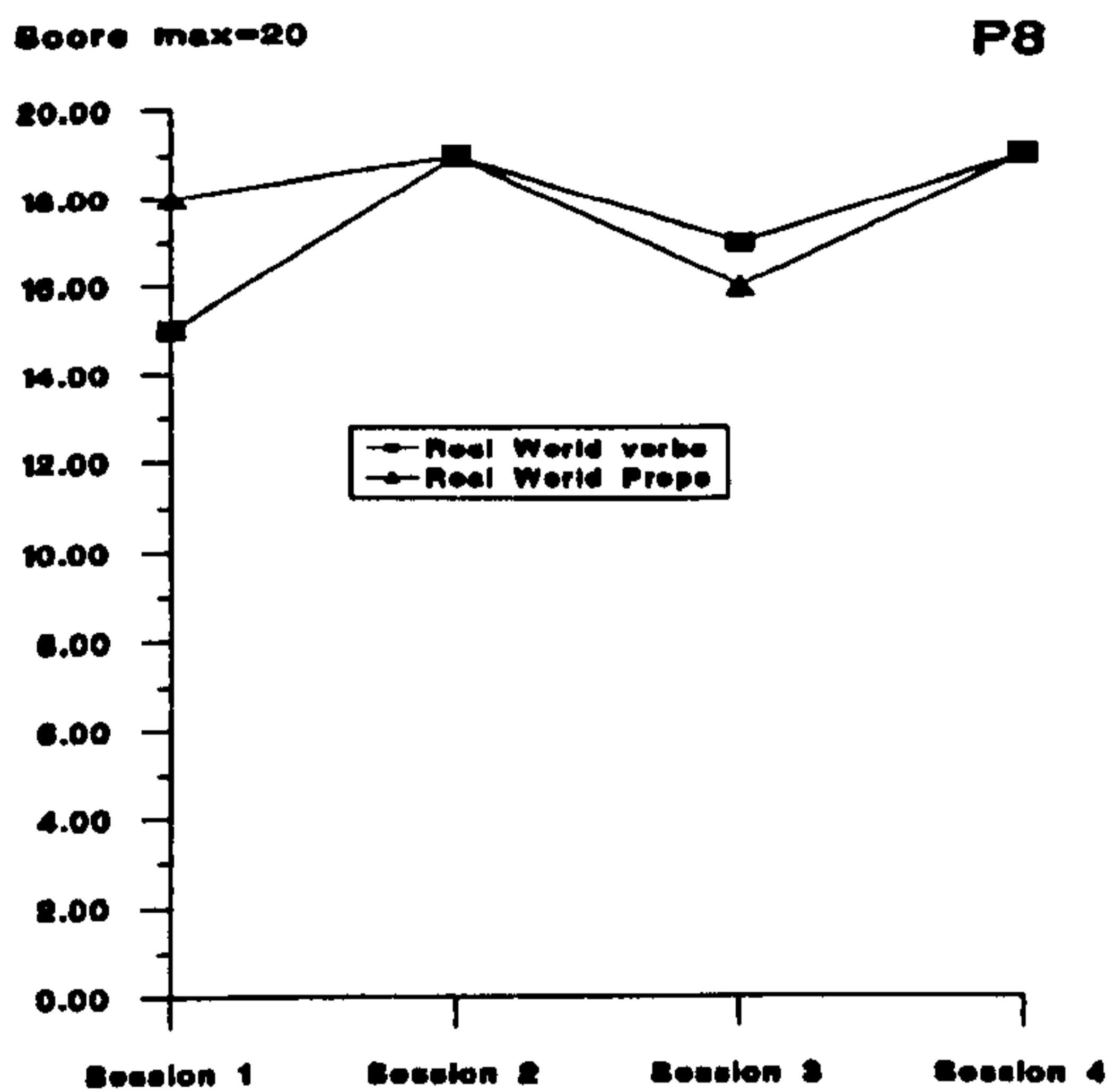
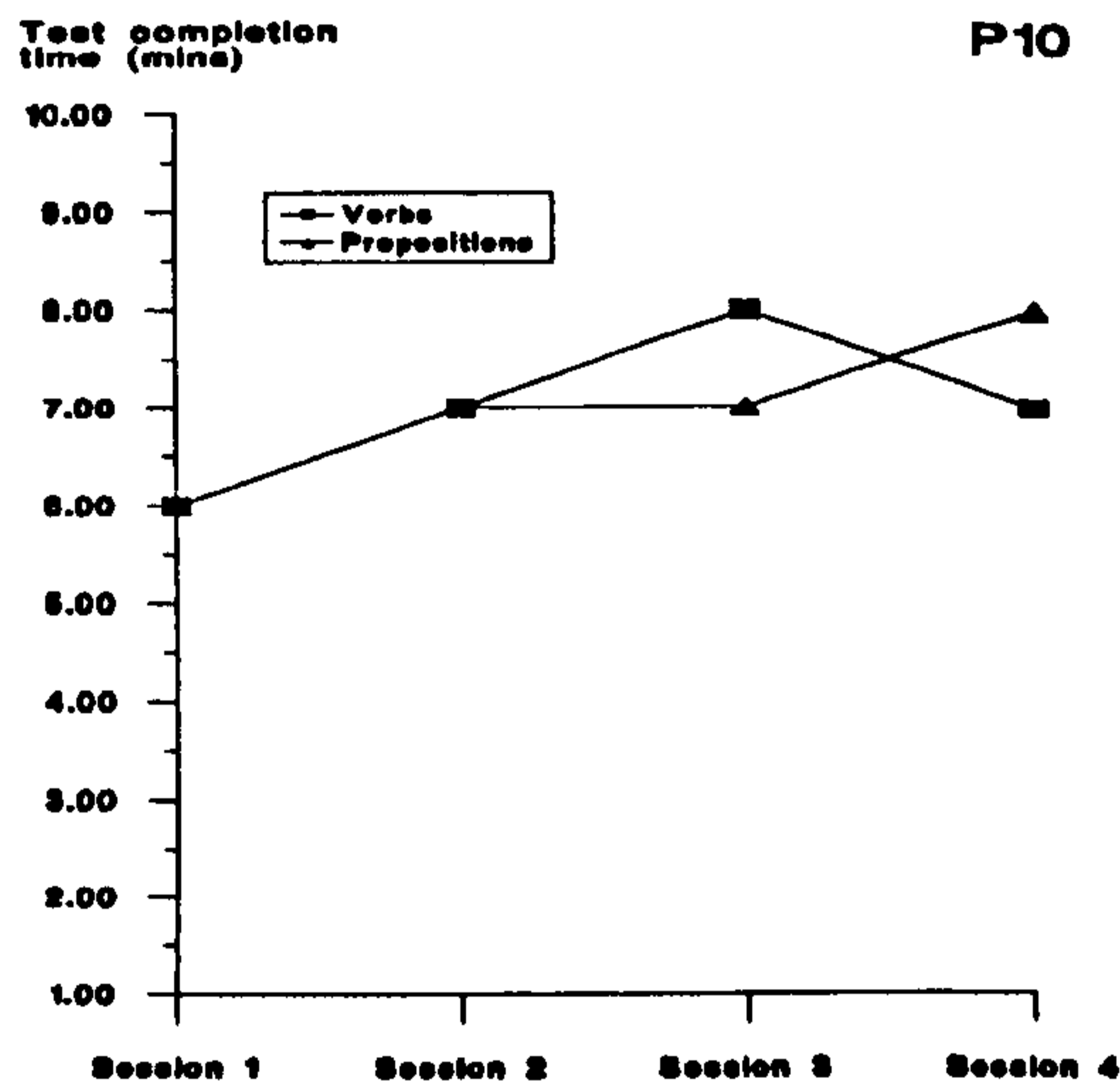
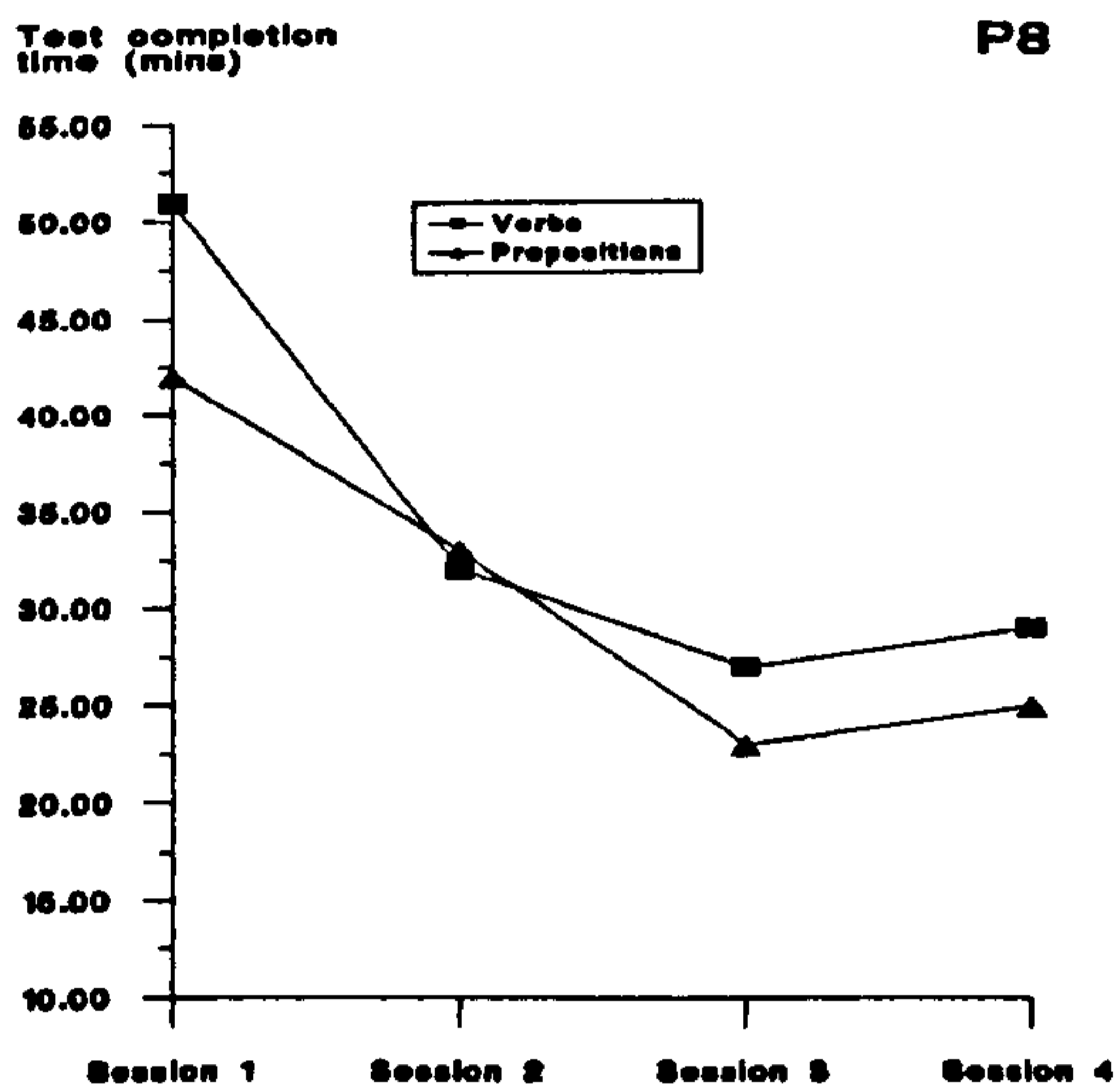
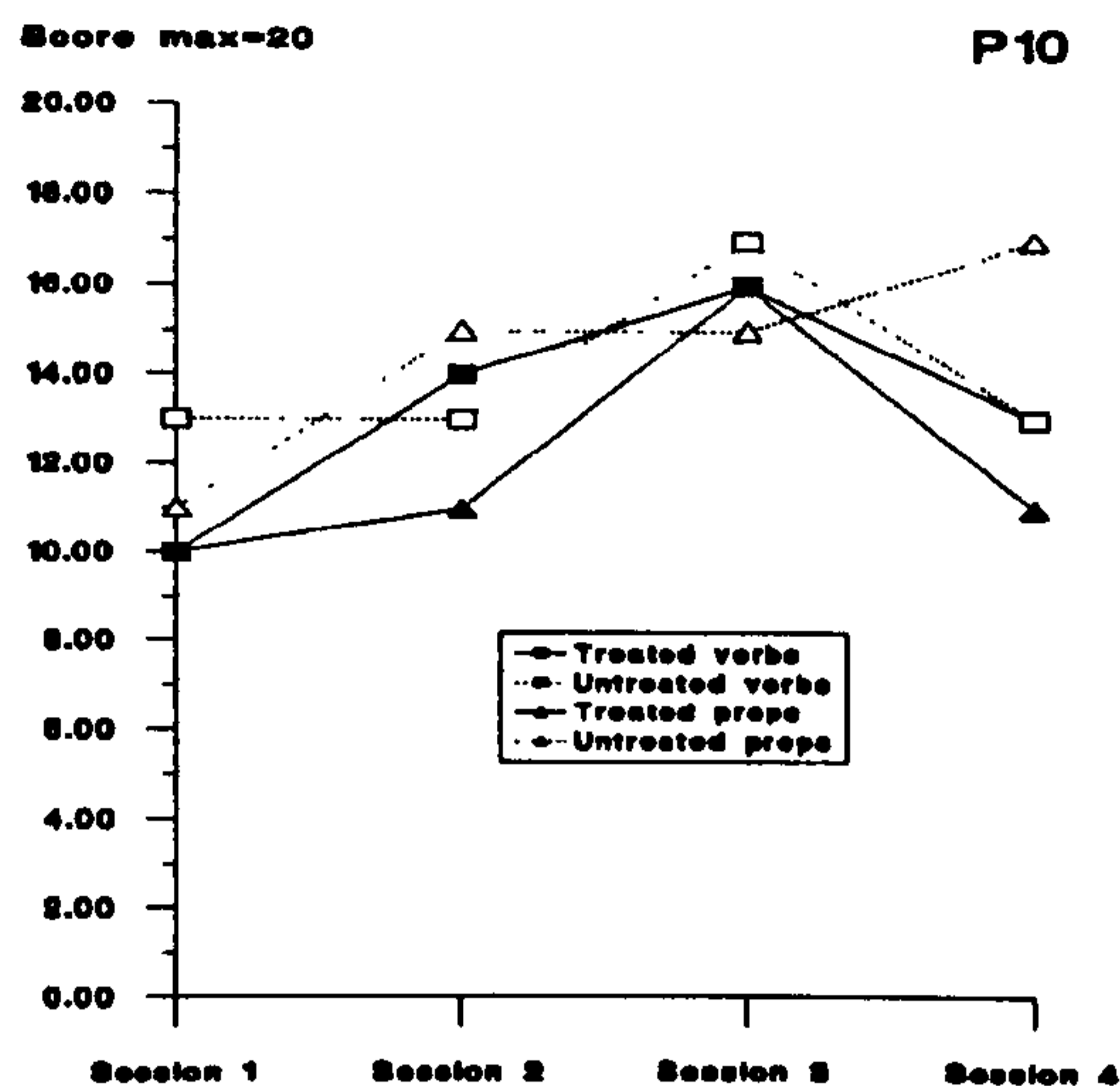
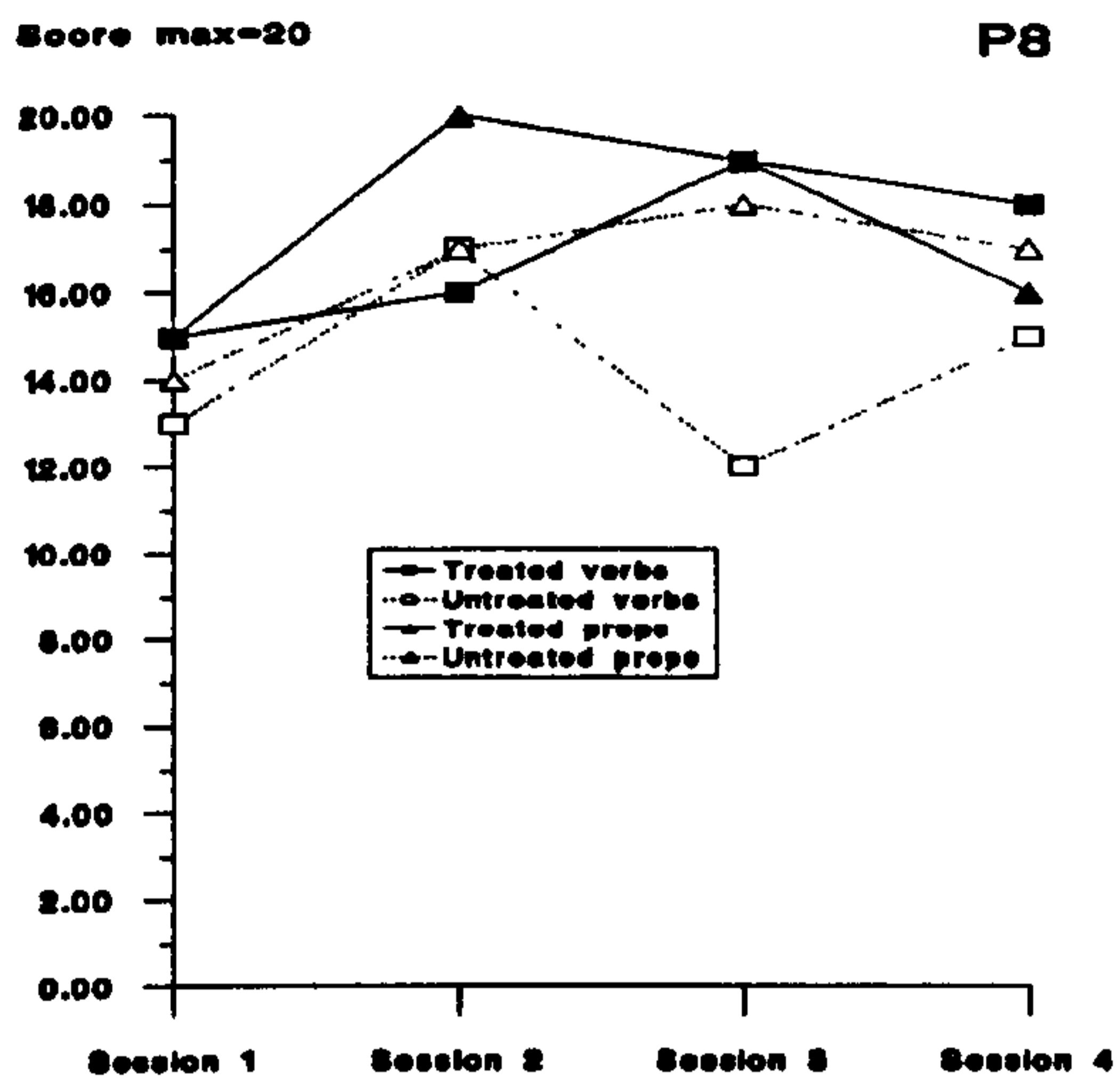


Figure 54c. Durability group individual accuracy and speed graphs.

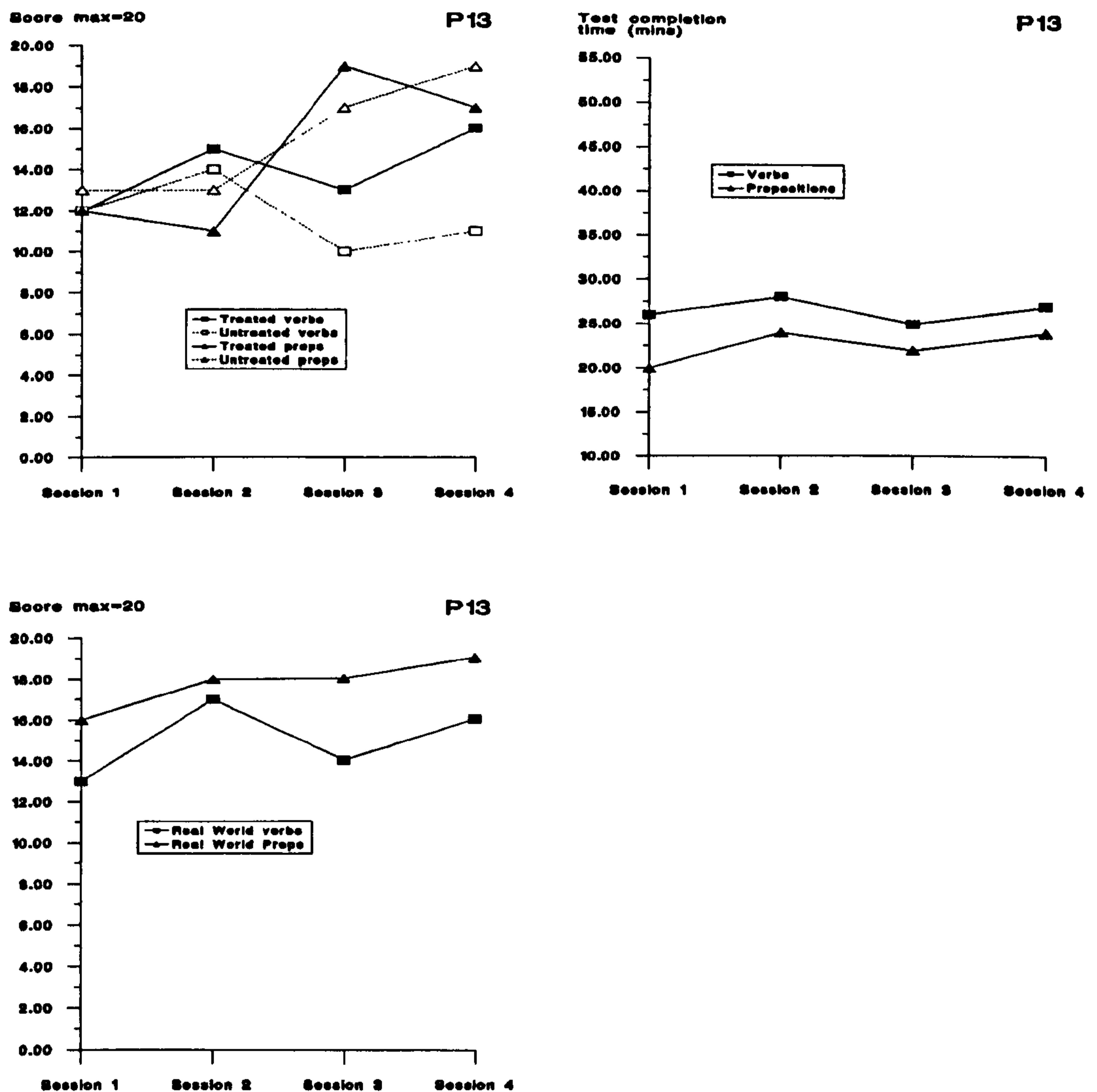


Figure 54d. Durability group individual accuracy and speed graphs.

P8 was the most accurate subject in the durability group at baseline, but his responses were very slow. Overall, his accuracy results were maintained between sessions 3 and 4, both in the microworld and 'real world'. The most encouraging aspect of P8's results was the substantial success in reducing his test completion times (see Figure 54c).

P10, by contrast, operated at normal speed. He had made good progress in accuracy by session 3 (see Figure 54c), but, unfortunately, declined in all but untreated preposition items between sessions 3 and 4. However, the upward trend in 'real world' performance was maintained through the no-treatment period. Finally, P13 maintained his progress in accuracy both in the microworld and 'real world' between sessions 3 and 4. His speed was static (and relatively fast

by aphasic standards) throughout. The only function which failed to improve in this patient between sessions 1 and 3/4 was untreated verbs.

Summary. Seven patients (the durability group), who were judged to have responded well to the treatment phase of the research, were recalled for repeat assessments five months after the end of the efficacy study proper. I had no contact with these subjects during the interval and they had no exposure whatever to the test materials, the remediation materials or to the computer system. ANOVA on the results obtained showed that the treatment effects, both in the microworld and on matched 'real world' items, had been maintained. Within the microworld, improvement had occurred as much to verb items as to preposition items and as much to untreated items as to treated items. There had been a difference between treated and untreated items (the former being better) at session 3, but after five months, this discrepancy had resolved. There was a suggestion that generalisation to untreated verbs may have been marginally less successful than to untreated prepositions. ANOVA also showed that improvement on the Real World Test had been sustained between sessions 3 and 4. Again, verbs and prepositions benefited equally. However, a significant effect of treated items was found, showing more improvement on 'real world' sentences containing verbs/prepositions treated in the microworld than on those containing untreated verbs/prepositions.

Only two patients in the durability group, P3 and P10, were found to have declined in accuracy between sessions 3 and 4. Of these, only P3 showed little positive change since baseline. Six out of seven subjects had improved by 10 points or more on the microworld tests (verb and preposition tests collapsed, $n=80$) between sessions 1 and 4 (the range of improvement was +10 to +45 points). P1, P2 and P8 showed substantial improvements in time taken for test completions, however, the mean test completion times for the group across sessions 1, 3 and 4 showed only a very slight downward trend (see Table 61). Thus, while the durability group had been successful in sustaining session 3 accuracy levels for a no-treatment period of five months, this assimilation period had not resulted in improved automaticity.

CHAPTER 6

This final chapter draws the thesis to a close by summarising what has been achieved and suggesting promising directions for future work arising from this study. Section 6.1 gives a synopsis of the primary theoretical and practical results of the research, relating these to the aims stated in section 1.3. The general findings are amplified in sections 6.1.1 and 6.1.2. Section 6.1.1 briefly recapitulates the different treatment effects in the two aphasic groups and possible reasons for the discrepancies. Section 6.1.2 presents individual profiles, discussing the nature of each subject's observed deficits and how diagnosis guided the remediation process for each patient. Speculations are offered, where possible, as to the reasons for the success or otherwise of the intervention. In section 6.2 the efficacy results are supplemented by information gained from the aphasic subjects and their carers, concerning the wider functional generalisation of microworld therapy. The thesis concludes by suggesting, with benefit of hindsight, methodological improvements which might be incorporated in replication studies and ways in which the software might be extended. Finally, suggestions are made concerning other areas of language research where a computer-based microworld approach might be profitably applied.

6.1 SUMMARY OF MAIN FINDINGS

This study set out to satisfy the list of aims presented in section 1.3 (pp. 63-64). The purpose of the present section is to confirm that the objectives of the study have been met and to summarise the major findings. In doing this, it will be apparent that several aspects of the results were found to support previous evidence, but that the thesis presents both clinical tools and clinical results that are substantially new.

The original list of aims was distributed under four headings, corresponding to the major areas of literature review - these were Agrammatism, Microcomputers in Aphasiology, Cognitive Neuropsychology and Clinical Research Methodology. The twelve aims stated in section 1.3 can be broadly subdivided into those of a practical nature that involved the creation of the microworld, the design of

assessment and remediation materials and the implementation of the computer software (aims 2, 4, 5, 6, 7 and 12), and those of a theoretical nature which called for the application or extension of existing theory (aims 1, 3, 8, 9, 10 and 11). Clearly, the subdivision is an over-simplification as the test contents and software design were theoretically motivated, but it helps the organisation of this section to be able to refer to the goals as practical or theoretical.

The practical aims were all satisfied by the integrated suite of assessment and remediation programs. Aim 6 ('To create and determine the utility of a computerised microworld for diagnosis and treatment of sentence processing deficits') was satisfied by the creation of the ball, box and star world and its computer-based realisation (described in Chapter 3). The utility of the microworld as a diagnostic and remediative facilitator was evident in the formulation of therapy goals (section 3.4), the efficacy results (Chapter 4) and the durability results (section 5.6). Further evidence of its effectiveness is provided in sections 6.1.2 and 6.2 below. An interface suitable for use by hemiplegics was built and tested (Chapter 2) and formed the basis for a software shell which was used by all assessment programs (aim 5). Aims 2 and 4 were satisfied by the development of the modular Syntax Screening test (SST) (Chapter 2) and by the new Verb and Preposition Remediation Programs (Chapter 3) respectively. All the computer-based assessment tests satisfied the criteria set out in aim 12 (i.e. that they should be 'quantitatively precise, free of inter-observer variation and diagnostically informative'). Finally, the complete set of assessment and remediation software significantly extends existing clinical computer use, fulfilling aim 7 and satisfying the goal stated at the end of section 1.2.2, that 'the next generation of clinical software should strive for a clinician-computer partnership in which the strengths of each are exploited'.

The principal findings arising from the fulfilment of practical aims were as follows:

- 1) The use of a miniature artificial world was found to offer advantages over natural English for investigating and treating deficits of sentence processing in aphasic subjects. The limited vocabulary, fixed number of contrastive sentence structures and minimisation of contextual bias were important in providing an experimental domain in which linguistic factors could be manipulated and in which syntactic weaknesses, if present, would be exacerbated. The microworld approach was found to offer a parsimonious teaching medium in which the

principles of language could be explored (see section 3.3.1). Crucially, evidence was found that effects of microworld treatment generalise to untreated microworld tasks, to similar 'real world' reading tasks and more widely to other areas of language (see section 6.2).

2) The aphasic subjects were found to be able to cope with the conceptual abstractness of the microworld (e.g. the notion of a box painting a ball) and with the abstractness of the computer graphics used (i.e. the visual representations were highly stylised, unrealistic images (see the photographs in Chapters 2 and 3)). It was not found necessary to provide animation for verb remediation, as Steele et al. (1989) had suggested.⁹⁴

3) All the aphasic subjects tested, including those not selected for this study, were found to be able to master a 'single click' mouse-driven interface.⁹⁵ In more severe cases of limb apraxia up to 20 minutes of instruction was needed before any degree of useful control was gained. However, there were two important findings in this connection; firstly that all subjects, irrespective of initial difficulties achieved semi-automatic mouse operation, and secondly, that mouse skills endured over long periods with no exposure to the equipment (e.g. between the three test sessions reported in Table 2 (p. 73) and during the five months between the end of treatment and the assessment of durability effects reported in section 5.6).

4) The findings just highlighted in point 3) have important implications for the building of investigative and treatment environments. The present study exposed the patients to a graduated set of exercises (Interface Test, Lexical Test, SST and later Verb Test, Preposition Test etc.). HCI skills were transportable from one program to the next and the patients quickly became familiar with the operational characteristics of the programs, so that barely any verbal instructions needed to be given. The utility of this approach was clearly demonstrated when patients were able to self-administer the Digit-span Recall Test (which was very different

⁹⁴ This may have been because P1..P14 were not required to select icons from collections where nouns and actions could be confused. It may also be that their single-word comprehension was better than that of Steele et al.'s patients.

⁹⁵ The simplicity of the interface was very important in minimising interference with concentration. For example, P2 was inconsistent in her use of mouse buttons, sometime pressing the right button and sometimes the left. As the software was designed to respond to either, her thought processes were never interrupted by the occurrence of an unintended effect (which would then have to be 'undone'), or indeed of no effect at all, which would have been equally disrupting.

in visual appearance but similar in principle) with minimal explanation. The success of the interfaces designed for this research suggest that there is enormous potential in this approach to tapping the cognitive processes of the language impaired.

5) Through clinical use of the software built for this project some useful information was learned concerning the range of sentence processing speeds of aphasic subjects compared with normal subjects. This has practical value for the design of therapeutic materials and for expectations of rehabilitation. For example, response latencies in the SST guided the content of the later Verb Test and Preposition Test and the detailed data from both of these (section 5.3) provides new information which allows us to begin to formulate speed-based prognoses. On the basis of this study, 25 minutes (plus or minus 5 minutes) is considered to be a reasonable aphasic speed for a 40 item sentence processing test (this compares with a *maximum* of around 10 minutes for normal subjects). This study showed little prospect of substantially reducing time taken for speeds in that range. However, the prognosis for reducing time taken in subjects taking much longer than this was found to be excellent, with the possibility of reducing by as much as a third or a half, initial times in the 45-80 minute range. This finding has important implications for patient selection and the formulation of realistic clinical objectives.⁹⁶

6) The results of this study showed that treatment outcome, measured by accuracy, was related not simply to baseline scores but to consistency in baseline error patterns and particularly to whether or not the *reason* for breakdown could be discovered. Hence, a very poor initial score was not counter-indicative of responsiveness to treatment, on the contrary; a very poor initial score together with a consistent error pattern was a promising sign (c.f. P1 and P14, section 3.4.1) - this is explained more fully in discussing P1 in section 6.1.2 below.

7) On the basis of this study, it seems that aphasic subjects are capable of much more sustained cognitive effort than is commonly supposed. P1..P14 were found to be able to work productively for one hour at a time. They enjoyed being stretched and my impression is that less progress would have been made if the treatment sessions had been of the more usual 20-30 minute length. The reason

⁹⁶ P2, who had great difficulty initially operating the mouse (see Table 2, p. 73) and took 84 minutes to complete the baseline Verb Test, might have been rejected at selection stage as unsuitable for this study. Her results (see Figure 54a, p. 265 and Table 50, p. 227) show that profiles of this sort are certainly worth treating.

for this is that concentrated effort on the patients' part is required to effect change, and many of the diagnostic insights would not have occurred without the opportunity of uninterrupted investigation.

8) One negative observation, which has implications both for the design of therapeutic materials and for the prospect of patients working unsupervised with software, is that these aphasic subjects appeared to be less able to draw inferences from visual cues than had been anticipated. For example, the Verb Remediation Program, in picture-building mode, carefully distinguished active and passive sentences. To passive targets, the agent was represented as a figure with an octagonal head (not ball, box or star-shaped) with a question mark inside it until the final selection had been made revealing its identity. Patients seemed not to notice the significance of this. They could complete all five passive sentences in picture-building mode successfully, and then, confronted by sentence-building tasks, proceed to attempt agent-first constructions. Despite excellent performance in most cases on Raven's coloured progressive matrices (CPM)⁹⁷ (Raven, 1975) the patients were found to be impaired in what one might call 'inferential semantics'. This is a factor which bears more investigation.

A point which may be related to this one in underlying cause, is that I also found some subjects to be insensitive to the grammatical structures I was trying to promote, even within a homogeneous set of instances, where patients should have been primed to produce a response in the format of the preceding examples. For instance, working on the passive voice with P5, we had tackled the treated microworld items and moved on to some spoken real world examples to reinforce the use of the construction (e.g. *the pen is held by alison, the car is driven by X (P5's wife), the watch is worn by J (P5)*) then, pointing to his spectacles, I invited P5 to finish the sentence *the glasses are...* (expecting the continuation 'worn by J') - he responded '*all steamed up*'. They were not, of course. Similarly, P7 participated in describing a series of microworld preposition pictures verbally, such as *the box is under the ball, the star is behind the ball*. After we had done several together, I put up a picture for her to describe in the same way, there was a star and a ball in the picture, her response was, '*Where's the bloody box?*'. These two incidents betray a failure to perform normal logical induction (i.e. to be able

⁹⁷ Raven's matrices were administered out of interest to check for visual processing, logical inferencing and relative hemispheric preservation. There are 36 items in this test, the mean score was 29.93 (min. = 20, max. = 36).

to abstract principles from a number of illustrative examples) - clearly the patients had not grasped the point of what we were doing.

These observations suggest that there is much more to be done in exploring the nature and extent of inferential disturbance in aphasia, for this obviously has fundamental implications for approaches to therapy. They also indicate that it is unrealistic to expect aphasic subjects to interact profitably with software aimed at complex cognitive tasks, unsupervised. In the present state of knowledge, skilled human clinical support remains essential and a genuine clinician-computer partnership as described here, is advocated as the best way of proceeding.

9) Inevitably, the question arises as to whether the therapy was aimed at restoration or reconstitution (Howard and Hatfield, 1987) of syntax processing. Before the clinical phase of the research, I was unsure of whether to expect (in the event that therapy was successful) re-acquisition of parsing skills, perhaps with some sign of recognition in the re-accessing of them, or whether to expect that patients could be re-taught to derive the intended meaning from sentences, but using different methods than they had pre-morbidly. Since so little is known about the cognitive processes underlying intact parsing, it is difficult to know how far the aphasic subjects who are now accurate on some sentence types vary in their methods from normal subjects (except of course that they are so much slower because they consciously execute processes of which the normal reader, if he indeed uses them, is unaware). The remediation strategy used was considered to be equally appropriate for reactivating syntax processing mechanisms were they susceptible of it, or for re-teaching in the event that they were not.

My views on what took place can only be subjective and tentative, however, in more than one hundred treatment hours I only once witnessed what seemed like remembrance.⁹⁸ Otherwise, progress was extremely effortful; as discussed below in section 6.1.2, abstract closed-class words were often not recognised as familiar words and their functions were entirely forgotten and not easily reinstated. The principle of a passive sentence, for example, was found to be extremely hard to impart, there seemed to be no recognition of this structure or what its purpose is

⁹⁸ This occurred in explaining to P3 the function of the word 'that' in structure 4 verb sentences such as *The ball paints the box that the star holds*. I was doing so in terms of a conjunct of two simple active declaratives, 'that' reinforcing the point that it was 'the same box' and obviating the need to repeat *the box* at the end of the sentence. P3 instantly understood and said *The ball paints the box and the star holds it*. I confirmed his interpretation and he never made an error again on that sentence type (see Table H). He also showed signs of generalising to untreated items by session 3 (Table L structures 4 and 7).

and as reported in section 5.2 passives proved particularly difficult to treat.⁹⁹ Even when I had managed to trace the source of a patient's difficulty, such as P1 who was consciously operating an incorrect rule with respect to locatives, the correct interpretation and method of arriving at it continued to feel alien to him, even though he was capable of acquiring a correct strategy. In no case (with the exception of P10 who operated at normal speed at baseline) did any of the subjects perform after therapy with anything approaching the automaticity of normal subjects, as is clear from the speed data. I therefore have little confidence in arguing for restoration and more in having achieved a measure of *reconstitution* in the Lurian sense (Howard and Hatfield, 1987).

Moving on to the six aims stated in section 1.3 (pp. 63-64) which have been designated **theoretical aims** (aims 1, 3, 8, 9, 10 and 11), several of these have been covered in the thesis so far, but others remain to be discussed - the latter concern the theoretical implications of the present study. Clearly, the methodological aim (aim 11) of providing an experimental design which satisfies the criteria discussed in section 1.2.4, that is clinically feasible and workable in the context of sentence-level assessment, has been met. The research design is capable of delivering unequivocal evidence of the efficacy of treatment and the assessments, being automated and patient-controlled, are objective and hence highly suitable for replication studies. The experimental design permitted the study of comparative verb and preposition processing and aim 9 (to explore dissociability) was fulfilled in the results of Group A after verb treatment. The objective of applying cognitive neuropsychological principles to the study of syntax problems (aim 8) can be seen to have influenced the contents of the SST, the experimental design, the contents of the Verb Test and Preposition tests (which allowed within and between-function comparisons) and in the investigative procedures (the clinical application of cognitive neuropsychological principles will be clearer on reading section 6.1.2). Aim 3 (to furnish comparative data on the performances of aphasics and normals on the new modular SST) was met in Chapter 2; the main results of the SST are summarised below. The main theoretical objective was aim 1, to discover more about the nature and functional causes of deficits of written sentence processing. A precis of the findings is given below and this is amplified in

⁹⁹ My findings therefore do not support those of Weigl and Bierwisch (1970) cited by Hatfield and Shewell (1983), that the "practice of one sentence-type with an aphasic patient had the effect of de-blocking production of other sentences different in their surface structure but all related to the same deep structure; for example, active, declarative sentences and their corresponding passives...".

section 6.1.2 where data from individual patients are discussed on a case by case basis.

The most important findings arising from the fulfilment of theoretical aims were as follows:

10) It is possible to achieve significant and durable improvements in the sentence understanding abilities of long-term aphasic subjects with stable impairments of verb and preposition processing.

11) Only a modest correlation was found between degree of impairment in spoken language input/output (measured by the WAB) and written sentence comprehension (measured by my SST) (section 2.6.2). This finding supports earlier conclusions by Caplan and Hildebrandt (1986) that expressive and receptive impairments may differ in extent.

12) The processing of simple active declarative sentences and simple locative prepositional sentences is dissociable (this was shown in the results of aphasic Group A after verb therapy (section 4.1.1) and is discussed with relation to subject P1 in section 6.1.2).

13) All the patients were found to have deficits of visual digit-span recall (DSR) which did not improve as language processing improved (section 2.6.1 and 4.2.1). There was no apparent relationship between degree of DSR impairment at baseline and impairment in written sentence comprehension measured by the SST. Hence the results of this study support earlier findings by Byng (1988) and Waters, Caplan and Hildebrandt (1991) that normal STM capacity is not critical to being able to carry out syntax processing operations. The present study also determined, through P10, that an impairment of STM (digit-span recall of 3) does not preclude sentence processing at normal *speed*.

14) The Syntax Screening Test (SST) yielded important information on the performance of aphasic subjects compared with normal subjects and on the relative preservation and impairment of functions in single cases. The test was found to differentiate normal and aphasic subjects. One of the aphasic subjects tested was found to operate at normal speed; otherwise there was no overlap between the two samples of subjects tested in speed or accuracy (see Figures 5 and 6, p.96 and p.98). The SST furnished new data on response speeds and error

patterns, showing a great deal of commonality between the aphasics and the normals in their behavioural characteristics (e.g. in the high positive correlation between mean response latency and number of errors made, and in the relative ordering of the linguistic modules by mean response latency).

The comparison of group data (one test each for 45 normal subjects compared with three tests each for 14 aphasic subjects) showed the aphasic scores to be depressed by a minimum of 30% on normal values across all six linguistic modules tested. In addition to this general degradation¹⁰⁰ the SST revealed particular difficulty among this sample of aphasics in the processing of verbs, prepositions and morphology, which were all considerably more impaired compared with normal scores. Verbs and morphology had been the hardest two modules for normal subjects (measured by mean response latency), but normal subjects had had no difficulty with prepositions (which were ranked fifth out of six in order of difficulty; 1=hardest). The aphasics returned a very similar rank ordering to the normals, with the exception that prepositions were found to be second in order of difficulty. Hence, the SST detected a disproportionate problem in these subjects, for locative prepositional items.

A strong positive correlation was found between the results of the aphasic subjects on the new SST and on the existing TROG test. However, the SST was half the length, and for present purposes much more diagnostically informative because of its modular design and ability to monitor speed as well as accuracy. It should be stressed, however, that the modules in the SST was chosen with regard to the previous literature on receptive agrammatism (section 1.2.1) but are exploratory in nature. While the test fulfilled its purpose, it is recognised that errors within modules can be made for reasons other than impairment in the function that is the module's intended focus (e.g. section 6.1.2 explains how a compensatory rule invoked by P1 accounted for his difficulty with prepositional items, but also for some of the errors designated as morphological). However, it is also important to realise that without such an exploratory framework one cannot begin the process of evaluating the bases for module demarcations or identifying where errors patterns cut across them.

15) The functional causes of sentence processing breakdown were found to arise from an extremely complex interaction between a number of factors. These

¹⁰⁰ which is compatible with the theory of an underlying 'computational capacity restriction' proposed by many previous studies and reviewed by Frazier and Friderici (1991).

varied between subjects and to some extent within subjects, although on the whole patients' error patterns were found to be more consistent than some previous studies had implied (e.g. Howard et al., 1984), so that in spite of variability, conspicuous and reliable error patterns did emerge. Despite setting out to study disorders purely of syntax processing - screening the patients for single-word understanding and paring the microworld vocabulary to a minimum - large numbers of confounding factors were encountered including single-word problems, absent in isolation, but seemingly induced by the cognitive load of multi-word processing. The conclusion was that any realistic model of sentence processing would have to accommodate these.

Briefly, it was confirmed that there is a disorder complementary to expressive agrammatism which may aptly be termed *receptive agrammatism*, characterised principally by loss of recognition of, and/or loss of the syntactic function of, closed-class words (e.g. *the, is, by, that*). These words are the 'syntactic cement' of sentences but, crucially, they do not have meanings in the sense that content words (or even pronouns and prepositions) do. Pronouns were found to be comparatively well preserved, but the syntactic function of prepositions (as opposed to their meanings) proved almost universally elusive. More evidence for these assertions is given in section 6.1.2 where the ancillary factors detected are also explained. These included elements of acquired dyslexia, interference of impaired phonological output, anomia for microworld items, limitations of internal retention during parsing, reliance on inappropriate compensatory rule-based strategies, and errors elicited by the assessment environment (such as visual interpretive problems and inability to handle sentence processing, verbal output, visual processing and mouse movement concurrently). These problems were for the most part intermittent; the problems with closed-class words were in almost all cases constant and the global computational deficit mentioned above was constant, hence the subjects were found to be *probabilistically and multidimensionally impaired*.

6.1.1 GROUP EFFECTS

The 14 aphasic subjects were divided into two groups for treatment purposes. Group A was given verb therapy before preposition therapy and Group B received treatments in the opposite order. The purpose of this section is to

summarise briefly the main treatment effects and to comment on the factors which may have contributed to the poorer results of Group B.

The outcomes for Groups A and B were different both in the magnitude of change and in the effects of treatments on the other functions tested. In the case of Group A, a classic cross-over profile was obtained showing significant treatment-specific effects accompanied by generalisation (see Figure 15, p. 160). ANOVA on the accuracy scores showed that performance on verbs improved significantly as a consequence of verb treatment. There was a degree of generalisation both to untreated items in the Verb Test and to more naturalistic items in the paper-based Real World Test but accuracy on prepositions was unchanged. Preposition treatment was then administered, after which performance on preposition items was found to have improved significantly with generalisation to 'real world' preposition items. Following preposition therapy, the improved performance on verbs had been maintained (for five weeks). The control function, morphology, remained at the baseline level throughout, further confirming the function-specific effects of both treatments.

Group B failed to produce a complementary cross-over pattern (see Figure 17, p. 165). ANOVA showed a significant overall improvement on the Verb Test, Preposition Test and Real World Test coinciding with the treatment of prepositions (which was given first), but no significant change after verb treatment. Although preposition items responded more than verb items to preposition therapy, the difference did not reach significance. As with Group A, morphology remained static throughout, showing that this function was unaffected by verb and preposition treatments.

The central question posed by the different treatment outcomes of the two groups is, were they due to the different treatment conditions experienced (i.e. to the ordering of the therapies), were they due to endogenous factors (i.e. characteristics of the group memberships) or were they the result of a complex interaction between treatment conditions and endogenous factors? The short answer is that on the basis of a single experiment these possibilities cannot adequately be disentangled. Replication studies are required to verify whether there is an inevitable disadvantage to treating prepositions before verbs. The evidence from this study leaves the question open; there was reason to argue that 'verbs first' is the logical treatment ordering, but there were also signs in some of the individual performance profiles of Group B members, that 'prepositions first'

ordering does not necessarily prejudice results. The combined effects of several Group B subjects produced the disappointing profile illustrated in Figure 17, by not showing function-specific effects of treatment appropriately, by not improving on untreated items after therapy or by not maintaining improvement in treated items after withdrawal of therapy. The poorer results of Group B are encapsulated in these observations. Particularly important was the failure to improve in untreated preposition items between sessions 1 and 2 and the failure to sustain progress in treated prepositions between sessions 2 and 3.

Concerning the different clinical experience of the two groups, there are two factors to consider: firstly the treatment ordering and secondly the possible effect of the administering clinician. There is evidence from the results of Group A that there *may* be an inherent disadvantage to treating prepositions first. Group A had verb treatment first, as a result of which verbs improved, but while speed of performance on preposition items also improved there was no change at all in accuracy on the Preposition Test. As Group B showed improvement, albeit less, on verb items following preposition therapy, there are grounds for arguing a degree of reciprocity between the two functions (e.g. in the commonality between word order significance in sentences of similar structure such as *The ball paints the box* and *The ball is under the box*). However, beyond this, there is clearly an element of specificity about locative prepositions which is unique and which is not affected by therapy for verbs.¹⁰¹ On the basis of these findings there is reason to believe that 'verbs first' is the more logical and perhaps more beneficial treatment ordering.

As mentioned in section 5.4, the clinician as contributory factor cannot be eliminated, but neither is there any compelling evidence to support the suggestion. I treated all of the subjects in Group A and P6 and P12 in Group B (neither of these subjects contributed to the poorer Group B results). However, there are three reasons why it seems unlikely that the administering clinician was a critical factor. Firstly, Group B produced a marked response to treated preposition items (see Figure 17, p.165), treated and untreated verbs also improved less, but equally, as a result of preposition treatment - one is less happy about querying the effectiveness of the clinician in these circumstances, than if the subjects had failed to show improvement. The second and a related point concerns the dramatic decline in performance on treated preposition items,

¹⁰¹ This point is brought out more clearly in the discussion of P1 in section 6.1.2, but for the time being the group results illustrate it adequately.

accompanied by an improvement both in treated and untreated verb items, after verb therapy. Similarly, loss of a treatment effect after withdrawal of therapy seems less likely to be clinician-dependent than a failure to improve in the first place (particularly when improvement generalised to 'real world' preposition items between sessions 1 and 2 and was maintained between sessions 2 and 3). Thirdly, in view of P9's bizarre performance during the treatment phase (see Figure 21a, p.183) I was keen to investigate his prepositions myself. In the extended treatment phase reported in section 5.5 I treated him for three hours, and my colleague and a student therapist for two hours each. Figure 46 (p. 252) shows that P9's (treated) prepositions improved dramatically between sessions 3 and 4 (1/20 -> 15/20), however, his untreated prepositions were static and he declined substantially on treated items between sessions 4 and 5 after verb therapy. Considering points one and two above and my part in this last 'classic Group B result', it seems unlikely that the administering clinician was a major influence on the different group outcomes.

There is a possibility that at least part of the explanation for the dissimilar outcomes lies in differences in the composition of the two groups. When the patients were initially assigned to the two groups there was no way of foreknowing who would respond to treatment and who would not. The therapy was untried and one had no idea whether the weakest patients would make the greatest advances or whether they would prove unreceptive. Nevertheless, the mean scores of the two groups on the last SST (Group A mean = 23.71; Group B mean = 23.14) and all three SSTs (Group A mean = 23.62; Group B mean = 23.10) were compared to check that there was no glaring imbalance. While Group B was poorer on the pre-therapy WAB (Group A mean = 75.48; Group B mean = 68.83) this was considered unimportant because there was only a weak correlation between degree of impairment in spoken input/output and in written sentence understanding. The mean scores of the two groups on Raven's CPM were also very similar (Group A mean = 29.86; Group B mean = 30.00) so the supposition was that they would be equally likely to be able to benefit from a therapy which was right-hemisphere mediated.

As reported in section 5.4, when the different treatment outcomes were known a retrospective exercise was undertaken, to see whether any causative factors could be identified. A variety of external factors were considered, such as age, interval post-onset and previous occupation, but these proved unilluminating. However, on examining the pre-therapy WAB and SST results in greater detail it became

apparent that there was much greater variability of performance in Group B - this group tended to have the strongest and the weakest subjects in it, while Group A was found to be more homogeneous. Specifically, Group B happened to contain P9, P11 and P14. These subjects had been largely responsible for the poorer results of Group B (see Figures 21a and 21b, pp. 183-184) and were ranked 11th, joint 12th and 13th respectively over the three SSTs. As explained in section 5.4, while there was no way of forecasting that P9 and P11 would continue to be weak subjects (whereas P2 (in Group A) and P6 (in Group B) who were also very weak initially, would make impressive progress) they, and P14, were nevertheless all assigned to Group B. It seems unlikely that the performance of these subjects was group-dependent and more probable that Group B's results suffered by the chance allocation to it of these patients.

The suggestion of Group B being a weaker Group was also supported by observations made in section 5.2, the analysis of performance by sentence structure. In that section the profiles of the two groups across the various sentence structures and the treated and untreated items, betrayed differences which could not plausibly be ascribed simply to treatment ordering. For example, the discussion surrounding Figure 24 (p. 195) draws attention to the failure of Group B to benefit from verb therapy as much as Group A in treated items, most notably in structures 2 and 4 (passives and two-argument verb sentences). The discussion accompanying Figure 27 (p.199) points out that the weaker performance of Group B is evident in three structures on the untreated side of the Verb Test failing to reach 50% accuracy at session 3, whereas in Group A, even the untreated structures (5..7) managed to attain the 50% level. Group B's preposition results were characterised by a loss in all three treated structures after withdrawal of therapy and a notable failure to generalise to untreated structures.

The lack of generalisation was a hallmark of Group B's results; it is clearly seen in prepositions (Figure 17, p. 165) and verbs (Figure 18, p.165). In fact, looking at the performance profiles of individual subjects in that group and considering supplementary information such as P9's preposition performance in the extended treatment phase (section 5.5), it seems that the ability to generalise is perhaps the best indicator of the capacity to make and maintain progress.

So far the weakness of Group B has been stressed, but in keeping with the greater within-group variability of this group, its potential to return a classic cross-over pattern was also thwarted by the high pre-therapy accuracy of some members.

P12 was close to ceiling on prepositions at session 1 (18/20 on both untreated and to-be-treated items, he required help for speed), thus although he did not regress, there was no opportunity here for much gain. A further point in this vein that appears to have prejudiced the Real World Test results of Group B (which were also inferior to those of Group A, c.f. Figure 16 (p. 162) and Figure 18, p. 165)) was that, oddly, Group B were very much better on 'real world' verb items than on matched microworld verb items at first assessment. After preposition therapy 'real world' verbs had improved further, such that three subjects had attained 19/20 *prior* to verb treatment. This allowed almost no room for generalisation to occur and in fact all three 'bounced off this ceiling' on the final assessment, with small declines that contributed to a disappointing result between sessions 2 and 3.

In conclusion, that there is no simple explanation for the inter-group variation observed in the treatment results. The answer is likely to lie in a combination of the factors discussed, only replication studies can hope to settle the question. There is evidence that Group B contained a less homogeneous set of patients with respect to their pre-therapy status; this greater variability may have been responsible for Group B's more chaotic result profiles. There may in addition have been an inherent disadvantage to the treatment ordering experienced by Group B. However, the treatment results of P4, P6 and P12 (see Figures 21a and 21b, pp. 183-184) indicate that the 'prepositions first' treatment condition does not inevitably yield a muddied cross-over pattern, and suggests that with a different set of patients, a complementary outcome to that of Group A might have been obtained.

Finally, the organisation of this study and the size of the patient cohort has implications for the single-case versus group-study debate which was discussed in section 1.2.4. In working with 14 patients in two groups of seven, the aim was to have enough subjects to be able to analyse group trends (this is especially useful in sentence-level investigations since it is difficult to give an individual subject a large number of tasks to complete), yet not so many that the results could not also be explored on an individual basis. The importance of not being too quick to generalise from single-case data is brought out in the present study. Clearly, one could isolate an individual (e.g. P9), or a small number of individuals (e.g. P9, P11 and P14), who if they had been the only subjects studied, would have yielded a very different impression of the efficacy of this approach to therapy. The wealth of data obtained in the present study has been due to the combined group-with-single-case approach. A small positive improvement in an individual may be a

chance occurrence, whereas the same improvement in 13 out of 14 individuals becomes statistically significant - it is therefore desirable to have sufficient numbers to discern trends. Likewise, an aberrant compensatory strategy observed in a single subject becomes much more theoretically interesting if its use is discovered to be common among aphasics (thus indicating that the discovery has general implications for remediation). Many issues have been raised by this study, for example the possible effect of treatment orderings and prognostic implications of the effect of treatment on speeds, which would not have been feasible without embracing a group approach. The problem of selecting homogeneous groups, which may have marred the present results despite precautions, is no worse than the problem of what Newcombe and Marshall (1988) called 'pathological individuals'.¹⁰² The recommendation of this study is that there is much to be gained from methodologically sound experiments on the scale of this one.

6.1.2 CLINICAL OBSERVATIONS

In this section the 14 aphasic subjects are briefly reviewed in terms of the main sentence processing deficits that each showed, how therapy was targeted at those problems and why it was, or was not, successful. As explained in Chapter 3, in the present state of knowledge it is generally not possible to complete a diagnosis of sentence-level impairments before offering remediation. The function of the 'remediation' phase of this research was therefore heavily diagnostic. Therapy activities for each subject were guided by the assessment results, as illustrated in section 3.4.1, but the picture-building and sentence-building activities of the treatment phase provided the means to exploring the deficits in greater detail and it was in treatment sessions that many of the important diagnostic insights were obtained.

P1 was the most successful of the 14 subjects (see Figure 54a, p.265 and Table 51, p.232). He achieved large and durable increases in accuracy both on verbs and

¹⁰² This point relates to the fact that single-case (pathological or 'normal') studies may suffer from invalidity due to the subject being grossly atypical, just as ill-chosen group studies can return average values which bear little relation to actual individual performances. The group-with-single-case approach adopted here (i.e. analysis of *both* group and single-case data) is a productive method which facilitates identification of patients who are atypical with respect to their peers (e.g. P12 who was found to have visual interpretive problems and P10 who operated at normal speed) as well as allowing significant treatment effects to be obtained as a result of small parallel changes in many subjects.

preposition items in the microworld, showed strong generalisation effects both in the microworld and on the Real World Test and simultaneously increased his processing speed both for verb and preposition items. The formulation of therapy goals for P1 was discussed in section 3.4.1.

The cause of P1's difficulty with three-argument-verb sentences emerged during therapy. His interpretation of *The ball gives the box to the star* as *The ball gives the star to the box* arose not because of proactive reading or a saliency-guided linear ordering strategy (i.e. mapping the first two noun phrases on to animate characters), but seemed to be due to having retrieved along with the verb *gives*, the directional preposition that *gives* uses. P1 seemed to be unable to suppress output of the whole 'gives to' unit. Early in remediation, P1 uttered sentences of the form *The ball gives to the box...* on being asked to read a target sentence, and spontaneously in response to a target picture. Interestingly, picture-building mode of the Verb Remediation Program sorted out this problem for P1 very quickly, without it ever having to be tackled explicitly.

P1's reverse role errors to passive targets turned out to be due to failing to register the *is verbed by* construction. Abstract words such as *is, a, by, that, the* meant nothing at all to this patient, he could not read them aloud readily and on being asked to repeat them, did so hesitantly and with abnormal intonation. During his first therapy session P1 grasped the significance of the *a/the* contrast used to reinforce topicalisation of the inanimate object in the passive sentences. P1 was also able to learn very quickly from picture-building tasks. By his second therapy session he was faultless on mixed actives and passives.

The problem with sentences of the form *The ball paints the box that the star holds* again hinged on P1's failure to recognise all but the emboldened words. Crucially, in common with many of the subjects he did not understand the function of the relative clause. Firstly the presence of, and the structural importance of *that* was highlighted, then the function of the relative clause was taught by writing out in full the corresponding conjunct sentence *The ball paints the box and the star holds the box*, before moving to a second version where the conjunction was replaced with a comma. After stressing the redundancy of repeating *the box* at the end of the sentence, this noun phrase was crossed out and the word *that* inserted between the two clauses with an arrow head pointing backwards to the noun-phrase it refers to. This step-by-step explanation together with the computer graphics proved useful in conveying the notion of it being *the same box*.

After verb therapy, which he received first, P1's verb performance improved to 34/40, but he remained static at 11/40 on prepositions. P1's second data row in Table F (Appendix 12) shows that after verb therapy, all 8 to-be-treated structure 1 preposition sentences (such as *The ball is under the box*) elicited reversal errors (on the untreated side, Table J, the more salient prepositions (sentences 23, 24, 27, 28) were correct, while the subordinate ones (sentences 21, 22, 25, 26) caused reversals). So, after verb treatment P1 was securely in possession of word order significance and of the meanings of the three nouns (as demonstrated by his verb results) but this had not helped his preposition accuracy. He showed a clear **dissociation between the processing of verbs and prepositions** - specifically he could reliably handle simple active declarative sentences (e.g. *The ball paints the box*), but not locative prepositional ones (e.g. *The ball is under the box*).

Picture-building mode of remediation established that P1 was in no doubt about the preposition meanings, which he gestured with no trouble. He was quick to notice that the antonyms of treated prepositions were not included on the lexical palettes (i.e. *over* and *in front of* were not there). Clearly, he had previously seen opposites in therapy, knew that he confused them and was sceptical of making progress with only one half of the pair. P1's subvocalisations finally revealed his difficulty. While interacting with the computer he muttered "*Ball first so...*" or "*Box bigger so...*". *Ball first*, of course, referred to first-mentioned in a sentence and *Box bigger*, to a picture he was looking at. P1 was consistently applying *normal* perceptual saliency rules and *normal* grammatical hierarchy rules (Levelt, 1989). He neither had a mapping problem nor a lexical access problem for prepositions. P1 demonstrates unequivocally, that it is possible to be in possession of word order significance rules and single-word understanding and still to get non-salient locative prepositions wrong.

P1's impairment was thus not one of syntactic processing as such, it was due to the loss of a crucial piece of information concerning locative specificity i.e. **that a locative preposition specifies the spatial relationship of the preceding object with respect to the following object(s)**. This was an important finding. Not only is the dissociation of verb and preposition processing established (something that was suspected in the literature review (sections 1.2.1 and 1.2.3) and demonstrated in Group A's results), but in a very interesting way. The operation of normal saliencies *minus* a knowledge-based deficit is seen to have caused a *consistent* and persistent sentence understanding problem. S-V-O ordering plus meanings are

not enough to handle locatives - this information is surprising to intact users and as far as I am aware the missing layer has not previously been identified in the aphasia literature.

A further related finding was that P1 did not only apply his pragmatic strategy to prepositions - he made similar errors on morphological items where the subject of the sentence was subordinated, as in *The ball is smaller than the box*. Again he knew that 'smaller' implied that one thing was smaller than the other, but word order significance told him that the ball was the subject of the sentence (therefore dominant) so he chose the picture where the box was smaller. This behaviour illustrates how compensatory rule-based behaviour can cut across grammatical boundaries. The extent to which reliance on this particular rule is common in aphasia, and may explain a variety of seemingly disparate problems, deserves a great deal of further investigation.

P1 is thought to have responded well to microworld therapy because of the consistency of his errors, his ability to make inferences from the computer graphics and his metalinguistic skills. P1 was able to reflect on his own language processing, he had a very logical approach to the application of compensatory strategies and was therefore able to acquire alternative (correct) procedures.

P2 had a successful and durable treatment outcome as can be seen from Table 51 (p.232) and her graphs in Figure 54a (p.265). P2 received verb therapy first. Her pre-therapy Verb Test took 84 minutes (of which less than one minute was occupied by a pause) and yielded the responses shown in Table H (Appendix 12) to to-be-treated items. Following analysis of her errors, the hypothesis was that the patient failed to recognise the passive construction, had mapping difficulties with more than two arguments and did not understand the function of the relative clause.

As with P1, therapy sought to work on structure 3 sentences before moving on to passives and those incorporating two verbs. In fact, P2's difficulties were found to stem largely from a failure to recognise and read abstract function words. She found words such as *the, is, that, to* very difficult to say and therefore seemed to neglect them in her reading. Her struggles to read aloud sometimes produced neologisms and much frustration. P2 also had phonological difficulties forming content words (such as *star => scar*). These problems should not have affected silent reading had she been able to read without pronouncing, but P2 seemed to

need to utter the words before she could retrieve their meaning (as if semantic memory was not receiving adequate stimulation from the printed form alone). The partitioning of sentences in remediation helped P2 to focus on each segment of the sentence in turn. Once the units began to be recognised, reading and semantics improved markedly and speed of processing increased in parallel. Interestingly, P2's progress on passives occurred in two stages - she was not wholly accurate until the assessment which followed preposition therapy (indicating, perhaps that assimilation is necessary in the learning of complex skills and that assessment directly after therapy may not capture the full extent of change).

P2's second Preposition Test showed considerable confusion (see Table F, Appendix 12). For example, in structure 1 sentences she chose a distractor depicting *in* instead of *under*, another one depicting *in* instead of *behind* and on two occasions chose the reverse role distractor (i.e. the relationship was correct but the subject and object were swapped). P2's errors in the other two structures were equally inconsistent. The hypothesis was that P2 had difficulty accessing semantic information from the orthographic forms of prepositional items.

In remediation sessions it became apparent that P2's main problem was reading closed-class words. She seemed unable to use a sub-lexical reading route (using grapheme-phoneme conversion rules to sound out words) and the prepositions and abstract function words seemed to be differentially impaired in that P2 found it very difficult to retrieve their whole-word phonology from the written form. As described above, she seemed unable to access the meaning (or function) of these words without first uttering them, but once they were spoken (by her or by me) she had no trouble in interpreting sentences. The auditory-verbal and graphical stimulation offered by the remediation environment suited this patient well. In addition, the partitioning of sentence components encouraged her to pay close attention to the number of words present in each segment and to the whole-word shapes. It seems likely that the increase in time taken after therapy (see p. 265) was due to P2 consciously grappling with her reading problem. Five months after cessation of treatment she was operating once more at her baseline speed, but had sustained her improved accuracy.

P3 received verb therapy first. His responses to the treated side of the Verb Test appear in Table H (Appendix 12) and his overall results are shown in the graphs in Figure 54b (p. 266). *P3* scored 12/20 on the to-be-treated side of his pre-therapy Verb Test. From Table H it can be seen that *P3* made two errors to

simple active declarative targets, one of which was an error of type 3 (*The star paints a box => The star paints a ball*) which should not have occurred following success on the Lexical Test (which screened for single-word understanding). P3 clearly had some recognition of the passive voice, scoring 3/5 to passive targets. Three-argument-verb sentences elicited only one error, but it was uncommon - a switching of subject and indirect object rather than the much more usual object/indirect object confusion. Like most of the subjects, P3's processing of relative clause constructions was inaccurate (2/5 correct). P3 operated at a good aphasic speed (between 20 and 25 minutes for both 40 item tests at baseline).

Picture-building mode of verb remediation showed that lexical items in isolation were well understood, but that P3 suffered from intermittent anomie difficulties on being asked to name the microworld shapes. Conversely, he sometimes had difficulty reading aloud a noun-phrase written on the text line. *Ball* and *box* were most often confused, probably because of their common initial phoneme. When P3 uttered, for example, *ball* instead of *box*, his correct semantic intention could often be seen in the appropriate accompanying hand-gesture - generally he appeared not to notice his incongruous vocalisation and selected the right item, on other occasions his original intention appeared to have been 'overwritten' by the processing of his own speech. P3 achieved flawless performance on passives in the therapy environment, but by the end of the efficacy study he was still making 4/5 reversal errors to passive targets, so therapy had not been successful in reinstating this structure. However, early in therapy for relative clauses (as described for P1), P3 spontaneously offered the paraphrase *The box paints the ball and the star holds it*, his interpretation was affirmed and he made no further errors on this structure in assessment.

P3's pre-therapy preposition performance (2nd data row, Table F, Appendix 12) shows a confused pattern of responses indicating both reversals and incorrect locative relations. In therapy, P3 could correctly identify the prepositional relationships in isolation, but on being given pen and paper and asked to draw to written target sentences, he produced reverse role pictures every time. He seemed to be operating a weaker form of P1's saliency rule; it was elicited in picture-drawing but not always in picture-matching. To the target *The box is in the ball* he said "Box first" and proceeded to draw a large box with a ball inside it. But a second confusion was evident in other subvocalisations, i.e. there was a reinforcing tendency to interpret *under the box* as *box is under*. After therapy, P3 was still reversing 3/8 of the simple treated items and after 5 months with no

further treatment P3 had slipped back towards his baseline position. Overall, P3 showed very little benefit of therapy either in the microworld or on 'real world' reading tasks. This was both disappointing and puzzling as he took particularly well to the computer-based environment, had good auditory comprehension and speech output and was thus able to participate very actively during treatment.

P4 was one of the three subjects who undertook an extended phase of therapy. He is discussed on pages 247-251 where graphs of his overall performance appear. In the first phase of treatment P4 received preposition therapy first. His pre-therapy Preposition Test responses to to-be-treated items can be found in Table G (Appendix 12). He presented a mixed set of errors including apparent confusions with preposition meanings (e.g. *behind* => *in*) and reversals (which could, of course, also be semantic problems, the preposition having been understood as its reverse). Therapy sought to reinforce the individual treated prepositions in picture-building mode before exploring the reasons why reversals had occurred.

Similarly, P4's Verb Test responses to to-be-treated items (Table I, Appendix 12) showed inconsistencies in the interpretation of passives and two-verb sentences. The passives, for example, elicited 4/5 errors; two reversals, one incorrect noun and one incorrect verb. This profile indicates multiple problems. In fact, P4's main problems seemed to be poor concentration and reduced internal capacity and these impinged upon all his sentence processing tasks. This subject had extreme difficulty in retaining the target sentence or a meaningful part of it, internally, long enough to operate on it, either for lexical access or for the formulation of a semantic model. His excessive response latencies post-therapy were due to a very effortful repetition of the sentence components, sometimes 20 or so times, in the course of trying to build up a mental model of meaning (e.g. "*The ball... the ball... the ball is under... under... the ball is.. the ball is under... the ball.. the ball..*" etc.).

With such a severe computational impairment it was difficult to assess the status of P4's language processing functions. He clearly did know the single-word meanings in isolation, but the cognitive load imposed by the whole-sentence tasks caused sub-tasks (such as lexical access and argument mapping) to collapse in unpredictable ways. P4's accuracy improved as his concentration span increased. The second phase of therapy was aimed specifically at speed, by for example,

giving the patient quick-fire exercises in sentence-building where only one element was missing. The results of this were very promising (see p.249).

Table 51 (p. 232) shows that *P5* had a disappointing outcome on account of the large increase in time taken for both tests after therapy. *P5*'s pre-therapy Verb Test responses to to-be-treated items are shown in Table H (Appendix 12). He was treated on verb items first and the focus of his therapy was structures 2 and 4, the passives and two-verb sentences. His test results suggested that the passive voice was sometimes recognised and interpreted correctly (3/5 correct), however, in therapy it became apparent that his grasp was very fragile. He had word ordering problems and omission of function words on being asked to generate a spoken sentence to a picture target (e.g. "ball boxpainting"), he also had great difficulty reading target sentences accurately (e.g. in assessment, to the target *The star's box is smaller than the ball's* *P5* said "*The balls and the box and the star*" and looking at the candidate pictures declared "*It could be any*". The same difficulty was evident in his reading of locative sentences - as with the verbs, he managed much better on the shorter sentences, but in those including a relative clause his function word reading combined with internal limitations, defeated him.

P5 was very alert during therapy and, like *P1*, appeared to be amazed at the presence and function of words he had previously not noticed. However, his cognitive processes were slow. He needed a great deal of time to reflect on matching pictures and words and to internalise the correspondence. *P5* showed the same tendency as *P3* to apply perceptual saliencies to preposition items but neither of these patients applied a rule as consistently as *P1*. *P5* (and others) found *in* harder than the other treated prepositions because it violated his feeling that the first noun-phrase should be dominant in the picture more acutely than depictions of *under* or *behind*. He was slow to appreciate the pattern that was being reinforced within a homogeneous sentence set and often failed to make normal inferences from graphical sequences. For example, like several of the subjects, *P5* failed to learn anything at all from passive sentences in picture-building mode. *P5*'s very slow speed in both functions after therapy (see p.266) was because he was struggling to process parts of language which he had previously neglected, under severe computational degradation. However, he benefited from a further assimilation period and after 5 months was found to have maintained accuracy while improving speed, especially on locative items.

P6, P9 and P14 can be conveniently considered together. They all belonged to Group B, the group that received preposition therapy first. The responses of these subjects to the to-be-treated sides of the Verb Test and Preposition Test can be found in Tables G and I (Appendix 12). Their overall performances on these tests is shown in Figures 21a and 21b (pp.183-184). All three subjects had very little intelligible spoken output as indicated by their fluency, repetition and naming scores on the WAB (See Table 17, p. 106) and all had severe articulatory problems. In terms of being able to participate actively in diagnostic interaction, these three patients were the most impaired. Because of their almost non-existent vocal output it was difficult to gauge how much of the auditory verbal stimulation they were receiving in therapy was being understood. These patients were unable to ask questions or to discuss their problems in the way that many of the others could. As therapy was designed to be highly interactive at the level of reinstating concepts such as action, agent and theme, these patients were perhaps less able to benefit due to the severity of lower level breakdowns.

Sentence-level processing was confounded for these individuals by anomic difficulties, phonological output problems (where, for example the word-form for *box* was retrieved from the phonological lexicon instead of the intended *ball*, this also happened with prepositions) and reading difficulties (i.e. the meaning of words on lexical palettes could not be retrieved from their whole-word forms, neither could the words be reliably pronounced). Subjects seemed at times to be in internal deadlock - to understand they needed to read aloud and to read aloud they needed to understand. The role of phonological recoding in reading was mentioned in section 1.2.3. There is a good deal of evidence that phonological processes (particularly whole-word 'addressed phonology') supplement purely visual processes in normal reading for meaning, although the exact mechanisms involved are ill-understood (Patterson and Coltheart, 1989).

In terms of their responses to therapy, all three were patients who seemed to achieve more in the remediation environment than their picture-matching re-assessments suggested. Although P6 appeared to have a favourable outcome (see Table 51, p.232), this was due to small increases in accuracy combined with decreases in time taken - he was still nowhere near a useful functional level after therapy (17/40 verbs; 13/40 preps). A common feature of P14's and P9's performances was the spectacular improvement each made on *treated* preposition items after therapy (P9 during extended treatment (see p. 252) and P14 after his first therapy input (see p. 184)) and the equally dramatic fall-off in performance

once therapy was withdrawn. The failure to show generalisation effects after treatment seems to be a promising indicator of unlikeliness to sustain benefit even of treated items. Likewise random error patterns to homogeneous assessment targets (as discussed in section 3.4.1 with respect to P6 and P14) is considered to be a poor prognostic indicator. In retrospect, these subjects were probably too weak to benefit from therapy at this level.

P7 was one of the three subjects who undertook an extended phase of therapy. She is discussed on pages 255-258 where graphs of her overall performance appear. In the first phase of treatment P7 received verb therapy first. Her pre-therapy responses to to-be-treated verb and preposition items can be found in Tables F and H (Appendix 12). Both sets of errors appeared to be due to syntactic problems, lexical selection was accurate.

However, in the remediation environment P7 had a lot of difficulty initially in selecting the correct picture components and lexical forms. This did not seem to be a visual problem, but more to do with naming difficulties under stress as shown by the following two examples from her accompanying speech: "Is drawn by.... no, is painted.... I beg your pardon, is held by"; "Is held by the box.... I mean the star.... no BALL!!" This subject varied considerably in her level of alertness and consequently in her capacity to perform concurrent activities. The effects of general cognitive degradation were very clearly observed in P7 when she was unable to utter the sentence component she had just selected, navigate the mouse upwards towards the palettes and perform the visual processing required to determine which palette to select, virtually simultaneously. Her accuracy improved markedly on being encouraged to serialise these tasks. Likewise, she quickly reached overload in trying to parse a whole sentence and had to be prevented from reading ahead by means of covering up parts of the VDU screen.

Although P7's clinical outcome was a little disappointing (even after an second phase of treatment), the decomposition strategies she was taught to try to overcome her internal processing limitations did seem to help her private reading, as reported in section 6.2.

P8 was one of the most accurate subjects at baseline (28/40 verbs; 29/40 preps), but on both tests he was well outside useful functional speed (51 mins verbs; 42 mins preps). On both verb and preposition sentences he was accurate on all but the final sentence sets (indicating structural rather than lexical difficulties). The

goals for him were to try to improve speed without losing accuracy and to work on the functional decomposition of sentences incorporating relative clauses.

During therapy P8 was challenged with a variety of speed exercises where his responses to sets of sentences were timed, where he was asked to complete partially worked screens in 'quick-fire' presentation and where he was asked to fix errors purposely made by the clinician as quickly as possible. During assessment, P8 had had no feedback as to the correctness of his picture selection. He had therefore checked and double-checked each response before proceeding. Since P8 was accurate, he was encouraged in remediation to trust his own intuitions, to make his selections quickly, and to use the feedback provided by the software at the end of each task to verify accuracy. By this method P8 gained confidence in the integrity of his decisions and showed very encouraging gains in speed, both in microworld and 'real world' reading tasks (see Table 51, p.232; and P8's graphs on p.267).

P10 was an interesting subject being the only one of the 14 who operated at normal speed (see p. 216). This patient had severe articulatory problems, but fairly fluent speech (when he could be persuaded to talk). He was in the group that received verb therapy first; his assessment results for the two treated functions are shown on page 176. During therapy, when P10 was forced to slow down on account of the sentences having been decomposed, a number of elementary errors occurred. He sometimes made *retroactive* errors (i.e. repetition of, or perseveration on, an item previously read); the microworld *assessment* environment minimised these, because pictures never contained two objects of the same shape (or characters with the same head shape). The *remediation* software though, both in picture-building mode and in sentence-building mode did allow such errors to occur; P10 regularly constructed sentences such as *The ball is under the ball*, or chose a star as the last pictorial element to a target such as *The star is under the ball*.

Apart from perseveration, P10 regularly made phonological paraphasias (e.g. *in(side)*¹⁰³ => *beside*) he also made semantic paraphasias, almost invariably overwriting his correct semantic intention by processing his own vocalisation. During remediation P10 began calling ball and box, *roundhead* and *squarehead*. Sometimes he used the preferred terms, but more often used a contraction of his own names - *round* and *square*. I noticed in remediation that he frequently moved

¹⁰³ I had sometimes reinforced the meaning of *in* by saying 'inside'.

the cursor onto a picture of a star when the target was 'box', he sometimes self-corrected, but often did not. The reason was that P10's pronunciation of *square* approximated more closely to *star* than to either of the other two microworld names. Sometimes his original semantic intention was not strong enough to withstand the stimulation of semantic memory by output from his auditory word recognition system. This gives an indication of the diverse and probabilistic nature of problems which can complicate the diagnosis of 'sentence processing' disorders. P10's errors could easily have been interpreted as lexical access problems. It should be pointed out that P10 also manifested this particular error via the inner voice route - had he not sometimes vocalised, it would have remained undetected. A major focus of P10's therapy was to try to establish clear phonological distinctions between the microworld items. His treatment outcome was successful and wider benefits are reported in section 6.2.

P11 was in the 'prepositions first' group. His auditory-verbal performance was significantly better than that of P6, P9 and P14 as measured by his pre-therapy WAB aphasia quotient (see p. 106). Nevertheless, P11 presented in clinic as a severely impaired individual with almost no spontaneous expressive language, little ability to reflect on his own language processing and he had no insights to offer as to where his sentence-processing problems lay. Baseline assessments showed P11 to be operating at chance level (See Tables G and I, Appendix 12) with a great deal of inconsistency of responses to homogeneous items. P11 failed to show generalisation effects of treatment and was not near a useful functional level after treatment.

In therapy, this patient was found to have multiple difficulties. He suffered from cognitive overload to a more extreme degree than P7, so that it was often more productive to operate the mouse under verbal directions from P8. P8 had word-finding difficulties (for example in finding the appropriate preposition to describe a given spatial relationship, even though the lexical palettes were on the screen). It was necessary to provide a sheet of paper depicting the three treated prepositions with the words *in*, *under* and *behind* written beneath them. P11 could then match the screen picture with one of the relationships on the page, utter the correct preposition and then match its orthographic form with the corresponding word in the lexical palettes - all this with great effort. Even having identified the preposition, P8 found it very hard to order the two noun-phrases correctly around it. In treating verb sentences my colleague did have some

success in simplifying P11's error patterns towards reversals, but felt that passive sentences and two-verb sentences were outwith this patient's grasp.

As with P6, P9 and P14, it seems likely that if P11 had been subjected to more comprehensive single-word testing, he would not have been accepted for therapy at this level of complexity.

P12. It was promised in section 2.4 (in connection with his abnormally long mean response times to the Lexical Test items), that P12 would be mentioned again as having problems unique among this set of patients. P12 showed mild signs of visual agnosia during his pre-therapy WAB test when he mis-named 6/20 objects (he named all these items after a tactile cue). It will be recalled that P12 was accurate on locative prepositional sentences at the baseline assessment but less so on verb sentences (see Figure 21b, p. 184). Apart from being less accurate in verbs, P12 was very much slower, as can be seen from his speed profile in Figure 38b (p. 218).

In assessment mode (where he only had to perform a single mouse click to select a picture) P12 turned out to have mild visual interpretive problems for the verb pictures, but almost no trouble with the preposition pictures (which were composed exclusively of inanimate objects, many pictures involving no visual overlap between the items depicted).¹⁰⁴ However, on starting preposition remediation, when he had a great deal more object identification to do, it was observed that he had difficulty even in choosing pictures for *ball*, *box* and *star* from the picture palettes. Unlike most patients, for whom breaking down the sentence/picture-matching tasks was helpful, P12 found remediation sessions bewildering. For example, he had great difficulty in being able to find *the box* in a picture depicting the ball painting a box. He saw the object, but was unable to identify it from its rectangular outline, instead, focussing on the paint fill-pattern within it, he declared it to be *a mirage* (the part that had been coloured by the ball character was reminiscent of a sand dune).

This profile suggests that P12's deficit was primarily in the visual interpretive process rather than higher up in the object recognition process. Interestingly, when asked to draw simple microworld-type pictures to target sentences P12 had

¹⁰⁴ Although P12 was very accurate on prepositions, he took around 36 minutes to complete the Preposition Test. He spent his time checking and rechecking the pictures, so I feel that this was due to visual problems rather than to sentence understanding ones.

great difficulty knowing where to start, and the images he produced were strikingly primitive. For instance, on being asked (aurally) to draw a picture showing *A ball is held by the box*, he produced the sketch shown in Figure 55. There is no doubt that he understood the sentence, but his ability to generate the sort of images I had accustomed him to, was remarkably poor. P12 was not hemiplegic, so he was not attempting to draw with his non-preferred hand. P12 presented as a similar case to the patient JB of Riddoch and Humphreys (1987), who had a bidirectional impairment involving semantic access from vision (reported in Ellis and Young (1988)).

In addition to his visual interpretive problems, P12 had severe problems in understanding the remediation environment. By the final verb remediation session, having already had preposition treatment, he was still no nearer to understanding what the programs were about or how they operated. He seemed to have no idea what he had to do, no appreciation of the cause and effect connection between mouse clicks and screen displays and very little understanding of what the microworld approach was aimed at. He appeared to have sequencing problems (i.e. that he was unable to formulate a series of steps to achieve an end, or to understand the significance of a series of subtasks - each act was done in isolation and he had no idea what came next).

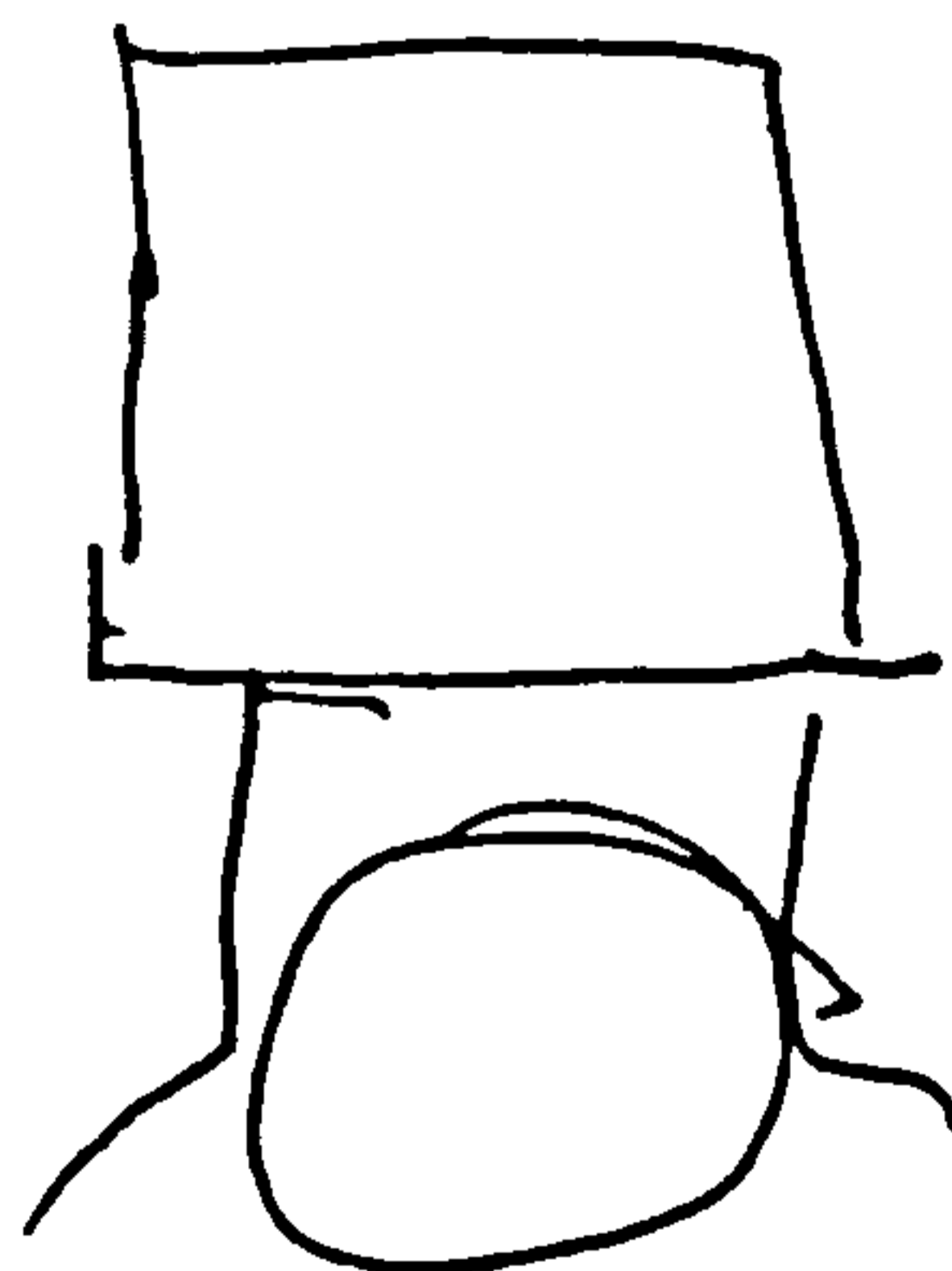


Figure 55. P12's drawing of '*A ball is held by the box*'.
(actual size)

P12's problems were exacerbated by the computer environment in an unhelpful way. That it was a highly visual medium was a key factor, but I also felt that P12 (who at 75 was the oldest subject in the study) simply failed to conceptually grasp the technology. This is quite different from being a little technophobic, as many of the subjects were initially. His remarks were very odd during the treatment sessions e.g. "*What happens now?* (long pause) *Oh, I've to do it have I?* (pause) *I'm clueless.* (long pause) *What do I do... blow this one out now?*"

The case of P12 leads to the recommendation that unduly long reaction times to simple targets (as in the Lexical Test) by subjects with good single-word comprehension should be carefully investigated before embarking on language processing therapy of this type. Performance of this sort, coupled with a speed profile such as P12's in Figure 38b (p. 218) is suggestive of visual interpretive complications. A further point about P12, which is independent of the foregoing, is that he had attitudinal hostility to microworld therapy because he had not come to terms with his brain damage. He was only 7 months post onset at the first SST and 10 months post onset when treatment started.¹⁰⁵ He was still in a state of inner turmoil and was really not ready to have his problems subjected to microanalysis. The microworld approach of relentlessly probing beyond the level of a patient's competence is probably unsuitable for subjects still in a state of trauma.

P13 was a member of the 'verbs first' group. His performance graphs on p.268 show that microworld therapy was more successful for prepositions than for verbs and that this situation prevailed after 5 months without further treatment.

P13 showed difficulty in recognising the word-form in the lexical palette for a concept he understood from the target picture and could gesture (such as *under* or *behind*). He also regularly missed out function words and morphological items when reading aloud a target sentence e.g. *The ball is under the box* => "*The ball is ... the box*". On being asked to generate a sentence to a target picture, he would circumlocute (e.g. "*The ball is nearer to my eye than the star*"). P13 also suffered anomia for the three microworld nouns, adamantly maintaining that he would not have had naming difficulties if the offending characters had been called *circle* and

¹⁰⁵ This after three quarters of a century of above average cognitive performance. P12 had been a church minister, a figure on whom others depended for comfort and counsel. He found not being able to rely on his own brain any more extremely distressing, and having been brought up in a Scottish island community where divine retribution was preached, was tormented by the conviction that he must have done something terrible to have been struck down in this way.

rectangle. The reader may recall that I had eschewed Schwartz et al.'s (1980) names *circle* and *square* on the basis that ball and box were more familiar (higher frequency) and without the geometrical overtones (and certainly star was better called star than decahedron!). P13's argument seemed to be that circle and square described the *shapes* or the attributes of these figures and as such came more easily than the *names* which to him seemed more arbitrary. Whether he was right or not I had no opportunity to discover. However, what was clear from the difficulties subjects experienced, was that the names ball, box and star *are* arbitrary, and that the name-shape association which had been thought strong and potentially helpful, was much less so than originally supposed.

In common with some of the other subjects, P13 had a tendency to apply a left-to-right mapping strategy between sentence components and picture components. For example, to 'real world' target *The dog is between the boy and the girl*, P13 declared that none of the pictures matched (the reason being that the correct picture showed the girl, dog and boy from left to right). He *did* know what 'between' meant, but was employing a linear mapping strategy in absence of the knowledge that the spatial ordering of the objects on the outside is immaterial. As locative prepositions do specify the relative spatial relationships of objects, it is a potentially difficult idea that parts of a relationship are mandatory and parts variable, as in *The ball is under the box and the star* (where the ball must be under both the box and the star, but the relative positions of the last two with respect to each other are not specified).¹⁰⁶

P13 is thought to have responded to preposition therapy because practice did improve access to this closed-class set. However, his problems with verb sentences appeared to be structural and treating passives appeared to undermine his accuracy on actives and vice versa. Possibly P13 would have benefited from extended treatment for thematic role assignment.

Summary. This study has had considerable success in improving both the accuracy and speed of sentence comprehension in long-term neurologically stable aphasic subjects. The results were obtained after only six one-hour sessions of treatment in each of verbs and prepositions. The patients were assessed conservatively, i.e. in a microworld environment in which their impairments would

¹⁰⁶ The Preposition Remediation Program in picture-building mode always constructed pictures to sentences of this form with the second and third objects in right to left order to be able to bring out this very point. In sentence building mode mention of these objects in either order was acceptable.

be exacerbated and *not* using the same environment that was used for treatment. On the basis of P1..P14 receptive agrammatism was found to be a far more complex impairment than single-cause hypotheses suggest. It has been characterised as a probabilistic and multidimensional problem in which global cognitive degradation is overlaid with interacting selective impairments such as acquired dyslexia, anomia and disorders of phonological output.

From the foregoing observations and from the treatment results it can be seen that the microworld proved to be an extremely informative diagnostic tool. The use of a restricted vocabulary was a valuable (if not essential) aid to distinguishing lexical access problems from combinatory ones. The artificiality of the microworld was important in minimising contextual bias, which is known to improve the performance of aphasic subjects in the case of non-reversible, sensible sentences and degrade it in the case of improbable scenarios. The differential between the performances of P1..P14 at baseline on the Real World Test and the microworld tests confirms that the microworld environment was successful in trapping problems which might otherwise be missed. However, it was both interesting and surprising that so many of the subjects should experience anomic difficulties for *ball*, *box* and *star* in a setting where recency and frequency effects should have combined with visual cues to facilitate naming.

In view of the this finding and the well-documented difficulties aphasic subjects have with abstract concepts compared with concrete ones, it is likely that the processing of microworld sentences imposes an extra cognitive load on patients which perhaps accounts for the degree of single-word problems which emerged despite screening. However, as patients on the whole had more difficulty with locative sentences than with verb sentences (yet only the verb sentences incorporated strange notions of balls painting boxes with accompanying rather abstract graphics - the locative sentences were quite normal English sentences depicted using only inanimate objects) it seems unlikely that artificiality was interfering in a major way. Some commentators would argue that working with geometric shapes is more difficult for aphasics than working with everyday objects. Further research is needed to determine whether an alternative choice of microworld items would be more beneficial. However, any experimentation should preserve the most important attributes of the microworld, i.e. that the vocabulary size is minimised and that the target sentences are reversible with equal plausibility and that lexico-pragmatic cues are eliminated. These requirements are difficult to meet other than in an artificial microworld. The

evidence of this study tends to suggest that the diagnostic advantage of artificial scenarios outweighs their disadvantages.

6.2 FUNCTIONAL GENERALISATION OF MICROWORLD THERAPY

When the efficacy phase of this research was devised (and indeed during the first half of it) there was no plan to assess the generalisation of treatment effects other than through the DSR, WAB and TROG tests, The Real World Test and the untreated sides of the Verb Test and Preposition Test. It was felt that this array of tests would adequately capture the ramifications of therapy. Moreover, as the treatment given was both short in duration and very sharply focussed and the subjects were long-term aphasics stable in their deficits, noticeable improvements beyond those to which these tests were sensitive, had not been expected. However, as the treatment phase progressed, it became increasingly apparent that changes were taking place in many of the subjects, which although hard to articulate and even harder to quantify, were nevertheless extremely important to them and well worth investigating.

Over the early weeks of therapy an increased confidence in some of the subjects became apparent, amounting for example in the cases of P1 and P5, to nothing short of a transformation. Their very appearances spoke of an optimism and self-belief, which were new. Many of the patients reported feeling as if their brains were starting to work again and feeling a tremendous sense of relief and excitement that after months or years of stagnancy it seemed that they really were capable of progress. Spontaneous comments by several of the subjects (for example P2 who said that she wanted to go the library again (not having been since her stroke) and P7, who was 11 years post onset and had undergone many different therapies in the past for various aspects of aphasia, who said that this was the best therapy she had experienced) led me to suspect that the microworld approach was having beneficial effects other than those I was planning to measure.

The remarks made by, and the changes evident in, the eight subjects previously attending the Queen Margaret College clinic were especially impressive. These subjects had received a range of therapies for various aspects of their language problems over several years. They were regular attenders (at least weekly) at the clinic and in addition several of them participated in a social group one evening

per week. They were used to being involved in research projects and to being investigated by student therapists. This was a very sophisticated set of patients in terms of their experience of previous treatments, of their ability to judge the quality of therapeutic inputs and in their realistic, not to say slightly sceptical attitude to the likelihood of improvement. Indeed, rather than being predisposed to expect improvement, I found many of them unwilling to accept that progress had taken place until all the obstacles we could devise (in the remediation environment) had been disposed of and until the computer (in assessment mode) delivered judgement. I am therefore certain that the majority of the data reported in this section were not due to the general stimulation effects of *some* therapy as opposed to no therapy, and that many of the comments indicate genuine breakthroughs in patients who were many years post-onset and who had been exposed to a variety of previous therapies without similar effects.

Obviously, the fact that these subjects were almost all multi-dimensionally language-impaired, made capturing supplementary data very difficult. Most had impairments of reading, writing, auditory-verbal input and spoken output. It was decided to design a questionnaire to be completed by the subjects (with help) in their home environments, and, given that the perceptions of patients and their families or carers might well be different, a separate and very similar questionnaire was included for carers. A multiple-choice format was considered (since it would have necessitated minimal writing) however, this proved impracticable for two reasons. Firstly, it would have constrained answers to those I had prescribed (perhaps encouraging patients to tick those boxes they thought I would expect/like them to tick) and secondly, the whole purpose of the exercise was to seek information on changes not foreseen. For these reasons a free-format design was used, requiring minimal reading and simply guiding participants to consider changes under a number of broad headings.

The questionnaires were despatched days after the end of the treatment phase, arriving at patients' homes between Christmas Day and New Year's Day 1990. The accompanying letter, included as Appendix 13, explained the purpose of the forms, pointed out that it was quite likely that patients and carers would have different perceptions of the effects of treatment and that they should both be completely honest, since negative results were as valuable as positive ones in evaluating new therapies. The letters also pointed out that the festive season might be a good time to capture the comments of friends and relatives who had

not seen the subject regularly since the onset of therapy and therefore might be in a position to notice changes less obvious to those in daily contact.

Of the fourteen sets of questionnaires sent out, twelve were returned. The subjects about whom no responses were forthcoming were P3 and P11. These were both married men who would have relied on the help of their wives in providing feedback. In both cases I had reason to suspect that relationships were strained and therefore did not press the matter. Appendix 14 shows the format of the questionnaires, the responses in the appendix relate to P4; his name has been deleted to preserve anonymity. P4's forms were chosen for illustration simply because the responses were more legible than most on reproduction. The remainder of this section is devoted to summarising the responses to the ten questions on the patients' questionnaires using information gleaned both from patients and from carers.

Ability to speak. Ten out of twelve responses reported a noticeable improvement in spoken language (in five cases (P1, P2, P5, P7, P10) the improvement was described as marked and in three cases (P2, P13, P14), families/carers were more aware of the improvement than the subject concerned. The two patients who did not show progress were P12 (who was virtually normal in expressive output, his wife nevertheless reported a slight reduction in semantic paraphasias) and P6 (who according to his therapist had regressed, due to the trauma of being rejected by his wife and being consigned to long-stay accommodation outwith the hospital environment where he had been since his stroke up until the onset of the treatment phase of this research).

The questionnaire responses specifically mentioned use of a wider vocabulary in P1, P8, P9 and P14. Other recurring comments were to do with increased fluency and/or greater motivation to try and take part in conversation (P1, P2, P4, P5, P7, P8, P13).

Makes more effort to participate in a conversation (although sometimes it takes a little time to understand what he is trying to say) whereby before he just sat and stared into space. (P5's wife).

P1's wife noted an improvement in the quantity and quality of his speech:

A marked improvement in the amount of speech (difficult to get him to stop sometimes), in the grammatical structure of his speech

(now using some pronouns, verbs, prepositions), and in his use of speech as a means of true communication. By this I mean that to some extent we can now 'talk' to one another - a sharing - rather than my having to always be the leader or the questioner. (P1's wife).¹⁰⁷

P9, P10 and P14 had very little speech output.¹⁰⁸ They all had severe phonological problems. P9 and P10 were reported as being much more comprehensible and P14 was reported to be using many more two and three-word utterances. I had been struck during treatment sessions with the fact P10, who was virtually incomprehensible in everyday speech, almost never speaking as a result, was much more intelligible in the microworld environment. This impression was not simply due to my being better able to anticipate his intentions in the microworld. Concurrently with microworld therapy, he was having traditional therapy for the phonological contrasts /b/ and /p/, with no success. The student therapist involved in the voice work expressed frustration at hearing P10 make sounds during microworld therapy for sentence processing which he was later incapable of repeating in *speech* therapy. This particular regime and previous attempts to improve P10's enunciation had been unsuccessful. By Christmas 1990, I was so impressed with the difference between P10's microworld and 'real world' speech that I tape-recorded him in spontaneous speech, in the reading aloud of a simple children's book and in the reading aloud of mixed microworld sentences.

Coinciding with the end of the treatment phase of this research, P10 was discharged from the QMC clinic as being unlikely to benefit from further traditional therapy. He therefore had no therapy whatsoever between December 1990 and May 1991 when I saw him for follow-up assessments. The improvement in the comprehensibility of his 'real world' spoken language by May 1991 was unexpected. On being asked how his talking was he replied, "My wife says it's better but I don't notice the difference" and every word was intelligible. In view of the marked change, I re-recorded P10 on the same speech output tasks he had been given five months previously. The difference in articulatory quality was unmistakable. P10's wife was unaware of my observations concerning his speech

¹⁰⁷ P1's wife had taken a great deal of interest in aphasiology and had read widely on the subject since her husband's stroke, she was also studying Psychology with the Open University. As a result, her responses tended to be fuller and more insightful than the rest.

¹⁰⁸ P2 also had severe phonological problems but was talkative. She self-monitored well and during the course of therapy her very effortful pronunciation of *star* as *scar*, and her frequent neologism of 'we' which occurred involuntarily under stress, all but disappeared.

after the treatment phase, but they were confirmed both by her and corroborated enthusiastically by a third party on the questionnaires.

The extent to which microworld therapy had seemed to facilitate spoken output was surprising. I had anticipated that it might perhaps improve the structural quality of output (such improvements had been reported by others (Byng, 1988)), but had not expected reports of increased fluency, wider vocabulary and certainly not of improvements to chronic phonological problems. This finding merits further investigation. On reflection, perhaps traditional one-to-one 'confrontation therapy' may not be the most productive approach to some articulatory disorders, an analogy being repeatedly pointing a horse at a jump he has refused. Perhaps the breakthrough made by P10 resulted from spoken language being tangential to the sentence understanding tasks on which he was concentrating. For example, it was sometimes necessary to work on pronunciation where this was clearly interfering with semantic access (see section 6.1.2), however, this was always as a means to an end, rather than as an end in itself.

Writing or coordination. Three patients and their families reported marked improvements in the quality of written output (P4, P5, P7). P4 used a word-processor at home and his family reported a noticeable improvement in the structure of his sentences.¹⁰⁹ A further subject, P1, showed evidence of improved ability at written sentence generation within the treated vocabulary, but was not using it:

No change in general. B. just does not write in everyday life. However, I tried a session with him, using the words you have been working on, and for the first time he composed and wrote his own sentences, and only using the words already worked on, but he did it by himself. (P1's wife).

P9's writing was judged to be more legible with better-formed letters, and his coordination was reported to be slightly improved. P12's wife reported an improvement in her husband's coordination about the home. Relatedly, P14's wife reported that his writing was unchanged, but his drawing was "clearer". Microworld therapy therefore seems to have affected writing much less than spoken output. This is not surprising, since most of the patients were hemiplegic,

¹⁰⁹ This was determined on asking P4's parents more about the nature of the improvement they had reported.

and as several respondents pointed out, they did not write much, so the families were not in a position to comment. I had wondered whether mouse skills would have helped with hand control, and general coordination - evidence of this was slight.

Reading. Five of the questionnaires reported improvements in reading (P2, P4, P7, P9, P12). An increase in reading span was reported in connection with P4, P9 and P12 and P12's reading speed had improved. P4 was now tackling a variety of reading matter from novels to the British Medical Journal (whereas just a few months previously he had been unable to sustain concentration). P7's mother, with whom she regularly engaged in reading aloud, reported that P7's reading had greatly improved, she was now reading in phrases. P7 said that she was able to read alone for pleasure for the first time since her stroke (11 years ago).¹¹⁰ In addition, P1's wife reported perceptively:

I think he can read more, but I think it's mainly restricted to the voicing of words - understanding is still very difficult - so in fact, he's not benefiting from it. I made up sentences using the words worked on, and there was no difficulty - voicing and understanding have come together - and he knows it. He can tell the difference here himself.

P14 was reported to be now able to point out items of interest in the newspaper or Radio Times. Whether this was because his reading had improved, or whether, as reported elsewhere in his questionnaires, he just felt more incentive to participate, was unclear.

Understanding of speech. There were reports of small improvements in auditory-verbal comprehension in five cases. P7 responded that "the brain has a better grasp" and her mother confirmed some improvement but noted that this modality was relatively intact anyway. P5 felt that his understanding of speech had improved. P12 had not noticed any difference, but his wife reported that he was "quicker at picking up ideas being discussed". P13 felt that his understanding of spoken language had improved and his wife confirmed that he was functioning better on a one-to-one basis (P1, P2 and P13 were reported to be markedly worse at speech input/output in unfamiliar company). Both P14 and his wife reported a small improvement in his performance.

¹¹⁰ In June 1991 P7 claimed that she was continuing to make progress in her reading, that written language was becoming clearer to her and that she was now taking a book to bed and getting pleasure from her reading.

Attention span / general alertness. Ten out of twelve families/carers reported an increase in attention span and/or alertness. The two patients who were judged not to have improved in this regard were P2 (who allegedly had no problems in that area) and P10 (who was described as having very poor concentration). Of the ten subjects who were reported to have improved, only two, P6 (who was thought to have better perseverance in the clinical situation) and P14 had not noticed the improvement themselves. It seems highly likely that requiring the patients to concentrate for an hour at a time on difficult cognitive tasks, was responsible for the widely reported benefits to attention span.

Confidence / sense of well-being / interest in life. Eight of the twelve sets of questionnaires returned reported increases in self-confidence. The patients who showed no change were P2 and P13, who were well-adjusted, sociable characters, P10, who was a virtual recluse and P6, whose domestic trauma made the question inappropriate for him. At the outset of the study, I had certainly not expected the ramifications of this style of therapy to be so far-reaching. Of the patients who improved, only P1 seemed unaware of having done so (although his wife was not sure if he had fully understood the question). Some of the remarks were extremely encouraging as the following quotations indicate:

I was surprised at his answer to this. To me, his very appearance speaks of greater confidence. He moves around the town more on his own now, seems confident of making himself understood in the shops. To me, this is a wonderful improvement, but he seems so casual about it! Maybe this is the true sign of success - the improvement has come, has been totally absorbed and is now 'normal' and useful. No need to think about it any more! (P1's wife).

I feel more confident and I now take more interest in life. (P5).

Has made a tremendous difference. J. had not ventured outside the house on his own since his stroke. Now he can go for a short walk and also, when I go shopping I can leave him to browse on his own. (P5's wife).

Confidence has certainly dramatically improved and with this followed a better sense of well being and increased interest in things around him. (P9's carer).

Confidence has increased to the extent that I get annoyed with myself when I do not perform as well as I think I should. I have a greater sense of well being and am now much more interested in the world around me and possibilities, and what I could do in the future. (P12).

How does this new approach compare with other therapies you have tried? (This question was only put to patients). Ten out of twelve patients preferred computer-based microworld therapy to the range of previous therapies they had experienced (despite many beginning the study with apprehension about using a computer). P14 did not answer the question due to his family mishandling the questionnaires (the questionnaire addressed to him was attempted by his son, who left the second page blank!) and P12 failed to comment on microworld therapy in his answer. Responses included :

This has been the most important. (P8).

Enjoyable, more stimulating. (P6).

I feel it makes him feel more of a person rather than a patient in his eyes. (P6's speech therapist).

It is better than previous therapies and easier to understand. (P9).

The best!!! (P7).

It is sometimes difficult, but more interesting. (P5).

Interesting. I think it is beneficial and more stimulating. (P4).

P1 responded "better" but found it hard to say why, his wife amplified: "He seems to like working with the computer and the mouse... I think he feels he gets a check on right/wrong. Things seem to make more sense when he can see something - an extra clue- rather than just having explanations in words".

The most important benefit of microworld therapy. Only P10 and his wife failed to be able to mention anything specific.¹¹¹ The other subjects all answered this question, several mentioning more than one area of improvement which they

¹¹¹ This was surprising as P10's speech had been his major problem and earlier in the questionnaire a noticeable improvement had been reported.

considered important, and, of course, the priorities of patients and their carers sometimes differed. Hence the same patient may appear under more than one heading below.

Increased confidence was cited in connection with P1, P8, P9 and P12. Improved concentration was an important factor for P5, P6 and P13. An improvement in reading was felt to be of particular benefit to P2, P7, P9, P12 and P13. Improved speech was mentioned in connection with P8, P9 and P13. The sense of challenge was important to P2 (her husband attributed her renewed interest in visiting the library to this) and to P6 (it was stimulating and made him think). P12 and P14 were said to have benefited from the structure which the biweekly visits imposed on their lives.

One of the most pleasing aspects of the returns was that so many respondents should have singled out the *realisation that learning was taking place* as a significant factor (P1, P5, P7, P12). Some quotations will illustrate the tenor of these remarks.

The most important benefit for me seems to have been a growing sense of confidence and relief that my brain was beginning to function again. (P12).

A lot of the brain has come up. (P7).

Within himself he felt that he was learning something and kept repeating "I'm going to try". (P5's wife).

He has had success which even he has had to admit to - very hard for B.! Things which were closed to him before, are now clear and able to be used. In some areas he now has the confidence of realising that he *knows*. This is a great step forward and he is keen to extend it. (P1's wife).

Criticisms to help us improve the therapy. (Answered by patients only) None of the patients had any criticisms to offer except P13 who wrote that "there were two things in the screen", but on asking him about this he was unfortunately unable to explain what his idea was. Five subjects used this question as an opportunity to say that they would like more computer-based treatment - P7 asked for a

computer at home¹¹² and P1, P4 and P8 requested daily treatments. In addition, P2, P5 and P9 separately indicated that they would be very keen to continue. P1 would have like microworld therapy extended to other areas of language and would have like more challenge in the programs so that he could really test his understanding.¹¹³

Recommendation of this therapy. (Answered by patients only) Eleven of the twelve subjects who returned questionnaires said that they would recommend this form of treatment to others. P14 did not attempt the question (due to having his responses entered on the wrong questionnaire).

Summary and discussion. There is no doubt that many of the participants in this study and their families noted benefits of microworld therapy over and above the purely quantitative measures of improvement recorded in clinic. Both the commonality between questionnaire responses relating to different subjects, my own observations and the corroboration in many cases by carers, testifies to much wider-ranging functional generalisation - although the therapy itself was aimed only at written sentence comprehension, and within that domain, at only a small set of lexical items and sentence structures.

While the opinions represented in this section are anecdotal, in the context of a scientifically designed study reporting unequivocal benefits of treatment, they deserve to be given credence. Had the same efficacy results been obtained without patients and their families noticing a change in everyday life, the results would have been of academic interest but of much less practical value. The questionnaires were designed because the patients convinced me that there were changes taking place that were worth recording, not because I entertained hopes of diverse behavioural change from the outset. I was both surprised and pleased that the quality of life of many of these long-term aphasics had been enhanced by such a short input of treatment.

The clinical outcomes of the patients (see section 5.4) were considered alongside the questionnaire returns to gain an impression of whether there were any

¹¹² By June 1991 she had acquired a second-hand machine which she planned to use for general cognitive stimulation.

¹¹³ This confirms my impression that many of the subjects were reluctant to believe that progress had occurred unless they could verify it by means of self-imposed hurdles. In fact, P1 did manage to satisfy himself on the items treated, but clearly knew that there were still vast areas of language untouched by the therapy.

observations made at home which were in conflict with clinical performance. P14 was the only subject who consistently reported an impression of no or little progress; he was so grossly impaired in mobility, and in every language modality that his perception of no functional change may have been fairly accurate.¹¹⁴ On the whole, I found the two sets of results to be compatible. For example, P6 improved on the study but was still nowhere near useful functional level; his therapist reported mostly the stimulation value of therapy. P13's clinical progress had been less than I had hoped and he and his wife had not noticed a great deal of change. P1 made striking progress in both environments. P2, on the other hand, made more progress in clinic than she and her husband noticed at home (but she was a well-adjusted, talkative person, whose life revolved around a close family, her functional communication was good) whereas P9 seemed to feel more benefit of his treatment outside than clinical results would have predicted (he lived alone in sheltered accommodation). It was particularly pleasing to see P12's speed of reading mentioned specifically by his wife (he was relatively intact in comprehension and speech; speed had been the therapeutic focus for him).

To conclude this section, it was found that the efficacy results reported in Chapter 4 had been accompanied by wider functional generalisations outside the clinical environment. It was noteworthy, as this study addressed receptive language (reading), that patients and carers had noticed more change in the quality and quantity of speech output (10/12 subjects having allegedly improved) than in auditory-verbal comprehension (5/12 subjects) or reading (5/12 subjects). The other areas of most benefit were attention span and general alertness (10/12 subjects) and confidence, sense of well-being or interest in life (8/12 subjects). Reports of greater motivation to participate in conversation most probably reflected the increased confidence and alertness reported. Structural improvements in speech output are compatible with the intervention, but effects on range of vocabulary, fluency and especially phonological quality are more surprising and merit further investigation.

There were several features of the microworld and the way in which therapy was conducted that I think were important in achieving the improvements in

¹¹⁴ P14 had serious attitudinal problems which were wholly understandable. He had had a first class brain (Professor of Mathematics). Neither he nor his family had adjusted to his incapacity, he had a very negative attitude to therapy and had almost no social contact outside the family. I had been warned that he probably would not agree to take part in the study. His lack of interest was typified by his response to the final question of the carers' questionnaire, viz. that he did not wish to receive details of the outcome of the study.

confidence and concentration. The subjects were worked extremely hard and were expected to concentrate for one hour in clinical sessions. Sometimes they were exhausted afterwards, but they enjoyed the challenge and their stamina improved. The nine patients I treated were approached no differently from students seeking remedial help (having had no clinical experience, I had no 'clinical manner' and several subjects explicitly commented on this e.g "You treat me like a friend, not a patient" (P7)). The microworld itself was an important factor, putting the patient in total control of his own assessments and on at least equal footing with the clinician in remediation sessions. The diagnostic process was a participative one for the patients and they found the investigative procedures absorbing. In addition, patients developed confidence and trust from the feeling that order was being made of chaos. One of the most frightening aspects of aphasia is not being able to depend on one's own cognitive processes (P12 was tormented by his erratic behaviour and his lack of dependability "I've gone to bed exhausted with this battle going on inside ...you can't easily live with the thought that you are unsafe in some ways" (P12)). Patients gained greatly from receiving instant, and in their eyes totally objective, feedback from the computer. The assessment results were always discussed with them straightaway and interesting patterns in the errors were highlighted. They derived reassurance from seeing the consistency in their errors, and from knowing that I understood what they were doing wrong and was optimistic about helping. They were also encouraged to know that other subjects on the study had similar difficulties. In short, I feel that the patients benefited not just from the microworld itself and the advantages it offered for assessment and treatment, but from the change in clinical style and the enhanced status of patients in the clinical partnership that this approach to treatment fostered.

6.3 SUGGESTED REFINEMENTS AND DIRECTIONS FOR FUTURE WORK

This final section explains, with benefit of hindsight, how certain aspects of the present study might have been improved. Following the recommended refinements, the thesis concludes with a number of suggestions for further work arising from the present findings and indicates many other areas of language research to which the computer-based microworld approach might be applied.

The most obvious modification to the protocol used here, which would allow statistically significant results to be obtained for individuals and for separate

sentence structures, would be to increase the number of items in each assessment test (and thereby the number of items of each treated structure). The concern to create assessment tests which could be completed in a single clinical session might perhaps have been better sacrificed in favour of obtaining many more observations per subject. However, while statistically speaking, a larger number of observations would undoubtedly have been an advantage, I do have serious reservations about the feasibility of subjecting patients to larger amounts of assessment than P1..P14 endured in this study. This point highlights the therapy versus research dilemma, which is very much more of an issue at sentence-level than in single-word studies simply because of the very long response latencies involved and the exhausting nature of sentence processing tasks.

If assessments become too unwieldy, inevitably more time is spent on assessment than on treatment. In the present study, equal amounts of time were spent on assessment and therapy, and more assessment was carried out than was diagnostically necessary. For example, the forty-item assessment in the second function treated was administered twice before treatment (once at baseline and again after therapy in the first function treated), and in addition the second function was tested twice in the Real World Test prior to treatment. P1, as mentioned in section 6.1.2, found all this assessment in prepositions, which he had more than adequately shown he could not do, extremely tedious. He would ask how many items were in the test, 20 or 40, and on being told 40 would sigh heavily. My fear is that if the amount of assessment had been substantially more, subjects might have become disenchanted and stopped trying i.e. given up struggling with each sentence and giving an honest response. If this had happened it could have prejudiced their attitude to the project - and hence their receptiveness to treatment, and the results obtained, while being more numerous, would have been misleading.

I have mentioned this point in some detail because it is a thorny problem which the majority of cognitive neuropsychological studies of language avoid in tackling single-word deficits. Future research seeking to replicate the results of this study, but wishing to remedy the 'significance drawback', might consider one of two strategies; either testing the feasibility of longer assessments by doubling the lengths of the ones used here and perhaps compensating by offering three treatment sessions per week for three weeks, or deciding to leave the assessment lengths as they are, but treating and assessing a single sentence structure. Use of the microworld with non-brain-damaged populations (e.g. deaf children) of

course, would not be constrained by the exceptionally long latencies reported here and the assessments could be extended without difficulty.

Having only 20 verb items and 20 preposition items in the Real World Test led to unfortunate ceiling effects in some subjects (notably in Group B, see section 6.1.1). It is recommended that a more satisfactory test size would be 40 items per function, administered if need be across two sessions.

In selecting subjects for this study and conducting preliminary screening for single-word understanding I failed to anticipate two factors which turned out to be important. The first was the preponderance of single-word problems which would emerge in a sentence-processing context (induced by the extra cognitive load), and the second was the crucial role of abstract function words such as *the, a, by, that* which could not be tested in isolation through picture-matching. With benefit of hindsight, it would have been useful to have included word/non-word recognition tests for these to see if they were not recognised at all, or whether they could be identified as words, but that their functions were unknown. The latter case was presumed in the present study, but P1..P14 have provided sufficient evidence of acute difficulty that it would be worthwhile to systematically explore the possibility of an impairment tantamount to 'function word blindness'. Likewise, in view of the reliance on auditory-verbal processes in therapy and of the likelihood that remediation would affect spoken output as well as written comprehension (which informal feedback suggests that it did), it would have been valuable to have included matched auditory-verbal tests in the assessment blocks. Had such tests been administered it is likely that P6, P9, P11 and P14 would not have been selected for therapy of this type and complexity and that further evidence would have been obtained regarding the modality-independent nature of processes underlying both the comprehension and generation of sentences.

There is a case for altering the form of the present tense used in the verb sentences (*The ball paints the box*) to the continuous present (*The ball is painting the box*) which is a more natural construction. This could certainly be considered for use with other populations. An argument for not using the present participle in pathological research, however, is that the diagnostic edge of the microworld consists in deliberately challenging natural saliencies (hence in this case allowing us to observe that the patients are not reading *what is there*).

A minor change to the protocol is suggested in prefacing each assessment test with a small number of warm-up items, as was done by Kolk and van Grunsven (1985) and several others. P1..P14 were treated in a completely different software environment to the one they were tested in, with 4-5 weeks between using an assessment program and seeing the program again. Likewise, after a 5 month gap they were expected to perform from a 'cold start'.

In similar vein, my clinical colleague expressed the view, and I thoroughly concur, that large improvements were evident in some subjects in remediation, which did not carry over into assessment. This was especially true of the Group B subjects she treated. There was no mechanism built in to formally capture such improvements - if the patient could not perform in selecting the correct picture from four, then even if he had made tremendous progress during remediation, there was nothing to show for it.¹¹⁵ In view of the practice of recording, for example in naming studies, how many items pre- and post-therapy were named straight away and then after a phonemic or semantic cue, there is certainly a case in assessing these much more complex cognitive tasks, for a means of recording different levels of progress.

In terms of extending this work, a need was often felt in remediation mode for facilities other than sentence-building and picture building (as outlined in section 3.3). I often wanted to test understanding by being able to present the target and reverse role picture to see if the distractor was still compelling (this was done by paper sketches). If such a mode had been present in the remediation software, it might have gone some way to bridging the gap between the remediation and the assessment environments. A further interesting extension of the remediation software, which might have led to many interesting insights into grammaticality, would have been a picture/sentence-matching option, that is, not a constructional sentence-building task, but four sentences to a target picture (along the lines of Friederici, Schonle and Garrett, 1982), with a single-click selection requirement.

This study suggests many promising directions for future work, both with receptive agrammatics and with many other populations. Some of these are listed below.

¹¹⁵ A great deal of evidence is available from clinical record sheets, but because the recording method was not systematised it amounts to anecdotal evidence and nothing more.

- a) Replication studies are needed to confirm the treatment effects reported here and to experiment with duration and frequency of treatment. Such work would help to build up prognostic experience.
- b) Further work is needed to establish the claim that there may have been a treatment advantage to treating verbs before prepositions.
- c) Only a very few lexical items and sentence structures were treated in this study. There is much more work to be done in expanding the range of verbs, prepositions and sentence structures tackled.
- d) The success reported with verbs and prepositions suggests expansion of this approach to other categories of language such as pronouns and other sentence structures such as interrogatives.
- e) The discovery that normal saliency hierarchies were at work behind many of the errors made, such that they could be explained by universal rule-based behaviours, invites a re-examination of how many different types of sentence processing problems (such as locative and comparative reversals in P1) can be explained by over-reliance on normal perceptual and grammatical precedences.
- f) With very little modification (i.e. removal of written target sentences and spoken delivery instead), the assessment software could be used to test auditory-verbal comprehension. Follow-up work might compare auditory-verbal and written comprehension.
- g) Again, with minor modifications to the software, visual interpretive assistance in the parsing process could be explored by having the target sentence disappear (under patient control) before appearance of the pictures.
- h) An interesting avenue of research arising from this study is exploration of the possible dissociation between inductive and deductive visual processing. The suggestion is that aphasic patients may have preserved ability to perform logical deductions from abstract visual material (e.g. Raven's CPM, Raven (1975)), presumably processed by the intact hemisphere, in the face of poorer ability to make semantic inferences about the significance of representational (single or sequenced) graphic images (which perhaps need language mediation).

- i) With modification only to the text files, the software could be translated into other languages to enable matched cross-linguistic studies.
- j) The results reported in section 6.2, of improved fluency and structure in spoken output and of articulatory improvements in P10 merits further investigation of the efficacy of microworld interaction as a (tangential rather than confrontational) approach to speech output facilitation.
- k) The computer-based microworld approach is ideally suited to assessing syntax processing in a variety of populations with speech input or output problems e.g. hearing impaired or mute children.
- l) The assessment software shell could be readily used as the basis for non-linguistic cognitive assessment programs.
- m) The interface operating skills exhibited by P1..P14 suggest that further work in producing mouse-driven systems nor just for clinical use, but for wider (appropriately pitched) diversional activities would be of enormous benefit to aphasic subjects.
- n) Following the experience of this study, a basis now exists for going at least part way to automating a more meaningful diagnostic output, by summarising significant error patterns and suggesting possible underlying causes to explore. Such a project would be advised to standardise on only one set of consistent distractors per sentence structure (something which was not always followed in the present work, for breadth, but also mindful of the criticism of the picture-matching paradigm, and not being able to foreknow what the most compelling distractors would be).
- o) The microworld approach might turn out be an economical and effective way of teaching English syntax to foreigners. It would unquestionably offer a means of studying language acquisition in normal and developmentally disordered children.
- p) Finally, it would be interesting if receptive agrammatism (and the compensatory strategies observed) were found to be related, not so much to language acquisition, or to second language learning, but to *second language forgetting in normal subjects*. This would be a fascinating study to which ball, box and star could contribute.

I should like to close by paying tribute once more to P1..P14. They have permitted me to scrutinise that most quintessentially human faculty - language. I hope I have done so with sensitivity, with honesty and with humour. If this study inspires further clinical work it will have served its purpose. If that work results in an enhanced view of the prospects for rehabilitation in subjects with long-term brain damage, P1..P14 will have done a great service indeed.

This research has shown that both cognitive psychologists and aphasic patients have a lot to gain from treatment studies - as noted in Chapter 1 (p. 20), too many previous investigators have assessed impairments without attempting remediation or considering the therapeutic implications of their findings. In doing so they have denied themselves a rich source of data and the rewards of a reciprocal relationship with their subjects. Computer technology offers the means to a genuine clinician-client partnership, more accurate diagnosis and better-targeted treatment. This study is a small step towards the provision of a new generation of clinical tools and techniques.

APPENDIX 1

Details about the 14 aphasic subjects who took part in this study are summarised in Tables A and B below.

| | Age | Sex | P-O | Previous occupation | PH | HP |
|-----|-----|-----|------|---|-------------------|----|
| P1 | 47 | m | 5/0 | Actuary | rt | rt |
| P2 | 57 | f | 1/11 | School cook | rt | rt |
| P3 | 40 | m | 1/3 | Restaurant owner/manager, Iranian, educated to degree level in English. | rt | no |
| P4 | 27 | m | 3/3 | Medical doctor | rt | rt |
| P5 | 60 | m | 5/8 | Dockyard driver | ambi | rt |
| P6 | 67 | m | 0/7 | Retired van driver | rt | rt |
| P7 | 44 | f | 11/2 | Hotel administrator, Diploma in Home Economics | rt ¹¹⁶ | no |
| P8 | 54 | m | 4/2 | Steel erector | rt | rt |
| P9 | 53 | m | 7/2 | Civil Servant | rt | rt |
| P10 | 44 | m | 3/1 | Slater | rt ¹⁴⁵ | no |
| P11 | 46 | m | 7/0 | Medical Physicist | rt | rt |
| P12 | 74 | m | 0/6 | Retired Cleric | rt | no |
| P13 | 56 | m | 3/3 | Stereotyper | rt | rt |
| P14 | 64 | m | 6/1 | Professor of Mathematics | rt | rt |

Table A. Biographical details of the aphasic subjects (P1..P14).

Age (mean=52.4) and interval post-onset (P-O, expressed as years/months; mean = 4/4) are as at first appointment, i.e. first Syntax Screening Test, (see Table 13, p. 93). Where a patient had more than one major incident, the most recent date is the one recorded. The column headed PH shows premorbid handedness and the HP column, whether the patient has residual hemiplegia.

¹¹⁶ Used mouse with left hand. This was due to finding the mouse on the left side of the computer and not feeling the need to change it over. (Usual handedness does not matter very much for competent mouse operation; I became a left-handed mouse user by preference as a result of this study!)

| Aetiology | |
|------------------|--|
| P1 | Left CVA. |
| P2 | Left CVA |
| P3 | Penetrating injury to right eye causing extensive cerebral haematoma with intra-ventricular haemorrhage, plus ethmoid, sphenoid and right orbital fractures. Patient lost right eye. |
| P4 | Subarachnoid haemorrhage following bleed from a left parietal arteriovenous malformation. |
| P5 | Left CVA (3rd stroke since 1968, recovered from previous ones). |
| P6 | Middle cerebral artery territory infarct. |
| P7 | Aneurysm in Canada, no further details. |
| P8 | Massive subarachnoid haemorrhage. |
| P9 | Large left fronto-parietal infarct. |
| P10 | 1966 brain surgery following traffic accident, no details. Subarachnoid haemorrhage, right posterior artery aneurysm. |
| P11 | Intracerebral haematoma due to left middle cerebral artery aneurysm. |
| P12 | Left posterior cerebral artery infarct with area of density in left occipital lobe. |
| P13 | Left CVA |
| P14 | Large ischemic type low density lesion left hemisphere, vast area. |

Table B. The brain damage sustained by P1..P14.

Table B gives as much information about the nature of each patient's brain damage as could be determined from their speech therapy case notes. Most cases were so long post-onset that it was not feasible to make further enquiries.

APPENDIX 2

LIST OF NORMAL SUBJECTS

| ID | Sex | Age | Occupation | Education |
|-----|-----|-----|--------------------------|--------------|
| C1 | f | 29 | secretary | intermediate |
| C2 | f | 37 | postgraduate student | advanced |
| C3 | f | 32 | lecturer | advanced |
| C4 | m | 36 | student | advanced |
| C5 | m | 31 | administrative officer | advanced |
| C6 | m | 25 | administrative assistant | advanced |
| C7 | f | 27 | administrative assistant | advanced |
| C8 | m | 34 | senior technician | intermediate |
| C9 | f | 26 | clerk | basic |
| C10 | m | 29 | janitor | basic |
| C11 | f | 28 | cleaner | basic |
| C12 | f | 34 | cleaner | basic |
| C13 | f | 30 | cleaner | basic |
| C14 | m | 36 | technician | intermediate |
| C15 | m | 35 | technician | intermediate |

Table C. Normal subjects age band 25..39.

| ID | Sex | Age | Occupation | Education |
|-----|-----|-----|--------------------------|--------------|
| C16 | f | 40 | physiotherapist | advanced |
| C17 | m | 53 | service unit director | advanced |
| C18 | m | 48 | lecturer | advanced |
| C19 | m | 44 | senior lecturer | advanced |
| C20 | f | 47 | administrative assistant | intermediate |
| C21 | f | 43 | personal assistant | intermediate |
| C22 | m | 46 | finance secretary | intermediate |
| C23 | f | 43 | secretary | intermediate |
| C24 | f | 46 | cleaner | basic |
| C25 | f | 54 | secretary | intermediate |
| C26 | f | 45 | clerk | basic |
| C27 | f | 49 | clerk | basic |
| C28 | f | 47 | canteen worker | basic |
| C29 | f | 43 | canteen worker | basic |
| C30 | f | 40 | clerk | basic |

Table D. Normal subjects age band 40..54.

| ID | Sex | Age | Occupation | Education |
|-----|-----|-----|--------------------|--------------|
| C31 | m | 59 | head of department | advanced |
| C32 | f | 60 | college librarian | advanced |
| C33 | m | 61 | senior lecturer | advanced |
| C34 | f | 56 | head of department | advanced |
| C35 | f | 62 | head of department | advanced |
| C36 | f | 56 | cleaner | basic |
| C37 | f | 60 | cleaner | basic |
| C38 | f | 58 | cleaner | basic |
| C39 | f | 61 | cleaner | basic |
| C40 | f | 59 | kitchen maid | basic |
| C41 | f | 59 | cleaner | basic |
| C42 | f | 53 | library assistant | basic |
| C43 | m | 57 | technician | intermediate |
| C44 | m | 63 | messenger | basic |
| C45 | m | 61 | senior janitor | basic |

Table E. Normal subjects age band 55..69.

APPENDIX 3

The content of the Syntax Screening Test is given below. The seven emboldened sentences in each module are the target sentences, the three sentences that follow them are verbal descriptions of the associated pictorial distractors. Parentheses in the distractor descriptions are used to provide information necessary to visualise the distractors or to convey how they are distinct from the target and each other. Square brackets indicate how a sentence should be parsed. Notice that lexical distractors were included only for the first two sentences of each module. Lexical distractors are pictures involving nouns not mentioned in the target sentence for all modules except pronouns, where the substitution is of an incorrect verb. Lexical mistakes should not occur following successful performance on the Lexical Test, however, a small number were included in case lexical errors were induced in the context of sentence processing.

VERBS

- | | |
|--|---|
| <p>1. The box draws a star. The star draws a box. The ball draws a star. The box holds a star.</p> | <p>2. A box is drawn by the star. A star is drawn by the box. A box is drawn by the ball. A box is painted by the star.</p> |
|--|---|
- 3. The box gives a star to the ball.**
 The ball gives a star to the box.
 The box gives a ball to the star.
 The star gives a box to the ball.
- 4. It is the ball that gives a box to the star.**
 It is the star that gives a box to the ball.
 It is the ball that gives a star to the box.
 It is the box that gives a ball to the star.
- 5. The ball paints a box and thinks of the star.**
 The box paints a ball and thinks of the star.
 The ball paints a star and thinks of the box.
 The star thinks of the ball painting the box.
- 6. The box that the ball paints holds a star.**
 The ball that the box paints holds a star.
 The box paints the ball and holds a star.
 The star holds the ball who is painting a box.

7. The star paints the box that the ball holds.

The box paints the star that the ball holds.

The star paints the ball that the box holds.

The ball holds the star who is painting the box.

ADJECTIVES**8. The red box.**

The red ball.

The yellow box.

The blue star.

9. The big blue star.

The big blue box.

The big red star.

The small blue star.

10. The small red ball and the big yellow box.

The small red box and the big yellow ball.

The small red ball and the big yellow ball.

The big red box and the small yellow ball.

11. The small box and the big star are yellow.

The small (red) box and the big yellow star.

The box and the star are small and yellow.

The small yellow star and the big (red) box.

12. The box, the ball and the star are big.

The box and ball are small and the star is big.

The box, the ball and the star are small.

The box, ball and star are red (and small).

13. The star that is in the big box is blue.

The (red) star is in the big blue box.

The big blue star is in the (small) box.

The (small) blue star is in the small box.

14. The star in the ball is small and red.

The star is in the small red ball.

The ball in the star is small and red.

The star and the small red ball.

SCOPE AND QUANTIFICATION**15. All the balls are blue.**

Some of the balls are blue.

All the boxes are blue.

All the (coloured) balls are big.

16. Some of the stars are yellow.

One of the stars is yellow.

Some of the balls are yellow.

Some of the (red) stars are big.

17. None of the balls is red.

Some of the balls are red.

One of the balls is red.

All the balls are red.

18. Only the box is red.

The box and the star are red.

All but the box are red.

Only the box is big.

19. The star is blue and the box is not yellow.

The star is blue and the box is yellow.

The box is blue and the star is not yellow (red).

The star is not blue and the box is yellow.

20. Only the star and the box are not blue.

Only the star and box are blue.

The star, box and some balls are not blue.

Only the box is not blue.

21. All but the big blue box are yellow.

The big blue box, some yellow things and some red.

All but the big yellow box are blue.

All but the (small) blue box are yellow.

PRONOUNS**22. She draws.**

She thinks.

He draws.

They draw.

23. She thinks of him.

He thinks of her.

She thinks of them.

She paints him.

24. The ball has a red star in it.

The star has a red ball in it.

The red ball has a star in it.

The red star has a ball in it.

25. He thinks of them.

They think of him.

She thinks of him.

He thinks of him.

26. The star thinks of himself.

He (box) thinks of the star.

The star thinks of her.

The star thinks of herself.

27. They give the ball to her.

She gives the ball to them.

He gives the ball to her.

They give the ball to him.

28. The box paints itself.

The box paints a box (inanimate).

The box paints.

The box (male) paints the box (female).

PREPOSITIONS**29. The star is in the ball.**

The ball is in the star.

The star is under the ball.

The star is in the box.

30. The ball is under the box.

The box is under the ball.

The ball is beside the box.

The star is under the box.

31. The star is behind the box.

The box is behind the star.

The star is beside the box.

The star is under the box.

32. The box and the ball are above the star.

The star is above the box and the ball.

The box is above the ball and the star.

The box and the ball are behind the star.

33. The star is between the ball and the box.

The ball is between the star and the box.

The star is behind the ball and the box.

The ball and the box are between the stars.

34. The ball is in the star that is under the box.

The star is in the ball that is under the box.

The ball and the star are under the box.

The ball is in the star that is beside the box.

35. The box behind the ball is under the star.

The star is under [the box behind the ball].

The box is behind [the ball under the star].

The ball behind the box is under the star.

MORPHOLOGY**36. The boxes.**

The box.

(Two) balls, (two) stars and a box.

The balls.

37. The balls and the stars are blue.

The ball and the star are blue.

The ball and the stars are blue.

The boxes and the stars are blue.

38. The ball is bigger than the box.

The box is bigger than the ball.

The ball and the box are big.

The ball is bigger than the boxes.

39. The star is the smallest.

The star is the biggest.

The star and the ball are small (box is big).

The star is the smaller.

40. The star painted the box.

The box painted the star.

The star is painting the box.

The star is going to paint the box.

41. The box's ball is red.

The ball's box is red.

The red box is holding a ball.

The box and ball are red.

42. The ball's box is bigger than the star's.

The star's box is bigger than the ball's.

The box's ball is bigger than the star's.

The ball's box is bigger than the star.

APPENDIX 4

Verb Test, target sentences and distractors.

The annotations following the distractors are S=subject, O=object, IO=indirect object, Rev=reversal, SS=subject substitution, VS=verb substitution, OS=object substitution, OQ=object qualification, SQ=subject qualification, IOQ=indirect object qualification. More OS than SS distractors were included in the simple sentences, on the basis that errors were perhaps more likely to occur towards the end of a sentence.

1. The ball paints a box.

The box paints a ball. (Rev)
The star paints a box. (SS)
The ball holds a box. (VS)

2. The box paints a ball.

The ball paints a box. (Rev)
The box paints a star. (OS)
The box holds a ball. (VS)

3. The star paints a box.

The box paints a star. (Rev)
The star paints a ball. (OS)
The star holds a ball. (VS)

4. The box holds a star.

The star holds a box. (Rev)
The box holds a ball. (OS)
The box paints a star. (VS)

5. The star holds a box.

The box holds a star. (Rev)
The star holds a ball. (OS)
The star paints a box. (VS)

6. A box is painted by the star.

A star is painted by the box. (Rev)¹¹⁷
A ball is painted by the star. (SS)
A box is held by the star. (VS)

7. A star is painted by the box.

A box is painted by the star. (Rev)
A ball is painted by the box. (SS)
A star is held by the box. (VS)

8. A ball is painted by the box.

A box is painted by the ball. (Rev)
A ball is painted by the star. (OS)
A ball is drawn by the box. (VS)

9. A box is held by the ball.

A ball is held by the box. (Rev)
A box is held by the star. (OS)
A box is painted by the ball. (VS)

10. A ball is held by the box.

A box is held by the ball. (Rev)
A ball is held by the star. (OS)
A ball is painted by the box. (VS)

11. The box gives a ball to the star.

The ball gives a box to the star. (Rev S/O)
The box gives a star to the ball. (Rev O/IO)
The star gives a ball to the box. (Rev S/IO)

¹¹⁷ By giving verbal descriptions of the distractors used we do not imply that in choosing the associated picture, the patient necessarily parsed the sentence as it is expressed here. In fact, most of the errors made on passive sentences were in interpreting them as actives ('box painting star'), not in incorrectly assigning subject and object around a passive verb.

12. The star gives a ball to the box.

The ball gives a star to the box. (Rev S/O)
 The star gives a box to the ball. (Rev O/IO)
 The box gives a ball to the star. (Rev S/IO)

13. The ball gives a star to the box.

The star gives a ball to the box. (Rev S/O)
 The ball gives a box to the star. (Rev O/IO)
 The box gives a star to the ball. (Rev S/IO)

14. The box gives a star to the ball.

The star gives a box to the ball. (Rev S/O)
 The box gives a ball to the star. (Rev O/IO)
 The ball gives a star to the box. (Rev S/IO)

15. The star gives a box to the ball.

The box gives a star to the ball. (Rev S/O)
 The star gives a ball to the box. (Rev O/IO)
 The ball gives a box to the star. (Rev S/IO)

16. The star paints the ball that the box holds.

The ball paints the star that the box holds. (Rev S/O)
 The star paints the box that the ball holds. (Rev O/IO)
 The star that the box holds paints the ball. (OQ:=SQ)¹¹⁸

17. The star holds the box that the ball paints.

The box holds the star that the ball paints. (Rev S/O)
 The star holds the ball that the box paints. (Rev O/IO)
 The star holds the box that paints the ball. (IOQ:=OQ)

18. The box paints the ball that the star holds.

The ball paints the box that the star holds. (Rev S/O)
 The box paints the star that the ball holds. (Rev O/IO)
 The box paints the ball that holds the star. (IOQ:=OQ)

19. The ball paints the box that the star holds.

The box paints the ball that the star holds. (Rev S/O)
 The ball paints the star that the box holds. (Rev O/IO)
 The ball paints the box that holds the star. (IOQ:=OQ)

¹¹⁸ Read ':= ' as 'becomes'.

20. The box holds the star that the ball paints.

The star holds the box that the ball paints. (Rev S/O)
 The box holds the ball that the star paints. (Rev O/IO)
 The box holds the star that paints the ball. (IOQ:=OQ)

21. The ball paints a star.

The star paints a ball. (Rev)
 The ball paints a box. (OS)
 The ball holds a star. (VS)

22. The box holds a ball.

The ball holds a box. (Rev)
 The box holds a star. (OS)
 The box paints a ball. (VS)

23. The ball draws a box.

The box draws a ball. (Rev)
 The ball draws a star. (OS)
 The ball holds a box. (VS)

24. The box draws a star.

The star draws a box. (Rev)
 The ball draws a star. (SS)
 The box holds a star. (VS)

25. A ball is painted by the star.

A star is painted by the ball. (Rev)
 A ball is painted by the box. (OS)
 A ball is held by the star. (VS)

26. A star is held by the ball.

A ball is held by the star. (Rev)
 A star is held by the box. (OS)
 A star is painted by the ball. (VS)

27. A box is drawn by the ball.

A ball is drawn by the box. (Rev)
 A star is drawn by the ball. (SS)
 A box is held by the ball. (VS)

28. The ball gives a box to the star.

The box gives a ball to the star. (Rev S/O)
 The ball gives a star to the box. (Rev O/IO)
 The star gives a box to the ball. (Rev S/IO)

29. The ball puts a star on the box.

The star puts a ball on the box. (Rev S/O)
 The ball puts a box on the star. (Rev O/IO)
 The box puts a star on the ball. (Rev S/IO)

30. The star puts a ball on the box.

The ball puts a star on the box. (Rev S/O)
 The star puts a box on the ball. (Rev O/IO)
 The box puts a ball on the star. (Rev S/IO)

31. The ball paints the star that the box holds.

The star paints the ball that the box holds. (Rev S/O)
 The ball paints the box that the star holds. (Rev O/IO)
 The ball that the box holds paints the star. (OQ:=SQ)

32. The box holds the ball that the star paints.

The box holds the ball that the star paints. (Rev S/O)

The box holds the star that the ball paints. (Rev O/IO)

The box that the star paints holds a ball. (OQ:=SQ)

33. The star draws the box that the ball paints.

The box draws the star that the ball paints. (Rev S/O)

The star draws the ball that the box paints. (Rev O/IO)

The star draws the box that paints the ball. (IOQ:=OQ)

34. The ball thinks of the star that the box draws.

The star thinks of the ball that the box draws. (Rev S/O)

The ball thinks of the box that draws the star. (Rev O/IO)

The ball thinks of the star that draws a box. (IOQ:=OQ)

35. The ball paints a box and holds the star.

The box paints a ball and holds the star. (Rev S/O)

The ball paints the box that holds a star. (Conjunct:=OQ)

The ball paints the box that the star holds. (Conjunct :=OQ)

36. The star draws a ball and thinks of the box.

The ball draws the star and thinks of the box. (Rev S/O)

The star draws and the ball thinks of the box. (premature conjunction)

The star draws a box and thinks of the ball. (Rev O/IO)

37. It is the box that gives a ball to the star.

It is the ball that gives the box to the star. (Rev S/O)

It is the box that gives a star to the ball. (Rev O/IO)

It is the star that gives a ball to the box. (Rev S/IO)

38. It is the ball that puts a star on the box.

It is the star that puts a ball on the box. (Rev S/O)

It is the ball that puts a box on the star. (Rev O/IO)

It is the box that puts a star on the ball. (Rev S/IO)

39. The star that the ball paints holds a box.

The ball that the star paints holds a box. (Rev S/O)

The ball paints the box that holds the star. (Rev O/IO)

The star holds the box that paints a ball. (SQ:=OQ)

40. The ball that the box holds draws a star.

The box that the ball holds draws a star. (Rev S/O)

The ball that the box draws holds a star. (contiguous verbs switched)

The ball draws the star that the box holds. (SQ:=IOQ)

APPENDIX 5

VERB PROCESSING RESULTS

Subject : p7 Date : 7/11/1990

| TREATED ITEMS | | UNTREATED ITEMS | |
|---------------|---------|-----------------|---------|
| Score | Mean RT | Score | Mean RT |
| 13/20 | 2494 hs | 13/20 | 3762 hs |

Result : 26/40
 Total Time Taken : 23.23mins
 Pauses : 0

VERB PROCESSING PERFORMANCE DATA

Subject : p7 Date : 7/11/1990

| TREATED ITEMS | | | | UNTREATED ITEMS | | | |
|---------------|-----|------|------|-----------------|-----|------|-------|
| Sent | Pic | Posn | RT | Sent | Pic | Posn | RT |
| 1 | 1 | 3 | 4515 | 21 | 1 | 1 | 3180 |
| 2 | 1 | 3 | 2208 | 22 | 1 | 2 | 3559 |
| 3 | 1 | 3 | 1450 | 23 | 1 | 4 | 1999 |
| 4 | 1 | 3 | 1401 | 24 | 3 | 4 | 2653 |
| 5 | 1 | 1 | 1159 | 25 | 2 | 2 | 2241 |
| 6 | 2 | 3 | 1802 | 26 | 1 | 1 | 1455 |
| 7 | 2 | 1 | 1791 | 27 | 2 | 4 | 2263 |
| 8 | 2 | 3 | 2395 | 28 | 1 | 2 | 2488 |
| 9 | 1 | 2 | 3290 | 29 | 1 | 1 | 1802 |
| 10 | 2 | 4 | 2153 | 30 | 1 | 2 | 3587 |
| 11 | 1 | 3 | 2378 | 31 | 1 | 1 | 3954 |
| 12 | 1 | 3 | 1983 | 32 | 4 | 4 | 8881 |
| 13 | 1 | 2 | 2889 | 33 | 4 | 3 | 1472 |
| 14 | 1 | 1 | 1428 | 34 | 1 | 1 | 7174 |
| 15 | 1 | 3 | 4674 | 35 | 1 | 4 | 2719 |
| 16 | 3 | 4 | 3208 | 36 | 1 | 3 | 2664 |
| 17 | 1 | 1 | 1626 | 37 | 1 | 4 | 3092 |
| 18 | 4 | 4 | 4833 | 38 | 1 | 4 | 3476 |
| 19 | 3 | 3 | 2422 | 39 | 2 | 1 | 12770 |
| 20 | 1 | 4 | 2269 | 40 | 2 | 4 | 3818 |

APPENDIX 6

Preposition test, target sentences and distractors.

The annotations following the distractors are: Rev=reversal, PS=preposition substitution, S(s)=subject(s), O(s)=object(s), O1=object1, P1=preposition1, P2=preposition2.

- | | |
|--|---|
| <p>1. The ball is under the box. The box is under the ball. (Rev) The ball is in the box. (PS) The ball is beside the box. (PS)</p> | <p>2. The box is under the ball. The ball is under the box. (Rev) The box is in the ball. (PS) The box is beside the ball. (PS)</p> |
| <p>3. The ball is behind the box. The box is behind the ball. (Rev) The ball is under the box. (PS) The ball is beside the box. (PS)</p> | <p>4. The box is behind the ball. The ball is behind the box. (Rev) The box is in the ball. (PS) The box is beside the ball. (PS)</p> |
| <p>5. The ball is in the box. The box is in the ball. (Rev) The ball is under the box. (PS) The ball is beside the box. (PS)</p> | <p>6. The box is in the ball. The ball is in the box. (Rev) The box is behind the ball. (PS) The box is above the ball. (PS)</p> |
| <p>7. The star is behind the ball. The ball is behind the star. (Rev) The star is in the ball. (PS) The star is above the ball. (PS)</p> | <p>8. The ball is in the star. The star is in the ball. (Rev) The ball is behind the star. (PS) The ball is beside the star. (PS)</p> |
| <p>9. The ball is under the box and the star. The box and the star are under the ball.¹¹⁹ (Rev S/Os) The box is under the ball and the star. (Rev S/O1) The ball is behind the box and the star. (PS)</p> | |
| <p>10. The box is under the ball and the star. The ball and the star are under the box. (Rev S/Os) The ball is under the box and the star. (Rev S/O1) The box is behind the ball and the star. (PS)</p> | |

¹¹⁹ Again, it should be stressed that the wording of distractors is to allow the reader to reconstruct the pictures that were offered. For example, a patient choosing this distractor may have done so because he confused *under* and *above* and not because he reversed the subject and objects around the correct preposition.

11. The box is behind the ball and the star.

The ball and the star are behind the box. (Rev S/Os)

The ball is behind the box and the star. (Rev S/O1)

The box is under the ball and the star. (PS)

12. The star is behind the ball and the box.

The ball and the box are behind the star. (Rev S/Os)

The ball is behind the star and the box. (Rev S/O1)

The star is between the ball and the box. (PS)

13. The ball is under the star and the box.

The star and the box are under the ball. (Rev S/Os)

The star is under the ball and the box. (Rev S/O1)

The ball is behind the star and the box. (PS)

14. The box is behind the star and the ball.

The star and the ball are behind the box. (Rev S/Os)

The star is behind the box and the ball. (Rev S/O1)

The box is under the star and the ball. (PS)

15. The ball is in the star that is under the box.

The star is in the ball that is under the box. (Rev S/O1)

The ball is in the star that is in the box. (PS)

The ball is in the star that is beside the box. (PS)

16. The star is in the ball that is under the box.

The ball is in the star that is under the box. (Rev S/O1)

The star is in the ball that is in the box. (PS)

The star is in the ball that is above the box. (PS)

17. The ball is behind the star that is under the box.

The ball is behind the box that is under the star. (Rev O1/O2)

The ball is under the star that is behind the box. (Rev P1/P2)

The ball is behind the star that is beside the box. (PS)

18. The box is behind the star that is under the ball.

The box is behind the ball that is under the star. (Rev O1/O2)

The box is behind the star that is behind the ball. (PS)

The box is behind the star that is above the ball. (PS)

19. The ball is under the star that is behind the box.

The star is under the ball that is behind the box. (Rev S/O)

The ball is behind the star that is under the box. (Rev P1/P2)

The ball is under the star that is beside the box. (PS)

20. The star is under the ball that is in the box.

The star is under the box that is in the ball. (Rev O1/O2)

The star is under the ball that is behind the box. (PS)

The star is under the ball that is beside the box. (PS)

21. The star is in the ball.

The ball is in the star. (Rev)

The star is under the ball. (PS)

The star is beside the ball. (PS)

22. The star is under the box.

The box is under the star. (Rev)

The star is in the box. (PS)

The star is beside the box. (PS)

23. The star is above the ball.

The ball is above the star. (Rev)

The star is in the ball. (PS)

The star is beside the ball. (PS)

24. The box is beside the ball.¹²⁰

The box is above the ball. (PS)

The box is in the ball. (PS)

The box is behind the ball. (PS)

25. The star is under the ball and the box.

The ball and the box are under the star. (Rev S/Os)

The ball is under the star and the box. (Rev S/O1)

The star is between the ball and the box. (PS)

26. The ball is behind the box and the star.

The box and the star are behind the ball. (Rev S/Os)

The box is behind the ball and the star. (Rev S/O1)

The ball is between the box and the star. (PS)

27. The box is above the ball and the star.

The ball and the star are above the box. (Rev S/Os)

The ball is above the box and the star. (Rev S/O1)

The box is behind the ball and the star. (PS)

28. The ball is between the star and the box.

The star and the box are between the balls. (Rev S/Os)

The ball is under the star and the box. (PS)

The ball is beside the star and the box. (PS)

29. The box is in the ball that is under the star.

The box is in the star that is under the ball. (Rev O1/O2)

The box is behind the ball that is under the star. (PS)

The box is in the ball that is beside the star. (PS)

¹²⁰ The subject and object cannot be reversed, since this would be correct for 'beside', so three preposition substitutions are offered for distractors.

30. The star is behind the box that is under the ball.

The star is behind the ball that is under the box. (Rev O1/O2)

The star is in the box that is under the ball. (PS)

The star is behind the box that is above the ball. (PS)

31. The star is beside the ball that is under the box.

The star is beside the box that is under the ball. (Rev O1/O2)

The star is under the ball that is beside the box. (Rev P1/P2)

The star is beside the ball that is above the box. (PS)

32. The ball is above the star that is in the box.

The ball is above the box that is in the star. (Rev O1/O2)

The ball is in the star that is above the box. (Rev P1/P2)

The ball is above the star that is beside the box. (PS)

33. The ball and the star are behind the box.

The ball and the box are behind the star. (Rev O1/O2)

The ball and the star are under the box. (PS)

The ball is behind the star and the box. (conjunct S:=conjunct O)¹²¹

34. The ball and the box are under the star.

The star is under the ball and the box. (Rev Ss/O)

The ball and the box are in the star. (PS)

The ball is under the star and the box. (conjunct S:=conjunct O)

35. The ball and the star are above the box.

The box is above the ball and the star. Rev Ss/O)

The ball and the star are behind the box. (PS)

The ball and the star are in the box. (PS)

36. The box and the ball are between the stars.

The stars are between the box and the ball. (Rev Ss/O)

The box and the ball are under the stars. (PS)

The box and the ball are above the stars. (PS)

37. The box behind the ball is under the star.

The star is under the box behind the ball. (Rev Ss/O)

The ball behind the box is under the star. (Rev S/O1)

The box beside the ball is under the star. (PS)

¹²¹ Read ':= ' as 'becomes'

38. The ball in the star is under the box.

The box is under the ball in the star. (Rev Ss/O)

The ball behind the star is under the box. (PS)

The ball beside the star is under the box. (PS)

39. The box in the ball is above the star.

The star is above the box in the ball. (Rev S/O)

The ball in the box is above the star. (Rev S/O1)

The box in the ball is beside the star. (PS)

40. The box above the ball is under the star.

The ball above the box is under the star. (Rev S/O1)

The box behind the ball is under the star. (PS)

The box beside the ball is under the star. (PS)

APPENDIX 7

PREPOSITION PROCESSING RESULTS

Subject : p7 Date : 16/11/1990

| TREATED ITEMS | | UNTREATED ITEMS | |
|---------------|---------|-----------------|---------|
| Score | Mean RT | Score | Mean RT |
| 10/20 | 3603 hs | 14/20 | 2939 hs |

Result : 24/40
 Total Time Taken : 23.88mins
 Pauses : 0

PREPOSITION PROCESSING PERFORMANCE DATA

Subject : p7 Date : 16/11/1990

| TREATED ITEMS | | | | UNTREATED ITEMS | | | |
|---------------|-----|------|-------|-----------------|-----|------|------|
| Sent | Pic | Posn | RT | Sent | Pic | Posn | RT |
| 1 | 1 | 4 | 3762 | 21 | 1 | 1 | 2153 |
| 2 | 2 | 4 | 3185 | 22 | 1 | 3 | 2340 |
| 3 | 1 | 4 | 4273 | 23 | 1 | 1 | 1609 |
| 4 | 2 | 2 | 1889 | 24 | 1 | 4 | 1730 |
| 5 | 1 | 2 | 2296 | 25 | 1 | 2 | 2895 |
| 6 | 2 | 1 | 1395 | 26 | 1 | 3 | 4642 |
| 7 | 1 | 1 | 2577 | 27 | 1 | 3 | 3054 |
| 8 | 1 | 1 | 2620 | 28 | 1 | 3 | 1939 |
| 9 | 1 | 4 | 3504 | 29 | 1 | 1 | 2713 |
| 10 | 2 | 1 | 3625 | 30 | 4 | 1 | 3449 |
| 11 | 2 | 1 | 2285 | 31 | 1 | 4 | 2533 |
| 12 | 1 | 1 | 2790 | 32 | 1 | 3 | 4224 |
| 13 | 3 | 2 | 2631 | 33 | 1 | 4 | 2033 |
| 14 | 1 | 4 | 2983 | 34 | 2 | 2 | 2955 |
| 15 | 2 | 3 | 3922 | 35 | 1 | 3 | 2796 |
| 16 | 2 | 2 | 7124 | 36 | 2 | 2 | 2592 |
| 17 | 1 | 4 | 10628 | 37 | 3 | 2 | 4471 |
| 18 | 4 | 1 | 4295 | 38 | 1 | 3 | 3768 |
| 19 | 1 | 3 | 2504 | 39 | 2 | 1 | 2702 |
| 20 | 2 | 4 | 3773 | 40 | 2 | 1 | 4185 |

APPENDIX 8

Morphology Test, target sentences and distractors.**1. The yellow stars.**

The yellow star.

The coloured stars.

The yellow balls.

2. The balls and the stars are blue.

The ball and the star are blue.

The ball and the stars are blue.

The boxes and the stars are blue.

3. The boxes are big.

The box is big.

One of the (two) boxes is big.

The balls are big.

4. The balls, the boxes and the stars are small.

The ball, the box and the star are small.

The balls, the boxes and the star are small.

The balls, the box and the stars are small.

5. The red boxes are big.

One big red box, one small.

The red box is big.

The red boxes are small.

6. The box's ball is red.

The ball's box is red.

The (red) box holds a (non-red) ball.

The box and the ball are red.

7. The star's ball is big.

The ball's star is big.

The big star holds a ball.

The star and the ball are big.

8. The ball's box is yellow.

The box's ball is yellow.

The yellow ball holds a box.

The box and the ball are yellow.

9. The box's ball is bigger than the star's.

The star's ball is bigger than the box's.

The ball's box is bigger than the star's.

The box's ball is bigger than the star.

10. The star's box is smaller than the ball's.

The ball's box is smaller than the star's.

The box's star is smaller than the ball's.

The star's box is smaller than the ball.

11. The ball is smaller than the box.

The box is smaller than the ball.

The box and the ball are small.

The ball is smaller than the boxes.

12. The box is bluer than the ball.

the ball is bluer than the box.
The box and the ball are blue.
The box is bigger than the ball.

14. The ball is blueish.

The ball is blue.
The box is blueish.
The ball is red.

16. The ball is boxless.

The ball holds a box.
The box holds a box.
The box is boxless.

18. The ball painted a box.

The box painted a star.
The ball is painting a box.
The star is about to paint a box.

20. The box the ball gave is reddish.

The ball the box gave is reddish.
The box the ball gives is reddish.
The box the ball gives is red.

13. The box is starry.

The box has a star in it.
The star and the box.
The box draws a star.

15. The star is the smallest.

The star is the smaller.
The star is the biggest (tallest).
The ball is the biggest.

17. The star drew a ball.

The ball drew a star.
The star is drawing a ball.
The star is about to draw (a ball).

19. The star is the painter.

The ball is the painter.
The star was painted by the box.
The star is the bigger.

APPENDIX 9

MORPHOLOGY PROCESSING RESULTS

Subject : p7 Date : 19/12/1990

Score Mean RT
7/20 2590 hs

Result : 7/20
Total Time Taken : 9.67mins
Pauses : 0

MORPHOLOGY PROCESSING PERFORMANCE DATA

Subject : p7 Date : 19/12/1990

| Sent | Pic | Posn | RT |
|------|-----|------|------|
| 1 | 2 | 4 | 1351 |
| 2 | 1 | 3 | 3625 |
| 3 | 1 | 2 | 1620 |
| 4 | 1 | 1 | 3878 |
| 5 | 1 | 4 | 1686 |
| 6 | 4 | 4 | 2922 |
| 7 | 2 | 4 | 2444 |
| 8 | 2 | 3 | 2571 |
| 9 | 4 | 3 | 4757 |
| 10 | 4 | 3 | 4625 |
| 11 | 3 | 4 | 1988 |
| 12 | 1 | 1 | 1345 |
| 13 | 1 | 2 | 1653 |
| 14 | 2 | 2 | 797 |
| 15 | 2 | 1 | 3707 |
| 16 | 2 | 2 | 2461 |
| 17 | 3 | 2 | 1615 |
| 18 | 3 | 1 | 1225 |
| 19 | 1 | 4 | 2324 |
| 20 | 2 | 4 | 5207 |

APPENDIX 10

Real World Test target sentences and distractors.

The vocabulary for the distractors was chosen to provide both semantically and phonologically related foils, for example **holds/hits, boy/book, cup/jug, clown/cloud, flower/feather, table/chair, cat/mat/rat, door/chair, cat/cup/coat, paints/draws, behind/beside/between**. However, as with the previous distractors described verbally, the selection of a distractor by a patient does not guarantee that he has interpreted the candidate picture exactly as worded below. For example, my choice of *mat* as a phonological distractor for *cat* is immaterial if a patient considering sentence 22, considers the object behind the door in picture 2 to be a *rug*!

- | | |
|---|--|
| <p>1. The clown paints a girl. (1) The girl paints a clown. (2) The boy paints a girl. (3) The clown draws a girl. (4)</p> | <p>2. The girl holds a boy. (2) The boy holds a girl. (1) The girl holds a book. (3) The girl hits a boy. (4)</p> |
| <p>3. The boy paints a clown. (3) The clown paints a boy. (2) The boy paints a girl. (1) The boy draws a clown. (4)</p> | <p>4. A girl is painted by the clown. (4) A clown is painted by the girl. (3) A boy is painted by the clown. (1) A girl is drawn by the clown. (2)</p> |
| <p>5. A clown is painted by the boy. (3) A boy is painted by the clown. (4) A clown is painted by the girl. (2) A clown is drawn by the boy. (1)</p> | <p>6. A boy is held by the girl. (2) A girl is held by the boy. (1) A book is held by the girl. (4) A boy is hit by the girl. (3)</p> |
| <p>7. The clown gives a flower to the girl. (4) The girl gives a flower to the clown. (3) The clown gives a feather to the girl. (2) The boy gives a flower to the girl. (1)</p> | |
| <p>8. The girl gives a cat to the boy. (1) The boy gives a cat to the girl. (2) The girl gives a coat to the boy. (4) The girl thinks of the boy with the cat. (3)</p> | |
| <p>9. The boy holds the ladder that the girl climbs. (1) The girl holds the ladder that the boy climbs. (4) The boy and girl climb the ladder. (2) The boy kicks the ladder that the girl climbs. (3)</p> | |

10. The girl paints the ladder that the boy holds. (2)

- The boy paints the ladder that the girl holds. (4)
- The clown paints the ladder that the boy holds. (1)
- The girl climbs the ladder that the boy holds. (3)

11. The girl draws a boy. (1)

- The boy draws a girl. (3)
- The girl draws a dog. (4)
- The girl paints a boy. (2)

12. The dog thinks about the cat. (4)

- The cat thinks about the dog. (2)
- The dog thinks about the rat. (3)
- The dog chases the cat. (1)

13. The girl pulls the dog. (4)

- The dog pulls the girl. (2)
- The boy pulls the dog. (1)
- The girl draws the dog. (3)

14. A boy is chased by the dog. (2)

- A dog is chased by the boy. (1)
- A girl is chased by the dog. (3)
- A boy is pulled by the dog. (4)

15. A clown is drawn by the boy. (2)

- A boy is drawn by the clown. (3)
- A cloud is drawn by the boy. (4)
- A clown is painted by the boy. (1)

16. The clown draws a girl and thinks of the dog. (3)

- The girl draws a clown and thinks of the dog. (4)
- The clown draws a girl thinking of a dog. (1)
- The clown draws a dog and thinks of the girl. (2)

17. The girl draws a clown and thinks of the boy. (1)

- The clown draws a girl and thinks of the boy. (4)
- The girl draws a clown thinking of the boy. (3)
- The girl draws the boy and thinks of the clown. (2)

18. It is the clown that gives a cat to the girl. (1)

- It is the girl that gives a cat to the clown. (2)
- It is the clown that gives a cup to the girl. (3)
- It is the clown that draws a girl with a cat. (4)

19. The clown that the boy draws holds a flower. (3)

- The boy that the clown draws holds a flower. (1)
- The clown that draws the boy holds a flower. (4)
- The clown that the boy paints holds a flower. (2)

20. The girl that the dog pulls holds a newspaper. (2)

- The dog that the girl pulls holds a newspaper. (4)
- The boy that the dog pulls holds a newspaper. (1)
- The girl pats the dog that holds the newspaper. (3)

21. The dog is under the bed. (2)

The dog is on the bed. (3)

The dog is beside the bed. (4)

The dog is under the table. (1)

22. The cat is behind the door. (1)

The cat is in front of the door. (door behind cat) (3)

The cat is behind the chair. (2)

The mat is behind the door. (4)

23. The picture is in the book. (3)

The book is in the picture. (1)

The picture is behind the book. (4)

The picture is under the book. (2)

24. The cups are under the tea and the biscuits. (3)

The tea and the biscuits are under the cups. (2)

The cups are in front of the tea and the biscuits. (4)

The plates are under the tea and the biscuits. (1)

25. The boy is behind the girl and the dog. (4)

The girl and the dog are behind the boy. (2)

The boy and the dog are behind the girl. (3)

The boy is between the girl and the dog. (1)

26. The tea is under the cups and the biscuits. (1)

The cups and the biscuits are under the tea. (3)

The tea is behind the cups and the biscuits. (2)

The tea is under the cups and the saucers. (4)

27. The biscuits are behind the cup and the saucer. (3)

The cup and the saucer are behind the biscuits. (2)

The biscuits are beside the cup and the saucer. (4)

The tea is behind the cup and the saucer. (1)

28. The pencil is under the book that is behind the cup. (4)

The pencil is behind the cup that is on the book. (3)

The pencil is on the book that is behind the cup. (2)

The pencil is in the cup that is on the book. (1)

29. The cat is under the table that is behind the chair. (2)

The cat is under the table that is in front of the chair. (4)

The dog is under the table that is behind the chair. (1)

The cat is on the table that is behind the chair. (3)

30. The dog is behind the cat that is under the chair.(2)

The cat is behind the dog that is under the chair. (1)

The dog is beside the cat that is under the chair. (4)

The dog is behind the cat that is under the table. (3)

31. The cup is above the tea. (3)

The tea is above the cup. (4)

The cup is in front of the tea . (1)

The biscuits are above the tea. (2)

32. The tea is above the biscuits. (4)

The biscuits are above the tea. (1)

The tea is behind the biscuits. (3)

The cup is above the biscuits. (2)

33. The cup is between the tea and the biscuits. (2)

The tea is between the cup and the biscuits. (4)

The cup is in front of the tea and the biscuits. (3)

The jug is between the tea and the biscuits. (1)

34. The dog is between the boy and the girl. (4)

The boy is between the dog and the girl. (1)

The dog is behind the boy and the girl. (3)

The cat is between the boy and the girl. (2)

35. The cup is above the tea and the biscuits. (2)

The tea and the biscuits are above the cup. (3)

The cup is in front of the tea and the biscuits. (1)

The tea is above the cup and the biscuits. (4)

36. The tea and the biscuits are between the cups. (1)

The cups are between the tea and the biscuits. (2)

The tea and the biscuits are behind the cups. (3)

The tea and the biscuits are between the jugs. (4)

37. The boy and the girl are behind the door. (2)

The boy and the girl are in front of the door. (3)

The dog and the girl are behind the door. (1)

The boy and the girl are behind the chair. (4)

38. The cat is above the tea and the biscuits. (3)

The tea and the biscuits are above the cat. (2)

The cup is above the tea and the biscuits. (4)

The cat is beside the tea and the biscuits. (1)

39. The dog in the window is above the cat. (4)

The cat in the window is above the dog. (3)

The dog in the window is above the boy. (1)

The dog in the window is behind the cat. (2)

40. The girl on the ladder is above the boy. (4)

The boy on the ladder is above the girl. (1)

The girl on the ladder is above the dog. (3)

The girl on the table is above the boy. (2)

APPENDIX 11 REAL WORLD TEST

Patient Id P3
 Patient Name _____
 Date 5/10/90

| | | | | | | | | | | | | | | | | | | | | |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| VERBS | 1 | 2 | 3 | 4 | 3 | 2 | 4 | 1 | 1 | 2 | 1 | 4 | 4 | 2 | 2 | 3 | 1 | 1 | 3 | 2 |
| | 2 | 2 | 3 | 4 | 3 | 2 | 4 | 1 | 1 | 2 | 1 | 3 | 4 | 2 | 3 | 3 | 1 | 1 | 3 | 4 |

Total 16 14 mis

| | | | | | | | | | | | | | | | | | | | | |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| PREPS | 2 | 1 | 3 | 3 | 4 | 1 | 3 | 4 | 2 | 2 | 3 | 4 | 2 | 4 | 2 | 1 | 2 | 3 | 4 | 4 |
| | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 2 | 3 | 4 | 2 | 4 | 2 | 1 | 2 | 3 | 4 | 4 |

Total 14 11 mis

Result 30 25 mis

Date 13/11/90

| | | | | | | | | | | | | | | | | | | | | |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| VERBS | 1 | 2 | 3 | 4 | 3 | 2 | 4 | 1 | 1 | 2 | 1 | 4 | 4 | 2 | 2 | 3 | 1 | 1 | 3 | 2 |
| | 1 | 2 | 3 | 4 | 3 | 2 | 4 | 1 | 2 | 2 | 1 | 4 | 4 | 2 | 4 | 3 | 2 | 1 | 1 | 4 |

Total 15 11 mis

| | | | | | | | | | | | | | | | | | | | | |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| PREPS | 2 | 1 | 3 | 3 | 4 | 1 | 3 | 4 | 2 | 2 | 3 | 4 | 2 | 4 | 2 | 1 | 2 | 3 | 4 | 4 |
| | 2 | 1 | 3 | 3 | 4 | 1 | 3 | 4 | 1 | 2 | 3 | 3 | 3 | 4 | 3 | 2 | 2 | 3 | 4 | 4 |

Total 15 10 mis

Result 30 21 mis

Date 4/12/90
 10.5.91

| | | | | | | | | | | | | | | | | | | | | |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| VERBS | 1 | 2 | 3 | 4 | 3 | 2 | 4 | 1 | 1 | 2 | 1 | 4 | 4 | 2 | 2 | 3 | 1 | 1 | 3 | 2 |
| | 1 | 2 | 3 | 4 | 3 | 2 | 4 | 1 | 1 | 2 | 1 | 4 | 4 | 2 | 2 | 3 | 1 | 1 | 1 | 4 |

Total 18
 16 8 mis
 9 mis

| | | | | | | | | | | | | | | | | | | | | |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| PREPS | 2 | 1 | 3 | 3 | 4 | 1 | 3 | 4 | 2 | 2 | 3 | 4 | 2 | 4 | 2 | 1 | 2 | 3 | 4 | 4 |
| | 2 | 1 | 3 | 3 | 4 | 3 | 3 | 4 | 2 | 2 | 4 | 4 | 2 | 4 | 3 | 1 | 2 | 3 | 4 | 4 |

Total 17
 15 8 mis

Result 35 16 mis
 31 10 mis

APPENDIX 12

A full list of responses by the 14 aphasic subjects to the treated and untreated items in the Preposition Test and Verb Test is given below. The composition of the tests was described in Chapter 3. The first row of patient responses are the results obtained at the first test session, i.e. before any therapy had been given, the second row shows results after treatment on the first function treated and the final row in each case is the patient's performance after termination of the second treatment block. '1' always denotes a correct response. Actual target sentences and distractors in any instance can be determined with reference to Appendix 4 (verbs) and Appendix 6 (prepositions). In Tables J, K, L and M (the untreated items) the annotations *tp*, *up*, *tv* and *uv* stand for *treated preposition*, *untreated preposition*, *treated verb* and *untreated verb* respectively. Structures 5, 6 and 7 in the Verb Test and structures 4 and 5 in the Preposition Test were *untreated structures* as explained in Chapter 3 (see Table 19, p. 111 and Table 20, p.114).

| Preposition Test data - verbs treated first group | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|-------------|----|----|----|----|----|-------------|----|----|----|----|----|
| Structure 1 | | | | | | | | Structure 2 | | | | | | Structure 3 | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P1 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 2 | 2 | 2 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 4 | 4 | 2 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 4 | 3 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| P2 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 2 | 1 | 2 | 4 | 2 | 1 | 4 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 4 | 1 | 1 | 3 |
| 3 | 1 | 1 | 2 | 2 | 1 | 3 | 1 | 1 | 4 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 | 3 |
| 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 4 | 1 |
| P3 | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 4 | 2 | 1 | 2 | 2 | 2 | 1 | 4 | 4 | 1 | 2 |
| 3 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 4 | 2 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |
| 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| P5 | | | | | | | | | | | | | | | | | | | |
| 3 | 1 | 1 | 2 | 1 | 1 | 3 | 1 | 4 | 1 | 1 | 1 | 3 | 1 | 2 | 3 | 1 | 3 | 1 | 3 |
| 1 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 3 | 3 | 3 |
| 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 1 | 2 |
| P7 | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | 1 | 2 | 1 | 2 | 2 | 2 | 4 | 1 | 2 | 1 | 2 | 1 | 2 | 4 | 1 | 3 | 3 | 1 |
| 1 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 3 | 1 | 2 | 2 | 1 | 4 | 1 | 2 |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 1 | 2 | 2 | 4 | 1 | 4 | 3 | 3 |
| P10 | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| 1 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 2 | 1 | 4 | 3 | 3 | 1 | 2 | 1 | 1 | 3 | 1 | 2 |
| 2 | 2 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| P13 | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 1 | 1 | 1 | 2 | 3 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 | 4 | 2 |
| 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 4 | 1 | 1 | 1 | 2 | 4 | 1 | 4 | 3 | 2 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 |

Table F. Preposition Test data (treated items) Group A.

| Preposition Test data - preps treated first group | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|-------------|----|----|----|----|----|-------------|----|----|----|----|----|
| Structure 1 | | | | | | | | Structure 2 | | | | | | Structure 3 | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P4 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 1 | 3 | 1 | 2 | 3 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 4 | 3 | 1 | 4 |
| 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 1 | 1 | 2 | 1 | 2 |
| 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 1 |
| P6 | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | 1 | 3 | 2 | 2 | 2 | 2 | 4 | 4 | 2 | 1 | 4 | 3 | 3 | 3 | 2 | 2 | 1 | 3 |
| 1 | 2 | 2 | 1 | 1 | 2 | 3 | 2 | 4 | 4 | 3 | 2 | 2 | 1 | 2 | 3 | 1 | 2 | 1 | 3 |
| 3 | 3 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 4 | 1 | 2 | 4 | 2 | 3 | 3 | 1 | 2 | 3 | 1 |
| P8 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 2 | 1 | 3 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| P9 | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 1 | 3 | 4 | 1 | 4 | 1 | 2 | 1 | 2 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 1 | 1 |
| 2 | 1 | 2 | 1 | 1 | 2 | 4 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 3 | 1 |
| 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 2 | 4 | 3 | 3 | 4 | 2 |
| P11 | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | 2 | 3 | 1 | 4 | 1 | 1 | 2 | 1 | 3 | 2 | 4 | 3 | 2 | 3 | 3 | 3 | 1 | 3 |
| 1 | 2 | 1 | 3 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 2 | 1 | 2 | 4 |
| 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 3 | 4 | 3 | 2 | 1 | 3 | 4 | 1 | 4 |
| P12 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| P14 | | | | | | | | | | | | | | | | | | | |
| 3 | 3 | 2 | 3 | 1 | 2 | 4 | 2 | 1 | 4 | 3 | 4 | 4 | 2 | 3 | 3 | 3 | 3 | 1 | 2 |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 3 | 1 | 2 |
| 2 | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 4 | 4 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 4 | 1 | 1 |

Table G. Preposition Test data (treated items) Group B.

| Verb Test data - verbs treated first group | | | | | | | | | | | | | | | | | | | |
|--|---|---|---|---|-------------|---|---|---|----|-------------|----|----|----|----|-------------|----|----|----|----|
| Structure 1 | | | | | Structure 2 | | | | | Structure 3 | | | | | Structure 4 | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P1 | | | | | | | | | | | | | | | | | | | |
| 1 | 4 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 1 | 3 | 1 | 3 | 4 | 2 | 3 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 |
| P2 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 4 | 2 | 2 | 2 | 2 | 2 | 1 | 3 | 2 | 1 | 1 | 3 | 3 | 4 | 3 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 |
| P3 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 3 | 3 |
| 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| P5 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 4 | 1 | 1 | 1 | 4 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 4 | 1 | 3 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 3 | 3 | 4 |
| 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| P7 | | | | | | | | | | | | | | | | | | | |
| 1 | 4 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 4 | 4 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 | 3 | 1 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 |
| P10 | | | | | | | | | | | | | | | | | | | |
| 3 | 4 | 1 | 1 | 1 | 1 | 2 | 4 | 2 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 4 | 3 | 4 | 4 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 3 | 1 | 3 | 1 | 1 |
| P13 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 |
| 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 4 | 4 |
| 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 1 |

Table H. Verb Test data (treated items) Group A.

| Verb Test data - preps treated first group | | | | | | | | | | | | | | | | | | | |
|--|---|---|---|---|-------------|---|---|---|----|-------------|----|----|----|----|-------------|----|----|----|----|
| Structure 1 | | | | | Structure 2 | | | | | Structure 3 | | | | | Structure 4 | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P4 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 3 | 1 | 1 | 2 | 4 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 3 |
| 1 | 1 | 1 | 1 | 1 | 3 | 4 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 4 | 3 | 4 |
| 1 | 4 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 4 | 1 | 4 |
| P6 | | | | | | | | | | | | | | | | | | | |
| 4 | 3 | 1 | 2 | 1 | 4 | 2 | 3 | 3 | 1 | 3 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 1 | 2 |
| 1 | 4 | 3 | 4 | 3 | 2 | 2 | 2 | 1 | 1 | 4 | 2 | 4 | 2 | 1 | 3 | 4 | 2 | 1 | 2 |
| 1 | 1 | 1 | 1 | 3 | 2 | 2 | 4 | 1 | 4 | 4 | 2 | 2 | 4 | 3 | 1 | 1 | 2 | 3 | 1 |
| P8 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 |
| P9 | | | | | | | | | | | | | | | | | | | |
| 4 | 4 | 1 | 4 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 3 | 1 | 1 | 2 | 2 | 1 | 3 | 3 | 3 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 3 | 4 |
| P11 | | | | | | | | | | | | | | | | | | | |
| 2 | 2 | 1 | 1 | 3 | 3 | 3 | 2 | 1 | 1 | 4 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 2 | 4 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 2 | 1 | 3 | 1 | 3 | 1 | 1 | 3 | 4 | 4 | 4 | 2 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 4 | 4 | 1 | 3 | 1 | 3 | 3 | 4 | 4 | 3 |
| P12 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 2 | 1 | 1 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 3 | 3 | 2 | 4 |
| 1 | 1 | 4 | 1 | 1 | 4 | 4 | 4 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 4 |
| P14 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 3 | 1 | 1 | 1 | 3 | 4 | 1 | 3 | 4 |
| 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

Table I. Verb Test data (treated items) Group B.

| Preposition Test data - verbs treated first group | | | | | | | | | | | | | | | | | | | |
|---|---|----|---|-------------|---|----|---|-------------|----|----|----|-------------|----|----|----|-------------|----|----|----|
| Structure 1 | | | | Structure 2 | | | | Structure 3 | | | | Structure 4 | | | | Structure 5 | | | |
| tp | | up | | tp | | up | | tp | | up | | tp | | up | | tp | | up | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P1 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 4 | 3 | 3 | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 4 | 3 | 2 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 4 |
| 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 2 | 1 | 1 | 1 | 2 |
| P2 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 3 | 3 | 3 | 4 | 3 | 2 | 1 | 3 | 3 |
| 1 | 1 | 1 | 3 | 4 | 4 | 4 | 1 | 1 | 3 | 3 | 3 | 4 | 3 | 1 | 1 | 3 | 1 | 3 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 1 | 4 | 3 | 2 | 1 | 4 | 3 | 4 | 1 | 1 |
| P3 | | | | | | | | | | | | | | | | | | | |
| 1 | 3 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 2 | 3 | 2 | 1 | 4 | 2 | 2 | 1 | 1 | 1 | 4 | 3 | 1 | 3 | 3 | 1 | 3 | 1 | 1 | 4 |
| 1 | 2 | 2 | 1 | 4 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 2 |
| P5 | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 4 | 4 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 2 |
| 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 2 | 4 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| P7 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 3 | 4 | 1 | 2 | 1 | 1 | 4 | 4 | 4 | 2 | 2 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 2 |
| 1 | 2 | 1 | 1 | 4 | 2 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| P10 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 2 | 1 | 1 | 4 | 1 | 2 | 3 | 4 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 3 | 1 | 4 |
| 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 |
| P13 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 4 | 1 | 1 | 4 | 1 | 1 | 2 | 3 | 3 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 2 | 4 | 3 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

Table J. Preposition Test data (untreated items) Group A.

| Preposition Test data - prepositions treated first group | | | | | | | | | | | | | | | | | | | |
|--|---|----|---|-------------|---|----|---|-------------|----|----|----|-------------|----|----|----|-------------|----|----|----|
| Structure 1 | | | | Structure 2 | | | | Structure 3 | | | | Structure 4 | | | | Structure 5 | | | |
| tp | | up | | tp | | up | | tp | | up | | tp | | up | | tp | | up | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P4 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 1 | 1 | 2 | 4 | 2 | 1 | 1 | 4 | 4 | 1 | 4 | 2 | 2 | 1 | 1 | 3 | 2 | 4 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 3 | 1 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 |
| P6 | | | | | | | | | | | | | | | | | | | |
| 1 | 3 | 3 | 3 | 3 | 2 | 4 | 4 | 2 | 4 | 4 | 1 | 2 | 1 | 4 | 1 | 3 | 2 | 2 | 1 |
| 1 | 1 | 1 | 1 | 1 | 3 | 4 | 4 | 1 | 2 | 3 | 1 | 2 | 3 | 3 | 4 | 3 | 1 | 1 | 3 |
| 2 | 1 | 3 | 3 | 1 | 1 | 4 | 1 | 3 | 2 | 1 | 2 | 1 | 2 | 3 | 3 | 2 | 1 | 4 | 3 |
| P8 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 4 | 3 | 2 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |
| P9 | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 4 | 4 | 2 | 1 | 3 | 3 | 1 | 2 | 1 | 3 | 1 | 1 |
| 2 | 2 | 1 | 4 | 2 | 2 | 1 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 1 | 2 | 2 | 4 | 2 | 1 |
| 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 3 | 2 | 3 | 1 | 2 | 3 | 2 | 2 |
| P11 | | | | | | | | | | | | | | | | | | | |
| 1 | 3 | 2 | 1 | 1 | 3 | 2 | 4 | 4 | 4 | 1 | 1 | 1 | 4 | 1 | 2 | 2 | 3 | 4 | 3 |
| 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 4 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 4 | 2 | 2 |
| 1 | 2 | 2 | 1 | 2 | 2 | 1 | 3 | 2 | 4 | 2 | 4 | 1 | 3 | 1 | 2 | 1 | 2 | 2 | 3 |
| P12 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 1 |
| 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| P14 | | | | | | | | | | | | | | | | | | | |
| 2 | 3 | 1 | 3 | 2 | 1 | 4 | 2 | 4 | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 1 | 3 | 2 | 1 |
| 2 | 1 | 2 | 4 | 2 | 1 | 2 | 1 | 1 | 3 | 1 | 3 | 4 | 3 | 2 | 2 | 1 | 1 | 2 | 1 |
| 1 | 3 | 2 | 3 | 1 | 4 | 4 | 1 | 1 | 3 | 4 | 1 | 4 | 2 | 4 | 1 | 2 | 2 | 2 | 2 |

Table K. Preposition Test data (untreated items) Group B.

| Verb Test data - verbs treated first group | | | | | | | | | | | | | | | | | | | |
|--|---|----|---|--------|----|---|--------|----|----|-------------|----|----|----|--------|----|--------|----|--------|----|
| Structure 1 | | | | Str. 2 | | | Str. 3 | | | Structure 4 | | | | Str. 5 | | Str. 6 | | Str. 7 | |
| tv | | uv | | tv | uv | | tv | uv | | tv | | uv | | tv | uv | tv | uv | tv | uv |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P1 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 4 | 1 | 1 | 3 | 2 | 3 | 1 | 1 | 1 | 3 | 1 | 4 | 3 | 1 | 3 | 3 | 2 | 2 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 1 | 2 | 1 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 4 | 1 | 3 | 2 |
| P2 | | | | | | | | | | | | | | | | | | | |
| 3 | 1 | 1 | 1 | 2 | 1 | 2 | 3 | 4 | 1 | 1 | 3 | 3 | 4 | 1 | 1 | 2 | 1 | 2 | 1 |
| 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 4 | 1 | 1 | 2 | 3 |
| P3 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 3 | 3 | 1 | 4 | 3 | 4 | 2 | 3 |
| 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 2 | 1 | 1 | 4 | 4 | 3 | 1 | 1 | 4 | 2 | 4 |
| 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| P5 | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 1 | 3 | 2 |
| 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 4 | 3 | 4 | 1 | 1 | 2 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 1 | 1 | 1 | 2 | 4 |
| P7 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 4 | 4 | 2 | 3 | 2 | 1 | 1 | 1 | 4 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 3 | 1 | 4 | 1 | 2 | 3 | 1 | 1 | 1 | 4 | 2 |
| P10 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 1 | 1 | 2 | 4 | 1 | 2 | 1 | 1 | 4 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 3 |
| 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 4 | 2 | 1 | 3 | 3 | 2 | 1 | 1 | 1 | 4 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 3 | 1 | 2 | 1 |
| P13 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 4 | 1 | 2 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 3 | 2 |
| 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 3 | 1 | 1 | 2 | 2 | 1 |
| 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 4 | 4 | 4 | 3 | 1 | 1 | 3 | 2 | 2 |

Table L. Verb Test data (untreated items) Group A.

| Verb Test data - prepositions treated first group | | | | | | | | | | | | | | | | | | | |
|---|---|----|---|--------|----|---|--------|----|----|-------------|----|----|----|--------|----|--------|----|--------|----|
| Structure 1 | | | | Str. 2 | | | Str. 3 | | | Structure 4 | | | | Str. 5 | | Str. 6 | | Str. 7 | |
| tv | | uv | | tv | uv | | tv | uv | | tv | | uv | | tv | uv | tv | uv | tv | uv |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| P4 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 1 | 1 | 2 | 3 |
| 1 | 1 | 1 | 1 | 4 | 1 | 4 | 1 | 1 | 1 | 3 | 3 | 3 | 4 | 1 | 1 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 2 | 2 |
| P6 | | | | | | | | | | | | | | | | | | | |
| 1 | 3 | 2 | 4 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 3 | 2 | 2 | 4 | 2 | 2 | 2 | 4 |
| 4 | 1 | 3 | 1 | 2 | 4 | 1 | 3 | 4 | 3 | 4 | 2 | 3 | 4 | 4 | 4 | 4 | 1 | 1 | 2 |
| 1 | 4 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 1 | 4 | 4 | 4 | 1 | 1 | 4 |
| P8 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 4 | 4 | 3 | 1 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 2 | 4 |
| P9 | | | | | | | | | | | | | | | | | | | |
| 4 | 1 | 4 | 1 | 2 | 1 | 2 | 2 | 4 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 4 |
| 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 3 | 4 | 3 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 4 | 1 | 4 | 3 | 1 | 2 | 2 |
| P11 | | | | | | | | | | | | | | | | | | | |
| 2 | 1 | 1 | 3 | 2 | 1 | 2 | 3 | 1 | 2 | 4 | 2 | 4 | 1 | 4 | 4 | 4 | 3 | 3 | 3 |
| 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 2 | 4 | 2 | 4 | 3 | 3 | 1 | 4 | 2 |
| 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 1 | 3 | 1 | 2 | 4 | 2 | 1 | 3 | 3 |
| P12 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 4 | 2 | 1 | 4 | 1 | 1 | 2 | 1 |
| 1 | 1 | 4 | 1 | 4 | 1 | 4 | 1 | 1 | 1 | 1 | 4 | 1 | 3 | 2 | 4 | 1 | 1 | 1 | 2 |
| 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 4 | 3 | 2 | 4 | 1 | 1 | 1 | 1 |
| P14 | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 2 | 4 | 1 | 2 | 1 | 3 | 4 | 2 | 4 | 4 | 4 | 1 | 2 | 1 | 2 | 2 |
| 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 4 | 4 | 4 | 1 | 1 | 2 | 2 |
| 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 4 | 1 | 4 | 3 | 1 | 2 | 1 | 2 | 2 |

Table M. Verb Test data (untreated items) Group B.

APPENDIX 13

20th December 1990

I am writing to thank you. The time and effort you have put in to the computerised sentence reading project are greatly appreciated.

You are one of 14 people who have helped me to discover whether this new method is of use in the diagnosis and treatment of sentence understanding difficulties. My task over the next few months is to analyse the resulting data and make the findings known, so that others can benefit.

In addition to the measurements we have recorded, there may be other changes that have taken place since we started work at the beginning of October. Your family, friends or carers may have noticed improvements, not just in reading, over the past three months. Christmas is a time of year when you are likely to see people who have not seen you for a while, and who may have valuable comments to make.

Included with this letter are two sets of questions. One for you to complete and one for your family, friends or carers. The two sets of responses may differ. It may be that you feel benefits that are not obvious to others, or that they see changes that you have not noticed. Please give your honest opinions, even if these are negative. It is very important in evaluating new treatments to know when they have not been helpful, as well as when they have. The more specific you can be in your comments, the better. For example, if your reading has improved, you may be able to tell me whether you are reading faster, perhaps that you could only concentrate for a few minutes before and can now read for half an hour, or that you are understanding more of what you read. Details like this are very helpful.

Thank you for taking the trouble to think about this. An envelope is enclosed for your reply.

Yours sincerely,

Alison Crerar

FOR P4

TO COMPLETE (with help)

Since you started the new computerised sentence reading project in October 1990, tell me about any changes you have noticed in your

1. Ability to speak.

Very possibly - I am more confident about conversing. This may be due to a change in my medication and eliminated my fear of fits

2. Writing or use of your hand(s).

Yes - especially using prepositions in sentences.

3. Reading.

I can ~~now~~ read for longer periods, I am faster and enjoying it!

4. Understanding of speech.

This not a problem usually.

5. Attention span / general alertness.

Attention span + concentration much increased.

6. Confidence / sense of well-being / interest in life.

All these have improved.

7. How does this new approach compare with other therapies you have tried?

Interesting. I think it was beneficial and more stimulating.

8. What do think was the most important benefit for you?

I found the repetition of familiar shapes easier as time went on.

9. Do you have any criticisms which may help us to improve the therapy?

Daily treatments, please!

10. Would you recommend this form of therapy to others?

Yes.

FOR THE FAMILY, FRIENDS or CARERS OF **P4**
TO COMPLETE

Since _____ *started the new computerised sentence reading project in October 1990, tell me about any changes you have noticed in his/her*

1. Ability to speak.

Has improved, and is confident when talking on his own behalf.

He now goes into shops on his own.

But, his medication was changed in the summer, and has had no fits since. This in itself has greatly improved his self-confidence.

2. Writing or coordination.

This has much improved, but he finds using a key-board on his computer easier than handwritting. This is the part of language he finds most difficult

3. Reading.

Dramatic. Reads everything from the B.M.J. to newspapers and light novels, and enjoys reading very much.

4. Understanding of speech.

Michael has not much problem understanding speech.

5. Attention span / general alertness.

He can concentrate for longer periods and is more alert.

LIST OF ABBREVIATIONS USED

| | |
|--------------------|--|
| AA | The Astley Ainslie Hospital, Edinburgh |
| AI | Artificial Intelligence |
| DSR | digit-span recall |
| HCI | human-computer interface |
| HNC | Higher National Certificate |
| IBM PC | personal computer manufactured by IBM |
| KB | knowledge-base |
| mb | megabyte - a measure of computer volatile memory or disc storage capacity. 1 mb is sufficient to store approximately 1 million alphanumeric characters. |
| NP | noun-phrase |
| PB mode | picture-building mode |
| PDP | parallel distributed processing |
| PP | Prestonpans Health Centre, Prestonpans, East Lothian. |
| PRP | Preposition Remediation Program (Crerar, 1990) |
| QMC | Queen Margaret College, Edinburgh |
| RAM | read\write random access memory, this is volatile memory |
| Raven's CPM | Raven's coloured progressive matrices (Raven, 1975) |
| RT | reaction time |
| SB mode | sentence-building mode |
| SST | Syntax Screening Test (Crerar, 1990) |
| SST1..SST3 | The SSTs associated with each of three pre-therapy test sessions |
| STM | short term memory |
| TROG | Test for Reception of Grammar (Bishop, 1982) |
| VDU | visual display unit |
| VGA | video graphics array, essentially a high resolution colour monitor |
| VRP | Verb Remediation Program (Crerar, 1990) |
| WAB | Western Aphasia Battery (Kertesz, 1982) |

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