Edinburgh Napier UNIVERSITY

Performance on a tablet-based visual-spatial-motor task is compromised in adults and children with dyslexia: implications for the development of a novel screening tool.

Dr Alexandra Willis[1], Ms Barbara Piotrowska[1], Ms Alexandra Bannach-Brown[1], Dr Rory MacLean[1], & Prof. Jon Kerridge[2]

[1]School of Life, Sport, and Social Sciences & [2]School of Computing, Edinburgh Napier University, Scotland, UK.

Introduction

- Many adults and children with dyslexia also have problems with lower-level sensory, attentional, or motor tasks. In particular, there may be problems with auditory processing[1], visual motion processing[2-3], visual-spatial attention[4], and motor control[5-6]. However, whether these low-level sensory or motor problems underlie dyslexia, or merely co-exist with it, remains a topic of much debate[7-8].
- If these sensorimotor problems do underlie dyslexia, they should be demonstrable in young children, **before they learn to read**. Early identification of dyslexia is important because targeted interventions appear to be most effective when introduced early in childhood: however, there is currently little evidence from longitudinal studies to explore the antecedents of dyslexia in children. The few longitudinal studies published on this topic do indeed suggest that low-level sensory deficits may predict later reading difficulties in young children[9].

Aims

- We have developed a simple tablet-based "dot-to-dot" (DtD) task which we believe taps into the visual-spatial attention and visual-motor integration systems, and which may help identify children at higher risk of dyslexia earlier and more quickly than existing tests. Unlike existing tests, our DtD task does not depend on any phonological or general knowledge: as such, it could be developed for use in young children before they fail to learn to read, from a wide range of cultural backgrounds, and in whom English may not be the first language.
- **Here, we present preliminary data from the first phase of a new longitudinal study of pre-school and primary aged children in Edinburgh, UK, to explore whether performance on our DtD task can be used to predict later reading success.**

Methods

Participants

So far, 70 **children** (36 females, 34 males) aged between 4 yrs, 10 months and 8 yrs, 4 months (mean = 6 yrs 4 m; SD = 1 yr 1 m) have taken part from a single primary school in Edinburgh. Future testing will encompass pre-school children (aged 4-5 yrs), and schools with different demographic profiles to ensure the sample is representative of the wider population.

46 **adults** (12 females, 34 males), aged between 17 and 46 years (mean = 23.6 yrs; SD = 6.50) were recruited from the staff and student population of Edinburgh Napier University. Of these, 19 had been identified as dyslexic by the University's Student Support team, and 27 stated they were not dyslexic.

Tests

Visual-Spatial-Motor Skills were measured using our "dot-to-dot" task (see below). In addition, children completed a short battery of tests to measure phonological awareness and other cognitive abilities, including (**1**) **LUCID-Rapid** dyslexia screening test; (**2**) **phonological awareness** (DEST-2 / DST-J); (**3**) **rapid automatized naming** (DEST-2 / DST-J); (**4**) **working memory** (digit span; WISC/WPPSI-IV); (5) verbal reasoning (similarities; WISC/WPPSI-IV); (**6**) **fluid/perceptual reasoning** (block design & matrix reasoning; WISC/WPPSI-IV); (**7**) **fine motor skills** (bead-threading; DEST-2). Data collection in adults for equivalent tests is currently underway.

Procedure

All data collection in **children** was carried out by authors BP and ABB. Children were tested individually over two sessions, lasting 20-30 min each, in a quiet room at their school. During the first session, children completed the dot-to-dot task and LUCID screening test; during the second, they completed the rest of the cognitive tasks. Test order was randomized across participants.

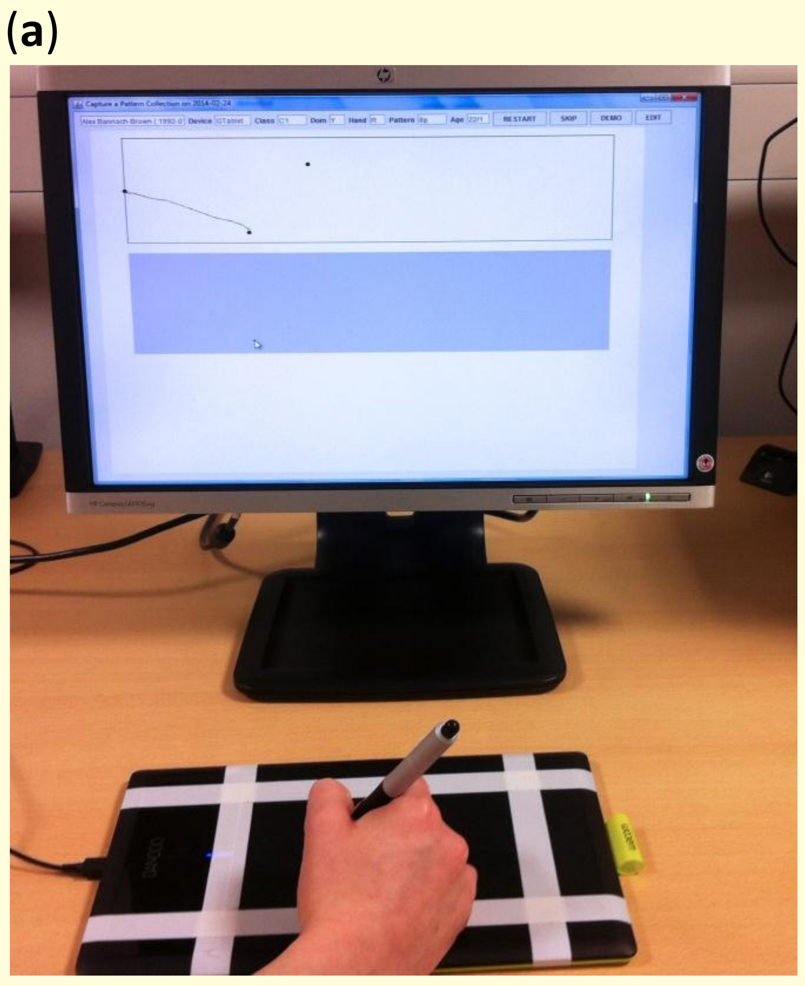
All the **adults'** data were collected by JMK. The dot-to-dot task was completed by all participants, in a single session lasting 10 - 20 minutes: data collection for the other cognitive tests is ongoing.

The Dot-to-Dot Task

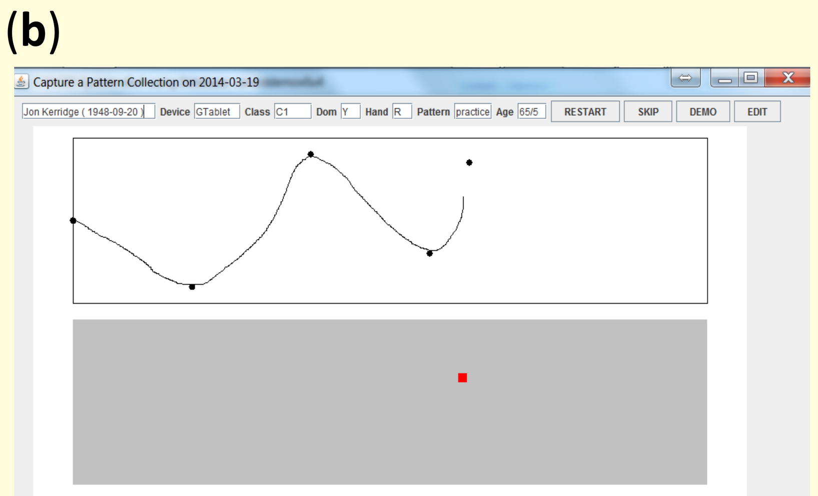
Participants were asked to look at a sequence of dots on a display monitor and draw a line as quickly and accurately as possible between them on an adjacent touch-screen tablet using a stylus (see **Figure 1**). Single dots appeared sequentially, at a random location, as soon as the stylus moved sufficiently close to the previous dot. Participants completed three trials for each of 8 and 9 dot displays, using both the dominant and non-dominant hand. The sequence of trials was randomized.

We measured: (**1**) the **maximum error** between the drawn line and the line of best fit in the first sector of the pattern (DtD First Sector Max Error); (**2**) the **total error** between the drawn line compared to the line of best fit over the whole pattern (DtD Total Error) ; and (**3**) the **time** taken to complete the task (DtD Time).

(a)



(b)



(**b**) Example of the display screen during a practice trial.

(c)

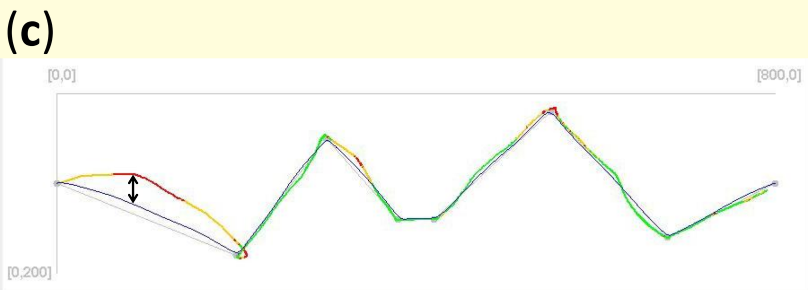


Figure 1: The dot-to-dot task. (**a**) Experimental set up showing the display monitor, touch-screen tablet, and stylus. Participants looked at the top panel of the display and joined up the dots on the tablet below with the stylus. When the stylus gets to within a certain distance of the dot, the next dot appears in a random location. Participants must divide their attention in space between the display panel in front of them and the tablet below.

(**c**) Example of the output from a single trial, for one participant (8-dot condition). The grey line shows the line of best fit, calculated by the software. The coloured line shows the line drawn by the participant. Note that in this example, the **DtD First Sector Max Error** is very large (see ↕ above): the yellow and red sections of the line indicate that the points fell beyond 1 and 2 SD of the mean, respectively, for the sample as a whole.

Results & Discussion

1. Adults: Dot-to-Dot (DtD) Task.

Performance on our dot-to-dot task in adults with and without dyslexia are shown in **Figure 2**, for the dominant hand. Dyslexic adults made significantly greater maximum errors in the first sector of the pattern, on average, compared with non-dyslexics (t (22) = 2.62; p < 0.01; **2a**). Adults with dyslexia also made more errors over the pattern as a whole (**2b**), and took less time to complete the task (**2c**), on average, compared with those without dyslexia, but these differences were not significant.

These results suggest that accuracy on our dot-to-dot task is lower in adults with identified dyslexia – at least in the first sector of the pattern – and suggest value in exploring young children's performance on this task to see if it can predict reading success.

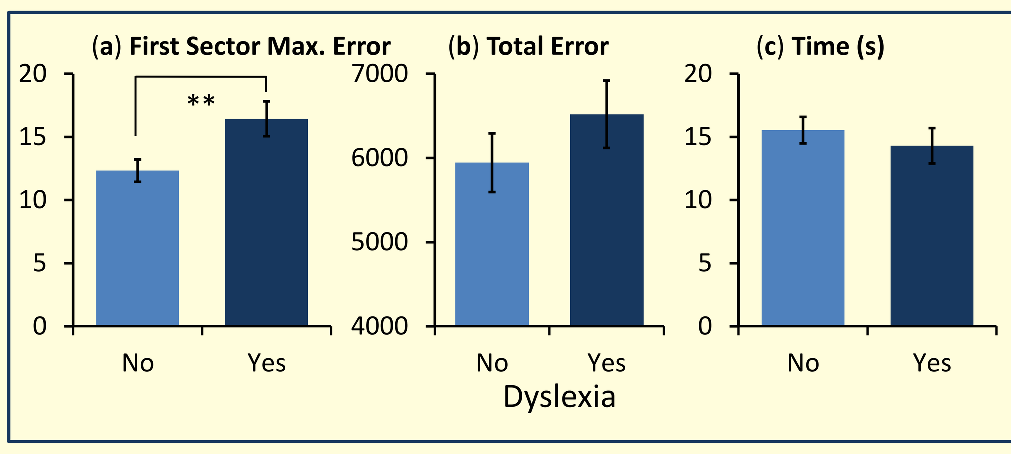


Figure 2: Adults' performance on our dot-to-dot task. (**a**) First Sector Max Error: the maximum error (in pixels, from the line of perfect fit between dots) made between dots 1 and 2; (**b**) Total Error: the mean sum of the difference (in pixels) between each point drawn by the participant compared with the corresponding pixel on the line of perfect fit; (**c**) Time: mean time (in s) taken to complete the pattern. Error bars indicate ±1 SEM. ** difference is significant at p < 0.01.

2. Children: Dot-to-Dot and Other Tasks.

In children, the First Sector Max Error measure of performance on our dot-to-dot task was significantly correlated with both Phonological Awareness and Rapid Automatized Naming (RAN), arguably the two most powerful predictors of reading success in children, as well as both working memory (Digit Span) and perceptual reasoning (Matrix Reasoning).

	Block Design	Matrix Reasoning	Similarities	Digit Span	RAN	Bead Threading	Phon. Awareness	DtD First Sector Max Err	DtD Total Error	DtD Time
DtD First Sector Max Err	**-.260***	**-.418****	.003	**-.383****	**.343****	**-.354****	**-.300***	1	.759**	.482**
DtD Total Error	**-.335****	**-.324****	.054	**-.347****	**.332****	**-.387****	-.223	.759**	1	.685**
DtD Time	-.114	**-.323****	-.015	-.213	**.312***	**-.414****	-.219	.482**	.685**	1

Table 1: Pearson's correlations. * indicates that the correlation is significant (two-tailed): * p < 0.05; ** p < 0.01.

Groups of children classified as "high" (n=18) and "low" (n=13) risk of dyslexia on the basis of their scores on LUCID-Rapid were compared for each of the tasks (see **Figure 3**). Independent-samples t-tests revealed that children deemed at high risk of dyslexia made significantly greater maximum errors in the first sector of the pattern (DtD: First Sector Max Error) and made more errors over the whole pattern (DtD: Total Error), compared with low-risk children: however, there was no significant difference in time taken to complete the task.

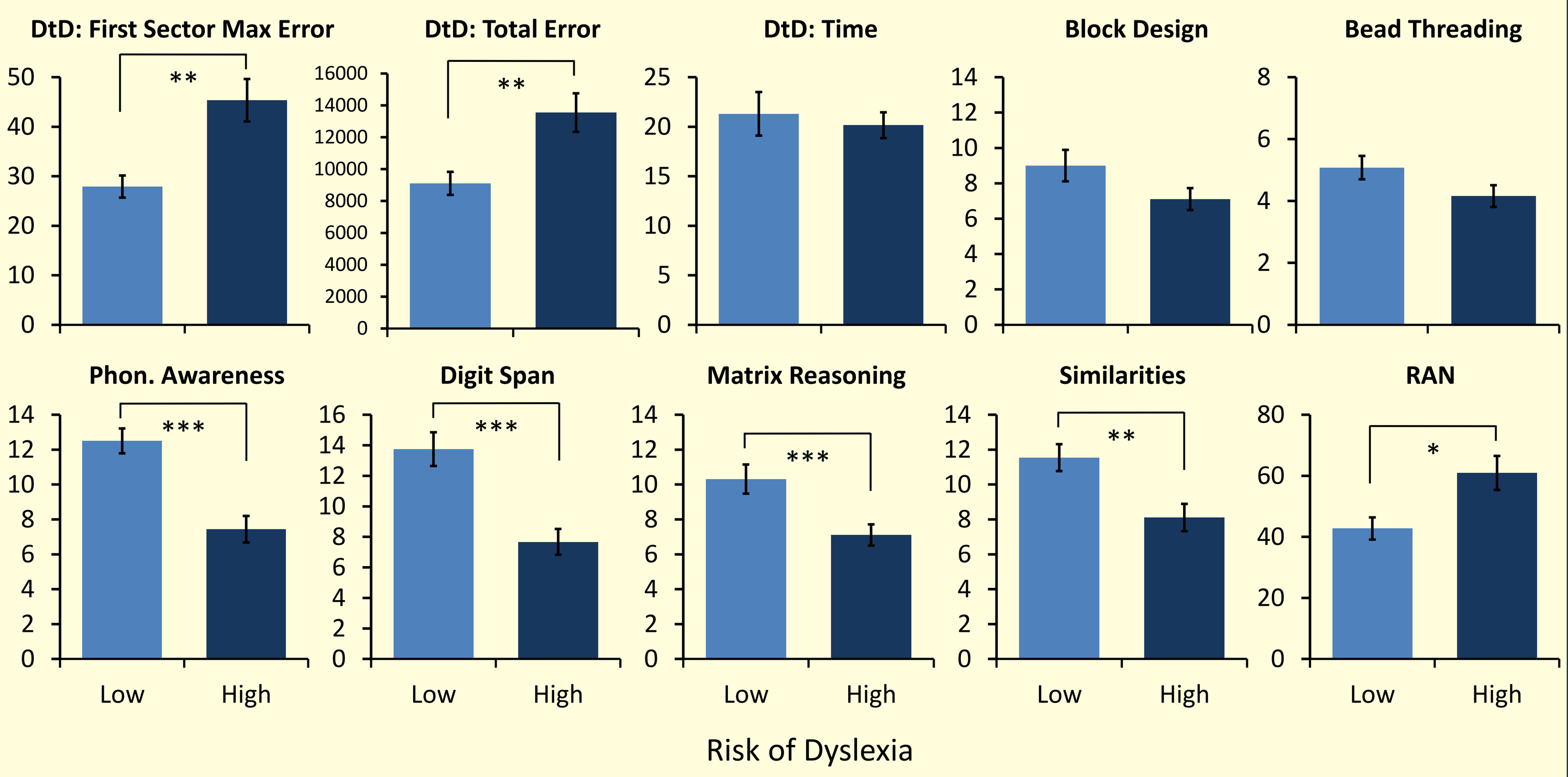


Figure 3: Children's performance on all tasks, grouped according to **risk of dyslexia** (low vs. high), as determined by the LUCID-Rapid Dyslexia Screening Tool. Error bars indicate ±1 SEM. Differences are significant at p < 0.05 (*); p < 0.01 (**); p < 0.001 (***).

The findings that **DtD First Sector Max Error** was significantly greater in both adults with identified dyslexia and children at high risk of dyslexia, and correlated robustly with phonological awareness are intriguing. We will revisit these children in future years to examine whether or not the DtD task can reliably predict reading and writing success, and whether poor performance on the DtD task is best explained by problems in the underlying visual-spatial-motor system(s) that may underlie dyslexia in many individuals, or by factors such as poor motor or cognitive skills alone.

Conclusions

- Both adults with dyslexia, and children deemed at high risk of dyslexia, performed significantly worse than their non-dyslexic / low-risk counterparts on our dot-to-dot task – especially in the first sector.
- Performance on our dot-to-dot task is significantly correlated with phonological awareness and RAN, which suggests the task may be useful in predicting reading success.
- Longitudinal data will explore whether or not deficits in performance on the dot-to-dot task precede reading difficulties. If so, we will explore the possibility of developing the task for use as a dyslexia screening tool in children and adults from a range of linguistic backgrounds.

References

[1] Goswami, U., Thomson, J., Richardson, U., Stainthorp, R., Hughes, D., Rosen, S., & Scott, S.K. (2002). *PNAS*, **99**: 10911-10916.

[2] Cornelissen, P., Richardson, A., Mason, A., Fowler, S., & Stein, J. (1995). *Vision Research*, **35**: 1483-1494.

[3] Witton, C., Talcott, J. B., Hansen, P. C., Richardson, A. J., Griffiths, T. D., Rees, A., *et al*. (1998*Current Biology*, **8**: 791-797.

[4] Bosse, M.-L., Tainturier, M. J., & Valdois, S. (2007). *Cognition*, **104**: 198-230.

[5] Nicolson, R. I., Fawcett, A. J., & Dean, P. (2001). *TINS*, **24**: 508-511.

[6] Stoodley, C. J., Harrison, E. P. D., & Stein, J. F. (2006). *Neuropsychologia*, **44**: 795-798.

[7] Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., *et al*. (2003). *Brain*, **126**: 841-865.

[8] Vidyasagar, T. R., & Pammer, K. (2010). *TICS*, **14**: 57-63.

[9] Kevan, A., & Pammer, K. (2009). *Neuropsychologia*, **47**: 3174-3181.