Process Dissociation of Familiarity and Recollection in Children:

Response Deadline affects Recollection but not Familiarity

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Abstract

According to dual-process theories recollection (slow and associated with contextual details) and familiarity (fast and automatic) are two independent processes underlying recognition memory. An adapted version of the process dissociation paradigm was used to measure recognition memory in 5-, 7-, 11-year-olds and adults. In Experiment 1 it was found that 5-year-olds already recollect details of items (i.e., number). Recollection increased particularly between 5- and 7-years. Familiarity differed between 5-years and adulthood. In Experiment 2, under limited response time during retrieval, recollection was eliminated in 5-year-olds and reduced across all ages whereas familiarity was left unaffected. Together, these findings are consistent with dual-process theories of recognition memory and provide support for two processes underlying recognition memory from a developmental perspective.

Keywords: recognition memory; familiarity; recollection; process dissociation; source monitoring

A large body of research over the past 20 years has focused on quantitative changes in children's true and false memories (for a review see Raj & Bell, 2010). Little is known about the qualitative mental state that accompanies a child's memory. A fundamental question is whether a child's memory is associated with a specific memory of a past event (recollection) or a sense of "oldness" (familiarity). For example, if a child brings some toy cars to school that get lost, the memory of the cars can be specific (e.g., 2 red cars) (recollection) or can be accompanied by a vague feeling of bringing some toys to school (familiarity). According to dual process theories, recollection is defined as an effortful and slow acting process where qualitative details about an event are recalled whereas familiarity is automatic, fast acting and not associated with contextual details (Jacoby & Dallas, 1981; Yonelinas, 2002).

The current aim is to examine the role of recollection and familiarity in 5-, 7-, 11-year-olds'and adults' memories implementing the process-dissociation paradigm (Jacoby, 1991), and to explore whether there is evidence for a dual-process model across childhood. If there is evidence for dual-processes then limiting response time during retrieval is expected to lead to a reduction in recollection but not in familiarity (Yonelinas & Jacoby, 1994).

Investigating the mental states that accompany memory is of particular theoretical relevance as developmental changes in quality of memories can occur independently of a change in quantity (Brainerd, Holliday, & Reyna, 2004). That is, theoretical explanations in quantitative changes in children's true and false memories and their underlying processes such as source-monitoring, associative activation, gist and verbatim extraction (Brainerd & Reyna, 2005; Howe, Wimmer, Gagnon, & Plumpton, 2009; Johnson, Hashtroudi, & Lindsay, 1993) do not currently account for mental states that accompany memories and thus, explain developmental changes in memories fully.

To get a complete picture of recognition memory development throughout childhood it is important to investigate the full age range between 5 years of age up to young adulthood.

However, to date the few studies that examined recollection and familiarity in children have either focused on children older than 8 years or have not examined age groups between age 5 and adulthood (Anooshian, 1999; Billingsley, Lou Smith, & McAndrews, 2002; Brainerd, Reyna, & Howe, 2009; Brainerd et al., 2004; Czernochowski, Mecklinger, Johansson, & Brinkmann, 2005; Friedman, de Chastelaine, Nessler, & Malcolm, 2010; Ghetti & Angelini, 2008; Holliday & Hayes, 2000, 2001, 2002; Mecklinger, Brunnemann, & Kipp, 2011). One reason why evidence of recognition memory is lacking in younger children is that the standard paradigm applied in research with adults (i.e., the remember-know paradigm, Tulving, 1985) requires accurate self-report of memory experience (metacognitive monitoring). This aspect of metamemory develops around age 8 and increases in accuracy until early adulthood (Ghetti, Mirandola, Angelini, Cornoldi, & Ciaramelli, 2011). Recent evidence also suggests that the remember-know procedure distinguishes strong from weak memories rather than recollection from familiarity (Wixted & Mickes, 2010). Moreover, remember/know responses may not be a proxy for recollection and familiarity *per se* but rather reflect the subjective experience of the recognition process (Knott & Dewhurst, 2007). Thus, the remember-know procedure may measure how metacognitive monitoring develops during childhood (Ghetti et al., 2008, 2011) instead of examining the development of differing remembering processes *per se*.

Other procedures assume a positive correlation between memory accuracy and confidence (e.g., receiver operating characteristic procedure (ROC), Yonelinas, 1994). However, the ability to monitor memory strength continues to develop during middle childhood (Ghetti et al., 2008; Hembacher & Ghetti, 2013; Roebers, 2002; Roebers, Gelhaar, & Schneider, 2004).

Ghetti and Angelini (2008) examined recollection and familiarity development in 6-, 8-, and 10-year-old children and young adults using ROCs (Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996). ROCs were derived by plotting hits and false alarms as a function of confidence. A dual-process signal detection model that assumes that recollection and familiarity are independent processes was fitted to the ROCs to provide estimates for recollection and familiarity. Here recollection is modelled as single threshold process and familiarity assumed to be a continuous process. In their Experiment 2 children studied pictures and judged their characteristics (e.g., hard versus soft) either under short (1500ms) or long study duration (4500ms). Increases in recollection occurred throughout childhood until age 10 independent of study duration. Age related increases in familiarity were observed only after short study duration but not after long one. These findings indicate that recollection and familiarity have different developmental trajectories. Further, short study duration reduced familiarity but not recollection. To our knowledge to date this is the only study revealing clear evidence for a dissociation between the developmental trends in familiarity and recollection between 6- and 10 years.

The disadvantage of the ROC procedure is that it requires a high number of trials (*N* = 240) (Ghetti & Angelini, 2008), which may be problematic specifically for 5-year-old children. Moreover, although the ROC method does not require direct introspection into memory states it does require confidence ratings to be reported. The ROC approach relies on participants' ability to vary their response criterion given a certain level of memory sensitivity (Yonelinas et al., 1996). However, the ability to distinguish between correct and incorrect responses with confidence ratings increases between 5- and 10-years of age (Ghetti et al., 2008; Roebers et al., 2004). Thus, it is not entirely certain whether these changes in recollection and familiarity values reflect different remembering phenomenology or children's developing ability to monitor and report on memory performance.

To overcome the need for self-report of metacognitive monitoring, a few studies (Anooshian, 1999; Brainerd et al., 2004; Brainerd, et.al, 2009; Holliday & Hayes, 2000, 2001,

2002) implemented indirect methods of assessing memory processes such as the dual-retrieval model, the conjoint recognition paradigm and the process dissociation paradigm (PDP).

Brainerd et al. (2004) used the conjoint-recognition procedure to assess recognition memory in 7-14-year-olds (Experiment 1) and 5- and 11-year-olds (Experiment 2). Participants were presented with semantically related words (e.g., *celery*, *lettuce*) followed by one of three recognition tests, in which they had to respond "yes" to either previously seen items (e.g., *lettuce)*, to semantically related items that were not earlier presented (e.g., *carrot*) or to both targets and semantically related items. Here, familiarity and recollection estimates were derived from saying "yes" only to semantically related items (familiarity) or to both targets and semantically related items (recollection = both - familiarity). Findings revealed a difference in recollection between 7- and 14- years (Experiment 1) and 5- and 11-years (Experiment 2). Familiarity did not differ between 7- and 14-years (Experiment 1) but differed between 5- and 11-years (Experiment 2). However, as this paradigm requires forming semantic associations it is not entirely clear whether these developmental effects are due to different remembering phenomenology or a maturing semantic network that undergoes considerable qualitative and quantitative developmental change between 5, 7, and 11 years of age (Dewhurst & Robinson, 2004; Wimmer & Howe, 2009).

Finally, a well-established method assessing recollection and familiarity in adults without introspective report on memory is the process dissociation paradigm (PDP) (Jacoby, 1991). Traditionally participants are presented with two word lists (e.g., one list of visually and one list of auditory presented words) during encoding. Recognition consists of two conditions: In the inclusion condition participants are instructed to say "yes" to all earlier presented words (no matter whether an item was presented auditory or visually) and reject new words. In the exclusion condition participants are instructed to accept only items from the target group (e.g., auditory presented words) and exclude (reject) new items and non-targets (e.g., visually presented words). Familiarity and recollection parameters can be derived from contrasting performance in exclusion and inclusion. In inclusion yes-responses to targets (auditory words) and non-targets (visual words) are correct, in exclusion "yes" is only correct in response to targets (auditory words), not to non-targets. Correct yes-responses to non-targets in inclusion can be based on both, familiarity or recollection (as shown in equation 1). Incorrect yes-responses to non-targets in exclusion show that participants are unable to recollect qualitative details (i.e., auditory vs. visual) about the presented item and recollection failed. This indicates that the response is based on familiarity (as shown in equation 2). Thus, recollection is calculated by contrasting yes-responses to non-targets in inclusion to yes-responses to non-targets in exclusion (as shown in equation 3). An incorrect yes-response in exclusion to a non-target is based on familiarity. To control for recollection this value is divided by 1-recollection meaning that familiarity is calculated from estimates of recollection (as shown in equation 4) (Jacoby, 1991).

(1) $\text{"Yes"}_{\text{Inclusion-"non-target"}} = \text{Recollection} + \text{Familiarity} - \text{Familiarity} \times \text{Recollection}$

(2) $\text{"Yes"}_{\text{Exclusion-non-target}} = \text{Familiarity} \times (1 - \text{Recollection})$

$= \text{Familiarity} - \text{Familiarity} \times \text{Recollection}$

$\text{"Yes"}_{\text{Inclusion-"non-target"}} = \text{Recollection} + \text{"Yes"}_{\text{Exclusion-non-target}}$

(3) $\text{Recollection} = \text{"Yes"}_{\text{Inclusion-"non-target"}} - \text{"Yes"}_{\text{Exclusion-non-target}}$

(4) $\text{Familiarity} = \text{"Yes"}_{\text{Exclusion-non-target}} / (1 - \text{Recollection})$

The PDP was adapted in a few studies to examine the development of recognition memory (Anooshian, 1999; Holliday & Hayes, 2000, 2001, 2002). A series of studies by Holliday and Hayes (2000, 2001, 2002) used the PDP to investigate how recollection and familiarity are linked to the acceptance of misinformation. Here, 5- to 9-year-old children were first presented with a picture story. Afterwards they were given a summary of this story that contained misleading details. These details were either read to children or self-generated by children (e.g. kitchen was replaced with bathroom). In the recognition phase children first had to accept earlier presented pictures (inclusion). In the second part children had to exclude items from either the first or the second version of the story (exclusion). Findings revealed that both recollection and familiarity contribute to the acceptance of misinformation where the latter decreased with age (Holliday & Hayes, 2000). They also showed that in contrast to familiarity, recollection based responding to misinformation was stronger after self-generated misinformation items than after read items (Holliday & Hayes, 2000, 2002). Thus, misinformation elicits both a feeling of familiarity and recollection, where both show different developmental trajectories.

Additionally, in a study by Anooshian (1999) that directly examined recognition memory, 5-year-olds and adults first studied a list of pictures accompanied by a story. Then they were presented with another list of pictures which were part of the same story but not presented earlier. The recognition phase consisted of an inclusion (accept all earlier seen pictures) and an exclusion phase (accept only pictures from the second list). Importantly, 5-year-olds as well as adults accepted more non-targets (second list) in inclusion than in exclusion. This finding suggests that participants followed the instructions, thus recollection and familiarity could be assessed appropriately. Using this list-based design Anooshian (1991) found that adults showed higher levels of recollection than 5-year-olds whereas familiarity did not differ between the two age groups.

However, this study only examined single age groups, and thus does not allow examination of developmental trends between the ages of 5 and adulthood. It is of particular interest to examine recognition memory phenomenology in children after the age of 4, once they have acquired an understanding of their own and others' mental states (Gopnik & Astington, 1988; Wimmer & Perner, 1983), during their important "5- to 7-year" developmental memory shift (Sameroff & Haith, 1996) and "post-metamemory" (8 years) (Ghetti, 2003) compared to adults. Therefore, further research in intermediate age groups is crucial in assessing developmental trajectories. Thus, in the current research recognition memory phenomenology was examined in 5-, 7- 11-year-olds and adults.

Moreover, the Anooshian (1999) study examined familiarity and recollection in a *list-based design* where recollection was measured as the ability to discriminate between first and second list. This design does not allow examination of which information has been used for recollection, that is, the qualitative details of the items themselves. Therefore, in the current research the PDP (Jacoby, 1991) was adapted to measure remembering phenomenology in an item-based design. This allows examining directly whether participants can recollect a characteristic of a specific item, which in the present studies was number of representations of an item, as used previously with adults (Wais & Gazzaley, 2011). A series of pictures with either one or two objects were presented (e.g., two alligators, one glass). Thus, the number of presented objects was used as the criterion for recollective information. Importantly, the PDP does not require subjective reports about memory states and thus, allows examination of recollection and familiarity across a wide age range independent of the accuracy of metacognitive reports.

Even though the PDP is well established in the adult literature it has been critiqued for being sensitive to a change in response bias over conditions (e.g., Curran & Hintzman, 1997). Specifically, under inclusion participants may respond more liberally whereas under exclusion they may adapt a more conservative response criterion. Thus, familiarity and recollection values may reflect changes in response bias rather than differing remembering phenomenology (Curran & Hintzman, 1997). To avoid the occurrence of response bias we manipulated conditions within participants (Yonelinas & Jacoby, 1996). Additionally, to check whether those assumptions are met we examined response bias in both inclusion and exclusion conditions (i.e., c - response criterion) (Macmillan & Creelman, 2005). A further aim was to investigate at what point in childhood familiarity and recollection become two distinct recognition processes. Studies using the PDP in adults indicate that familiarity is a faster process than recollection (Yonelinas & Jacoby, 1994). This favours a dual-process model, indicating that familiarity and recollection are independent processes (Yonelinas, 2002). Dual-process theory can be examined by implementing manipulations which have an influence on one process but not on the other (Jacoby, 1998; for an overview see Yonelinas, 2002). One way to manipulate recollection without influencing familiarity is by limiting response time during recognition that reduces recollection but leaves familiarity unaffected (Benjamin & Craik, 2001). To examine whether familiarity and recollection underlie distinct memory processes in all age groups, response time was limited during recognition using an age-appropriate deadline procedure (Experiment 2). The extent to which the deadline procedure provides a selective impairment of recollection rather than familiarity provides a strong test of the developmental estimates of recollection and familiarity. One possible outcome of Experiment 1 is that above-chance recollection is observed in all groups. This could reflect genuine recollection in all age groups, or a failure of the underlying assumptions (in one or more groups). If the latter is the case, then the deadline procedure should not produce a clear dissociative effect between the estimates of recollection and familiarity. Conversely, if the deadline influences the estimate of recollection but not familiarity in all age groups, then this provides additional support for the validity of the underlying assumptions of dual-process theory.

Thus, the current aim was two-fold. The first was to use the PDP to examine the nature of recollection and familiarity from 5-, 7-, 11-years and adults (Experiment 1). The second was to test the dual-process model of recognition (comparison of Experiment 1 and 2). To our knowledge no research to date has used the PDP to investigate item recollection and familiarity across childhood into adulthood and tested its dual-process assumption developmentally.

Experiment 1

Method

Participants. Overall 107 children and adults (62.6 % female) took part; 26 5-year-olds (*M* = 5.1 years, *SD* = 3 months), 25 7-year-olds (*M* = 7 years, *SD* = 4 months), 25 11-year-olds (*M* = 11 years, *SD* = 5 months) and 30 adults (*M* = 20.5 years, *SD* = 5 years). In both experiments children were recruited from local schools with a predominantly Caucasian middle class intake, following parental consent and their own assent on the day of testing. Adult participants were recruited via the university's online system and received course credit for participation.

Materials and Procedure. Participants received 1 study phase followed by a recognition phase consisting of inclusion and exclusion conditions.

In total 130 coloured drawings from Rossion and Pourtois (2004) were used, originally based on Snodgrass and Vanderwart's (1980) line drawings (e.g., animals, food, furniture, etc…). Eighty of these items were used for study (presented as pictures) and recognition (presented orally and as written words) (40 target, 40 non-target items). Additional 40 nonstudied items served as distractors during recognition (presented orally and as written words) (see Figure 1).

Each participant received 4 study blocks (20 items each) and 2 recognition blocks (60 items each). Block order was counterbalanced between participants and words appeared in random order within each block.

Study phase. The study phase started with 4 practice trials. First, participants judged whether the item (e.g., sun) is typically found indoors or outdoors and visual feedback on correctness of response was given (happy or sad smiley). If participants failed the first 4 practice trials (2 suns, 1 glass, 2 crocodiles, and 1 toothbrush) another set of 4 practice trials was presented. None of the participants failed the practice test more than two times.

After completion of practice, the study phase started and participants were instructed to remember as many items as possible. Figure 1 illustrates the method. Participants were shown a series of pictures, each presented for 3000 ms. Half of the items displayed one object, the other half two copies of the same object. After each item a blank screen appeared until participants judged whether the object is more typically found indoors (half of items per block) or outdoors (the other half per block).

Recognition phase. Recognition followed immediately and consisted of two conditions: inclusion and exclusion each preceded by a practice phase. Whether inclusion or exclusion came first was counterbalanced across participants.

During practice for *inclusion* participants were again shown the 4 items from the study practice phase and told, “Remember, in the beginning we saw those objects. We saw a sun, a glass, a crocodile and a toothbrush.” Objects were presented as words both orally and visually (“glass” – one object, “crocodile” – two objects, “airplane” – new item, and “dress” – new item). Participants were instructed to respond "yes" to words that have been presented before and to reject new items ("no"). After each response visual feedback on correctness was given (happy or sad smiley) and an explanation of why the answer was correct or incorrect was provided. The practice procedure was repeated until participants responded correctly to each of the 4 items (maximum number of repetition was three times) and able to explain the instructions.

Then the *inclusion* test condition followed. Instructions were the same as for practice but without feedback. There were 60 items in total in random order, 20 target words (presented during study), 20 non-target words (presented during study), and 20 new words (not previously presented). Here, participants' correct response was "yes" to both targets and non-targets.

In the practice phase for *exclusion* the same items as in inclusion practice were used. Participants were told, "Remember, in the beginning we saw either one or two objects. We saw two crocodiles, one toothbrush, one glass and two suns." Then the first item was presented orally and visually as written word (e.g., "glass"). They were told, "Say "Yes" if you saw 2 objects of it earlier. Say "No" if you saw 1 object of it earlier. And say "No" if you did not see the object earlier." After the participants response visual feedback on correctness was provided. All children were able to complete 4 correct practice trials after a maximum of 3 repetitions. Whether 1 object items or 2 objects items were the target group was counterbalanced between participants.

Then the *exclusion* test condition followed, containing 60 items (20 targets, 20 non-targets, 20 new items). Here, participants' correct response was "yes" to targets only.

In the end participants were instructed to repeat the exclusion rules. Nine participants were unable to repeat the instructions and were therefore excluded from the analysis (five 5-year-olds, three 7-year-olds, one 11-year-old and 2 adults).

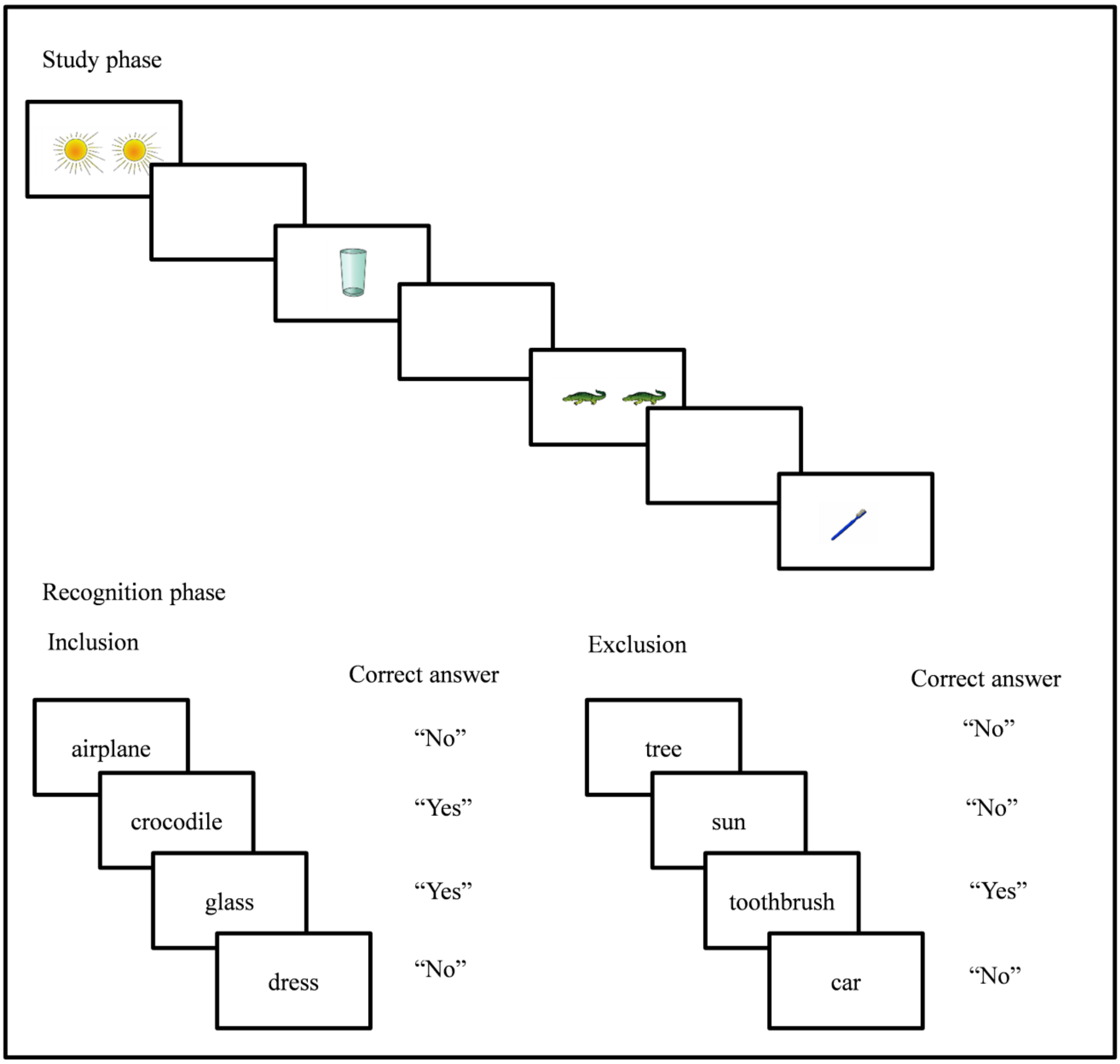

Figure 1. Method outline for both experiments.

Results and Discussion

Bonferroni post-hoc and confidence interval adjustments were used throughout. Mean proportions of "yes" responses as a function of age group and item type for inclusion and exclusion condition as well as parameter estimates for familiarity and recollection are shown in Table 1.

Table 1

Mean proportions of "yes" responses of item type for inclusion and exclusion condition as well as parameter estimates for familiarity and recollection across ages in Experiment 1.

	5-year-olds (n = 21)	7-year-olds (n = 22)	11-year-olds (n = 25)	adults (n = 28)
Exclusion				
New items	0.15 (.15)	0.07 (.08)	0.05 (.07)	0.10 (.15)
Non-targets	0.35 (.22)	0.32 (.25)	0.25 (.23)	0.28 (.22)
Targets	0.50 (.20)	0.56 (.26)	0.66 (.22)	0.80 (.15)
Inclusion				
New items	0.13 (.15)	0.10 (.09)	0.08 (.08)	0.09 (.10)
Targets	0.56 (.17)	0.77 (.10)	0.86 (.11)	0.89 (.05)
Parameter estimates				
Recollection	0.21 (.31)	0.47 (.31)	0.62 (.25)	0.61 (.22)
Familiarity	0.40 (.17)	0.52 (.29)	0.54 (.32)	0.65 (.19)

Note. Standard deviations are in parentheses.

Preliminary analysis. There were no order effects of whether exclusion or inclusion was first ($p > .05$), across all age groups as there was no interaction ($p > .05$). Further, in *inclusion* collapsing across targets and non-targets was warranted because acceptance rates for both did not differ, $F(1, 92) = .42$, $p = .52$, $\eta p^2 = .00$ and this was the case for all age groups, $F(3, 92) = .56$, $p = .64$, $\eta p^2 = .02$.

Assumptions that support the use of PDP. First, participants across all age groups and conditions discriminated successfully between targets and false alarms as measured by d' (d' = z(Hit) – z(False Alarm) (Macmillan & Creelman, 2005) (all *ds* > .51, all *ts* > 4.49, *ps*

$< .001$). This shows that even 5-year-olds were able to understand and follow the instructions. Second, in order to test whether response criterion as measured by c ($c = -0.5\,[(z(\text{Hit}) + z(\text{False Alarm})]$) (Macmillan & Creelman, 2005) differs across exclusion and inclusion (e.g., from conservative to liberal or *vice versa*) a 4 (age group: 5- vs. 7- vs. 11-year-olds vs. adults) x 2 (condition: Inclusion vs. Exclusion target-non-target) ANOVA with c scores was conducted. For all age groups response criterion was comparable across *inclusion* and *exclusion* (all *F*s < 2.27, all *ps* $> .06$). Thus, there was no shift in response criterion from inclusion to exclusion or *vice versa* and the PDP can be used to measure remembering phenomenology.

Familiarity and Recollection. To examine how recollection and familiarity develop across age two one-way ANOVAs were conducted with recollection and familiarity estimates as dependent variable and age group (age group: 5- vs. 7- vs. 11-year-olds vs. adults) as independent variable.

Recollection increased with age, where 5-year-olds used less recollection than older age groups who did not differ, $F(3, 92) = 11.23$, $p < .001$, $\eta p^2 = .27$. One-sample t-tests revealed that recollection values in all age groups differed significantly from zero (5-year-olds, $t(20) = 3.04$, $p = .006$; 7-year-olds, $t(21) = 7.10$ $p < .001$; 11-year-olds, $t(24) = 12.46$, $p < .001$ and adults $t(27) = 14.32$, $p < .001$). Thus, participants in all age groups, even 5-year-olds used recollection for their memory judgements.

Familiarity increased also with age, where 5-year-olds ($M = .40$) used less familiarity than adults ($M = .61$, $p = .007$), $F(3, 92) = 3.80$, $p = .013$, $\eta p^2 = .11$. The remaining age groups did not differ. Familiarity estimates in all age groups differed significantly from zero (5-year-olds, $t(20) = 10.81$, $p < .001$; 7-year-olds, $t(21) = 8.26$, $p < .001$; 11-year-olds, $t(24) = 8.33$, $p < .001$ and adults, $t(41) = 17.85$, $p < .001$), again showing familiarity based remembering across all ages.[1]

1 To account for potential differences in response criterion between age groups, we performed an alternative analysis using the dual-process signal detection model (Yonelinas & Jacoby, 1996) on these and all subsequent data. This led to an identical pattern of results.

Importantly, all age groups, even 5-year-olds used both, familiarity and recollection to recognize items as indicated by their above zero parameter estimates. These novel findings reveal that recollection increases between ages 5 and 7 and does not differ from age 7 onwards. Familiarity differed only between 5-year-olds and adults, but does not differ across childhood after the age of 5. This latter finding contrasts with Anooshian's (1999) who did not find differences in familiarity between 5-year-olds and adults.

One possible explanation could be the use of an item-based desing rather than a list-based design (Anooshian, 1999). The current item-based design allowed directly examining whether recollective information (one versus two objects) *per se* is remembered and at what age number can be used as a recollective detail. This provides insight into the nature of recollection independent of memory for list membership (Annoshian, 1999). However, another interesting finding stems from a meta-analytic cognitive modelling approach of developmental recall data (dual-retrieval model) where Brainerd et al. (2009) derived a recollection, a familiarity as well as a reconstruction (i.e. a comprehension process) parameter. This approach is suitable for research with children (Brainerd, Aydin, & Reyna, 2012) and populations with dementia and mild cognitive impairment (Brainerd et al., 2014). Their findings suggest that recollection and reconstruction increase between childhood and adolescence, whereas familiarity increases were mainly found between adolescents to young adulthood. Interestingly, this converges with our developmental pattern where item recollection increased particularly between 5 and 7 years whereas familiarity differs only in 5-year-olds and adults, thus providing novel insights into developmental trajectories of familiarity and recollection across 5-, 7-, 11-year-olds and adults.

In Experiment 2, in order to examine a dual-process model of familiarity and recollection (Yonelinas & Jacoby, 1994) it was investigated how limiting response time during recognition affects developmental trajectories of familiarity and recollection.

Experiment 2

Experiment 2 had two aims. The first was to shed light on the nature of recollection and familiarity across different ages by manipulating response time at retrieval. The second aim was to test the dual-process model of recognition. A well-established finding in the adult literature is that familiarity is a faster process which occurs earlier (between 900 and 1100 ms after the object has been presented) than recollection (between 1300 and 1500 ms) (Yonelinas & Jacoby, 1994). However, in the developmental literature there is no behavioural evidence for effects of limiting response time during retrieval. Developmental ERP evidence shows differing activation patterns for familiarity and recollection in both 8- and 10-year-ods (Czernochowski et al., 2005; Friedman et al., 2010; Mecklinger et al., 2011). These findings provide preliminary support for a dual-process model of independent remembering phenomenology. However, the absence of behavioural data or divergence of behavioural data and cortical activation patterns make interpretation difficult.

Thus, in the second experiment we limited response time to examine whether this reduces the use of recollection as a basis for responding (see Yonelinas & Jacoby, 1994). To establish adequate response limits for the according age groups, response deadlines were based on the mean response times per age group from Experiment 1 (mean minus one standard deviation). If familiarity is a faster acting process than recollection, recollection should be reduced whereas familiarity should be unaffected. Crucially, the extent to which this pattern is seen across age groups provides a strong test of the claim that the pattern seen in Experiment 1 reflects the availability of recollection across all age groups. If, for whatever reason, the parameter estimates do not reflect separable memory outcomes in the younger age groups then the clear prediction is that these groups would show a reduction in both recollection and familiarity with faster responding, rather than the selective effect that is expected in adults.

Method

Participants. Overall 96 children and adults (62.5% female) participated; 23 5-year-olds (*M* = 5.3 years, *SD* = 3 months), 24 7-year-olds (*M* = 7.2 years, *SD* = 3 months), 21 11-years-olds (*M* = 11.4 years, *SD* = 2 months) and 22 adults (*M* = 20 years, *SD* = 3.3 years).

Materials and Procedure. These were identical to Experiment 1 with the exception that during recognition participants were required to make a decision within a limited time period. Response time deadlines were set at one SD below mean response times per age group in Experiment 1, resulting in deadlines of 3397 ms for 5-year-olds, 2954 ms for 7-year-olds, 2258 ms for 11-year-olds and 1238 ms for adults. Participants were instructed to respond as quickly and accurately as possible. If participants did not respond within the deadline an alarm tone sounded and the message "too slow" appeared in red letters on the screen and child participants were orally reminded to respond as quickly as possible for the next trials. Twelve participants were excluded from the analysis (one 5-year-old, one 11-year-old and ten adults) because they were unable to repeat the instructions in the end of exclusion. Only responses within the response deadline were counted. Participants missed their responses very rarely; in sum 5-year-olds were timed out on 6.93% of trials, 7-year-olds on 3.61%, 11-year-olds on 4.29% and adults on 3.03%.

Results and Discussion

Bonferroni post-hoc and confidence interval adjustments were used throughout. Mean proportions of "yes" responses as a function of age group and item type for inclusion and exclusion condition as well as parameter estimates are shown in Table 2.

Table 2

Mean proportions of "yes" responses of item type for inclusion and exclusion instructions as well as parameter estimates for familiarity and recollection across ages in Experiment 2.

	5-year-olds (n = 22)	7-year-olds (n = 24)	11-year-olds (n = 20)	adults (n = 22)
Exclusion				
New item	0.18 (.21)	0.08 (.10)	0.14 (.14)	0.12 (.10)
Non-target	0.36 (.26)	0.28 (.26)	0.39 (.26)	0.40 (.23)
Target	0.35 (.24)	0.42 (.27)	0.54 (.22)	0.59 (.23)
Inclusion				
New item	0.25 (.27)	0.10 (.11)	0.12 (.14)	0.16 (.12)
Target	0.50 (.23)	0.63 (.21)	0.75 (.09)	0.80 (.10)
Parameter estimates				
Recollection	0.10 (.27)	0.37(.27)	0.36 (.29)	0.39 (.25)
Familiarity	0.38 (.23)	0.38 (.31)	0.53 (.24)	0.64 (.26)

Note. Standard deviations are in parentheses.

Preliminary analysis. There were no order effects whether exclusion or inclusion was presented first ($p > .05$) for all age groups as there was no significant interaction ($p > .05$). Further, in inclusion collapsing across targets and non-targets was warranted because acceptance rates were lower for new items ($M = .16$) than for both targets ($M = .68$) and non-targets ($M = .67$), which did not differ, $F(2, 168) = 428.14$, $p < .001$, $\eta p^2 = .84$. This was qualified by an age group x item type interaction, $F(6, 168) = 14.45$, $p < .001$, $\eta p^2 = .34$, where the difference between accepting new items vs. targets and new items vs. non-targets was lower in 5-year-olds than in older age groups. Importantly, acceptance rates for targets and non-targets did not differ and this was the case for all age groups.

Assumptions that support the use of the PDP. First, participants across all age groups and conditions discriminated successfully between targets and new items (all *ds* > .81, all *ts* > 4.21, *ps* < .001), showing all participants were able to understand and follow the instructions. Importantly, due to limited response time 5-year-olds were unable to discriminate between targets and non-targets in *exclusion* ($t(20) = -.39$, $p = .699$) whereas older age groups were able to do so (all *ds* > .46, all *ts* > 2.82, $p < .011$).

Second, participants were more conservative in *exclusion* than in *inclusion*, ($F(1, 82) = 8.47$, $p = .005$, $\eta p^2 = .09$). Importantly, there is no significant interaction between age and criterion shift as a function of condition ($F(3, 82) = 2.08$, $p = .109$, $\eta p^2 = .07$). This shows that, for all ages response criterion was comparable across *inclusion* and *exclusion* and thus the PDP can be used to measure remembering phenomenology.

In support of this, findings show that false alarms to new items did not differ between the exclusion ($M = .13$) and the inclusion ($M = .16$) condition (Table 2), $F(1, 84) = 2.04$, $p = .16$, $\eta p^2 = .02$, and this was the case for all age groups, $F(3, 84) = .68$, $p = .57$, $\eta p^2 = .02$). Thus, if base rates do not differ between the inclusion and the exclusion condition then a model of response bias is unnecessary (Jacoby, 1998; Rouder, Lu, Morey, Sun, & Speckman, 2008).

Recollection and Familiarity. To examine how recollection and familiarity develop across age two one-way ANOVAs were conducted with recollection and familiarity estimates as dependent variable and age group (age group: 5- vs. 7- vs. 11-year-olds vs. adults) as independent variable.

Recollection increased with age, where 5-year-olds obtained lower recollection values than older age groups who did not differ, $F(3, 84) = 5.43$, $p = .002$, $\eta p^2 = .16$. One-sample t-tests revealed that recollection values in 5-year-olds did not differ significantly from zero, $t(21) = 1.59$, $p = .128$, whereas they differed significantly from zero in older age groups (7-year-olds, $t(23) = 6.89$ $p < .001$; 11-year-olds, $t(19) = 8.81$, $p < .001$ and adults $t(21) = 7.19$, $p < .001$).

Familiarity increased with age, where both 5- and 7-year-olds used less familiarity than adults, and the other age groups did not differ, $F(3, 84) = 5.16$, $p = .03$, $\eta p^2 = .16$. Familiarity estimates were significantly different from zero across all ages (5-year-olds, $t(21) = 1.59$, $p < .001$; 7-year-olds, $t(23) = 6.08$, $p < .001$; 11-year-olds, $t(19) = 9.90$, $p < .001$ and adults, $t(21) = 11.42$, $p < .001$).

Together, under limited response time 5-year-olds relied exclusively on familiarity for their memory judgements, whereas older children also made use of recollection. Limiting retrieval time, eliminated recollection in 5-year-olds. Thus, 5-year-olds were unable to access qualitative details (i.e., number) of studied items to discriminate between seen items. In contrast, 7- and 11-year-olds as well as adults were able to access qualitative details under limited retrieval time. This finding may suggest that recollection is more effortful and less robust in 5-year-olds than it is in 7- and 11-year-olds.

In contrast, familiarity was unaffected under limited response time across all ages. Even under limited retrieval time participants can discriminate between seen and unseen items. This finding supports the notion that familiarity is a faster acting process than recollection (Yonelinas, 2002).

Testing the Dual-Process Model: Comparison Experiment 1 and Experiment 2

Recollection and Familiarity. To examine how recollection and familiarity were affected by limited response time two univariate ANOVAs were conducted with recollection and familiarity estimates as dependent variable and Experiment (Experiment: unlimited vs. limited response time) and age group (age group: 5- vs. 7- vs. 11-year-olds vs. adults) as between participant factors.

Recollection was higher under unlimited ($M = .48$) than under limited response time ($M = .31$), $F(1, 176) = 17.22$, $p < .001$, $\eta p^2 = .09$. This was the case for all age groups as shown by the non-significant age x experiment interaction, $F(3, 176) = .99$, $p = .398$, ηp^2

= .02. Recollection increased with age, where 5-year-olds obtained lower recollection values than older age groups who did not differ, *F*(3, 176) = 15.28, $p < .001$, $\eta p^2 = .21$.

Familiarity did not differ between unlimited (*M* = .53) and limited (*M* = .48) response time, *F*(1, 176) = 1.37, $p = .244$, $\eta p^2 = .01$ and this was the case for all age groups as indicated by the non-significant age x experiment interaction, *F*(3, 176) = .69, $p = .557$, ηp^2 = .01. Familiarity increased with age, where both 5- and 7-year-olds used less familiarity than adults, the other age groups did not differ, *F*(3, 176) = 8.40, $p < .001$, $\eta p^2 = .13$ (see Figure 2).

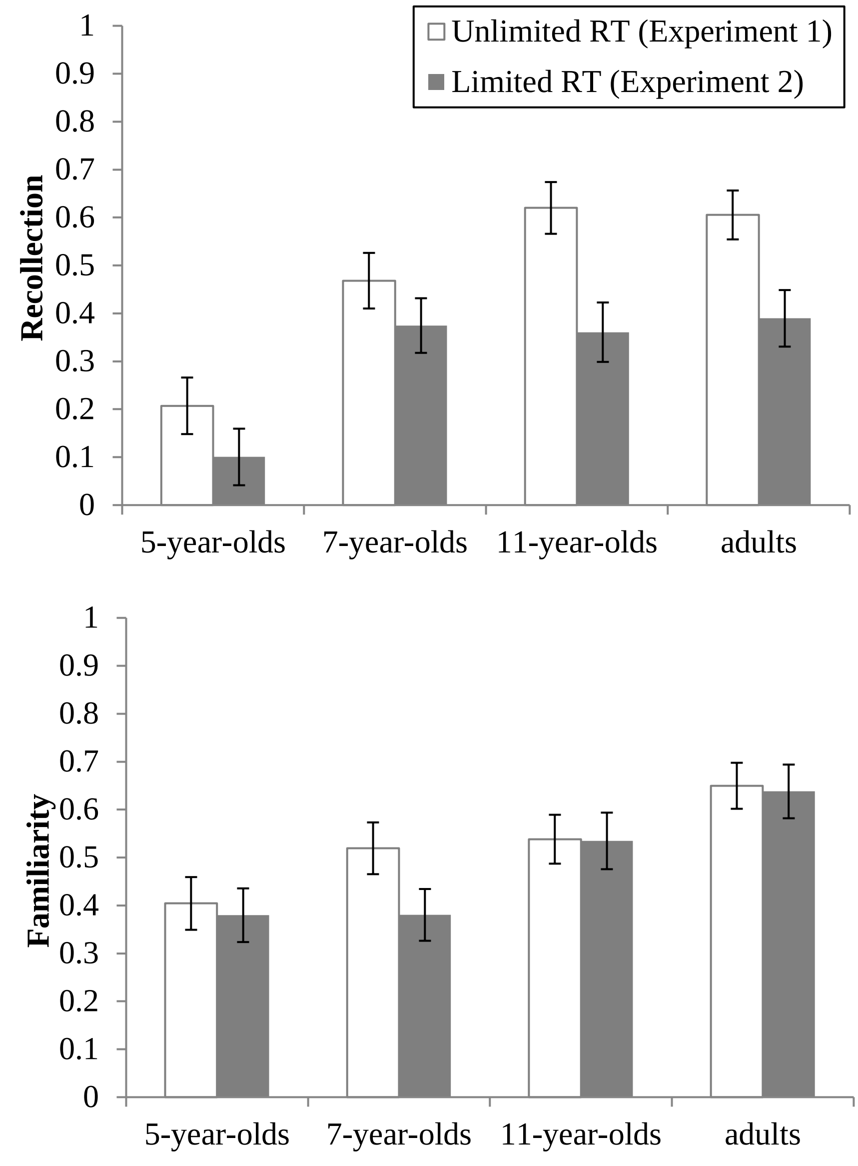

Figure 2. Parameter estimates as a function of response time and age group. The top panel shows recollection estimates, the bottom panel familiarity estimates.

Overall, limiting response time led to a decrease in recollection with invariance of familiarity, indicating that familiarity is available earlier than recollection. Importantly, these effects were found across all age groups. These findings suggest that familiarity and recollection may be independent processes in children, providing evidence for a dual-process theories of memory (Jacoby, 1998), where familiarity is a faster process than recollection (Toth, 1996; Yonelinas, 2002). To our knowledge these findings provide first behavioural evidence to support dual-process theory during recognition from age 5 onwards.

General discussion

The aim was to examine familiarity and recollection across childhood using the PDP. To summarize, in both experiments participants in all age groups were able to discriminate between previously presented and new items. Moreover, with no response time limit participants in all age groups were able to discriminate between the three different item types (i.e., targets, non-targets, and new items). However, under limited response time 5-year-olds were unable to discriminate between earlier seen items on the basis of recollective details.

Furthermore, current findings are consistent with the view that recollection and familiarity are two distinct processes (Yonelinas & Jacoby, 1994). In Experiment 1 already 5-year-olds were able to make memory judgements based on recollection. Further, recollection increased between 5 and 7-years only. Familiarity increased between 5-years and adulthood. Experiment 2 showed that under limited response time both 5- and 7-year-olds did not differ in the amount of familiarity but used less familiarity than adults. Recollection increased between 5- and 7-years only. However, limiting response time reduced recollection to zero in 5-year-olds’. This corresponds to a total absence of recollection (Yonelinas & Jacoby, 2012).

Thus, 5-year-olds relied exclusively on familiarity. These findings may suggest that recollection is less robust in 5-year-olds compared to older children and adults.

One limitation of this interpretation may be that the response deadlines (1 SD below the mean per age group) were not equally strict across age groups. That is, it is possible that the response deadline was more stringent for 5-year-olds than older children and adults. There was some evidence for this idea. Whilst the rate of failures to respond within the deadline was low in 5-year-olds (6.93% of trials) it was higher than that seen in the older age groups (7-year-olds: 3.61%, 11-year-olds: 4.29%, adults: 3.03%), which did not differ. To explore whether this played a role in the pattern of memory performance seen in Experiment 2, we decided to re-run our analyses with a group of 5-year-old children matched with the older groups on the rate at which they were able to respond within the deadline. Removing the poorest performing 7 children, resulted in a sample of 15 5-year olds with a failure rate of 3.78%, which did not differ from the rate observed in the other samples ($F(3, 77) = .81$, $p = .495$, $\eta p^2 = .03$). This made no difference to the pattern of data reported above: the recollection parameter estimate was ($M = .14$, for matched sample; $M = .10$, for whole sample), and the familiarity parameter was ($M = .36$ for matched sample, $M = .38$ for whole sample), and all main effects and interaction terms remained unchanged. Thus, the ability to respond within the deadline does not appear to mediate the differential effect on recollection and familiarity seen across all age groups.

A comparison of Experiment 1 and 2 shows that limiting response time had no differential effect on familiarity whereas recollection was reduced when participants were forced to respond quickly. This finding supports the notion that familiarity is a faster acting process than recollection (Jacoby & Dallas, 1981; Yonelinas, 2002). Importantly, this favours dual-process theory, assuming that recollection and familiarity are independent processes underlying recognition memory (for a review, see Yonelinas, 2002). This assumption is supported if a manipulation affects one but not the other processes (Jacoby, 1998). Interestingly already 5-year-olds' recollection was reduced under limited retrieval times whereas familiarity was unaffected. This finding provides support for dual processes being present at 5 years.

Overall, findings show that the PDP can be used in children as young as 5 as evidenced by their ability to distinguish between earlier seen items on the basis of recollective information (see also Anooshian, 1999). The PDP allowed us to directly assess underlying processes of recognition memory without asking participants to judge their memory (Billingsley et al., 2002; Ghetti & Angelini, 2008).

Baseline performance, that is, false alarms to new items, did not differ between conditions. Thus, familiarity and recollection estimates do not reflect changes in response bias but recognition phenomenology (Jacoby, 1998; Yonelinas & Jacoby, 1996) and can be used to measure recollection and familiarity in children aged 5. Moreover the PDP has been critiqued for its difficult instructions in the exclusion condition (Curran & Hintzman, 1997; Graf & Komatsu, 1994). In the present research we took a number of steps to make sure that participants understood the task and followed the instructions. First, before starting a new phase practice examples were provided to ensure that participants understood the instructions. Furthermore, they were required to repeat instructions at the end of the recognition conditions. Participants who were unable to do so were excluded from the analyses. Finally, differences in acceptance rates to different item types across all age groups demonstrate that participants were able to distinguish between the different item types proving that they understood and followed the instructions successfully (see also Toth, Reingold, & Jacoby, 1995).

The current research also provides novel findings on the nature of recollection. In particular, already 5-year-olds were able to use the number of objects as recollective information. This adds to previous findings demonstrating that 5-year-olds are able to recollect list membership of an item (Anooshian, 1999). Thus, not only are 5-year-olds able to indicate the source of item presentation, they also recollect qualitative details about an item itself such as number. Future research should extend this by examining recognition of different types of qualitative item-details, for example, spatial information such as above or below.

There are also theoretical considerations that follow from the current study. Previous research has investigated quantitative changes in memory development, such as the ability to distinguish between memories based on the origin of those events (i.e. source-monitoring; Johnson et al., 1993). Specifically, in source monitoring tasks participants discriminate, for example, which list a word was presented in during encoding (e.g., two lists in different modalities, auditory vs. visual lists) (Lindsay, Johnson, & Kwon, 1991). Depending on task difficulty source memory develops throughout childhood, between the age of 4 and 6, up to young adulthood (Cycowicz, Friedman, & Duff, 2002; Drummey & Newcombe, 2002; Lindsay, 1991; for a review, see Raj & Bell, 2010). These studies provide evidence of quantitative changes in recognition memory development. However, quantitative changes do not provide insight into qualitative changes of memory processes such recollection of contextual details (e.g., number) versus a vague feeling of familiarity. As familiarity and recollection have different developmental trajectories, purely investigating developmental changes in source memory does not provide full insight into why memory performance increases across age. Specifically, age related changes in source-memory can be a result of an increase in recollection, familiarity or both. Both processes may contribute to source memory (Diana, Yonelinas, & Ranganath, 2008; Mollison & Curran, 2012; Yonelinas, Aly, Wang, & Koen, 2010). Therefore, examining quantitative changes in source-memory does not reveal a complete picture of memory development as it does not account for qualitative changes. Thus, in the current research using the PDP allowed investigating qualitative processes underlying recognition memory whilst taking into account quantitative changes in resulting memory performance.

Conclusion

The process-dissociation paradigm was successfully implemented, revealing both familiarity and recollection being present at 5 years. Further, limiting response time during recognition eliminated recollection in 5-year-olds and lead to lower recollection values across all ages whereas familiarity was left unaffected. These findings indicate that also in childhood recollection is a less robust and slower process than familiarity. Furthermore, these findings are consistent with dual-process theory, revealing independent processes of recognition memory. Importantly, dual processes are already acting at 5 years of age.

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