Item repetition and response deadline affect familiarity and recollection differently across childhood

Laura Koenig[a], Marina C. Wimmer[b], & Dries Trippas[c]

[a]School of Psychology, University of Plymouth, PL4 8AA, UK

[b]Psychology, Edinburgh Napier University, Edinburgh, EH11 4DY

[c]Max Planck Institute for Human Development, Lentzeallee 94, 14195 Berlin, Germany

Words: 4421 (excluding abstract, references, tables, figures)

Send correspondence to:

Marina C. Wimmer

Psychology, Edinburgh Napier University, EH11 4DY

E-mail: m.wimmer@napier.ac.uk

Abstract

The aim was to examine how item repetition at encoding and response deadline at retrieval affect familiarity and recollection in 5-, 7-, or 11-year-old children (*N* = 156). Familiarity and recollection were estimated using a process dissociation paradigm. Direct comparison of the effects of repetition under unlimited and limited response time revealed a dissociation of familiarity and recollection. Recollection was both boosted (via repetition) and reduced (via a response time limit). Familiarity was unaffected by a response time limit. Moreover, repetition boosted familiarity only under unlimited response time. Together with several distinct age-related increases for recollection and familiarity, these results provide a challenge to single-process accounts of recognition memory.

Keywords: dual-process theory; recollection; familiarity; item repetition; memory development

When we encounter something, we believe we have experienced before, our recognition decision may be informed by different kinds of experiential evidence. We may find the item familiar without knowing anything more (*familiarity),* or we may remember specific details about the prior encounter with that item (*recollection)* (Mandler, 1980). While there is general acceptance that our experiences of remembering may vary, there is dispute as to whether this indicates the existence of two separate processes operating in recognition memory (dual-process theory: Jacoby, 1991; Yonelinas, 2002), or a single process that varies in strength (single-process theory: Donaldson, 1996). Most of the debate in this area has focused on performance of adults across different experimental manipulations, with relatively little work looking at developmental trends. Here we seek to add to the developmental literature by looking at the impact of two experimental manipulations, item repetition at study and response time limit at test, in samples aged between 5 and 11 years.

Dual-process theory posits that recollection and familiarity are independent processes (Diana, Reder, Arndt, & Park, 2006; Yonelinas, 2002) that vary in their time course. Recollection is slow and effortful whereas familiarity is a fast and automatic process (Jacoby, Toth, & Yonelinas, 1993; Tulving, 1985; Yonelinas, 2002; Yonelinas & Jacoby, 2012). In support of dual-process theory, developmental studies show that recollection and familiarity develop at different rates (Anooshian 1999; Brainerd, Holliday, & Reyna, 2004; Ghetti & Angelini, 2008; Koenig Wimmer, & Hollins, 2015) *and* are dissociable through experimental manipulation (Ghetti & Angelini, 2008; Koenig et al. 2015). For instance, Ghetti and Angelini (2008) found that a manipulation of study duration did not impact recollection in 6 – 18-year-olds, but did alter familiarity, such that longer study durations eliminated developmental differences in familiarity entirely. The reverse pattern occurs with a manipulation at test: recollection can be manipulated with familiarity unaffected (Koenig et al., 2015). Limiting response time at retrieval reduced recollection in 5-, 7-, and 11-year-olds but did not impact familiarity. Further, recollection reliably differed between 5- and 7-year olds, but showed no further developmental increase, in line with the previously reported rapid developmental increase (Brainerd et al., 2004; Ghetti & Angelini, 2008). In contrast, familiarity continued to increase between 7 years of age and adulthood (Koenig et al., 2015). The combination of different experimental dissociations of familiarity and recollection and different developmental trajectories have been used to support the claim that they may be independent processes that contribute to recognition memory (Koenig et al., 2015; Ghetti & Angelini, 2008).

In contrast, single-process theories characterise memory as a unified construct (Berry, Shanks, & Henson, 2008; Berry, et al., 2012; Donaldson, Mackenzie, & Underhill, 1996 Dunn, 2008) in which previously encountered items differ in memory strength from an equivalent pool of unstudied items. Memory decisions about the status of an item are made by comparing its strength against one or more response criteria (Donaldson, Mackenzie, & Underhill, 1996; Dunn, 2008; Wixted, 2007). In this framework, decisions about familiarity and recollection represent the use of two response criteria at test, where a liberal criterion distinguishes old from new items and a conservative criterion distinguishes familiarity from recollection (Wixted & Stretch, 2004). Developmental trends may represent differences in the strength of memory and the setting of these response criteria. Specifically, Hayes, Dunn, Joubert, and Taylor (2017) ran a study in which children aged 6- and 10-years old encoded pictures under deep (e.g., is it light or heavy?) and shallow conditions (e.g., what colour is it?) and rated their confidence in each recognition decision at test (see Ghetti & Angelini, 2008). ROC curves for the different age groups, generated as a function of encoding condition, revealed that single-strength models gave a better fit to the data than Yonelinas's (2002) dual-process account. The authors therefore concluded that developmental differences in recollection and familiarity may be explained most parsimoniously by a single underlying strength process. However, while this conclusion may be appropriate for the manipulation they used, and the ages they tested, it may be premature to conclude that a single-process model could account for all potential developmental patterns across different experimental manipulations.

The rationale for the present work was to provide a further, rigorous test of the single-process account of developmental trends in recognition. However, before we present the proposed work, we need to explain our approach, and why we favour this over attempting to model our data with ROC analysis. Here we use a process-dissociation approach to estimate recollection and familiarity, based upon simple instructions about which responses to include, or exclude at test (Jacoby, 1991). We favour this over a ROC-based approach because it does not require metacognitive monitoring judgements in the form of confidence ratings. There is good evidence that children's metacognitive ability to make accurate judgements of confidence increases between 5 and 10 years (Roebers, Gelhaar, & Schneider, 2004), yet they are equally able to understand inclusion and exclusion instructions (Koenig et al, 2015).

In the present study, we manipulate *item repetition* during encoding and *response time limits* at test, within a single experiment, including 5- to 11-year-olds. Prior research shows that item repetition during encoding increases both recollection and familiarity whereas a response deadline at test decreases recollection while leaving familiarity unaffected (Benjamin & Craik, 2001; Jacoby, 1999; Jacoby, et al., 1998). Both effects would be predicted in our current sample, but the crucial question of interest here is how these effects play out across the different age groups. Recollection increases steeply between 5 and 11 years (Brainerd et al., 2004; Ghetti & Angelini, 2008; Koenig et al., 2015) and age improvements may underlie item-specific elaborative encoding processes once children have contextual binding ability (Ghetti & Angelini, 2008; Riggins, 2014; Sluzenski, Newcombe, & Kovacs, 2006). Under deep encoding conditions (focusing on the semantic meaning) recollection increases significantly between 6- and 10 years but not under shallow ones (focusing on surface features) (Ghetti & Angelini, 2008). Therefore, we would expect increases in recollection between 5 and 11 years only under unlimited response time, allowing retrieval of item-specific details, but not under limited response time. Familiarity increases more gradually with increasing age (Brainerd et al., 2004; Ghetti & Angelini, 2008; Koenig et al., 2015) and increased encoding time eliminates developmental differences in familiarity, boosting 6-year-olds' familiarity but not recollection (Ghetti & Angelini, 2008). If processing time at task proportionally facilitates familiarity in younger children, then we would expect our 5-year-olds to have comparable familiarity under unlimited response time but not under limited response time.

We relied on the process dissociation paradigm (Jacoby, 1991) previously used to measure familiarity and recollection in 5-, 7-, and 11-year-olds (Koenig et al., 2015). Participants studied pictures (once or thrice) presented at the top or bottom of the screen and then received a recognition test either under self-paced conditions or with an age-appropriate response deadline. During recognition participants were instructed in the inclusion condition to accept all previously presented items and reject new words. In the exclusion condition they were instructed to accept only items which were presented at the top of the screen and to reject both items from the bottom of the screen and new items. Familiarity and recollection parameters were estimated by contrasting performance in the inclusion and exclusion conditions (see Jacoby, 1991).

Experiment

Participants encoded pictures either once or thrice presented at the top or bottom of the screen. At test participants either responded self-paced or under a response deadline. The amount of time available to respond was manipulated in the same way as reported in Koenig et al. (2015). For each age group, an age-appropriate time limit was calculated, based on the findings from unlimited response condition.

Method

Participants. Overall 156 children (71 girls) participated. There were 48 5-year-olds (*M* = 5.1 years, *SD* = 4 months), 53 7-year-olds (*M* = 7.4 years, *SD* = 3 months), and 55 11-year-olds (*M* = 11.0 years, *SD* = 5 months). Four additional children were excluded because they were unable to repeat the instructions of the recognition task. Power calculations (Gpower3; Faul, Erdfelder, Lang, & Buchner, 2007) revealed that 135 participants will be needed to detect a within-between factor interaction, giving a 95% chance of detecting medium sized effects on the mixed ANOVA ($f = .25$) with $p = .05$. 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.

Design, Materials and Procedure. The study employed a 2(item repetition at study: once vs. thrice) x 2(response time at test: unlimited vs. limited) x 3(age groups: 5-, vs. 7-, vs. 11-year-olds) mixed design where item repetition was manipulated within participant and both response time and age groups were the between participants variables. Materials and procedure followed closely Koenig et al. (2015). The task was computerized and presented using E-Prime. In total, 94 items from Rossion and Pourtois (2004) were used, originally based on Snodgrass and Vanderwart's (1980) line drawings.

The study phase started with four practice trials where participants judged whether the item is typically found indoors or outdoors. If participants failed the first four practice trials, another set of four practice trials was presented. None of the participants needed more than two repetitions to pass all practice trials.

Upon completing the practice task, participants completed the study-retrieval block. Participants were instructed to remember as many items as possible (Figure 1). The study phase was divided into 4 sets each containing 14 pictures, each presented for 3000 ms. After 14 pictures a star appeared to sustain motivation and the next set started. Half of the items were presented at the top, and the other half were presented at the bottom of the screen. Participants were not explicitly instructed to focus on location. 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). Half of the items were presented once, and the other half were presented thrice (location of individual items did not change between trials). There were between 10 and 18 items intervening between repetitions of any item, thus, study presentation order was fixed.

The recognition phase followed immediately. Just over half (*N* = 81) of the children completed the recognition task with an unlimited response time. The remainder (*N* = 75) were required to make a recognition decision before a response time deadline that was set at one standard deviation below mean response times per age group in the unlimited condition (cf., Koenig et al., 2015), resulting in deadlines of 3751 ms for 5-year-olds, 3248 ms for 7-year-olds, and 2293 ms for 11-year-olds. Participants were instructed to respond as quickly and accurately as possible. If participants did not respond within the deadline, an alarm tone sounded, the message “too slow” appeared in red letters on the screen and participants were reminded by the experimenter to respond within the allotted deadline.

There were two recognition conditions, inclusion and exclusion, with order counterbalanced across participants. Each started with a practice phase (Figure 1) in which participants were reminded of the four study items from the practice phase and were then presented with four recognition items. Participants were required to answer all practice items appropriately to the test condition, described below, to reach criterion and proceed to the recognition test. No participant required more than two practice test repetitions. In the inclusion condition participants were instructed to respond “yes” to all items that had been previously presented and to reject new items. In the exclusion condition participants were instructed to respond “yes” only to words that had been previously presented in the top half of the screen and to reject items that were presented in the bottom half of the screen (below the line) and new items. Both recognition conditions contained 42 items consisting of 14 items previously presented at the top of the screen, 14 from the bottom of the screen and 14 new items that were not semantically related to any of the studied items.

To obtain measure of familiarity and recollection for each participant it was necessary that participants completed both inclusion and exclusion recognition phases. Recollection was calculated by subtracting yes responses to non-targets in exclusion from yes-responses to targets in inclusion, R = yes $\text{inclusion}_{\text{non-target}}$ – yes $\text{exclusion}_{\text{non-target.}}$ Familiarity was calculated from estimates of recollection, F = yes $\text{exclusion}_{\text{non-target}}$/(1 - R) (see Jacoby, 1991; Koenig et al., 2015 for further details).

Insert Figure 1 about here

Results and Discussion

The data are available at 10.6084/m9.figshare.11396304. Bonferroni post-hoc and confidence interval adjustments were used throughout. Mean proportions of “yes” responses as a function of age group, repetition (once vs. thrice presented) and item type for inclusion and exclusion conditions are shown in Tables 1 (unlimited response time) and 2 (limited response time).

Insert table 1 about here

Insert table 2 about here

Preliminary analyses

In the limited response deadline condition, failure to respond within the deadline was low overall but higher in 5-year-olds (14.19 % of trials) than both 7-year-olds (5.51%, $p = .003$) and 11-year-olds (3.04%, $p < .011$) who did not differ ($p > .05$), $F(2, 158) = 10.87$, $p < .001$, $\eta_p^2 = .12$. Only responses within the response deadline were analysed.

Acceptance rates to new items

To establish whether assumptions underlying the PDP were met, it was first examined whether acceptance rates to new items differed between inclusion and exclusion across age groups (Curran & Hintzman, 1997; Graf & Komatsu, 1994). A 2(condition: inclusion vs. exclusion) x 2(response time: limited vs. unlimited) x 3(age group: 5-, vs. 7-, vs. 11-year-olds) mixed ANOVA on the proportion of yes responses to new items was conducted with condition as within participant variable and the latter two variables were manipulated between participants.

There was no evidence of a difference in yes responses to new items in inclusion ($M = .08$) and exclusion ($M = .09$), $F(1, 150) = 1.44$, $p = .23$, $\eta_p^2 = .01$ or between age groups $F(2, 150) = 2.67$, $p = .07$, $\eta_p^2 = .03$. There were more yes responses to new items during limited ($M = .12$) than unlimited response time ($M = .04$), $F(1, 150) = 32.79$, $p < .001$, $\eta_p^2 = .18$ (Tables 1 and 2). The age group x condition interaction was almost significant, $F(2, 150) = 3.03$, $p = .051$, $\eta_p^2 = .04$ (Tables 1 and 2) but even when it was disentangled, there was no evidence in any age group of a reliable difference in yes responses to new items in inclusion and exclusion (*p*s > .08). There were no further interactions, *F*s < 2.20, *p*s > .11.

To further assess the evidence, we calculated the Bayes factor, using a JZS prior (Rouder, Speckman, Sun, Morey, & Iverson, 2009) separately for limited and unlimited response times as there was an overall difference in yes responses to new items. For *unlimited response time* the odds, BF = 4.062 are in favour of the null hypothesis. For *limited response time* the odds, BF = 9.55 are also in favour of the null hypothesis. Thus, there was no reliable evidence to suggest that any age group changed their response criterion between inclusion and exclusion. Therefore, raw familiarity and recollection parameters are reported.[1]

Recollection and Familiarity

To investigate the effects of limiting response time and item repetition, recollection and familiarity estimates were entered into two 3 (age group: 5- vs. 7- vs. 11-year-olds) x 2 (time limit: unlimited vs. limited response time) x 2 (repetition: once vs. thrice) ANOVAs with age group and experiment as between-subjects variable and repetition as within-subject variable.

Recollection. Repeated item presentation (M = .57) increased recollection compared to single item presentation (M = .43), $F(1, 150) = 35.80$, $p < .001$, $\eta_p^2 = .19$. Limiting response time reduced recollection (M = .45) compared to no limit (M = .55), $F(1, 150) = 7.76$, $p = .002$, $\eta_p^2 = .05$. Additionally, recollection increased with increasing age, $F(2, 150) = 7.21$, $p = .001$, $\eta_p^2 = .09$, where recollection based responses were lower in 5-year-olds (M = .40) than both in 7- (M = .54, p = .009) and 11-year-olds (M = .56, p = .002) and the latter two did not differ (p = 1.00). There was also an age x time limit interaction, $F(2, 150) = 4.83$, $p = .009$, $\eta_p^2 = .06$. This interaction occurred because under unlimited response time

[1]When base rates to new items were taken into account by using the dual-process signal detection model to estimate R and F (Yonelinas, Regeher, & Jacoby, 1995) the same main results were obtained and so we do not discuss this further.

recollection increased with age, between 5- and both 7- (p = .001) and 11-year-olds ($p < .001$) who did not differ whereas it did not increase at all under limited response time (ps = 1.0) (Figure 2). There were no further interactions (Fs < 1.33, ps > .26).

Familiarity. Item repetition (M = .64) increased familiarity compared to no repetition (M = .55), $F(1, 150) = 6.38$, $p = .013$, $\eta_p^2 = .04$. Limiting response time (M = .58) did not affect familiarity compared to self-paced responses (M = .61), $F(1, 150) = .56$, $p = .46$, $\eta_p^2 = .004$. Additionally, familiarity increased with increasing age, $F(2, 150) = 5.78$, $p = .004$, $\eta_p^2 = .07$, which is due to an increase between 5 (M = .51) and 11 years (M = .68, p = .003). Seven-year-olds (M = .59) did not differ from the other two age groups (ps > .16) (Figure 3).

Moreover, the results were qualified by two interactions. The age group x response time limit interaction, $F(2, 150) = 5.47$, $p = .005$, $\eta_p^2 = .07$, showed that there were no age group differences under self-paced conditions (all ps = 1.00) whereas familiarity increased under limited response time, particularly, between 5- and both 7- (p = .03) and 11-year-olds ($p < .001$) who did not differ (p = .13). Further, the repetition x response time limit interaction shows that under self-paced conditions repetition increased familiarity (p = .001) but under limited response time repetition had no effect on familiarity (p = .73), $F(1, 150) = 4.09$, $p = .04$, $\eta_p^2 = .03$ (Figure 3). There were no further interactions (Fs < 1.92, ps > .15).

Insert figure 2 about here

Insert figure 3 about here

Discussion

In a single study we implemented two manipulations that differentially affected both recollection and familiarity. Recollection was increased by item repetition at study and decreased by a response deadline at test, and these two effects did not interact. In contrast, for familiarity the two manipulations had an interactive effect, such that familiarity was increased by repetition at study only with unlimited response time at test. Overall, response deadline had no overall impact on familiarity at all. Our findings that recollection can both be boosted and reduced, and familiarity can be boosted are in line with previous research with adults showing dissociating effects on both processes (Jacoby, 1999). For familiarity, in contrast to recollection, the boost for repetition disappeared under a response time limit. This additional finding poses explanation difficulties for the argument that recollection is a more sensitive measure (Henson, 2006) as the effect of repetition varied for familiarity under limited and unlimited response time as opposed to recollection.

We also observed different developmental patterns for the two measures. Recollection increased across the age groups: this effect was not altered by the encoding manipulation, but was impacted by the response deadline at test, such that age improvements were removed by the imposition of a test deadline. Thus, a time limit at test interferes with retrieval of item specific details particularly in older children. Familiarity also increased with age and, as with recollection, this pattern was not altered by repetition. Also, like recollection, there was an interaction between age and the response deadline effect, but the nature of this interaction was very different. For familiarity a developmental trend emerged with limited response time between 5- and 11-year-olds but there was no age difference with unlimited response time. Thus, extra time at test boosted 5-year-olds’ familiarity suggesting familiarity may be slower in younger children. These developmental trends support previous results imposing response time limits (Koenig et al., 2015) and add to findings of increased familiarity in 6-year-olds under increased processing time at encoding (Ghetti & Angelini, 2008). Together, manipulations of processing time affect developmental trends of familiarity and recollection differently whereas item repetition does not.

The response time limit used in the current research is more liberal than the 1500ms (or below) employed in research with adults (e.g, Koen & Yonelinas, 2011; Ngo & Lloyd, 2016). However, mean response times under unlimited response time were much higher in our developmental sample and a too strict time limit may have disproportionally affected the ability to respond within the deadline in the younger age group. As response times differed across age groups, we set the limit at one standard deviation below the mean response in the unlimited condition for each age group. The current finding that the response time limit impaired 7- and 11-year-olds' recollection and eliminated developmental differences suggests that the limit sufficiently hampered recollection at least in the older age groups. For 5-year-olds it is also unlikely that the response deadline was too liberal because failure to respond within the deadline was higher (14.19 % of trials) than in both 7-year-olds (5.51%) and 11-year-olds (3.04%) who did not differ. Thus, it is unlikely that the response time limit was too liberal to hamper recollection across age groups.

A potential criticism of the current methodology is the switch in modality from pictures during encoding and words at test that could affect performance particularly in the youngest age group. If so, we would have expected poorer recollection in 5-year-olds specifically under limited response time which was not the case. However, changes in study-test modality have generally larger reducing effects on familiarity than recollection (Yonelinas, 2002). This may explain the finding that 5-year-olds' familiarity was lower than both 7- and 11-year-olds under limited response time but could be boosted under unlimited response time, supporting the notion that familiarity may be slower in 5-year-olds.

Overall, it is difficult to see how these findings can be accounted for with a single-process assumption that familiarity and recollection underlie a single strength-based retrieval process (e.g., Donaldson et al., 1996; Wixted, 2007). According to a single process account (such as the equal variance signal detection theory model), repetition and a response time limit should have impacted familiarity and recollection parameters similarly, which was not observed.

However, recently, Hayes et al. (2017) compared the goodness of fit of several models representing the single- and dual process accounts across age, concluding that one of the single process models captured the results best. The youngest age-group tested was 6-7 years old, and the oldest age-group was 18 years old. As our present work demonstrates, much of the developmental change may already have taken place by the age of 7, with some stark differences emerging between 5 and 7 years and even earlier (Riggins & Rollins, 2015). In fact, if we had studied the 7-year-olds in isolation we would have concluded that the single-process model adequately explained the results.

Instead of using the process dissociation paradigm, Hayes et al. (2017) relied on the modelling of confidence ratings. Although this approach is common in research with adults, the assumption that children at different age groups indicate their confidence as accurately as adults is an open question. There is clear evidence that distinguishing between correct and incorrect responses with confidence ratings increases between 5 and 10 years (Roebers et al., 2004). One possibility is that any developmental differences in memory obtained from the modelling of confidence ratings are driven by the better development of meta-cognition. Similarly, any failures to find differences in the predicted direction in younger children may be driven by the confidence-rating procedure adding asymmetric noise into the response patterns. The process dissociation paradigm used here does not rely on the use of confidence ratings and is not susceptible to these issues. Our children’s response rates to new items were very low across all ages indicating that they had no problem to follow task instructions. Only four children were excluded because they could not repeat the exclusion and inclusion instructions at the end of the experiment.

One potential counterargument is that the most appropriate single process account in this context, the *unequal* variance signal detection theory model (Wixted, 2007), has an additional signal-to-noise variance ratio parameter which could hypothetically vary as a function of repetition, time limit and age. If one takes this perspective, it may be the case that any differential effects of time limit on recollection and familiarity as a function of age are merely changes to this variance ratio. In response, we would argue simply that we are unaware of any such predictions in a developmental context, and that formal model comparisons will have to be used to rule out this alternative interpretation. These models cannot be applied to our current data as we have not collected confidence ratings and we first would need to establish that children at different ages are equally accurate at distinguishing between correct and incorrect responses with confidence ratings which should be considered in future research. Overall, the process dissociation procedure is not susceptible to these issues and has been shown to be a valid tool in providing valuable behavioural insight into the development of familiarity and recollection processes.

Beyond the direct contribution to process theories, the current findings also add to a growing body of literature on the type of events children begin to recollect, that is, the number of items presented (Koenig et al., 2015), the list origin (Anooshian, 1990), and item location (current findings). In addition to recollecting single item properties, 4-year-olds also begin to recollect specific item-context associates (Lloyd, Doydum, & Newcombe, 2009) and different event aspects including a scene, person, and object (Ngo, Horner, & Newcombe, 2019). Together, findings highlight important qualitative developments in recognition memory in addition to the current result of dissociated memory processes.

In sum, the combined finding of different age trends for familiarity and recollection, the dissociation of boosted recollection when information is repeated but reduced under a response time limit and the repetition boost for familiarity only under unlimited response time pose explanation difficulties for the notion that familiarity and recollection underlie a single process.

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Table 1. Mean proportions of "yes" responses of item type for inclusion and exclusion condition under unlimited response time.

	5-year-olds (N = 27)		7-year-olds (N = 26)		11-year-olds (N = 28)	
	Once	Thrice	Once	Thrice	Once	Thrice
Exclusion						
New items	.04 (.08)		.04 (.06)		.03 (.04)	
Non-targets	.35 (.26)	.45 (.25)	.26 (.20)	.21 (.15)	.26 (.22)	.21 (.22)
Targets	.51 (.24)	.60 (.25)	.54 (.18)	.68 (.27)	.66 (.22)	.86 (.18)
Inclusion						
New items	.08 (.08)		.04 (.06)		.03 (.07)	
Targets	.68 (.18)	.84 (.12)	.77 (.15)	.91 (.09)	.87 (.10)	.94 (.08)

Note: Standard deviations are in parentheses. Note that in inclusion for the participants there are no non-targets, they are all targets.

Table 2. Mean proportions of “yes” responses for item type in inclusion and exclusion as a function of age and repetition under limited response time.

	5-year-olds (N = 22)		7-year-olds (N = 27)		11-year-olds (N = 27)	
	Once	Thrice	Once	Thrice	Once	Thrice
Exclusion						
New items	.13 (.20)		.11 (.12)		.11 (.13)	
Non-targets	.26 (.24)	.25 (.19)	.38 (.27)	.31 (.27)	.48 (.23)	.33 (.24)
Targets	.31 (.26)	.41 (.26)	.61 (.20)	.70 (.22)	.67 (.25)	.78 (.17)
Inclusion						
New items	.15 (.12)		.16 (.13)		.07 (.07)	
Targets	.66 (.15)	.75 (.13)	.77 (.11)	.86 (.10)	.81 (.14)	.90 (.13)

Note. Standard deviations are in parentheses. Note that in inclusion for the participants there are no non-targets, they are all targets.

Figure 1.

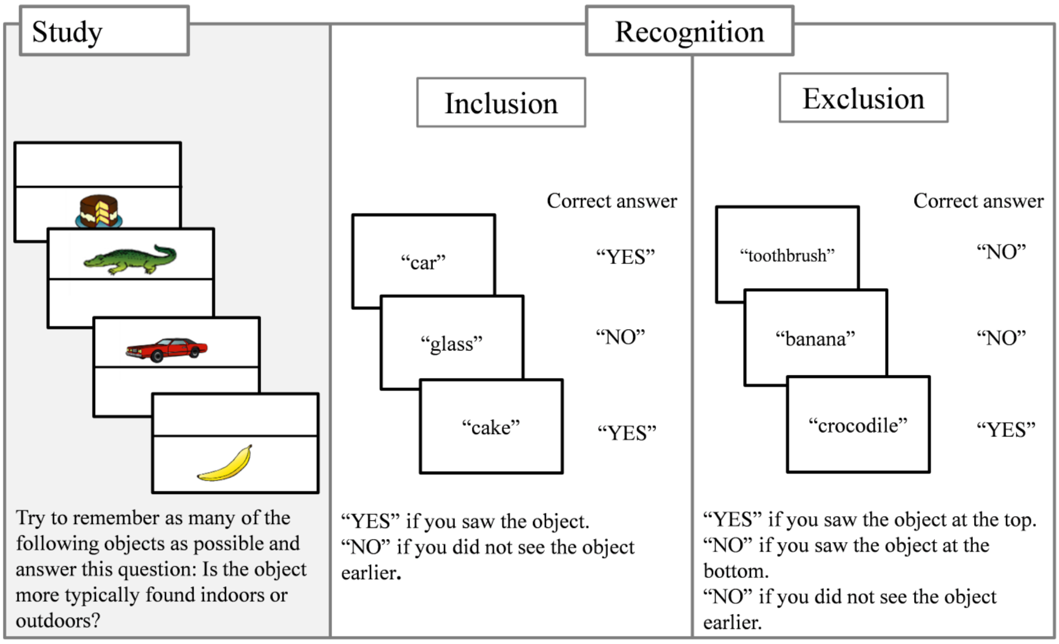
Study
Recognition
Inclusion
Exclusion
Correct answer
"car"
"YES"
"glass"
"NO"
"cake"
"YES"
Correct answer
"toothbrush"
"NO"
"banana"
"NO"
"crocodile"
"YES"
Try to remember as many of the following objects as possible and answer this question: Is the object more typically found indoors or outdoors?
"YES" if you saw the object.
"NO" if you did not see the object earlier.
"YES" if you saw the object at the top.
"NO" if you saw the object at the bottom.
"NO" if you did not see the object earlier.

Figure 2.

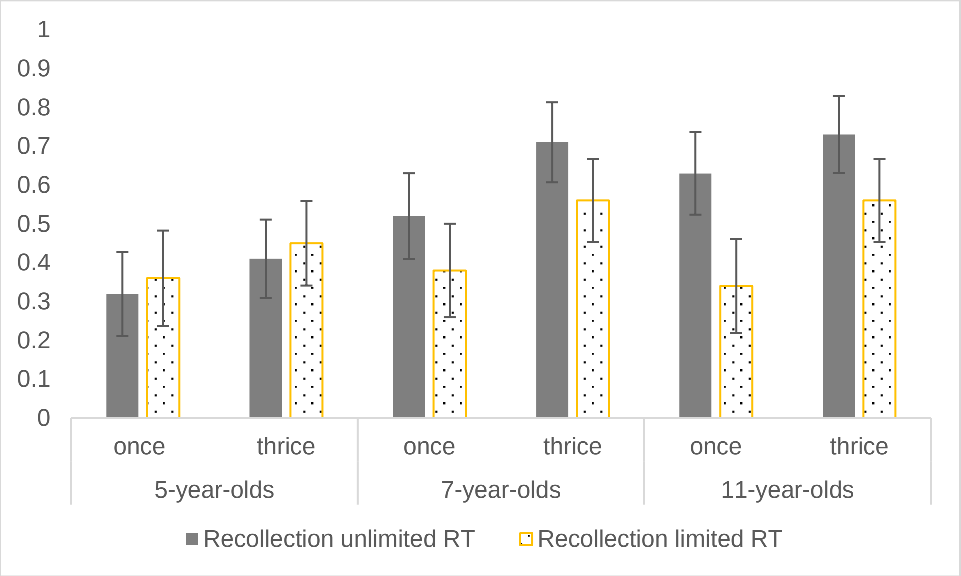
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
once
thrice
once
thrice
once
thrice
5-year-olds
7-year-olds
11-year-olds
Recollection unlimited RT
Recollection limited RT

Figure 3.

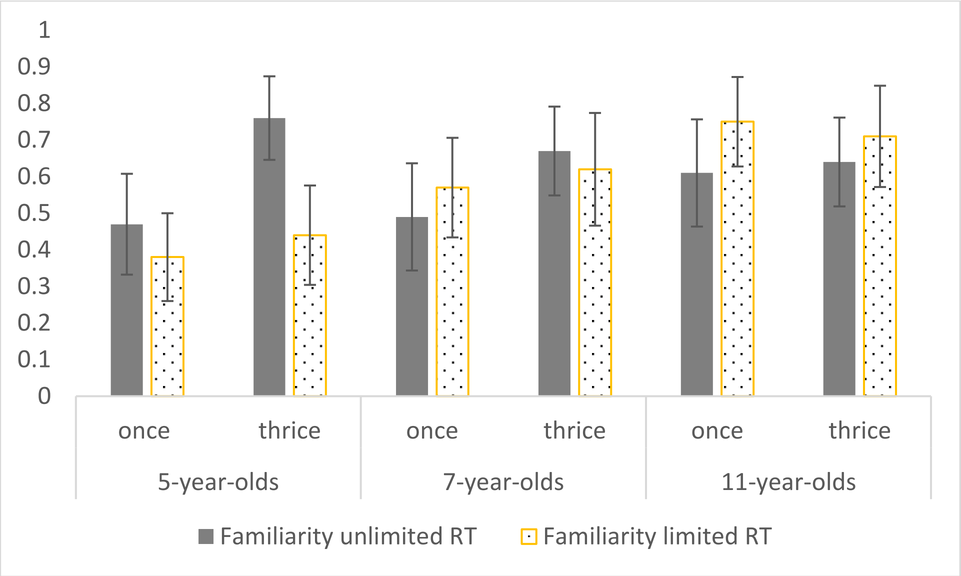
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
once
thrice
once
thrice
once
thrice
5-year-olds
7-year-olds
11-year-olds
Familiarity unlimited RT
Familiarity limited RT

Figure Captions

Figure 1. Experimental procedure. Some items were presented once (e.g., car, cake) and others presented thrice (e.g., crocodile, banana).

Figure 2. Recollection parameter estimates as a function of item repetition, age group and experiment (unlimited versus limited RT).

Figure 3. Familiarity parameter estimates as a function of item repetition, age group, and experiment (unlimited versus limited RT).