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# Are Children's Memory Illusions Created Differently than Adults'? Evidence from Levels-of-Processing and Divided Attention Paradigms

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Abstract

In two experiments we investigated the robustness and automaticity of adults' and children's generation of false memories by using a levels-of-processing paradigm (Experiment 1) and a divided-attention paradigm (Experiment 2). The first experiment revealed that when information was encoded at a shallow level, true recognition rates decreased for all ages. For false recognition, when information was encoded on a shallow level we found a different pattern for young children compared to older children and adults. Seven-year-olds' false recognition rates were related to the overall amount correctly remembered information whereas no such association was found for the other age groups. In the second experiment divided attention decreased true recognition for all ages. In contrast, children's (7- and 11-year-olds) false recognition rates were again dependent on the overall amount correctly remembered whereas adults' false recognition was left unaffected. Overall, children's false recognition rates changed when levels-of-processing or divided-attention was manipulated in comparison to adults. Together these results suggest that there may be both quantitative and qualitative changes in false memory rates with age.

Keywords: False memories; Memory development; Automaticity; Levels-of-processing; Divided attention

**Are Children's Memory Illusions Created Differently than Adults'?**

**Evidence from Levels-of-Processing and Divided Attention Paradigms**

A vast amount of research over the past fifteen years has used the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995) in order to investigate memory errors in adults. Here, participants study word lists containing items (e.g., *bed, rest snore, awake, dream*) that are all associated with a non-presented item, the "critical lure" (e.g., sleep). When asked to remember the presented items, some participants also falsely remember the critical lure among the correct list items. This robust false memory effect has also been observed in children. Interestingly, as children's overall memory capacity increases over the primary school period, so too does their false memory rate (e.g., Brainerd, Forrest, Karibian, & Reyna, 2006; Carneiro, Albuquerque, Fernandez, & Esteves, 2007; Dewhurst & Robinson, 2004; Howe, 2006; 2008). This finding from the DRM paradigm is striking because it suggests that here children's net memory accuracy decreases over childhood (Brainerd, Reyna, & Ceci, 2008).

In order to explain this counterintuitive increase in false memories with age, two theories have emerged. Fuzzy-Trace Theory (FTT; Brainerd & Reyna, 2005) suggests that presented information is encoded by two different memory traces, a verbatim trace that encodes surface features of items (e.g., the color of a word, specific font of a word) and a gist trace that encodes the overall meaning of an item or a list of items (i.e., the overall theme). It is this gist trace that is thought to be responsible for false memories in the DRM paradigm, particularly when verbatim traces, ones that fade more rapidly than gist traces, are no longer available. Developmentally, children's ability to extract the gist of to-be-remembered information improves with age. As this ability increases with age, so too does children's susceptibility to the DRM illusion (Brainerd & Reyna, 2005).

Alternatively, Associative-Activation Theory (AAT; Howe, Wimmer, Gagnon, & Plumpton, 2009a) suggests that true and false memories are both a product of automatic associative activation processes. In particular, this theory derives from the idea of spreading activation, also discussed in Activation-Monitoring Theory (Roediger, Watson, McDermott, & Gallo, 2001) for adults' false memory. The basic idea is that in an associative network, the processing of one word activates a corresponding node in our mental lexicon and this activation spreads to surrounding concept nodes (Collins & Loftus, 1975; Kimball, Smith, & Kahana, 2007; Landauer & Dumais, 1997). False memories occur because the critical lure is activated many times due to its association with the presented list items in the associative network. Children's false memories increase with age because of changes in children's knowledge base which result in increases in the automaticity with which children access and activate associations in their knowledge base, including associations that mediate false remembering (e.g., Howe, Wimmer, & Blease, 2009b).

In sum, both FTT a dual-process theory and AAT a single-process theory, provide an explanation of why the quantity of false memories increases with age. However, irrespective of the theoretical basis of the source of the occurrence of false memories, the question that remains to be answered is, *when* false memories occur, are these false memories qualitatively different for children and adults?

This question is of fundamental importance for the legal arena, where children are used as eyewitnesses. For some time it was thought that children were unreliable as eyewitnesses. Due to extensive research, it has been shown that although overall children remember fewer facts than adults, children are capable of providing accurate accounts of past experiences. However, what is still unclear is under which conditions false memories occur in children. For example, do false memories arise only out of consciously experienced events or also out of incidentally experienced events? The aim of the current research is to investigate these possibilities.

For adults, the general consensus is that false memories occur automatically, outside of conscious awareness (e.g., Dodd & MacLeod, 2004; Kimball & Bjork, 2002; Seamon, Luo, Shulman, Toner, & Caglar, 2002) but can reach conscious awareness in some circumstances (e.g., McDermott, 1997). For example, false memories occur even when information has been encoded incidentally (Dodd & MacLeod, 2004), or even after adults are forewarned about the false memory phenomenon (Gallo, Roberts, & Seamon, 1997; Gallo, Roediger, & McDermott, 2001; McDermott & Roediger, 1998). Similarly, when adults are instructed to "forget" a just studied word list then only true recall but not false recall is reduced (Kimball & Bjork, 2002; Seamon, et al., 2002; but see Marche, Brainerd, Lane, & Loehr, 2005 for a different finding using a different method). Thus, at least for adults, false memories appear to occur relatively automatically, both at the generation or encoding stage (i.e., evidence from incidental memory studies and forewarning procedures) and at the output or retrieval phase (i.e., evidence from directed forgetting studies).

What evidence do we have concerning the automaticity of children's false memories at the generation (encoding) and output (retrieval) phases? To date there is only one study that examined the development of automatic associative processes in relation to false memories at the generation stage (Wimmer & Howe, 2009) and only a single study on automaticity at the output stage (Howe, 2005). In particular, using a modified DRM paradigm it has been shown that there is a developmental increase of automaticity in activating associative relations in one's knowledge base. However, associative activation is already fairly automatic in 5-year-olds when it is mapped onto a child's knowledge base (Wimmer & Howe, 2009). This finding gives some indication that children's formation of associations that can lead to false memories may be relatively automatic. Alternatively, at the output stage the story is different. Here, in contrast to adults, children's false memories, like their true memories, all but disappeared when given a directed forgetting instruction (Howe, 2005). That is, children, but not adults, were able to inhibit false memories during the output phase. If information can only be intentionally inhibited if it is active in consciousness, then these results suggest that there are qualitative differences in children's and adults' false memories at the retrieval phase. That is, children's false memories can be consciously inhibited at output whereas adults' false memories are automatically output outside of conscious awareness. These developmental differences at the output stage raise the question as to whether similar qualitative differences in automaticity exist between children and adults during the generation or encoding stage. Because directed-forgetting paradigms assess conscious and explicit inhibitory processes after information has been encoded, the question is whether the generation or initial activation of false information occurs automatically in children as it does in adults. Although children generate fewer false memories than adults, the question is when they do generate false memories, are they generated in the same automatic, unconscious fashion as those of adults?

To date, the automaticity and robustness of false memory effects in adults has been shown in studies that have used a levels-of-processing or divided-attention paradigm. The assumption is that if false memories are generated automatically and unconsciously, then conditions that affect conscious associative activation or gist extraction, such as different levels of processing and attentional mode, should have very little effect on false memory generation. If false memories are generated via elaborative and conscious processes, then levels of processing and divided attention should affect the generation of false memories as it does for true memories. The aim of the current research is to investigate whether children's false memories are generated using similar automatic processes as those found in adults. To our knowledge there is no published research on children's false memories using a levels-of-processing or a divided-attention paradigm. Therefore, we investigate both children's and adults' automaticity of false memory generation under different levels-of-processing (Experiment 1) and divided-attention manipulations (Experiment 2).

*Levels-of-Processing*

Studies of the effects of levels-of-processing on adults' true and false memories have shown that these effects vary systematically depending on whether the studied information was processed in a shallow or deep manner. For shallow processing, participants focus on surface or verbatim features of presented information (e.g., number of vowels in a word) whereas for deep processing participants focus on the gist or meaning of a word (e.g., rating the pleasantness of a word). Deep processing increases associative activation whereas shallow processing decreases associative activation.

Research with adults using levels-of-processing has produced mixed results concerning the effects on true and false memories (Read, 1996; Rhodes & Anastasi, 2000; Thapar & McDermott, 2001; Toglia, Neuschatz, & Goodwin, 1999; Tussing & Greene, 1997). Three studies have demonstrated that when information is encoded using deep processing, significant increases occur in both true and false memory rates relative to when that same information is processed in a shallow fashion. Moreover, these effects were obtained regardless of whether recall or recognition measures were used (Rhodes & Anastasi, 2000; Thapar & McDermott, 2001; Toglia et al., 1999). In contrast, two other studies found few effects of levels-of-processing on true and false memories (Read, 1996; Tussing & Greene, 1997). Specifically, Tussing and Greene (1997) found no effect of levels-of-processing on true and false recognition. However, it has been noted that it was not clear in this study whether levels-of-processing did not affect true and false recognition or was simply not manipulated properly (see Thapar & McDermott, 2001; Toglia et al., 1999). As well, Read (1996) found that deep processing increased true recall but had no effect on false recall, whereas shallow processing decreased false recall. However, this study has been criticized because only a single DRM list was used (i.e., the sleep list) (see Thapar & McDermott, 2001; Toglia et al., 1999).

Together, these studies fail to provide a clear picture of the effects of,levels-of-processing on true and false memories. These inconsistent findings arising out of between-participants manipulations may be a result of individual differences in false memory formation. That is, some individuals are more prone to false memories than others (see Gallo, 2006 for an overview of individual differences in false memories). Therefore, in the current research we will control for individual differences between participants by using a within-participant design. Once these differences are reduced, like what the research above also suggests, false memories should still occur under shallow processing indicating that at least adults' false memories are generated automatically.

*Divided Attention*

Research using divided-attention paradigms has also produced inconsistent results concerning true and false memories. In a typical divided-attention paradigm, participants receive instructions to memorize presented information while performing a secondary task (e.g., generating random numbers). Overall, dividing attention decreases true memory in comparison to full attention. For false memories, dividing attention has different effects on false recall than on false recognition. In particular, it has been shown that the introduction of a secondary task at encoding increases false recall (Dewhurst, Barry, & Holmes, 2005; Pérez-Mata, Read, & Diges, 2002; Peters, Jelicic, Gorski, Sijstermans, Giesbrecht, Merckelbach, 2008) but decreases false recognition (Dewhurst, et al., 2005; Dewhurst, Barry, Swannell, Holmes, & Bathurst, 2007). Similarly, when introducing an additional memory load at encoding rather than using a divided attention paradigm, false recognition is reduced (but only in a between-participants condition not in a within-participant design) (Seamon, et al., 1998). It has also been shown that divided attention at encoding impairs true recognition but not false recognition (Seamon et al., 2003).

Overall, the research on divided attention yields inconsistent results and a direct comparison between studies is difficult because the secondary tasks that have been used differ across studies (Gallo, 2006). Furthermore, different results have been obtained depending on whether a within- or between-participants design has been used and whether recall, recognition, or both have been investigated. One explanation for the contrasting findings of an increase of *false recall* in comparison to a decrease of *false recognition* when dividing attention at encoding is that participants adopt a criterion shift in recall (Dewhurst et al., 2005, 2007). That is, at recall participants realize that their performance is poorer in a divided-attention paradigm and therefore compensate by adopting a lower threshold for considering an item as presented and thus recall is more prone to the false memory illusion.

In sum, despite the mixed results of divided-attention on true and false memories, similar to the studies that have used a levels-of-processing paradigm, false memories still occur when items are studied under conditions that divide attention. This finding indicates that adults' false memory production is fairly robust and is not eliminated under conditions that divide attention, another indication that adults' false memories arise out of automatic processing. In what follows, we examine whether children's false memories are generated in a similar, automatic fashion.

## Experiments 1 and 2

To our knowledge, no published study has directly investigated whether children's and adults' false memories are generated in a qualitatively different manner, particularly whether they differ in terms of their associative activation processes (i.e., conscious versus automatic). The aim of the current research is to investigate this by using a levels-of-processing paradigm (Experiments 1) and a divided-attention paradigm (Experiments 2). Across both experiments 7- and 11-year-old children and adults take part. These age groups were chosen because there is a significant developmental increase in the quantity of false memories generated (e.g., Howe, Wimmer, & Blease, 2009). Including this age range will allow us to directly compare changes in quantity to changes in quality of false memory formation. If children's false memories are generated less automatically than adults' and are constructed using conscious associative activation processes, then, like true memories, they should be considerably reduced under shallow processing conditions (Experiments 1) and under divided attention conditions (Experiments 2). In both experiments we used a recognition paradigm because as already noted, it is not clear whether encoding manipulations interfere with associative activation processes or cause a criterion shift in adult participants when measured using a recall paradigm. Furthermore, both levels-of-processing and divided-attention were manipulated within participant. This within-manipulation was necessary because, as noted above, it controls for individual differences in false memory formation, where some people are more prone to false memories than others (Gallo, 2006), something that may explain the inconsistent results of previous studies of levels-of-processing and divided attention.

Experiment 1 requires a specific response to each item during study whereas Experiment 2 requires dividing attention between a secondary task and the DRM task at study. If shallow processing and divided attention interfere with memory processes, then true recognition should be reduced compared to standard/deep levels-of-processing and full attention. If false memories arise out of conscious processes, then shallow processing and divided attention should also reduce false recognition compared to standard/deep processing levels and full attention. If false memories arise from automatic associative processes, then false recognition should not be significantly reduced under shallow processing levels and divided attention compared to standard/deep processing levels and full attention respectively

Experiment 1

In the first experiment, we implemented a classical levels-of-processing design, one that is similar to those previously with adults (e.g., Thapar & McDermott, 2001). However, instead of using pleasantness ratings as a deep processing manipulation, something that may pose problems for younger children, we presented DRM lists in a story format, one that bears similarities to that used in earlier research on children's false memories (Dewhurst, Pursglove, & Lewis, 2007). Presenting DRM lists in a story format has been already successfully implemented with 5-year-old children in Dewhurst and colleagues' study, thus, our 7-year-olds should have no problems with this type of manipulation. We created our own sentences conveying a story (see Appendix). This was necessary because each sentence was presented separately and the last word of each sentence was the to-be-remembered item.

We created a comparable shallow processing condition in which participants simply counted the number of words in each sentence of the story. Concerning the automaticity of false memories, there are two possible outcomes: If false memories are automatic, then levels-of-processing should have little effect on false memory rates whereas if false memories arise out of conscious processes, then shallow processing should decrease, and deep processing should increase, false memory rates. Moreover, if children's false memories are generated in a similar way as adults' then we expect no age differences in the pattern of shallow versus deep versus standard processing.

## Method

### *Participants*

A total of 63 children and adults (60% female) participated in this experiment, 20 7-year-olds (*M* = 7.7, SD = 3 months), 20 11-year-olds (*M* = 11.7, SD = 5 months), and 23 adults (*M* = 20 years, SD = 1 year). The children were predominantly White, from a working class background, and were tested following parental consent and their own assent on the day of testing. The adults were undergraduate students and received financial reimbursement for their participation.

### *Design*

Each participant received six 13-item DRM lists. The lists were presented in three different levels-of-processing study formats: (1) standard: 2 standard DRM lists, (2) deep: 2 sentence DRM lists, and (3) shallow: 2 sentence counting-the-number-of-words DRM lists. After that children received an age appropriate 3½-minute distractor task followed by a recognition task.

### *Materials and Procedure*

The six 13-item DRM lists[1] (*sleep, cold, bread, doctor, lion*, and *shirt*) were all presented orally and visually at a 2 second rate on a Mac computer. This dual presentation mode was implemented because in the shallow processing condition it was necessary to visualize the sentences in order to count the number of letters. Thus, for reasons of comparison, the standard and deep processing conditions had to follow the same modality of presentation. Moreover, presenting information in both formats simultaneously allows for controlling for potential differences in reading capacity between the younger and older participants. That is, because participants heard and saw each item/sentence simultaneously, they were not required to read them themselves. Participants across all conditions were instructed to remember as many items as possible. After each list, a neutral filler picture appeared for 2 seconds in order to mark the end of one list and the beginning of the next list. There were 3 list pairs (shirt/lion, sleep/doctor, and bread/cold). The list pairs used for each condition and the presentation order were counterbalanced across participants.

All participants received two standard DRM, two deep-meaning DRM, and two shallow-meaning DRM lists. In the *standard* levels-of-processing condition participants received a *standard DRM* paradigm. In the *deep meaning* processing condition participants received a *sentence DRM* paradigm, and were presented with sentences where the last item of each sentence was displayed in bold and underlined. Participants were instructed that this last item was the to-be-remembered item. All sentences within a list conveyed a story. In the *shallow meaning* processing condition, participants received a *sentence DRM* paradigm that followed the same procedure as the sentence paradigm except that participants were also asked to count the number of words in each sentence. Participants received two practise sentences that were not associated with the sentences that followed in order to familiarize them with the procedure. Next, participants received a 3½-minute age-appropriate distractor task (visual search game for children and mathematical calculations for adults), followed by a recognition task. The recognition task consisted of 48 items: 24 correct list items (4 per list), 12 related non-presented items (2 per list), 6 unrelated non-presented items (1 per list), and 6 critical lures (1 per list).

## Results

### *Chance Performance*

First, we examined whether participants' recognition performance was above chance[2]. We conducted a one-sample t-test with 0.5 as the test statistic comparing children's and adults' performance against chance on all 4 item types (correct, related non-presented, unrelated non-presented, and critical lures). Seven-year-olds performed above chance on all item types (at least $p < .05$ and higher) except during shallow processing for both correct items and critical lures. Thus, 7-year-olds had no problems with the task demands of processing and remembering information when it was presented in the form of single items or sentences conveying a story, but encountered problems when information was processed incidentally under shallow processing. In contrast, 11-year-olds and adults performed above chance on all item types (at least $p < .01$ and higher). In sum, shallow processing only affected 7-year-olds' chance performance for both correct items and critical lures.

### *True and False Recognition*

Next, we analyzed age and levels-of-processing effects for true and false recognition. Proportion of "yes" responses to studied items, critical lures, related items, and unrelated items were analyzed separately in a series of 3(levels-of-processing: standard vs. deep vs. shallow) x 3(age: 7-year-olds vs. 11-year-olds vs. adults) analyses of variance (ANOVAs) where the first factor was within-participant and the second factor was between-participants. Mean recognition scores are shown in Table 1.

For studied items there was a main effect for levels-of-processing, $F(2, 120) = 26.59$, $p < .001$, $\eta_p^2 = .31$, where Bonferroni post-hoc tests ($p < .001$) revealed that fewer items were correctly recognized following shallow processing (*M* = .65) than either the standard (*M* = .84) or deep processing conditions (*M* = .84), and the latter two conditions did not differ. There was also a main effect for age, *F*(2, 60) = 9.57, $p < .001$, $\eta_p^2 = .24$, where Bonferroni post-hoc tests showed that 7-year-olds (*M* = .66, *p* = .017) correctly recognized fewer items than both 11-year-olds (*M* = .80) and adults (*M* = .86, $p < .001$) and the latter two age groups did not differ. Further, there was a marginally significant Age x Levels-of-processing interaction, *F*(4, 120) = 2.35, *p* = .058, $\eta_p^2 = .07$. This interaction occurred because 7-year-olds ($p < .001$) recognized less following shallow processing (*M* = .48) than deep (*M* = .72) or standard processing (*M* = .80), and the latter two conditions did not differ. For 11-year-olds (*p* = .021) their correct recognition was lower following shallow (*M* = .70) than standard processing (*M* = .86) or deep processing (*M* = .84), and the latter two conditions did not differ. In contrast, adults (*p* = .006) remembered less following shallow (*M* = .76) than deep processing (*M* = .95) both of which did not differ from standard processing (*M* = .88). Thus across all ages, shallow processing reduced correct recognition whereas the effect of deep processing was less clear.

For false recognition of critical lures, there was no effect for levels-of-processing but there was a main effect for age, *F*(2, 60) = 3.37, *p* = .041, $\eta_p^2 = .10$. Post-hoc Bonferroni adjacent age groups' comparisons (*p* = .036) indicated that 7-year-olds (*M* = .66) had fewer false memories than 11-year-olds (*M* = .82) who in turn did not differ from adults (*M* = .74). However, the difference between 7-year-olds' and adults' false memories did not reach significance.

Finally, for related and unrelated non-presented items there were no main effects or interactions. Together, these results show levels of processing affected only true recollection. That is, although false memory rates increased with age, levels-of-processing had no effect on false recognition whereas it did have an effect on true recognition.

*Overall Accuracy and False Alarms*

Because children are known to have a yea-saying bias, in order to obtain an overall index of accuracy and an estimate of false alarms rates, we used the two-high threshold correction[3] (Snodgrass & Corwin, 1988). For true recognition we calculated H – FA(U), where H is the proportion of correct responses to studied items and FA(U) is the proportion of false alarms to unrelated distractors. For false recognition to critical lures we calculated FA(CL) – FA(U), where FA(CL) is the proportion of false alarms to the critical lures.

Using the corrected scores for true recognition we calculated a 3(levels-of-processing: standard vs. deep vs. shallow) x 3(age: 7-year-olds vs. 11-year-olds vs. adults) ANOVA. The results were similar to the uncorrected scores and revealed a main effect for levels-of-processing (Figure 1), $F(2, 120) = 18.68$, $p < .001$, $\eta_p^2 = .24$. Post-hoc Bonferroni comparisons ($p < .001$) showed that fewer items were correctly identified following shallow processing ($M = .58$) than deep ($M = .78$) or standard processing ($M = .78$), and the latter two conditions did not differ. There was also a main effect for age, $F(2, 60) = 10.30$, $p < .001$, $\eta_p^2 = .26$. Post-hoc Bonferroni age groups' comparisons indicated that there was a reliable difference between 7-year-olds ($M = .57$) and both 11-year-olds ($M = .76$, $p = .004$) and adults ($M = .81$, $p < .001$) and the latter two age groups did not differ. Furthermore, there was a Levels-of-processing x Age interaction, $F(4, 120) = 2.97$, $p = .022$, $\eta_p^2 = .09$. This interaction occurred because the youngest age group had a unique order of correct recognition as a function of levels-of-processing in comparison to the older participants. For 7-year-olds, more items were recognized following standard processing ($M = .75$) than deep ($M = .59$, $p = .041$) or shallow processing ($M = .38$, $p = .008$). For 11-year-olds, marginally significantly ($p = .059$) more items were recognized following deep processing ($M = .84$) than shallow processing ($M = .68$) but there was no difference in comparison to standard processing ($M = .76$). For adults we found the same pattern: deep processing ($M = .91$) increased correct recognition in comparison to shallow processing ($M = .67$, $p = .002$) and neither differed from standard processing ($M = .83$). Together these findings from the corrected scores suggest that deep processing enhances true recognition and shallow processing decreases true recognition for adults and 11-year-olds but not necessarily in comparison to standard processing conditions. In contrast, for 7-year-olds shallow processing decreases true recognition but only in comparison to standard processing. The effect of deep processing in 7-year-olds was less clear.

For false recognition (Figure 1), using the corrected scores, we did not find an effect for levels-of-processing but did find one for age, $F(2, 60) = 5.16$ $p = .009$, $\eta_p^2 = .15$. Bonferroni adjacent age groups' comparisons ($p = .006$) revealed that 7-year-olds ($M = .57$) had fewer false alarms to critical lures than 11-year-olds ($M = .77$) who did not differ from adults ($M = .68$). As for the uncorrected scores, the difference between 7-year-olds and adults did not reach significance. Overall, although the proportion of false memories increased between 7 and 11 years of age, levels-of-processing had no effect on false memories regardless of age.

In sum, levels-of-processing affected true recognition where shallow processing decreased and deep processing increased true memories. In contrast, although false memories increased with age, levels-of-processing had no effect on false memory rates regardless of age. Thus, levels-of-processing affects true but not false recognition and this latter effect is age invariant.

*Correlational Analysis*

In order to examine individual differences and the relation of true and false memories under different levels-of processing conditions, we conducted a correlational analysis for each age group separately. Interestingly, for 7-year-olds there was a strong association between true and false recognition under *shallow processing* ($r = .57$, $p < .001$). No further associations emerged, and none of the older two age groups' true and false recognition performance revealed any positive correlations. If anything, for adults there was a negative relation in the *deep processing* condition between true and false recognition ($r = -.53$, $p = .009$). These findings suggest that when information is encoded at a shallow level, 7-year-olds' true and false recognition performance are positively correlated, whereas for older children and adults they are unrelated.

<u>Discussion</u>

When we examined the effects of levels-of-processing for true and false recognition separately, we found that encoding information at a deep level (sentence DRM) increased true recognition for the older age groups whereas encoding information at a shallow level (sentence dual-task DRM) decreased true recognition and this was the case for all ages. Thus, both shallow and deep processing affected true recognition rates for both children and adults. In contrast, the levels-of-processing manipulation had no effect on false memory rates regardless of age. The lack of a levels-of-processing effect on false recognition contrasts with previous research with adults (Rhodes & Anastasi, 2000; Thapar & McDermott, 2001; Toglia et al., 1999) that found that levels-of-processing either decreased or increased false recognition depending on whether information had been encoded in a shallow or a deep fashion, respectively. However, these contrasting findings may be due to individual differences in the susceptibility to false memories, something a between-participants design cannot control for. Our results are in line with Seamon et al. (1998) who found that memory load had no effect or decreased false recognition depending on whether a within- or between-participants design was used, respectively. The advantage of a within-participant design is that it controls for variability in false memory rates that occur especially in children and is more comparable to an everyday life scenario where some information may be encoded more deeply (e.g., an event that is particularly unusual or interesting such as taking a plane for going on holidays) and some information may be encoded on a shallow level (e.g., events that have been encountered many times such as a trip to the supermarket). Furthermore, our results are consistent with the findings from Dewhurst and colleagues (Dewhurst et al., 2007). They examined true and false recognition rates in 5-, 8-, and 11-year-olds' in a standard DRM paradigm compared to a story condition. Specifically, they found that 5-year-olds' true and false recognition rates were increased when information was presented in a story compared to the standard list format whereas no difference occurred for 8- and 11-year-olds. This is exactly what we found with our 7- and 11-year-olds.

Thus, despite differences in story contents and presentation mode between Dewhurst and colleagues' and the current study, both found similar false memory rates when information was presented in a story (deep processing) compared to standard DRM lists (standard processing) for both 7- and 11-year-olds.

Despite our finding that there are no differences in levels-of-processing effects on children's and adults' false memories, shallow processing affected young children's and adults' memories differently as became apparent in the correlational analysis. Specifically, when 7-year-olds processed information in a shallow fashion, then the amount of false memories was dependent on the overall amount remembered and vice versa. In contrast, for 11-year-olds false memories occurred under different levels of processing, independent of how much information was correctly or incorrectly remembered. Moreover, for adults false memories occurred either independently of true memories or were even negatively related under deep processing. These correlational findings may indicate that there are qualitative differences between 7-year-olds' false memories and those of older children compared to adults. That is, young children's false memories may arise out of less automatic processes than adults' because when they encode information incidentally their false recognition is contingent on true recognition. In contrast for adults, there appears to be no relation between how much is correctly or incorrectly remembered. If anything, true and false recognition were negatively related under deep processing conditions in adults. We will investigate this potential qualitative difference further in Experiment 2 implementing a divided attention paradigm.

Experiment 2

In Experiment 2 we divided attention during encoding. A comparison of the different findings from research on divided attention and their mixed results may be difficult because of the different types of secondary tasks that have been used across studies (Gallo, 2006). However, the studies by Dewhurst and colleagues (Dewhurst et al., 2005; Dewhurst et al., 2007; Knott & Dewhurst, 2007) have shown that at encoding, any secondary task that is resource demanding, whether it inhibits associative processes (e.g., generating random numbers during list encoding) or increases the memory load (e.g., remembering several digits during list encoding), prevents the *generation* of associative processes which in turn may reduce false recognition. Because the tasks used in a divided attention paradigm in adult research are too demanding for children, we implemented a secondary task that is age appropriate and requires inhibitory processes. Inhibitory processes play a significant role in children's memory (Bjorklund & Harnishfeger, 1995; Harnishfeger & Bjorklund, 1994). Inhibition helps children to ignore irrelevant information and reduces sensitivity to interference (Dempster, 1992). A lack of inhibition for irrelevant information may cause relevant information to be encoded less efficiently which may in turn weaken memory traces for relevant events (Harnishfeger & Bjorklund, 1994). Further, younger children have more problems than older children and adults when trying to inhibit irrelevant information as an intrusion into the to-be-remembered information (Bjorklund & Harnishfeger, 1995). Thus, children's inhibitory strength is directly linked to the magnitude of irrelevant intrusions in memory tasks. Therefore, using an inhibitory task will directly interfere with memory processes. As an index for inhibitory processes, we implement the Day/Night-Stroop task (Gerstadt, Hong, & Diamond, 1994) that is derived from the most classical test for measuring inhibitory processes in adults, the Stroop task (Stroop, 1935). Previous research that has implemented the Day/Night-Stroop task with children has found significant increases in inhibitory abilities from 3½ to 7 years and to 11 years of age (Gerstadt, et al., 1994; Simpson & Riggs, 2005). Therefore, this task is an ideal measure for inhibitory processes within the child age range studied here. In order to keep a direct comparison with adults and to control for secondary-task consistency, this task is also administered with adults. Apart from classical studies investigating increases in inhibitory abilities, the Day/Night-Sroop task has also been used in several studies in order to predict memory errors following from suggestibility (e.g., Alexander, Goodman, Schaaf, Edelstein, Quas, Shaver, 2002; Roberts & Powell, 2005; Schaaf, Alexander, & Goodman, 2008). The basic idea is that children who are better at inhibiting a prepotent response may be less susceptible to suggestibility. Based on previous research, dividing attention with an inhibitory task should reduce true recognition, as shown in Dewhurst and colleagues' research where participants, for example, generated random numbers during list encoding. For false recognition there are two possibilities: if false memories are derived from conscious elaboration processes, then divided attention should also reduce false recognition. If false memories are derived from automatic associative processes, then false recognition should be little affected. Moreover, if children's false memories are generated in a similar way as adults' false memories then we expect no age differences in the pattern of full versus divided attention.

Method

*Participants*

A total of 60 children and adults (55% female) participated in this experiment, 20 7-year-olds (*M* = 7.9, SD = 4 months), 20 11-year-olds (*M* = 11.8, SD = 5 months), and 20 adults (*M* = 20 years, SD = 1 years). The children were predominantly White, from a working class background, and were tested following parental consent and their own assent on the day of testing. The adults were undergraduate students and received financial reimbursement for their participation.

*Design*

Overall, each participant received six 13-item standard DRM lists. Three of them were presented in a divided attention paradigm at study. Here, participants additionally performed the Day-Night Stroop task. After that each participant received a 3½-minute distractor task followed by the recognition task.

*Materials and Procedure*

The six 13-item DRM lists (*music*, *fruit*, *man*, *soft*, *needle*, and *foot*) were all presented orally at a 2 second rate on a Mac computer and selected according to the same criteria as in Experiment 1 (see footnote 1). Participants were instructed to remember as many list items as possible. In addition, for 3 out of the 6 lists participants performed the Day-Night Stroop task (Gerstadt, et al., 1994; Simpson & Riggs, 2005). Participants were instructed to press a dark blue button on the keyboard in response to a day scenario (yellow sun with white background) and a yellow button in response to a night scenario (white stars and moon with dark blue background). This requires inhibiting a prepotent response. Four practise trials preceded the study phase in order to familiarize participants with the procedure. Which 3 lists were presented in the divided-attention paradigm was counterbalanced between participants. Further, the order of divided-attention was counterbalanced (i.e., either the first 3 lists were presented under divided attention or the last 3 lists). After that all participants received a 3½-minute distractor task, followed by the 48-item recognition task, as in Experiment 1.

## Results

### *Day-Night Stroop Task*

First, we were interested in how participants performed on the secondary task in the divided-attention condition. Overall the proportion of correct responses was high and increased with age, $F(2, 57) = 8.06$, $p = .001$, $\eta_p^2 = .22$. Post-hoc Bonferroni comparisons indicated that 7-year-olds ($M = .85$) had fewer correct responses than 11-year-olds ($M = .98$, $p = .004$) and adults ($M = .98$, $p = .002$) and the latter two groups did not differ. Similarly, reaction time decreased with age, $F(2, 57) = 11.0$, $p < .001$, $\eta_p^2 = .28$; where both adults ($M = 1.69$, $p < .001$) and 11-year-olds ($M = 1.95$, $p = .013$) responded faster than 7-year-olds ($M = 2.42$). Both findings suggest an increase in inhibitory abilities between 7 and 11 years of age as well as adulthood.

### *Chance Performance*

As in Experiment 1, we examined whether children and adults performed above chance on all 4 item types across the different conditions. Seven-year-olds performed above chance on all item types (at least $p < .05$ and higher) except for correct items under divided attention and critical lures under full attention. Eleven-year-olds performed above chance on all item types (at least $p < .01$ and higher) except for critical lures under divided attention. Adults performed above chance on all item types ($p < .001$) except for critical lures under both full and divided attention. Thus, dividing attention affected children's and adults' performance differently.

*True and False Recognition*

As in the previous experiment, we investigated whether dividing attention at study affected true and false recognition in comparison to full attention and whether this effect was the same at all ages. Proportion of "yes" responses to studied items, critical lures, related items, and unrelated items were analyzed separately in a series of 2(attention: full vs. divided) x 3(age: 7-year-olds vs. 11-year-olds vs. adults) ANOVAs where the first factor was within-participant and the latter factor between-subjects. Mean recognition scores are displayed in Table 2.

For studied items there was a main effect for attention, $F(1, 57) = 12.25$, $p = .001$, $\eta_p^2 = .18$, where more studied items were correctly recognized under full attention ($M = .75$) than under divided attention ($M = .64$). There was also a main effect for age, $F(2, 57) = 10.12$, $p < .001$, $\eta_p^2 = .26$. Post-hoc Bonferroni comparisons ($p < .001$) indicated that 7-year-olds ($M = .57$) correctly recognized fewer items than both 11-year-olds ($M = .76$) and adults ($M = .75$) and the latter two groups did not differ. Thus, divided attention at encoding decreased true memory rates across all ages.

For critical lures there was a main effect for age, $F(2, 57) = 4.92$, $p = .011$, $\eta_p^2 = .15$. Post-hoc Bonferroni adjacent age groups' comparisons ($p = .008$) indicated that 7-year-olds ($M = .40$) had lower levels of false recognition than 11-year-olds ($M = .66$) who did not differ from adults ($M = .54$). The difference between 7-year-olds and adults did not reach significance. In contrast to studied items, there was no effect of attention.

There were no other main effects or interactions. Thus, whereas divided attention reduces accuracy (true recognition), there were no effects on false memories.

At first glance this pattern of results suggests that divided attention affects true but not false recall across all ages. However, when looking closer at the means in Table 2, the magnitude of the differences between the full and divided attention is comparable for the 7- and 11-year olds for the correct items and critical lures (mean differences, 7-year-olds = .12 and .14, respectively; 11-year-olds = .12 and .15, respectively). However, the pattern is different for adults (mean difference = .10 and -.02, respectively). Thus, despite differences in mean performance, statistically no interaction occurred and the pattern appears to be the same for children as for adults. The fact that there was no interaction, suggests that there was a large variation in individual performance. In order to investigate this further, we conducted a correlational analysis below.

*Overall Accuracy and False Alarms*

As in Experiment 1, we controlled for response bias and used the two-high threshold correction (Snodgrass & Corwin, 1988). As for raw scores, using the corrected scores for true recognition, a 2(attention: full vs. divided) x 3(age group: 7-year-olds vs. 11-year-olds vs. Adults) ANOVA revealed a main effect for attention; $F(1, 57) = 5.3$, $p = .025$, $\eta_p^2 = .09$, where more studied items were correctly recognized under full attention ($M = .56$) than under divided attention ($M = .46$). There was also a main effect for age group; $F(2, 57) = 4.25$, $p = .019$, $\eta_p^2 = .13$. Post-hoc Bonferroni comparisons indicated that there was a reliable difference between 7-year-olds ($M = .40$, $p = .016$) and adults ($M = .63$) whereas the 11-year-olds' level of recognition ($M = .50$) was in between and did not differ from the two age groups.

Using the corrected scores for false recognition, a 2(attention: full vs. divided) x 3(age group: 7-year-olds vs. 11-year-olds vs. adults) ANOVA did not reveal any main effects.

Thus, like the raw scores, for true recognition the level of attention affects performance and increases with age whereas for false recognition the level of attention had no effect. In contrast to the raw score analysis, with the corrected scores, the age increase in false memory formation disappeared.

*Correlational analysis*

In order to control for individual differences in the susceptibility to false memories, we conducted a correlational analysis comparing correct and false recognition performance under full versus divided attention for each age group separately. Interestingly, there was a strong association between true and false recognition under divided attention for both 7-year-olds ($r = .70$, $p < .001$) and 11-year-olds ($r = .57$, $p < .008$). There was no association between true and false recognition under full attention (7-year-olds: $r = .24$,n.s.; 11-year-olds: $r = .34$, n.s.). In contrast, for adults true and false recognition were unrelated irrespective of attentional mode (full attention: $r = .14$; divided attention: $r = .08$, n.s.). Thus, a different pattern emerges for children and adults under divided attention.

<u>Discussion</u>

The reduction of true recognition under divided attention is consistent with previous research that included adult participants (Dewhurst et al. 2005; 2007; Knott & Dewhurst, 2007). However, these studies also found a similar decrease in false recognition under divided attention whereas the current results did not reveal any effect of divided attention for false recognition. This latter finding is more consistent with Seamon et al.'s (2003) study that did not find any effect of divided attention on false recognition in adults. It is possible that the secondary task used may account for the differences in findings across studies. However, previously used secondary tasks would not have been appropriate for the current purpose. As noted earlier, it was important to use a secondary task that is taxing for both children and adults. The Day/Night Stroop task has been administered with children in previous studies (e.g., Gerstadt et al., 1994; Simpson & Riggs, 2005) but not with adults. It is possible that this task was less demanding for adults than it was for children. However, this seems unlikely given the finding that under divided attention true recognition decreased across *all* ages. This finding suggests that the Day/Night Stroop task was effective in dividing attention for both children and adults[4]. Moreover, the implementation of the Day/Night Stroop task allowed for objective measures of participants' performances on the secondary task in comparison to previous studies that have used (e.g.) random number generation as a measure of divided attention. The disadvantage with (e.g.) a random number generation is that participants perform this task internally. Thus, there is no objective measure whether all participants follow the instructions properly, something that requires control in children.

Overall, although findings vary across studies that have implemented a divided-attention paradigm, altogether it seems that the secondary task has to be a labor intensive continuous central executive task if it affects false memories (i.e., reduces them) as found in studies by Dewhurst and colleagues. If a task has to be so demanding before divided attention has an effect on false memories, then this may provide further indication that false memories are fairly robust and generated from automatic associative processes.

However, the important finding concerns false recognition compared to true recognition as a function of attention in children compared to adults. What the findings of our correlational analysis revealed is that for both child participant groups, true and false recognition were strongly associated when attention was divided. In contrast, for adults, true and false memory formation was unrelated. Specifically, when children encoded information under divided attention then the occurrence of false memories was dependent on the amount of true memories and vice versa. What this finding suggests is that there may be qualitative differences in children's and adults' false memories. That is, when the attentional level is low then children's false memories seem to be contingent on the overall amount remembered whereas no such relation exists in adults.

Finally, two of the current findings require closer attention. First, we found very low levels of false recognition for adults under full attention. We do not have a plausible explanation other than variations in populations and individual differences in susceptibility to false memories (also see Unsworth & Brewer, 2010). Second, we found higher levels of false alarms to unrelated non-presented items for 11-year-olds than for 7-year-olds. Here the threshold corrected analysis provides more insight. That is, despite 11-year-olds' high levels of false alarms to unrelated non-presented items, their overall true recognition rates are higher than those of 7-year-olds, although this is not statistically significant. Thus, although 11-year-olds made more errors, in relation they also recognized more than 7-year-olds.

**General Discussion**

The current experiments were designed to assess the robustness of adults' and children's false memories and to establish whether there are differences in the automaticity with which false memories arise during the generation stage itself. Across both experiments it has been demonstrated that manipulating levels-of-processing or dividing attention significantly affects both children's and adults' true memories. Conversely, false memory rates were left unaffected by any experimental manipulation of levels-of-processing or divided attention. Most importantly, this latter effect was age invariant.

At first glance these findings suggest that false memories are fairly robust and are generated automatically inasmuch as they are not affected by levels-of-processing or by dividing attention. However, the lack of and age x divided attention interaction in Experiment 2 and the findings of our correlational analysis across both experiments give some grounds for caution. In particular, in Experiment 1 we found that only under shallow processing and only for the youngest age group, false memory formation was significantly dependent on the amount of true recognition and vice versa. Further, in Experiment 2 we found a similar pattern for divided attention for both child participant groups. Here, only under divided attention and only for 7- and 11-year-olds, false recognition rates were dependent on true recognition and vice versa. In contrast for adults, there appeared to be no association between true and false recognition across both experiments. More importantly, we found this pattern despite an overall increase in the quantity of false recognition with age, which was due to an increase between the ages of 7 and 11 (raw scores in both experiments and corrected scores in Experiment 1). Adults' false memory levels were relatively low and comparable to those of 11-year-olds but statistically did not differ significantly from those of 7-year-olds. This finding reflects the fact that the susceptibility to false memories varies with variations in populations and converges on inconsistent findings from studies with adults on the effects of levels-of-processing and divided attention as noted in the introduction. Overall we found that when information is encoded incidentally (either through shallow processing or divided attention) then children's false memory rates appear to differ from adults' because their occurrence depends on the level of true memories (and vice versa) whereas for adults this was not the case.

Two additional findings support the reliability of the current results. First, across both experiments, levels-of-processing and divided attention affected true memory rates across all ages. Thus, the manipulations implemented were effective for both children and adults. Second, across both experiments, false memory rates increased with age, except for the corrected scores in Experiment 2. Specifically, in both experiments false memories increased between 7 and 11 years of age but not into adulthood. Additionally, the relation between true and false recognition under shallow processing and divided attention differed for 7-year-olds compared to both 11-year-olds and adults (Experiment 1) and for both child participant groups compared to adults (Experiment 2). This finding may indicate that potential differences in quality of false memories occur independently from quantitative changes.

Most of our findings can be explained by both developmental false memory theories. Both Fuzzy-Trace-Theory (Brainerd, et al., 2008) and Associative-Activation-Theory (Howe, et al., 2009a) predict an increase in false memories with age, which we found across both experiments. Both theories agree that children need to have a semantic/associative lexicon or the necessary knowledge base in order to elicit false memories. It is established that children can form associative links between concepts at a relatively young age, but these links are strengthened and refined with increases in both knowledge and experience (Bjorklund, 2005). Thus, increases in the quantity of false memories with age have something to do with the fact that children simply gain more experience and knowledge of concepts and their relations in the world[5].

However, as previous research has shown, this increase in knowledge base alone cannot explain false memory increases with age (Anastasi & Rhodes, 2008; Carneiro, Albuquerque, Fernandez, & Esteves, 2007; Metzger, Warren, Shelton, Price, Reed, & Williams, 2008). That is, false memory formation increases with age even when it is mapped onto the knowledge base of very young children. Where the two false memory theories diverge is in the suggested processes that activate our semantic lexicon: associative-activation (AAT) versus gist extraction (FTT). As noted above, quantitative increases can be well explained by both theories. Qualitative differences between children's and adults' false memories, specifically differences in automaticity, are predicted by AAT whereas FTT does not make any specific claims with regard to automaticity.

Altogether, our findings fit into recent research that found increases in the automaticity of the generation of word associates that may lead to false memories between the ages of 5, 7, and 11(Wimmer & Howe, 2009). This finding may indicate qualitative differences between younger and older primary school aged children in the generation of false memories. Other research has shown that there are developmental differences in automatic processing *after* false memories have been generated. Specifically, research on directed forgetting shows that adults' true memory rates are significantly reduced under directed forgetting instructions whereas false memory rates are not (Kimball & Bjork, 2002; Seamon et al., 2002). In contrast, both children's true and false memory rates are reduced given a directed forgetting instruction (Howe, 2005; Howe, Toth, & Cicchetti, in press). Thus, according to these studies there appears to be qualitative, as well as quantitative, developmental differences in false memories *after* information has been generated or encoded such that false items may enter children's conscious awareness whereas they can remain outside of conscious awareness for adults.

The question whether children's and adults' false memories differ qualitatively may be of fundamental importance for forensic settings. In particular, the finding that children's false memories may be less automatic than those of adults but may be derived from more effortful conscious processing, may allow for using different memorial strategies (e.g., directed forgetting, Howe, 2005) in order to control for the occurrence of false memories in an interview situation and may in turn increase the reliability of children's forensic reports.

A further important issue is whether results arising from the DRM paradigm can have implications for the legal arena. That is, because the DRM paradigm is limited to study-list procedures there is some discussion whether the DRM paradigm is a valid tool for investigating false memories in the real world (e.g., Pezdek & Lam, 2007). Evidence suggests that findings from the DRM paradigms can also translate into real world settings (e.g., Platt, Lacey, Iobst, & Finkelmann, 1998) but more research is warranted that explores this generalization. The advantage of using a controlled laboratory-based technique is that it allows examining the core cognitive processes underlying false memories that can occur in everyday-life. This may also explain the wealth of empirical research that has implemented the DRM paradigm over the last decade (see Brainerd et al., 2008 for an overview). For the current purpose, the implementation of the DRM paradigm proved useful because it allowed us to investigate whether there would be qualitative differences in children's and adults' false memories that can be attributed to cognitive factors *per se*.

In sum the current research reveals two main findings. Levels-of-processing and divided-attention manipulations both affect true recognition across all ages. Individually, the occurrence of false memories depends on the overall amount of information remembered when information is processed on a shallow level (7-year-olds) and under divided attention (7- and 11-year-olds) and vice versa whereas for adults false memories occur irrespective of the amount of information correctly remembered. This may suggest a qualitative difference in children's and adults' false memory formation. Recent research has shown that children's formation of associative concepts increases in automaticity with age but is already fairly automatic by the age of 5 (Wimmer & Howe, 2009). What the current research adds is that children's false memories may also differ in the quality to those generated by adults. Further research will be required to establish whether children's and adults' false memories are qualitatively different.

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Footnotes

[1] All DRM study lists/items were obtained from Roediger, Watson, McDermott, and Gallo (2001) and were chosen according to their high backward associative strength (BAS) to the critical lure and their high word frequency values using the word frequency norms of British primary school aged children's printed vocabulary (Stuart, Masterson, Dixon, & Quinlan, 1993-1996). All items were presented in descending BAS to the critical lure. This also applies to the DRM lists used in Experiment 2.

[2] One potential problem with analysing performance against chance is that it does not give us insights into why some participants do not differ from chance. That is, there are two possibilities: (a) participants are unable to remember the items and answer randomly "yes" or "no" (chance performance 0.5) or (b) participants answer systematically "no" when they do not remember the items and really remember only half of the items (true performance 0.5). Therefore, the two-high threshold method is a better measure for discrimination and response bias.

[3]The two-high threshold method is, according to Snodgrass and Corwin (1988), a more sensitive measure than other signal detection indices (e.g., A′), one that permits the identification of response bias and discrimination among participants even when they are performing close to chance.

[4] The possibility remains that the task was performed serially (i.e., item encoded then button pressed) rather than fully under divided attention (i.e., item encoded while button pressed). Nevertheless, it seems to have effectively divided attention across all ages because it reduced true recognition across *all* ages. If the task had been only effective in

children, then we should have found an age x attention interaction which was not the case.

[5] In the current research we tried to control for knowledge base effects by using DRM lists containing high word-frequency items suitable for primary school aged children. The finding that across both experiments in all standard conditions, even our youngest age group remembered significantly more than by pure chance suggests that the lists were appropriate for the age range examined. Nevertheless, a database as the Neslon, McEvoy and Schreiber (1999) database for adults' word association norms would be warranted for children.

Table 1. Mean proportions of recognized studied items, related non-presented items, unrelated non-presented items, and critical lures across ages as a function of level of processing (standard deviation in parenthesis) in Experiment 1.

| | | 7-year-olds | 11-year-olds | Adults |
|---|---|---|---|---|
| *Standard* | Studied | .80 (.19) | .86 (.13) | .88 (.21) |
| | Related | .09 (.17) | .09 (.15) | .12 (.18) |
| | Unrelated | .05 (.15) | .10 (.20) | .04 (.14) |
| | Critical Lures | .72 (.30) | .82 (.33) | .72 (.36) |
| *Deep* | Studied | .72 (.28) | .85 (.17) | .95 (.08) |
| | Related | .15 (.20) | .19 (.23) | .09 (.16) |
| | Unrelated | .12 (.27) | .00 (0) | .04 (.14) |
| | Critical lures | .65 (.29) | .85 (.29) | .72 (.33) |
| *Shallow* | Studied | .48 (.29) | .70 (.23) | .76 (.21) |
| | Related | .10 (.15) | .21 (.19) | .11 (.18) |
| | Unrelated | .10 (.20) | .02 (.11) | .09 (.19) |
| | Critical Lures | .60 (.35) | .77 (.30) | .78 (.25) |

Table 2. Mean proportions of recognized studied items, related non presented items, unrelated non presented items, and critical lures across ages in a full attention versus divided attention paradigm at *study* (standard deviation in parenthesis) in Experiment 2.

| | 7-year-olds | | 11-year-olds | | Adults | |
|---|---|---|---|---|---|---|
| | *Full* | *Divided* | *Full* | *Divided* | *Full* | *Divided* |
| Studied | .63 (.22) | .51 (.24) | .82 (.11) | .70 (.26) | .80 (.12) | .70 (.15) |
| Related | .15 (.20) | .17 (.20) | .22 (.26) | .23 (.27) | .12 (.15) | .14 (.17) |
| Unrelated | .17 (.25) | .17 (.28) | .27 (.32) | .25 (.36) | .12 (.16) | .12 (.22) |
| Critical Lures | .47 (.36) | .33 (.32) | .73 (.30) | .58 (.26) | .53 (.38) | .55 (.29) |

Figure Captions

Figure 1. Mean threshold corrected scores of true and false recognition across all ages as a function of level of meaning processing in Experiment 1.

Figure 2. Mean threshold corrected scores of true and false recognition across all ages as a function of attentional mode in Experiment 2.

Figures

Figure 1.

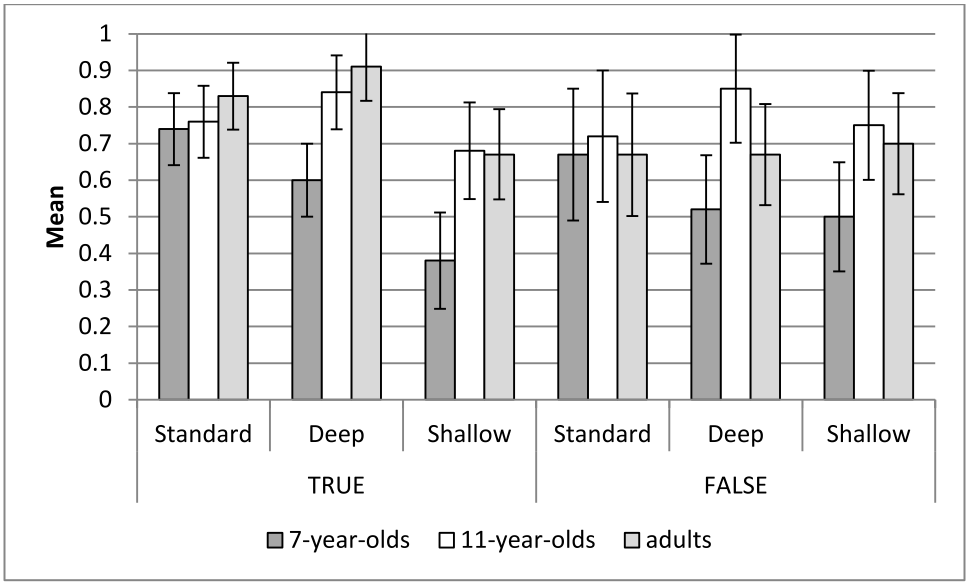
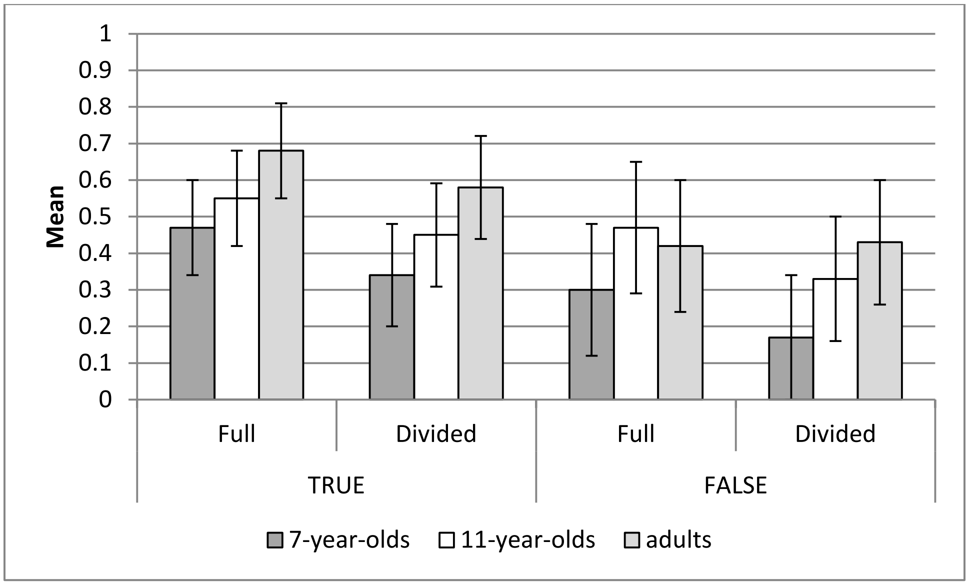


Figure 2.


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mean
Full
Divided
Full
Divided
TRUE
FALSE
7-year-olds
11-year-olds
adults

APPENDIX

Experiment 1: sentences used in the shallow and deep processing conditions.

**Critical Lure: Sleep**

After lunch I decided to have a short **nap**
Soon I started to **doze**
I thought that it would be more comfortable to go to **bed**
Suddenly I was **awake**
But I felt very **drowsy**
And I went for another **snooze**
I fell into a deep **slumber**
I was so **tired**
I needed a proper **rest**
Suddenly I heard a loud **snore**
And I started to **wake**
I was having a very funny **dream**
Then I opened my eyes and began to **yawn**

**Critical Lure: Cold**

Last summer it was **hot**
But today I started to **shiver**
The temperature is **arctic**
And it feels **frigid**
My hands are going to **freeze**
This year it has been **chilly**
This morning came the **frost**
By lunchtime it was a little bit **warm**
This has melted the **ice**
It may be a long **winter**
Hopefully with plenty of **snow**
Recently there was hardly any **heat**
And the rain from yesterday left the road **wet**

**Critical Lure: Bread**

My mouth tasted of **rye**
Probably because I took a bite from this huge **loaf**
There was also lots of **butter**
Which is really nice on top of **toast**
Sometimes I make the **dough**
And once I lost a tooth when biting into the thick **crust**
Another time my hands were white from all the **flour**
But my favourite is my grandma's special **sandwich**
With lots of home made **jam**
And a large portion of **jelly**
I like a very thin **slice**
And a glass of **milk**
This is my favourite type of **food**

**Critical Lure: Lion**

The mouth opened and there was a very load **roar**
Everything was under control according to the **tamer**
He also controlled the **tiger**
Then he touched his soft **mane**
His response was **fierce**
Then he looked into the **den**
Inside was this cute little **cub**
For safety he was put back into the **cage**
Originally he was living in the **jungle**
There were also some **bears**
Typically he has his head held high walking with the **pride**
Unfortunately he is not as free as in **Africa**
Life is different in the **circus**

**Critical Lure: Doctor**

I opened my eyes and saw the **physician**
Next to him stood a friendly looking **nurse**
And I felt something cold on my stomach, which must be the **stethoscope**
Then there was another person, probably the **surgeon**
It is not very comfortable being a **patient**
I do not like being in a **clinic**
But what I like even less is visiting the **dentist**
Originally I had an interest in **medicine**
Then I thought I better become a **lawyer**
I did not stay in good **health**
And became **sick**
I hope that there will be a quick **cure**
Hopefully I shall not be staying too long in **hospital**

**Critical Lure: Shirt**

This is a lovely blue **blouse**
I like it with long **sleeves**
And it has a nice **collar**
Oh, I will also need some **shorts**
Ideally with a **button**
In America they call them **pants**
I also like this one that looks like a **polo**
No, I prefer the **jersey**
Without any **cuffs**
Maybe I should also buy a **vest**
I also need to get a **tie**
Hopefully I have enough money in my **pocket**
And all these things do not need an **iron**