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The Development of Automatic Associative Processes and Children's False Memories

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Abstract

We investigated children's ability to generate associations and how automaticity of associative activation unfolds developmentally. Children generated associative responses using a single- (Experiment 1) or a DRM-like multiple-associates paradigm (Experiment 2). The results indicated that children's ability to generate meaningful word associates, and the automaticity with which they were generated, increased between the ages of 5, 7, and 11 years. These findings suggest that children's domain-specific knowledge base and the associative connections among related concepts are present and continue to develop from a very early age. Moreover, there is an increase in how automatically these concepts are activated with age, something that results from domain general developments in speed of processing. These changes are consistent with the neurodevelopmental literature and together, may provide a more complete explanation of the development of memory illusions.

The Development of Automatic Associative Processes and Children's False Memories

A well-established finding in the literature on children's memory is that younger children are frequently more susceptible to misinformation effects than older children and adults. This age effect has been reliably shown in studies that have used suggestibility or misinformation manipulations in order to taint children's memories (Ceci, Ross, & Toglia, 1987). Thus, the message from suggestibility research is that false memories *decrease* with age in childhood.

In contrast, over the past years, studies that have implemented the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), have shown that children's spontaneous false memories *increase* with age (Brainerd, Forrest, Karibian, & Reyna, 2006; Dewhurst, Pursglove, & Lewis, 2007; Dewhurst & Robinson, 2004; Howe, Wimmer, & Blease, 2009a). In the DRM paradigm participants study lists of words that are all associated with a non-presented word, the "critical lure". For example, "hot", "snow", "warm", "winter", "ice", and so forth, are all associated with the critical lure, "*cold*". Despite never hearing the word "*cold*", participants falsely recollect "*cold*" along with correctly remembering list items that were presented.

What the findings from these different paradigms reveal is that there exists one set of conditions under which false memories increase with age (DRM paradigm) and another set of conditions under which false memories decrease with age (suggestibility paradigm). A recent study by Ceci, Papierno, and Kulkofsky (2007) may provide some insight into why these different trends have emerged across these two paradigms. They investigated how 4- and 9-year-old children's individual associations for concepts influenced their suggestibility. Specifically, when a suggested distractor is judged to be strongly associated to an original item's representation (and these judgements differed between 4- and 9-year-olds), children's susceptibility to misinformation increased compared to when that information was less strongly associated, regardless of age. Apparently, there is an important relation between knowledge representation that is age dependent and suggestibility. That is, suggestibility is greater when it is mapped onto age-appropriate knowledge representations and the task encourages associative processing. What these results suggest is that the discrepancy between the findings for suggestibility and spontaneous false memories may be more apparent than real. Indeed, studies to date seem to show that at least one hallmark of children's false memories is the (often spontaneous) formation of associations and that the nature of these associations changes with age. In order to extend this line of inquiry and study these underlying associative processes in greater detail, we adopted a DRM-like procedure, as this has quickly become the *sine qua non* for research on associative processing in both children and adults (see Gallo, 2006).

One problem with using the DRM paradigm in child research is that the word lists that are typically used are those derived from adult word association norms (e.g., Nelson, McEvoy, & Schreiber, 1999). Research on children's memory organization, like that just reviewed (Ceci et al., 2007), suggests that although associative links between concepts appear at a relatively young age, they are further strengthened and refined with increases in both knowledge and experience (Bjorklund, 1987, 2005). Because children's knowledge base is different from adults', using adult normed word lists may explain why children have fewer false memories than adults.

Recently, three studies addressed this issue and used children's associations to construct word lists (Anastasi & Rhodes, 2008; Carneiro, Albuquerque, Fernandez, & Esteves, 2007; Metzger, Warren, Shelton, Price, Reed, & Williams, 2008). Interestingly, all three studies found that although developmental trends were considerably attenuated, false memories still tended to increase with age. These findings suggest that the increase in false memories with age cannot be

attributed solely to changes in the content or organization of children's knowledge base. Rather, as suggested in the Associative-activation theory (AAT; Howe, Wimmer, Gagnon, & Plumpton, 2009b), it is likely that these additional increases in false memory rates with age are due to increases in children's ability to automatically activate and use associative relations much in the same way as adults (Kimball & Bjork, 2002). In particular, AAT suggests that false memory development is the result of increases in the number and strength of associative relations in children's knowledge base as well as the speed and automaticity with which these associative relations are accessed and activated.

An alternative theory, Fuzzy-trace-theory (FTT; e.g., Brainerd, Reyna, & Ceci, 2008), suggests that children's memory is organized by two different memory traces: a verbatim and a gist trace. Verbatim traces encode surface features of items such as, for example, the phonological structure of a word. Gist traces encode the meaning or overall theme of a word or list of words. Children's false memories increase with age because gist extraction processes improve with age. The difference between the two theories is that FTT explains age increases in false memories in terms of coincident changes in *gist extraction* whereas AAT explains these same changes in terms of increases in the number and speed of direct *activation processes* among items in a semantic network.

Both AAT and FTT agree that for false memories to occur it is necessary to have a pre-existing lexicon of associations and this lexicon needs to be activated mentally (see also Gallo, 2006 for a more in depth discussion). Somewhat surprisingly, despite this agreement, there is little research on how children's ability to form spontaneous associations develops. The current research aims to shed more light on this. Specifically, in two experiments, we examine the development of both number and type of word associations and their interconnections in children's lexicons and the automaticity with which these items are accessed.

It has been demonstrated that children's false memories are produced less automatically than adults' (Howe, 2005). That is, when instructed to "forget" items that have been studied, both children's and adults' true memories decrease. In contrast, for false memories, only children's but not adults' decreased in comparison to a control condition with no instructions (Howe, 2005; Kimball & Bjork, 2002). Thus, when using a directed forgetting paradigm, although both children and adults can suppress true memories, only children seem to be able to suppress false memories. This lack of inhibition in adults' false memories in a directed forgetting paradigm, suggests that they are generated more automatically outside of conscious awareness. For children, these items, like items on the studied list itself, can be inhibited and appear to be treated as if they are part of the episodic list. To date, however, only Howe (2005) has investigated age differences in the automaticity of false memory generation and even this study was restricted to a single component of automaticity, namely response inhibition. Because little is known about the automaticity of children's associations, or how they come to automatically access and activate concepts in memory, the purpose of the current research is to investigate these developments in 5-, 7-, and 11-year-olds. To be precise, we examine a different aspect of automaticity than that studied by Howe (2005), namely, age changes in the speed with which children can generate associative responses. Here, we use speed of processing of an associative response as an index of automaticity. In particular, if the knowledge representation of an association is strong, then associative activation will be less effortful and faster. Less effortful and faster processing indicates automaticity. Therefore, for the purposes of the current research, we use speed of processing as an index of automaticity.

The study of age changes in speed-of-processing is well motivated from other areas of

research with children, namely, the finding that children's automaticity in solving cognitive tasks increases with age. For example, children's increase in processing speed on a variety of cognitive tasks (e.g., visual and memory search, mental rotation, mental addition) has been described by a single exponential function (Kail, 1988). This finding suggests that although the development of specific areas of knowledge may be a domain-specific characteristic of children's memory development, changes in speed of processing may be a more domain-general development, one that affects all areas of children's cognitive processing including memory and, potentially, false recollection. However, the question arises, how the development of both is connected. That is, studies that have examined false memory development have either addressed the issue of knowledge base (e.g., Howe et al., 2009b; Metzger et al., 2008) or of automaticity (e.g., Howe, 2005), but never both simultaneously.

An exception to this is an early study by Hall (1969) that gives an indication of how children's associative processes develop in relation to knowledge base and automaticity. He found that 6- and 9-year-old children have more difficulties correctly recognizing word associates that have been produced by themselves than recognizing words that have been produced by another person. This lack of memory advantage for the involvement of the self stands in contrast to an extensive literature that suggests an increased accuracy of remembering self-generated events (e.g., actions and thoughts) in comparison to external-generated events (Foley, Johnson, & Raye, 1983; Roberts & Blades, 2005). How can this discrepancy be explained? These inconsistent findings of a memory advantage for the self versus a memory disadvantage for the self, suggest that these responses are generated in a qualitatively different fashion. Specifically, Hall's (1969) finding that self-produced word associates are less well remembered suggests that they may be less conscious than ones generated by others. They may be less conscious because they may have been generated automatically based on a child's pre-existing knowledge base and the links among associations. Underwood (1965) used the phrase implicit associative responses (IARs) to describe the pattern of associations generated spontaneously by participants in response to words that have been presented.

Interestingly, Hall (1969) also demonstrated that with development, children get better at discriminating whether information was self-generated or generated by another person. Discriminating whether information is self- or other-generated is a form of source monitoring – the ability to distinguish between memories based on the origin or source of those memories (Johnson, Hashtroudi, & Lindsay, 1993). There is a large body of evidence showing that children's discrimination of internally versus externally generated actions and words increases with age (Foley, Durso, Wilder, & Friedman, 1991; Foley & Johnson, 1985; Foley, et al., 1983; Lindsay, Johnson, & Kwon, 1991; Roberts & Blades, 1998). Source monitoring errors can also be a source of false memories in adults. In particular, source monitoring has been embedded in the Activation-monitoring theory of false recollection in adults (AMT; Roediger, Balota, & Watson, 2001). Like AAT, AMT views false memories as a product of spreading associative activation processes. Unlike AAT, AMT also states that for adults whose source monitoring skills are better developed than children's, false memories occur because of source-monitoring errors. Specifically, false memories occur because participants cannot determine the source of the critical lure – whether it has been generated internally or was part of the episodic list. In fact, adult participants frequently believe that they accurately remember that a critical lure had been presented and do so with a high degree of confidence (Roediger & McDermott, 1995). Unfortunately, a source-monitoring explanation cannot account for children's increase in false memories with age because it would lead to the prediction that younger children should have more

false memories than older children because they have poorer source-monitoring skills (Johnson et al., 1993).

However, there may be conditions under which source-monitoring errors can explain children's increase in false memories with age. In particular, in conditions under which the spontaneous formation of associations is encouraged, as in the DRM paradigm, and where this association formation is derived from automatic processes, a correct source judgement may be more difficult. That is, if a "false" association is formed spontaneously then it may become part of the studied associative information and cannot be distinguished from non-presented information. Further, if false memories are generated more automatically with age, then the greater the automaticity, the more difficult a source judgment may be, resulting in a developmental reversal of source-monitoring abilities. We investigated this possibility in the current research. Specifically, we were interested in children's developing ability to discriminate self- from other-generated information when information is derived from either automatic or conscious associative processes. Moreover, we were interested in whether source confusions, like those observed in adults' false memories, can explain the increase in the number of false memories with age in childhood when those memories are generated automatically.

In sum, there are several processes that develop over childhood and their interplay may contribute to false memory formation: reorganization of knowledge, speed of processing, and source-monitoring developments. The aim of the current research was to shed more light onto the development of these processes, their interplay, and their relation to developmental increases in false memories. To do this, we used a word association task in Experiment 1 to investigate the development of children's spontaneous associative processes based on pre-existing knowledge. In Experiment 2 we investigated how children form associations between multiple word associates in a DRM-like paradigm. The crucial questions concerning children's spontaneous associations were (a) how does children's knowledge organization change with age, (b) how are spontaneous associations formed or activated when they are encouraged, and (c) does the automaticity of children's associative connections increase with age? In both experiments, we investigated how the speed of associative responses increased with age by measuring the time it took each child to generate their own word associations from their own knowledge base.

In addition, we were interested in how the development of associative representations and their activation relates to source-monitoring development and to false memories. The key question concerning source monitoring was whether we find increasing automatic processing with age is correlated with increasing difficultly judging the source of information in memory. In order to investigate this question, across both experiments we explored children's ability to discriminate the source of generated information (self versus other) as a function of whether that information is generated consciously or automatically. Investigating the development of implicit associative processes, the speed with which these associations are generated, and source-monitoring developments, as well as their relation to false memories, allows us to gain more insight into how these processes develop in isolation, in combination, and document their relevance for developmental increases in false memories.

Experiment 1

We used Hall's (1969) paradigm with slight modifications in order to investigate the development of implicit associative responses, their automaticity, and children's ability to discriminate the source of associations. We included a broader age range, 5-, 7-, and 11-year-olds, and used a two-step response mode. Children were given a word and asked to provide the first word that came to mind. We were interested in what type of responses children across

different ages would make (i.e., meaningful word associates versus non-meaningful responses). In addition, we explored whether there was a syntagmatic-paradigmatic shift in children's responses (see Nelson, 1977, for an overview). Syntagmatic refers to words from different grammatical classes that appear together in discourse (e.g., dog – bark) whereas paradigmatic refers to words from the same grammatical class (e.g., dog – cat). The time of occurrence of this shift is around the age 5-9. Specifically, in word association tasks, younger children are more likely to give syntagmatic responses in comparison to older children and adults who are more likely to give paradigmatic responses (Cronin, 2002)[1].

Our measure of automaticity was the time it took for the child to produce each association. The cue words given by the experimenter (other-generated items), the words produced by the child (self-generated items), and new items were then presented on a recognition test and children had to judge whether the words were old or new. If a word was judged old, children were required to state the source of information (self vs. other). This design allows making a distinction between recognition and discrimination. In particular, a recognition judgement (judging that an item had been represented) can be made without identifying the source of information. Therefore, in the following recognition paradigm we used a two-step response mode.

Method

Participants

A total of 106 children (61% female) participated in this experiment, 40 5-year-olds (M = 5.2, SD = 4 months), 31 7-year-olds (M = 7.4, SD = 6 months), and 35 11-year-olds (M = 11.3, SD = 6 months). All children (predominantly White and working class) were tested following parental consent and their own assent on the day of testing.

Materials, Design, and Procedure

The experiment consisted of three phases: production, distractor, and recognition. In the production phase, children were presented with 20 different words (other-generated words), one at a time in random order, and asked to produce the first word that came to mind (self-generated words). The 20 different words were child friendly, high word-frequency nouns, verbs, and adjectives (e.g., *rabbit, wash, long*) (word frequency values were obtained from Stuart, Masterson, Dixon, & Quinlan, 1993-1996) that were not directly associated with each other[2]. Children were instructed that they would be orally presented with a word and their task was to state another associated word (i.e., "I am going to say a word and I want you to say the first word that comes to your mind. For example, if I say "doctor" you could say "nurse" because they both work in a hospital or if I say "cow" you could say "milk" because cows give milk). This explicit instruction was necessary in order to prevent children from answering randomly rather than trying to generate word associates. Children first received three practise words (*bread, TV, school*), unrelated to the following 20 words, in order to familiarize them with the presentation-answer procedure. The first 31 children (10 5-year-olds; 11 7-year-olds; 10 11-year-olds) received words presented orally by the experimenter and no reaction times were recorded. The remaining 75 children received a computerized version of the task in order to measure reaction times. Out of these, 38 children saw a video of the female experimenter and 37 children of another female orally presenting 20 items. This manipulation was implemented in order to explore whether having the same person at presentation and at test (female experimenter) increased correct recognition in comparison to having a different person at presentation (another female) and at test (experimenter). After each

word presentation, the duration between stimulus-word offset and the child's word generation was measured via a button press with the right index finger of the experimenter. After word production, children received a 3½-minute distractor task (visual search game "Where is Walley?"). They then received a 60-item recognition task presented orally by the experimenter[3]. Here 20 items were stimulus words (other-generated items), 20 were response words (self-generated items), and 20 were new words unrelated to the presented or generated words. Children were instructed to say "yes" if the word appeared before (either self-generated or other-generated) and "no" if no one said the word before. If children responded "yes" to a word, they would then have to indicate the source of information: experimenter/second female presenter (other) or themselves (self).

Results

There were no performance differences when having the same person at item presentation and at test in comparison to having a different person at presentation and at test. Therefore, we combined both conditions into one analysis.

Word association task: Generation time analysis and type of word associates

In order to investigate the automaticity of word associates we analyzed how long children took to generate word associates. Initially, outliers (2 standard deviations from the mean) were removed from the analysis. Children's generation time of word associations increased significantly in speed with age, $F(2, 74) = 50.00$, $p < .001$, $?_p{}^2 = .58$. Post-hoc Bonferroni comparisons ($p < .001$) indicated that 5-year-olds ($M = 3.52$) took longer to generate word associations than 7-year-olds ($M = 2.56$) who took longer than 11-year-olds ($M = 1.18$).

Although this is a clear developmental trend, one might argue that children's decrease in reaction time with age is simply an artifact of age differences in the types of associative responses generated by children of different ages. That is, younger but not older children frequently generate irrelevant, rather than meaningful, responses to cue words. In order to exclude this possibility, we next analyzed only the generation times of children's meaningful responses. Two raters decided whether a child's response was a meaningful associate of the stimulus. A meaningful response was defined as any word that can be associated to the stimulus word on any relational dimension (i.e., taxonomy, synonymy, antonymy, entity, introspective, situational). Inter-rater reliability was high, 86%, Cohen's Kappa coefficient = .76. Disagreements were resolved through discussion.

Our first question was whether there were age differences in the number of meaningful word associations produced. Indeed, an ANOVA with the proportion of meaningful word associations generated as the dependent variable and the 3 age groups as a between-subjects factor showed a main effect for age, $F(2, 72) = 14.51$, $p < .001$, $?_p{}^2 = .29$. Post-hoc Bonferroni comparisons ($p < .001$) indicated that 5-year-olds ($M = .83$) produced fewer meaningful word associates than both 7-year-olds ($M = .96$) and 11-year-olds ($M = .98$), where the latter two age groups did not differ.

Further, we explored what type of word associates children generated out of these meaningful associates: syntagmatic (words from different grammatical classes, e.g., dog-bark) versus paradigmatic (words from the same grammatical class, e.g., dog-cat). An ANOVA with the two response types (syntagmatic vs. paradigmatic) as a within-subject factor and the three age groups as the between-subjects factor revealed a main effect for response type, $F(1, 72) = 88.95$, $p < .001$, $?_p{}^2 = .55$, where children produced more paradigmatic word associates than syntagmatic ones. Interestingly, there was an Age x Response type interaction, $F(2, 72) = 7.62$, $p = .001$, $?_p{}^2 = .18$. As confirmed by post-hoc tests, although 5-year-olds generated more paradigmatic responses

than syntagmatic ones ($p = .002$), the difference in the amount of syntagmatic versus paradigmatic responses increased with age such that 11-year-olds ($p < .001$) produced mostly paradigmatic responses (Table 1).

Second, because of these age differences in meaningful responses, it was necessary to analyze generation times of only the meaningful word associates. An ANOVA with the generation times of meaningful associates as dependent variable and the 3 age groups as a between-subjects factor revealed a main effect for age, $F(2, 72) = 46.47$, $p < .001$, $\eta_p^2 = .56$. Post-hoc Bonferroni comparisons indicated that 5-year-olds ($M = 3.40$) generated meaningful associates more slowly than 7-year-olds ($M = 2.51$, $p = .002$) and both of these age groups were slower than 11-year-olds ($M = 1.16$, $p < .001$) (Table 2). Thus, whereas overall 11- and 7-year-olds produced more meaningful word associates than 5-year-olds, the production of these meaningful associates was slower for 5- than for 7-year-olds and both of these age groups were slower than 11-year-olds.

Correct Recognition

As expected, children's correct recognition increased with age (left panel of Figure 1): $F(2, 103) = 35.06$, $p < .001$, $\eta_p^2 = .41$. Bonferroni planned comparisons ($p < .001$) indicated that 5-year-olds ($M = .70$) correctly recognized fewer items than 7-year-olds ($M = .80$) and 11-year-olds ($M = .89$), and the latter two groups also differed.

In order to control for response bias the signal detection method for computing A((Snodgrass & Corwin, 1988) was used. A value of 0.5 indicates an absence of true recognition (low accuracy – no higher acceptance rates for correct items than for unrelated distractors). A value of 1 indicates perfect true (high accuracy) recognition. When the analyses were based on A(scores, children's correct recognition increased with age, $F(2, 103) = 38.50$, $p < .001$, $\eta_p^2 = .43$. Bonferroni planned adjacent age groups' comparisons showed that 11-year-olds ($M = .97$) had almost similar levels of correct recognition as 7-year-olds ($M = .94$, $p = .083$) who recognized more than 5-year-olds ($M = .85$, $p < .001$). Overall, all A(scores were close to 1 indicating high accuracy across all ages.

Correct Recognition and Source Attribution (Self vs. Other)

First, we were interested in whether children correctly recognized self- and other-generated words and if so, whether they were able to indicate the source of generation (self v. other). Children's source attributions to correctly recognized items were analyzed using a 3(Age: 5-, 7-, and 11-year-olds) x 2(Source: self-generated vs. other-generated items) mixed ANOVA, where age was a between-subjects factor and source a within-subject factor. The results showed a main effect for source, $F(1, 103) = 75.00$, $p < .001$, $\eta_p^2 = .42$, where fewer self-generated items ($M = .61$) were correctly attributed than other-generated items ($M = .80$). There was also a main effect for age, $F(2, 103) = 64.39$, $p < .001$, $\eta_p^2 = .56$. Post-hoc Bonferroni comparisons ($p < .001$) showed that 5-year-olds ($M = .54$) correctly attributed fewer items than 7-year-olds ($M = .71$) who correctly attributed fewer items than 11-year-olds ($M = .86$) but the latter comparison was not reliable. Finally, there was an Age x Source interaction, $F(2, 103) = 5.10$, $p = .008$, $\eta_p^2 = .09$. As confirmed by post-hoc tests, the difference between correct self- and other-generated attributions decreased with age but was still significant at age 11 ($p < .05$) (right-panel of Figure 1).

Source-monitoring: Overestimation of Self- and Other-generated Responses

We were also interested in children's source-monitoring errors. For example, how many items that were judged to be produced by themselves were in reality produced by the other and vice versa? A 3(Age: 5-, 7-, and 11-year-olds) x 2(Overestimation type: self/other [items attributed to self that were in reality other generated] vs. other/self [items attributed to other that

were in reality generated by themselves]) ANOVA was conducted. The results showed a main effect for overestimation type (Table 3), $F(1, 103) = 5.45$, $p = .002$, $\eta_p^2 = .05$, where children overestimated fewer self ($M = .09$) than other responses ($M = .13$). There was a main effect for age, $F(2, 103) = 21.65$, $p < .001$, $\eta_p^2 = .30$. Post-hoc Bonferroni comparisons show that 5-year-olds ($M = .19$) overestimated more items than 7-year-olds ($M = .10$, $p = .001$) who overestimated more items than 11-year-olds ($M = .04$, $p = .062$). Thus, there was a stronger tendency to misjudge items to be produced by others that were in reality self-generated, especially for the younger children. However, overall these source confusions were very low even for 5-year-olds.

Discussion

Experiment 1 produced two key results. First, as shown in the word association task, children's lexicon of associations increases significantly in number between the ages of 5, 7, and 11 years of age. Further, also the types of associations produced changed with age. That is, although children across all age groups produced more paradigmatic than syntagmatic associates, 11-year-olds made very few syntagmatic responses. This change in type of associative response with age demonstrates a reorganization of existing knowledge (Nelson, 1977).

Second, the automaticity with which these associates are activated also increased with age. Specifically, across all three age groups, children were better at recognizing and identifying the source of information for items that were generated by another person in contrast to self-generated items and this difference decreased with age. Our findings agree with those obtained by Hall (1969) but stand in marked contrast to the usual finding of a memory advantage for the self (e.g., Foley, et al., 1983; Roberts & Blades, 2005). Perhaps these discrepant findings indicate that self-generated responses involve qualitatively different processes across different tasks and studies. In particular, the current finding that self-generated responses were less well remembered suggests that these responses occurred more automatically and outside of children's conscious awareness. Less conscious awareness implies lower level of processing, something that in turn, implies that these responses were generated relatively automatically. Thus, these current self-generated responses are implicit associative responses - implicit in the sense that they are derived from one's own pre-existing lexicon about concepts and the associative links between those concepts. Self-generated information based on implicit associative responses is qualitatively different from self-generated responses based on conscious processes, such as those generated in studies that explicitly instructed children to, for example, perform an action. The current finding that across all three age groups the memory advantage for the self disappears suggests that these implicit associative responses are already fairly automatic even by 5 years of age.

Moreover, direct evidence for an increase in automaticity of associative concepts with age comes from the generation time analysis. Here, the speed with which word associates were generated increased significantly with age. Specifically, 11-year-olds were significantly faster in generating word associates than 5- and 7-year-olds. Interestingly, although the 7-year-olds were slower than the 11-year-olds, they generated similar amounts of meaningful associative responses. This finding suggests that there is a trade-off at 7 years between knowledge and automaticity. That is, in this paradigm, although 7-year-olds' knowledge base of associations is comparable to 11-year-olds, their associative links between concepts are not activated as automatically as they are for 11-year-olds.

In addition, children's discrimination between self- and other-generated information (source-monitoring) increased significantly with age. This finding is consistent with the source-monitoring literature that suggests that 6-year-old children are already very good at discriminating between externally versus internally generated information and actions (e.g., Foley, et al., 1983;

Johnson, et al., 1993). Overall, source confusions were very low, even for our youngest age group, 5-year-olds. However, when source confusions occurred, there was a stronger tendency to misjudge items as having been produced by others, responses that were in reality self-generated, and this was especially true for the younger children. This latter result contrasts with findings from Foley and colleagues (Foley, Passalacqua, & Ratner, 1993) who demonstrated that younger children are more likely to state that an action has been self-performed when in reality, it had been other-performed than vice versa. The difference in findings from Foley et al.'s (1993) study and the current experiment may again be explained by different levels of processing involved: conscious explicitly performed actions (Foley et al., 1993) versus automatic implicit responses (current experiment).

In sum, under conditions in which associative processing is encouraged and generated internally, as in the current word association task, the memory advantage for the self disappears and the self is less likely to be judged as a source of information. Critically, these results are key to explaining the development of false memory illusions because the DRM paradigm represents one of those conditions in which associative processing is encouraged. Therefore, it is possible that the disappearance of the memory advantage for the self may partly accounts for the developmental increase in false memory generation that results from internally generated associative processes.

The question remains as to how changes in automaticity translates into increases in children's false memory rates with age, a question we address next in Experiment 2.

Experiment 2

In the previous experiment we focused on implicit associative responses to single words. In Experiment 2, we investigated how children form associations between multiple word associates and examine their relation to false memories. By using a modified DRM paradigm we explored what kind of responses children generated immediately after being presented with a list of word associates. The critical question was whether children would spontaneously produce the critical lure (i.e., the strongest associate) and whether this was more likely to occur for older children who are more likely to generate false memories. As in Experiment 1, we investigated how automatically these associates were generated and how well children discriminate the source (self or other) of presented and generated associates.

A critical question in this experiment was whether children's self-generated associates become part of the episodic list making them more difficult for children to distinguish them from the list members. Older children whose associative processes are more automatic may have particular difficulties making correct judgements about the source of information (self vs. other) resulting in more frequent source-monitoring errors. Indeed, this may explain why older children are more likely to produce false memories.

Method

Participants

A total of 65 children (62% female) participated in this experiment, 19 5-year-olds ($M =$ 5.1, SD = 3 months), 25 7-year-olds ($M = 7.2$, SD = 3 months), and 21 11-year-olds ($M = 11.1$, SD = 4 months). All children (predominantly White and working class) were tested following parental consent and their own assent on the day of testing.

Materials, Design, and Procedure

All children received a DRM word production task first and then a recognition test. Children were presented orally with 10 5-item DRM lists (*Black, Sleep, Mountain, Car, Soft, Lion, Cold, Fruit, Shirt, Foot*) with the lure's strongest backward associate removed (as we

explain later, the strongest backward associate was used only in the recognition test) (see Appendix). The lists were obtained from Roediger, Watson, McDermott, and Gallo (2001) and were chosen according to their total backward associative strength (BAS) to the critical lure. It was important to have lists that were relatively high in BAS in order to increase the likelihood of eliciting the critical lure. The lists comprised the 2nd to 6th strongest associates of each critical lure and were presented via a video of a female presenter on a computer screen, as in Experiment 1.

In the *word production paradigm* children were instructed that they would be presented with a list of words and, in contrast to Experiment 1 where children were explicitly instructed to generate word associates, children were explicitly instructed to generate the first word that came to their mind. This instruction was necessary in order to explore whether the presentation of 5-item DRM lists spontaneously elicits the critical lure.

First, children received two practice lists (i.e., *high, bread*) that were not associated with the 10 DRM lists that followed in order to familiarize them with the procedure. Next, children were presented with the first 5-item list (other-generated items) and asked to generate the first word that came to mind (self-generated items). There were four possible outcomes for children's answers: (1) children could generate the unpresented *critical lure*, (2) children could generate the unpresented *strongest associate* that was removed from the list, (3) children could generate a *related item* that was not part of the list, or (4) children could generate an *unrelated item* that was not associated to the presented items. As in Experiment 1, children's generation time was measured between the offset of the last list item and the onset of their own associate. Children's answers were written down and used in the later recognition task; as before, answers varied from child to child. This procedure was continued for the remaining 9 of the total 10 lists.

After a 3½-minute distractor task ("Where is Walley?"), all children received a 60-item recognition task presented orally by the experimenter. This included the 10 self-generated items, 10 critical lures (if a child generated the critical lure in the word-production paradigm it was replaced with the unpresented strongest associate), 10 weakly related but unpresented items, and 30 correct list items. Children had to say "yes" if the word appeared before (either self-generated or other-generated) and "no" if the word had not been presented before. If children responded "yes" they had to indicate the source of information (self vs. other).

Results

We begin by examining age differences in the number of critical lures, strongest associates, related items, and unrelated items produced during the generation task. We follow this by examining age differences in generation times. Finally we examine differences in the subsequent recognition task including source identification.

Age Differences in Item Generation

Critical Lures

The proportion of critical lures produced increased with age, $F(2, 62) = 11.61$, $p < .001$, $?_p^2 = .27$. Post-hoc Bonferroni comparisons of adjacent age groups indicated that 5-year-olds ($M = .11$) produced fewer critical lures than 7-year-olds ($M = .20$), although not significantly more, and 7-year-olds produced fewer lures than 11-year-olds ($M = .38$, $p = .003$) (Figure 2).

Strongest Associates

Almost none of the strongest associates to the critical lure were produced and this was the case for all age groups, 5-year-olds ($M = .005$), 7-year-olds ($M = .006$), and 11-year-olds ($M = .007$) (Figure 2).

Related Items

Like critical lures, the proportion of related items produced increased with age, $F(2, 62) = $

6.97, $p = .002$, $\eta_p^2 = .18$. Post-hoc Bonferroni comparisons of adjacent age groups indicated that 5-year-olds ($M = .28$) produced fewer related items than 7-year-olds ($M = .50$, $p = .01$) who produced similar amounts of related items as 11-year-olds ($M = .53$) (Figure 2).

Unrelated Items

In contrast, the amount of unrelated items produced decreased with age, $F(2, 62) = 19.58$, $p < .001$, $\eta_p^2 = .39$. Post-hoc Bonferroni comparisons of adjacent age groups indicated that 5-year-olds ($M = .61$) produced more unrelated items than 7-year-olds ($M = .30$, $p = .001$) who produced more unrelated items than 11-year-olds ($M = .07$, $p = .02$) (Figure 2). Thus, younger children spontaneously generated considerably fewer meaningful items than older children.

Generation Time Analyses

Here, we were interested in how long children took to generate an item. As in Experiment 1, outliers (2 standard deviations from the mean) were removed from the analysis. Next, we divided answers into meaningful associations produced (either critical lures, strongest associates, or related items) versus non-meaningful associations produced. Children's time to produce meaningful associations decreased significantly with age, $F(2, 57) = 6.83$, $p = .002$, $\eta_p^2 = .19$. Post-hoc Bonferroni comparisons indicated that 5-year-olds ($M = 4.11$) did not differ in time to generate meaningful word associations to 7-year-olds ($M = 3.28$), but both age groups took longer than 11-year-olds ($M = 1.48$, $p = .032$) [4]. In contrast, an analysis of the non-meaningful items that were produced did not reveal an age effect, $F < 1$ (Table 4). Thus, there was no age effect in generation times for non-meaningful associates but a significant effect for meaningful word associates. This dissociation suggests that older children are not faster *per se*. Rather, this effect is specific to the generation of meaningful word associates, something that is more automatic in older than younger children.

Age Differences in Recognition

Correct Recognition Other-generated Items

First, we analyzed correct recognition of other-generated items. An ANOVA with correct recognition of other-generated items as dependent variable and age group as the between-subjects factor indicated that children's correct recognition of presented items increased with age, $F(2, 62) = 11.91$, $p < .001$, $\eta_p^2 = .29$. Post-hoc Bonferroni comparisons of adjacent age groups indicated that 5-year-olds ($M = .52$) recognized fewer items than 7-year-olds ($M = .68$, $p = .011$) who had similar levels of recognition as 11-year-olds ($M = .78$). Further, source errors (judging that children themselves generated the item) were very low for all ages: 5-year-olds ($M = .02$), 7-year-olds ($M = .02$), and 11-year-olds ($M = .004$).

False Recognition of Critical Lures and Strongest Associates

In contrast to correct recognition, analyses of children's false recognition of critical lures combined with the strongest associates showed no age effects[5] (5-year-olds: $M = .43$; 7-year-olds: $M = .51$; 11-year-olds: $M = .46$). The same results were obtained when analyzing A(scores (5-year-olds: $M = .71$; 7-year-olds: $M = .76$; 11-year-olds: $M = .73$). However, when we analysed only false alarms to critical lures based on the number of critical lures that were given to each participant we found the expected age increase in false memories that was approaching significance; $F(2, 62) = 2.73$, $p = .073$, $\eta_p^2 = .08$. Bonferroni adjacent age groups' planned comparisons ($p = .048$) indicated that 5-year-olds ($M = .43$) had fewer false alarms to critical lures than 7-year-olds ($M = .60$) who in turn did not differ from 11-year-olds ($M = .61$). Further, if children falsely judged the critical lure or strongest associate to have been presented, they were more likely to judge that the item was part of the list than self-generated, $F(1, 62) = 718.42$, $p < .001$, $\eta_p^2 = .92$. There was no effect for age and no interaction.

Correct Recognition Self-generated Items

Next, we were interested in how well children recognized items that were self-generated. Children's recognition of self-generated items increased significantly with age, $F(2, 62) = 14.00$, $p < .001$, $\eta_p^2 = .31$. Post-hoc Bonferroni comparisons of adjacent age groups indicated that 5-year-olds ($M = .67$) recognized similar amounts of self-generated items as 7-year-olds ($M = .76$) both of whom recognized fewer items than 11-year-olds ($M = .91$, $p = .002$) (Table 5). Further, source errors (judging the item as other-generated) were fairly low for all ages: 5-year-olds ($M = .31$), 7-year-olds ($M = .18$), and 11-year-olds ($M = .22$) and none of these differences were reliable (Table 5).

We were also interested in how well those children who produced critical lures ($N = 46$; 9 5-year-olds, 17 7-year-olds, 20 11-year-olds) correctly recognized their self-generated critical lure and whether they were likely to confuse their self-generated critical lure with being part of the episodic list. Children across all ages recognized the lure as self-generated and there was a main effect for age, $F(2, 43) = 3.84$, $p = .029$, $\eta_p^2 = .15$. Post-hoc Bonferroni comparisons of adjacent age groups indicated that 5-year-olds ($M = .88$) recognized similar amounts of self-generated lures as 7-year-olds ($M = .69$) who recognized fewer lures than 11-year-olds ($M = .93$, $p = .032$). Moreover, source errors (judging the lure as other generated) decreased with age (all $ps > .05$): 5-year-olds ($M = .44$), 7-year-olds ($M = .35$), and 11-year-olds ($M = .30$). Thus, there is no reverse source-monitoring effect with age in relation to false memories. However, these source errors were higher in comparison to Experiment 1 (Table 3 versus Table 5).

Discussion

Consistent with the findings of Experiment 1, the novel DRM word-association paradigm showed that children's ability to generate meaningful word associates and most importantly, the number of critical lures spontaneously produced increased significantly with age. Thus, this novel paradigm demonstrates that the older children get, the more spontaneously relational information is accessed in memory. In addition, the generation of these word associates becomes increasingly automatic with increasing age, as indicated by the generation-time analyses. These findings add to the findings from Experiment 1 and suggest that there are significant increases in the automaticity with which children access and activate associations in their pre-existing knowledge base over the primary school period. However, despite this increase in automaticity, even older children did not confuse their self-generated lures as being part of the episodic list. It was hypothesized that if older children's false memories are derived from more automatic associative processes, then the critical lure may become part of the episodic list, something that in turn may make it increasingly difficult to correctly indicate the source. However, this was not the case. Once children produced the critical lure, they were more likely to recognize it and attribute the source to themselves. However, overall source errors were higher in comparison to Experiment 1, which suggests that the self-generation of the critical lure elicits more source confusions than an implicit associative response to a single word. It is possible, that source errors increase with increasing number of presented list items. That is, here we used a 5-item paradigm and this may have made it easier for older children to correctly reject information.

Interestingly, when children were questioned about whether the critical lure had been self- or other-generated, older children were more likely than younger children to correctly identify that they had generated the lures themselves. This additional prompting, something that is not typical in the standard DRM paradigm, may have caused older but not younger children to reflect on the source of information in their memory. This finding is consistent with metamemory research (e.g., Ghetti, 2003) that shows that children who are 8 years of age and older can reflect on and

use source information to edit memory. Such metamemorial information can be used to correctly reject items that did not appear on the list only when those items are recognized as having been self-generated. Correct rejection of information that has been consciously recognized as self-generated may occur either because this information gives rise to stronger verbatim representations of the source of such information (perhaps enabling the use of a recollection-to-reject strategy; see Brainerd, Reyna, Wright, & Mojardin, 2003) or because self-generated information gives rise to some other memorability-based strategy (e.g., Carneiro, Fernandez, & Dias, 2009; Ghetti, 2003).

General Discussion

The paradigm developed in the two experiments let children create their own individual associations, in their own time, and based on their own individual knowledge base. Whether word associations were derived from a single word (Experiment 1) or from a list of word associates (Experiment 2), children's ability to generate meaningful word associates increased significantly over the primary school period. Not only did the number of meaningful word associates that were produced increase with age, but there was also a reorganization of children's pre-existing knowledge with increasing age. Specifically, in Experiment 1, 11-year-olds responded almost exclusively with paradigmatic associates in contrast to 5- and 7-year-olds who produced both syntagmatic and paradigmatic associates. As Nelson (1977) has noted, the syntagmatic-paradigmatic shift can be an indication for a reorganization of children's pre-existing knowledge. This finding is consistent with studies of memory organization that suggest that the quantity and quality of associative relations between old and newly acquired concepts continue to undergo significant changes with development (Bjorklund, 1987, 2005). As children's knowledge base increases, their conceptual representations and the associative links among related concepts become better integrated in memory (Howe, 2000). With this in mind, studies exploring children's false memory development have created their own word lists based on children's aggregated word association norms (Anastasi & Rhodes, 2008; Carneiro, et al., 2007; Metzger, et al., 2008). Despite using child appropriate lists, and although attenuated, developmental trends in false memories were still observed.

Theories of the reasons for the increase in children's false memories with age (e.g., AAT and FTT) agree that a necessary prerequisite for false memories to occur is a pre-existing lexicon of associations and the mental activation of this lexicon. The current research has tried to empirically operationalize how this pre-existing lexicon of associations unfolds in development and how the automaticity with which items and associations are activated in this lexicon changes with age. The present research adds to the growing answer to these questions. In particular, we have shown that the number and type of meaningful associations produced by children increases and changes significantly with age. Interestingly, these self-generated associations appear to be generated outside of conscious awareness because they were significantly less well remembered than other-generated information (Experiment 1). What this finding suggests is that self-generated associates are derived from more automatic processes. Consistent with this suggestion is the finding that when presented with a DRM-like paradigm, as age increased, children were more likely to generate the critical lure spontaneously even when they were not explicitly instructed to generate an associative response (Experiment 2). Finally, direct support for the argument that automaticity of associative activation increases with age can be found across both experiments. Specifically, the speed with which children were able to generate meaningful associations increased significantly as age increased. Importantly, these increases in automaticity were observed solely for meaningful responses and not for non-meaningful output. Thus, it is not

simply an across-the-board change in speed of processing that occurs in children's knowledge base with age rather changes are directly related to the additional experience and strengthening of meaningful relations in children's associative memory.

That the number of concepts in a child's knowledge base increases, and that they become better integrated with existing concepts in memory, is one part (the domain specific part) of the story concerning the development of memory illusions. However, according to the current experiments that it is not the entire story concerning the development of false memories. The missing link concerns the domain general increase in children's speed of processing and its corresponding impact on the automaticity of memory processes, including associative ones.

There is ample evidence from a vast array of other research domains showing that children's task performance improves over the primary school period (e.g., verbal memory, visual and memory search, mental rotation, mental addition, use of mental imagery) and that all or much of this improvement can be explained by increased speed of processing (Kail, 1988, 1997; Kail & Park, 1994). Indeed, there is no reason to believe that this domain general increase in speed of processing should not also impact on meaningful associative memory processes in children's recollection, making memory search not only faster but also more automatic. When memory search becomes more automatic, it produces information more rapidly for retrieval. However, this comes at a price, namely, the activation of unpresented but related information. As automaticity increases with age over the primary school period, so too does false memory production.

Neurodevelopmental research also supports this domain general notion. In particular, it has been suggested that frontal and associative areas of the brain (prefrontal and lateral temporal areas) are the last to mature, resulting in the late development of higher-order executive and associative functions (see Craik, 2006, for a review). Specifically for memory and false memory development, it has been found that immaturities in the medial temporal lobe and the prefrontal cortex (left ventrolateral area) can explain age-related differences in false memories (Paz-Alonso, Ghetti, Donohue, Goodman, & Bunge, 2008). In contrast, knowledge and memory representations develop from birth and mature gradually during childhood. Thus, there are different neurodevelopmental trajectories associated with changes in cognitive representation and cognitive control (Craik & Bialystok, 2006). Altogether, there are three lines of evidence that support the notion that the increase in false memories with age cannot be solely explained by an increase in knowledge base: neurodevelopmental research, research that has used child-normed DRM lists or age-normed associates in a suggestibility paradigm, and the current findings. What changes with age is not only how knowledge is organized but also the automaticity with which this pre-existing knowledge is accessed and activated.

Finally, it is of considerable interest that regardless of age, children were better at recognizing and identifying the source of information for items that were other-generated than self-generated items. Moreover, children's discrimination between self- and other-generated information (source-monitoring) increased significantly with age. Overall, source confusions were very low, even for the youngest children studied here, the 5-year-olds. Together, the findings on source discrimination are consistent with the more general literature on children's source monitoring and suggests that even 5-year-old children are already very good at discriminating between externally- and internally-generated information and actions (e.g., Foley, et al., 1983; Johnson, et al., 1993).

However, even though source indication was reliable, self-generated information was less well recognized than other-generated information (Experiment 1). This latter result shows there is a memory disadvantage for self-generated events if they are based on implicit associative

processes, something that could increase false memory rates. This memory disadvantage may become particularly apparent under conditions in which multiple associates are presented and where internal implicit associative processing is encouraged, as in a typical DRM paradigm. Thus, the DRM paradigm, due to its associative nature, elicits a memory disadvantage for the self in contrast to other paradigms that do not encourage internal implicit associative processing *per se*.

How do the current findings fit into the three theories on the formation of false memories? As noted above, FTT (Brainerd, et al., 2008) suggests that false memories are a result of gist extraction mechanisms and children's false memories increase with age because their ability to extract the gist from presented information increases. Gist can be extracted from a single item of from a number of items. The findings from both of our experiments are consistent with FTT inasmuch as they showed that with increasing age, children were more likely to produce meaningful word associates. However, with respect to the findings concerning developmental increases in the automatic activation of associations in children's knowledge base, FTT does not make any specific claims.

AMT (Roediger et al., 2001) suggests that false memories are a product of associative activation processes and of source-monitoring errors. Specifically, false memories occur because participants cannot determine the source of the critical lure – whether it has been generated internally or was part of the episodic list. Consistent with AMT, the current findings (particularly Experiment 2) showed that the production of critical lures was more automatic in 11-year-olds than younger children (i.e., as shown in the generation time analysis). However, despite greater automaticity in older than younger children, there were no reverse age trends in children's source monitoring ability. Of course, it is possible that 11-year-old's false memories are still less automatic than those of adults and this may be why there was no reverse source-monitoring effect. Thus, although AMT can explain false memories in adults, it runs into difficulty when trying to account for developmental increases in false memory rates in childhood.

However, this does not mean that the development of certain metamemorial skills does not contribute to age changes in false memory. For example, recent research has demonstrated that children can use metamemorial information to correctly reject items that did not appear on the list, but only when those items are recognized as having been self-generated (Ghetti, 2003). Specifically, children can correctly reject information that has been consciously recognized as self-generated with the use of a recollection-to-reject strategy (Brainerd, et al., 2003) or with the use of a memorability-based strategy. The older children get, the more likely they are to use such strategies spontaneously (e.g., Carneiro, et al., 2009; Ghetti, 2008). Thus, there are opposing processes developing over childhood: ones that can reduce false memories (e.g., recollect-to-reject, memory editing, source-monitoring, or memorability-based strategy) and ones that can increase false memories (e.g., reorganization of knowledge, associative processing, and automatic associative activation).

This distinction is important because it may explain why false memories increase in some paradigms (e.g., DRM) and decrease in other paradigms (e.g., misinformation) with age. For example, whenever the paradigm relies on internally generated semantic processes that occur outside of conscious awareness, false memory rates tend to increase with age (e.g., in the DRM task; also see Ceci et al., 2007). Alternatively, whenever the paradigm relies on semantic processes whose generated contents are subject to conscious awareness, false memory rates tend to decrease with age as consciously controlled strategies (e.g., source-monitoring, memory editing strategies) can be used to edit memory outputs. Such speculation is also consistent with our

findings concerning the role of the self in memory. Specifically, what our research has shown is that the memory advantage typically observed for the self disappears if associative information is generated automatically outside of conscious awareness. When information is remembered as self-generated, memory-editing strategies can be used effectively to "correct" output during retrieval. That is, in order to correctly reject a memory that is false, memory for self-generated information may be a prerequisite.

Finally, AAT (Howe et al., 2009b) suggests that children's false memories are a product of associative activation processes. Children's false memories increase with age both because of changes in children's knowledge base (addition of new concepts and semantic relations, knowledge reorganization) and changes in the automaticity of associative activation. Altogether, the current findings fit well with AAT's claims that age increases in false memory development involve both domain specific (growth and reorganization of children's knowledge base) and domain general (increased automaticity of processing) developments.

The present experiments are a first step toward realizing a more complete theory of the changes in the content and structure of children's knowledge base, the age-related changes in the automaticity of conceptual processing within this knowledge base, and how these factors conjoin to bring about the development of memory illusions. We have reintroduced one measurement tool (in Experiment 1) based on some of Hall's (1969) earlier work and introduced a new paradigm (Experiment 2), one based on modifications of the DRM procedure, that can be used to investigate these developments. Using these novel procedures, we have been able to conclude that children's knowledge base of conceptual representation and the associative connections among related concepts are present and continue to develop from a very early age. This knowledge base of associative relations is domain specific and is gradually refined and changed with age, changes that are consistent with what we know from recent neurodevelopmental research and from studies that have used child-normed associative word lists. In addition, there are increases in the automaticity with which these concepts are activated, increases that also help explain the developmental changes in false memory production. Overall, conditions that encourage associative processing, such as in a DRM paradigm, can lead to developmental increases in false memory generation as children's knowledge representation changes with age and associative processing becomes increasingly spontaneous and automatic. It would seem that the DRM paradigm and its many modifications represents not just a powerful research tool to study false memory illusions and their development, but also affords us greater insight into children's memory organization and the development of automatic processes children use when activating and accessing mental representations.

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Appendix

Overview of the word lists used in Experiment 2 (taken from Roediger, Watson, McDermott, & Gallo, 2001). Total BAS (backward associative strength: likelihood that the list items elicit the critical lure) and FAS (forward associative strength: likelihood that the critical lure elicits the list items) values refer to the list items and do not include the BAS or FAS of the strongest associate. This is because the latter was not presented. Word Frequency (WF) values obtained from Stuart, Masterson, Dixon, and Quinlan (1993-1996) for each lure, the strongest associate (in parenthesis below), and list items are also presented.

Critical Lure	Strongest Associate	List Items	Total BAS	Total FAS	Total WF
Black (360)	White (441)	Gray	1.176	0.15	1054
		Brown			
		Coal			
		Dark			
		Colour			
Car (714)	Vehicle (5)	Automobile	2.516	0.255	338
		Garage			
		Drive*			
		Van			
		Keys			
Cold (446)	Hot (479)	Shiver	2.737	0.022	79
		Arctic			
		Frigid			
		Freeze			
		Chilly			
Foot (135)	Toe (14)	Ankle**	1.224	0.459	462
		Shoe			
		Sandals			
		Sock			
		Hand			
Fruit (133)	Kiwi (0)	Citrus	1.506	0.147	119
		Pear			
		Berry			
		Vegetable			
		Banana			
Lion (314)	Roar (122)	Tamer	1.206	0.446	281
		Tiger			
		Mane			
		Fierce			
		Den			
Mountain (173)	Climber (5)	Hill	1.418	0.428	546
		Climb			
		Molehill			
		Peak			
		Valley			
Shirt (32)	Blouse (3)	Sleeves	1.366	0.416	162
		Collar			
		Shorts			
		Button			
		Pants			
Sleep (557)	Nap (14)	Doze	2.972	0.255	823
		Bed			
		Awake			
		Snooze			

		|Slumber				
Soft	Hard	Loud	1.353	0.018	187	
(160)	(471)	Tender				
		Fluffy				
		Pillow				
		Downy				

*The item "sedan" was replaced with the word "drive", which is more appropriate for British children.
** The item "inch" was replaced with the word "ankle", which is more appropriate for children in this age range.

Footnotes

[1] The syntagmatic-paradigmatic shift is also dependent on the grammatical type of a word, where nouns produce a high-rate of paradigmatic responses but adjectives and verbs produce lower rates.

[2] The words were chosen in order to have a variety of non-associated nouns, verbs and adjectives and so that the strongest associate, according to the Nelson, McEvoy, and Schreiber (1999) norms, was associated with the stimulus word on any relational dimension (5 antonyms, 5 entity, 4 situational, 3 synonyms, and 3 taxonomy) according to the Wu and Barsalou (2007) norms (cf. Brainerd, Reyna, & Ceci, 2008). Out of the 20 items, 10 were from the DRM paradigm that fitted into those criteria - 5 critical lures and 5 strongest backward associates to a critical lure. Importantly, the words were chosen according to word frequency values of children's vocabulary form the Stuart, Masterson, Dixon, and Quinlan's (1993-1996) word frequency norms that contain norms of British children's printed vocabulary over the primary school.

[3] Each recognition task differed in the individually self-generated words from child to child.

[4] When reaction times were analysed separately for the critical lures generated, we found a trend in the same direction ($p = .08$). However, because younger children produced significantly fewer critical lures than older children (9 5-year-olds; 17 7-year-olds; 20 11-year-olds), the Ns were skewed and age effects were reduced.

[5] This is most likely to be a result of older children being more likely to produce the critical lure beforehand in the production paradigm. That is, if they produced the critical lure themselves, it was replaced with the strongest associate as a critical lure in the recognition paradigm. Thus, at recognition younger children were presented with more critical lures and fewer strongest associates whereas older children were presented with fewer critical lures and more, strongest associates reducing the probability of eliciting a false response for older children.

Table 1. Children's syntagmatic and paradigmatic responses as a function of age group (SDs in parentheses).

Age Group	Syntagmatic	Paradigmatic
5-year-olds	.39 (.16)	.59 (.17)
7-year-olds	.33 (.21)	.67 (.21)
11-year-olds	.23 (.14)	.78 (.12)

Table 2. Children's reaction times (seconds) for generating meaningful word associates as a function of age group (SDs in parentheses).

Age Group	Reaction Time
5-year-olds	3.40 (1.10)
7-year-olds	2.51 (.85)
11-year-olds	1.16 (.45)

Table 3. Children's source-errors: Mean overestimation of self (items recognized as generated by themselves that were in reality other generated) and other (items that were recognized as generated by the other that were in reality generated by themselves) responses (SDs in parentheses).

Age Group	Overestimation Self	Overestimation Other
5-year-olds	.17 (.18)	.2 (.13)
7-year-olds	.07 (.12)	.12 (.10)
11-year-olds	.04 (.05)	.05 (.05)

Table 4. Reaction times (RT, seconds) for self-generated meaningful and non-meaningful items (SDs in parentheses).

Age Group	RT Meaningful	RT Non-Meaningful
5-year-olds	4.11 (2.50)	6.52 (2.69)
7-year-olds	3.28 (2.86)	5.04 (5.86)
11-year-olds	1.48 (.87)	4.06 (3.44)

Table 5. Mean correct recognition of self-generated items and source-errors (judging an item as other-generated) plus mean correct recognition of self-generated lures and source errors (N = 46) (SDs in parentheses).

Age Group	Self-Generated Items	Source-Errors	Self-Generated Lures (N = 46)	Source-Errors (N = 46)
5-year-olds	.67 (.16)	.31 (.24)	.88 (.19)	.44 (.31)
7-year-olds	.76 (.17)	.18 (.19)	.69 (.33)	.35 (.35)
11-year-olds	.91 (.78)	.22 (.19)	.93 (.23)	.30 (.27)

Figure Captions

Figure 1. Children's mean correct recognition and correct recognition plus attribution for self- and other-generated items.

Figure 2. Children's production of the critical lure, strongest associate, related item, and unrelated item as a function of age.