Using Story Contexts to Bias Children's True and False Memories

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Abstract

The effects of embedding standard Deese/Roediger-McDermott (DRM) lists into stories whose context either biased interpretation towards or away from the overall theme of the DRM list on both true and false recognition were investigated with 7- and 11-year-olds. These biased story contexts were compared to the same children's susceptibility to false memory illusions using the standard DRM list presentation paradigm. The results showed the usual age effects for true and false memories in the standard DRM list paradigm, where 11-year-olds exhibited higher rates of both true and false recognition compared to the 7-year-olds. Importantly, when DRM lists were embedded in stories, these age effects disappeared for true recognition. For false recognition, although developmental differences were attenuated, older children were still more susceptible to false memory illusions than younger children. These findings are discussed in terms of current theories of children's false memories as well as the role of themes and elaboration in children's memory development.

Key Words: Children's false memories; DRM paradigm; Associative-activation theory; Fuzzy-trace theory; Memory development; Story memory

Using Story Contexts to Bias Children's True and False Memories

The Deese/Roediger-McDermott (DRM; Deese, 1959; Roediger & McDermott, 1995) paradigm is perhaps the most robust procedure used to investigate the development of children's spontaneous (as opposed to implanted or suggested) false memories (for a review, see Brainerd, Reyna, & Ceci, 2008). Here, participants are presented with a list of words (e.g., *sour, candy, sugar, bitter*) that are all associates of an unpresented but related concept, the critical lure (e.g., *sweet*). Recall and recognition tests reveal that subjects frequently mistakenly identify the critical lure as having been present on the previously studied list. More importantly, developmentally, younger children are less susceptible than older children and adults to spontaneous false memory illusions (Brainerd et al., 2008).

There are two main explanations concerning the development of false memories in children. First, fuzzy-trace theory (Brainerd et al., 2008) suggests that there are two qualitatively different memory traces that are formed in parallel, a verbatim trace that preserves surface details of studied material and a gist trace that preserves the meaning of the information that was studied. The retrieval of verbatim traces typically results in the correct recognition and recall of targets and the dismissal of semantically related critical lures. However, because these traces fade fairly rapidly, later tests of recall and recognition may rely more on gist traces, ones that are more likely to produce meaning related errors including false memory illusions. Thus, according to fuzzy-trace theory, a reliance on gist traces at retrieval can increase false memory rates and decrease true memory rates, whereas a reliance on verbatim traces can increase true memory rates and reduce false memory rates. More specifically, false memories can occur through one of two retrieval processes, similarity judgements between a gist trace and a possible memory candidate or phantom recollection in which strong gist traces permit memory reconstruction that includes related but unpresented items. Fuzzy-trace theory predicts false recognition reversals as these two retrieval processes can give rise to both accurate and inaccurate memories. That is, under conditions of gist cuing, there should be a monotonic increase in both true and false memory whereas under verbatim cuing, there should be a negative relationship between true and false memory. Developmentally, fuzzy-trace theory contends that the DRM illusion is less robust in young children because their ability to extract and encode the global gist (theme) of a DRM list is relatively immature. As children develop, their ability to extract gist improves and thus, they become more susceptible to these spontaneous false memory illusions (Brainerd et al., 2008).

An alternative theoretical account of false memory development is the associative-activation theory (Howe, 2005; Howe, Wimmer, & Blease, 2009a; Howe, Wimmer, Gagnon, & Plumpton, 2009b). This theory stipulates that associative activation of concepts in one's knowledge base is responsible for false memories in children and adults. The knowledge base consists of networks of interrelated concepts whose organization changes with development and experience. There are strong links between concepts that are highly related and weak or absent links between concepts that are less related (Gallo, 2006). When a specific concept or word is encountered, its corresponding memory representation is activated, activation that can spread to surrounding related representations in the knowledge base, including theme nodes that are related to the subset of concepts being activated (also see Arndt & Reder, 2003). These theme nodes exist like other nodes in the network and individual concepts can be linked to multiple themes (see Figure 1). When DRM or associative lists are studied, a number of different themes are activated, each of which can give rise to false recollection. Of course, lists evoking fewer themes give rise to false memories more easily than lists with more potential themes as each list member provides activation for a smaller set of potential themes (see Figure 1 for an illustration). Recall that because these lists are associative and there can be many potential integrating themes (e.g., relations can be varied and include temporal continguity, spatial proximity, feature overlap, shared perceptual properties, category membership, antonymity, synonymy; see Wu & Barsalou, 2009), lists with fewer themes stand a greater chance of activating a single theme more quickly, one whose overall activation may be greater than lists with more themes (also see Arndt & Reder, 2003; Reder, Park, & Kieffaber, 2009). Such activation, not just backward associative strength, can increase false memory rates.

The use of theme nodes brings associative-activation theory and fuzzy-trace theory into greater alignment. Some might argue that the introduction of theme nodes into what has been viewed as "simple" word association models is ad hoc and borrows heavily from fuzzy-trace theory's historically preeminent gist mechanism. However, a quick glance at the historical roots of associative memory models will prove this thinking wrong for at least two reasons. First, associative memory models have been around for centuries (e.g., Hamilton, 1859; Stewart, 1813; for a recent review, see Danziger, 2008), with twentieth century versions including assumptions about spreading activation in memory networks that flexibly represent multiple layers of meaning (Anderson, 1976, 1983, 1993; Anderson & Bower, 1973; Collins & Loftus, 1975). Second, because concepts can contain multiple meanings, depending on the context in which they occur, associative models have long acknowledged the importance contextual biasing of meaning. Context can refer to a number of different biasing conditions including physical features (e.g., font in which words appear, the room in which one hears or sees the word), internal states and emotional features (e.g., whether a person is hungry at the time, the person's current mood state), as well as other concepts in which the word is presented. A classic example of the latter point concerns biasing the meaning of the word "jam" as when it appears with the word "strawberry" or the word "traffic." Clearly, words do not always have simple one-to-one associations but rather have many-to-many as seen in Figure 1. Thus, what associations are activated by presentation of a list depends on a host of factors including the context in which it appears (also see Ayers & Reder, 1998).

Given the long-standing history of context effects in associative memory models, and the fact that they have been implemented in studies of misinformation effects (e.g., Ayers & Reder, 1998) and false memories (e.g., Arndt & Reder, 2003; Howe & Derbish, 2010) in adults, it is curious that they have not been implemented in models of false memory development. Indeed, fuzzy-trace theory has been the only model to adequately account for these effects developmentally. The primary purpose of this article is to show how associative models can also account for false memory development in the presence of contextual bias. To do this, we use a more traditional psycholinguistic paradigm designed to examine meaning errors when words are embedded in sentences which are in turn embedded in stories.

In this paradigm, the sentences and stories serve as a context that biases the interpretation of words toward a particular theme. The introduction of theme nodes in associative models is straightforward (see Reder et al., 2009). In associative-activation theory, theme nodes are just some of many concepts activated along associative pathways during encoding (e.g., see Howe & Derbish, 2010). As illustrated in Figure 1, when participants are presented with words such as *dog* and *cat,* the theme node *animal* might be activated along with other competing themes (e.g., *pet*, *domesticated, warm-blooded*). In addition, these theme nodes can activate other related but unpresented concepts (e.g., *horse*, *donkey*, *zebra*) and any additional concepts that are presented (e.g., *cow, pig*, *sheep*) can also activate other related concepts (e.g., *deer, elk, moose*) directly and indirectly, including other theme nodes (e.g., *herbivores, edible*). Only when a concept has been activated to some minimum threshold level will the word be recollected (either correctly or incorrectly). Although there are a host of variables affecting strength of presented and unpresented items in memory, in general, the more concepts each presented word activates (via direct associations or indirectly via themes) or the more pathways its activation spreads, the weaker the activation for each of the individual nodes. Thus, words that have fewer potential connections to other concepts and theme nodes tend to more strongly activate the concepts related directly to them and other, unpresented concepts indirectly through related theme nodes.

To date, much of the research that has examined the development of children's spontaneous false memories has relied on the standard DRM list-learning paradigm. However, the questions that arise from a consideration of both associative-activation theory and fuzzy-trace theory is whether there is any evidence that children's spontaneous false memories occur using materials other than word lists and whether the use (implicit or explicit) of contexts or themes alters the typically observed developmental increase in true and false memories. Fortunately, a few studies using different materials and procedures, ones that enhance theme availability, do exist. For example, Paris and Carter (1973) found that 7- and 10-year-olds incorrectly identified unpresented sentences that were semantically related to the sentences that they had previously been exposed to, as being present in the studied material. Brown, Smiley, Day, Townsend, and Lawton (1977) found that participants aged 8 years and older who had previously been presented with a story falsely recognized sentences that were similar to those in the story. More recently, Dewhurst, Pursglove, and Lewis (2007) reasoned that if they embedded DRM lists in a story format, one that emphasized the overall theme of the list, children's false memories should increase. They examined true and false recollection in 5-, 8-, and 11-year-olds who were either exposed to standard DRM lists or to DRM lists that had been embedded in a story that emphasized the theme of the list. Subsequent recognition tests revealed that older children (8- and 11-year-olds) had higher rates of false memories for the critical lures in the standard DRM list condition than younger children (5-year-olds). By contrast, for the stories, only the younger children showed higher rates of false recognition for the critical lures than when words were presented in standard list format and their false recognition rates increased to levels comparable to that of the older children. Interestingly, the older children's false memory rates were not enhanced when DRM lists were embedded in stories, something that was inconsistent with the prediction that all children's false memory rates, regardless of their age, should be elevated when DRM lists are embedded within a story format.

Other research has used thematic cuing to increase children's false memory rates. Here, when children are told in advance that the lists of words they were about to hear are related, levels of false recognition increase (Brainerd et al., 2008). Using a somewhat different technique, Odegard, Holliday, Brainerd, and Reyna (2008) cued the theme (or gist) of each individual word on standard DRM lists. In this cuing study, 11-year-olds and adults were exposed to DRM lists that had been structurally modified so that each word on the list was paired up with a "context" word, a word that served to bias the meaning of the list item either toward or away from the overall theme of the list. The findings revealed that 11-year-olds had higher false memories rates for critical lures when the DRM items had been paired with context words that biased their meaning toward the overall theme of the list than when they were paired with context words that biased their meaning away from the list theme. Biasing did not have an effect on the false memory rates for adults.

Although these results are intriguing, there are some methodological problems that give rise to a number of interpretive difficulties. First, unlike Dewhurst et al. (2007), Odegard et al. (2008) did not have a control condition or group who were exposed to the standard DRM procedure (i.e., presented stimuli without a biasing context). In the absence of this control condition or group it is difficult to know whether the toward manipulation increased false memories relative to the standard DRM procedure, the away manipulation reduced false memories relative to the standard DRM procedure, or both (also see Howe et al., 2009a, 2009b). Second, by pairing each list item with a context word that served to bias the meaning toward the corresponding critical lure in the context-toward condition, Odegard et al. (2008) effectively doubled the number of associates for each of those DRM lists. What this means is that one of the critical variables known to increase false memory rates, backward associative strength, was neither measured nor controlled across the toward and away biasing conditions. This is a critical oversight as doubling the number of words on a list may increase the probability that the critical lure is activated in memory independent of any gist extraction *per se*. Although Odegard et al. (2008) interpreted their findings as being consistent with fuzzy-trace theory's claim that the context-toward manipulation facilitated children's but not adults' gist extraction, doubling the number of associates on the list in the toward-condition could have also served to increase the children's (but not adults as they were already near ceiling) associative activation of the critical lure on those lists, something that would be consistent with predictions from associative-activation theory (see Howe et al., 2009a, 2009b).

In the current research, we eliminate these methodological problems and present an experiment that extends the domain of our understanding of the development of children's spontaneous false memory illusions to more complex materials than simple word lists. Borrowing from Dewhurst et al. (2007), we embedded DRM lists into stories and each participant was exposed to a block of four stories based on four DRM lists as well as a block of four standard DRM word lists. Unlike Dewhurst et al. (2007), who manipulated standard versus story-based DRM presentation between participants, we manipulated this within participant. In order to examine the effects of thematic bias, the stories either biased the interpretation of the words toward the overall theme of the DRM lists or biased the interpretation away from the overall theme of the DRM lists. For those stories that were biased away from the overall theme, we purposely and systematically biased these stories toward a different critical lure, one that was subsequently included in the recognition tests.

The introduction of this bias (toward vs. away) factor is meant to be similar cuing manipulations that were utilized by Odegard et al. (2008). However, unlike that research, we included a within-participant control where each child acted as their own control as they studied a standard set of four DRM lists with no bias manipulation as well as a set of four DRM lists embedded into stories with a bias manipulation. Moreover, our bias manipulation did not introduce the same confound between number of associates and bias toward versus bias away as in Odegard et al. (2008) because the number of cues was not altered for any of the DRM lists or stories. That is, the biasing material did not increase the number of associates in the list or change the overall amount of list backward associative strength (see Appendix). Finally, we used younger child participants in the current research, 7- and 11-year-olds, in order to assess whether there was any developmental change in the utility of this biasing manipulation.

Thus, in the current research we investigated the effects of embedding DRM lists into stories that were either biased toward or away from the overall theme of the corresponding DRM list on 7- and 11-year-olds' true and false recognition compared with their performance on standard DRM lists. In this way we can directly evaluate the effects of thematic bias relative to a control and determine whether a bias toward the theme increases false memory rates, whether a bias away from the theme decreases false memory rates, or both. Consistent with previous research, we reasoned that 11-year-olds would have higher false memory rates than 7-year-olds in the standard DRM list condition. In addition, there would be an elevated rate of false memories in the story (toward bias) condition compared to the DRM list condition for both the 7- and 11- year-old participants due to the story's emphasis of the overall theme of the embedded DRM lists. And finally, biasing the story towards the corresponding critical lure would result in a higher rate of false recollection of that critical lure as opposed to when the story is biased away from the corresponding critical lure and towards an unrelated concept.

Method

Participants

The participants were 64 children (37.5% male), 32 7-year-olds (M = 6.62, SD = .49) and 32 11-year-olds (M = 11.03, SD = .18). The participants, who were fluent in English, were selected from predominantly White, middle-class schools in Manchester, England. Both parental consent and the participant's assent on the day of testing were obtained prior to their participation.

Design, materials, and procedure

A 2(Age: 7- vs. 11-year-olds) x 2(Bias: toward vs. away) between-participants design was used in the current study. In addition, a control was introduced where each participant was also presented with DRM lists to study as well as DRM lists in story format to study. Eight DRM lists were chosen from the Stadler, Roediger, and McDermott (1999) norms for use in the current research (see Appendix). The lists were modified for use within the current study by taking one item from each of the eight lists (reducing each list from 15 to 14 words), selected at random, removing it, and using it as an additional related unpresented item in the later tests of recognition. The remaining 14 items on each list were presented in the usual manner, descending order of associative strength to the corresponding critical lure.

In addition, the eight DRM lists were converted into story format. One version of the story involved a context that was biased toward the corresponding critical lure (in a manner similar to Dewhurst et al., 2007) and the other version of the story involved a context that was biased away from the corresponding critical lure and toward a different critical lure. Whereas the original "toward" critical lures for the eight lists were *cold, doctor, lion, sleep, smell, bread, music*, and *fruit*, the new "away" critical lures were *birthday, cook, fairground, garden, ill, school, shopping*, and *wedding*. The 14 associates from the DRM lists appeared in the same descending order of associative strength throughout the bias-toward and bias-away stories as they did in the corresponding standard DRM list presentation. As per the usual DRM procedure, the eight "toward" critical lures, the eight "away" critical lures, and the item that had been removed from each of the eight lists, were not present in any of the stories that had been created. Additionally, the 14 associates from each of the eight DRM lists only appeared once in the corresponding bias-toward story and once in the corresponding bias-away story, and were deliberately omitted from the other bias-toward and bias-away stories that had been constructed for the remaining DRM lists. This was done to rule out the possibility that items were recognized due to repeated exposure across stories. The eight bias-toward stories were between 119 and 137 words in length, while the eight bias-away stories were between 116 and 131 words in length (see Appendix). Participants saw all eight lists, four in list format and the remaining four in story format (either bias-toward or bias-away).

In order to avoid short-term memory effects, a one-minute distractor task was introduced after presentation of the stimuli and before the recognition test. The distractor task required participants to insert a different symbol into each of five outlined shapes that were repeated in a random order on a sheet of paper. A key was provided at the top of the page, which indicated the correct symbol that was to be inserted into each of the five different shapes.

Two recognition tests were constructed. One recognition test was specific to the DRM lists with the critical lures *cold, doctor, lion,* and *sleep,* and the second recognition test was specific to the remaining four DRM lists with the critical lures *smell, bread, music,* and *fruit*. Both recognition tests were comprised of 36 items: the four unpresented critical lures (e.g., *cold, doctor, lion,* and *sleep*), the four unpresented items that had been removed from the original lists (e.g., *heat, patient, feline,* and *nap*), four unpresented critical lures chosen at random from unused DRM lists (e.g., *needle, black, rubber,* and *soft*), the four unpresented, corresponding "away" critical lures (e.g., *cook, school, birthday,* and *garden*), four unpresented, unrelated items chosen at random from unused DRM lists (e.g., *train, poison, sky,* and *emotion*) and 16 presented items that had been chosen at random from the four DRM lists. Each participant completed both recognition tests, one following presentation of the stimuli (DRM list vs. stories) based upon the critical lures for the DRM lists *cold, doctor, lion,* and *sleep,* and the other recognition test following presentation of the stimuli (DRM lists vs. stories) based upon the critical lures for the DRM lists smell, bread, music and fruit.

Children were tested individually in an unoccupied room in their school. To begin, general memory instructions were read aloud to each participant, which advised them to listen carefully to the stimuli and informed them that a memory test would follow. Participants were told that they would be read aloud four lists of words and then later four short stories, or four short stories then later four lists of words. Participants saw different blocked combinations of four stories and four DRM lists where those combinations were constrained such that items in the stories never served as items in the DRM lists for any individual participant. For example, if the participant was read the DRM lists for the critical lures *cold, doctor, lion,* and *sleep* they would later be read four stories based upon the remaining critical lures *smell, bread, music,* and *fruit*. Counterbalancing was employed such that half of the participants were presented with the DRM lists first and half of the participants were read the stories first. Additionally, half the participants were presented stories where the context biased the interpretation toward the critical lure (bias-toward condition) and half the participants were presented stories where the context biased the interpretation away from the critical lure (bias-away condition). Thus, there were four conditions for each of age group: (1) one in which the participants were read four bias-toward stories and later four DRM lists, (2) one in which the participants were read four DRM lists then later four bias-toward stories, (3) one in which the participants were read four bias-away stories then later four DRM lists, and (4) one in which the participants were read four DRM lists then later four bias-away stories.

On presentation of the DRM lists, the 14 associates of the critical lure were read aloud in descending order of associative strength at a rate of one item every two seconds. The four DRM lists were read aloud one after the other until all four had been completed. Presentation of the four lists was randomized for each participant. On presentation of the DRM lists in story format, participants were read aloud the four stories that they had been assigned to study, one after the other, until all four stories had been complete. Each story took between 30 and 45 seconds to recite. The order of presentation of the four stories was randomized for each participant. Immediately after presentation of the four lists or four stories, participants were given the distractor task to complete. Here, participants were required to spend one minute on the distractor task and complete as much of it as possible in the given time frame. If the participant completed the distractor task before the minute had passed then a second identical distractor task was given to them to continue with for the remaining length of time. Following the distractor task, participants were informed that they would be read aloud a list of words and that they were to respond “yes” if they were certain that they had heard that word previously in one of the four lists or four stories (dependent upon which stimuli they had a moment ago been presented with) that had been read to them, or say “no” if they were unsure or were certain that they had not heard the word previously in one of the four lists or stories. The four DRM lists or four stories that had been presented to the participants determined which recognition was given. Following the first recognition test, participants were presented with the last four lists or stories, another distractor task, and a final recognition test.

Results

There are two main sets of analyses. First, we analyzed performance on the DRM lists and stories separately. For these analyses, six proportions were calculated for each individual participant: true recognition in the list and story conditions, false recognition for the toward-critical lures in both the list and the story conditions, and false recognition for the away-critical lures in both the list and the story conditions. We were also interested in the rates at which children of different ages falsely accepted semantically related (but unpresented) distractors as well as more general false alarm rates (false acceptance of unrelated distractors). The mean proportions of true and false recognition, as well as the acceptance rates for related and unrelated distractors, are shown as a function of age and bias in Table 1. In addition to these raw score analyses, signal detection statistics were calculated and analyzed in order to disentangle children’s memory discrimination (d() from their response bias (C). We computed d(and C values for both true and false memories (critical lures), the values of which are reported in Table 2. Although signal detection analyses are often conducted to complement raw score analyses, they frequently show similar effects (e.g., see Howe, Candel, Otgaar, Malone, & Wimmer, 2010). Although these similarities were also observed here, the signal detection data are probative as they provide a better insight into how age differences in memory discrimination and response bias affect true and false memories. Thus, despite concerns about using signal detection analyses (e.g., Pastore, Crawley, Berens, & Skelly, 2003), because the two sets of analyses produce complimentary outcomes, we have opted to report both sets of analyses so that the current findings can be compared to previous research regardless of which statistic is of primary interest.

Second, in order to estimate the degree to which story bias affected children's true and false recognition rates, we analyzed the raw scores using an analysis of covariance (ANCOVA) where performance on DRM lists was the covariate and performance on the story task was the dependent variable (see Table 3). As well, like the first set of analyses, we also conducted an ANCOVA on the signal detection statistics d(and C (see Table 4). Although both sets of analyses converged on the same outcome, we report each of the analyses so other researchers can compare their results to ours regardless of the statistic of choice.

For all of data, the main analyses involved a series of 2(Bias: toward vs. away) x 2(Age: 7- vs. 11-year-olds) analyses of variance (ANOVAs). Because there was no main effect of gender or any interactions involving this variable it was omitted from subsequent analyses. In addition, before turning to the main analyses, we examine trends in the related and unrelated distractor data as the outcome of some of these tests, particularly false alarm rates to unrelated distractors, may have implications for whether signal detection analyses are essential when interpreting the other outcomes in this study. For DRM lists, there were no age or bias differences for unrelated lures. For semantically related distractors, there was a main effect for age, $F(1, 60) = 8.81$, $p = .004$, $?_p^2 = .128$, where older 11-year-old children falsely recognized related distractors more frequently than younger 7-year-old children, an effect akin to the age differences observed below for critical lures (see Table 1). For stories, again there were no age or bias differences for unrelated lures. For semantically related distractors, there was a main effect for bias, $F(1, 60) = 15.92$, $p < .001$, $?_p^2 = .21$. Here, there were more related distractors incorrectly accepted for participants who were exposed to bias-toward stories than bias-away stories, an effect that is once again akin to the bias differences observed below for critical lures (see Table 1). No other effects were reliable.

What these results show is that although there were some differences in acceptance rates of related distractors for lists and stories, ones that parallel those reported next for critical lures, there were no differences in false alarm rates for unrelated distractors. Indeed, as can be seen in Table 1, the false alarm rate for unrelated items was low (below .10) at both ages. What this means is that signal detection analyses are not, strictly speaking, required in order to interpret the data properly. In fact, this may explain why, when we conducted the signal detection analyses, they were so similar to the analyses conducted on the raw recognition scores. However, because false alarm rates to unrelated distractors tended to be modestly (but not significantly) higher for older than younger children, at least for the DRM lists but not the stories, we decided to compute the signal detection analyses to complement the raw score analyses, which we turn to next.

List and Story Recognition Analyses

True Recognition

Raw score analyses. The correct number of items recognized in the list condition and the story condition were analysed separately. For lists, there was a main effect of age, $F(1, 62) = 7.51$, $p < .01$, $?_p^2 = .11$, where 11-year-olds correctly recognized more items than 7-year-olds. No other main effects or interactions were significant. For stories, there was a main effect of bias, $F(1, 60) = 36.42$, $p < .01$, $?_p^2 = .38$, where participants who were exposed to bias-toward stories had higher recognition rates than the participants who were exposed to bias-away stories (see Table 1). No other main effects or interactions were significant.

Signal detection analyses. When d(and C were analyzed for true recognition of list items, no significant effects were obtained. Of course, it is not unusual for age differences to be eliminated when signal detection statistics are used because they "correct" for differences due to response bias. For stories, analysis of d(revealed a main effect for bias, $F(1, 60) = 8.28$, $p = .006$, $?_p^2 = .121$, where, like the raw score analyses, participants who were exposed to bias-toward stories had higher d(scores than the participants who were exposed to bias-away stories (see Table 2). No other main effects or interactions were significant. For C, there was also a main effect for bias, $F(1, 60) = 5.54$, $p = .022$, $?_p^2 = .085$, where, as would be anticipated, participants who were exposed to bias-toward stories exhibited lower response bias than those participants who were exposed to bias-away stories (see Table 2).

False Recognition

Raw score analyses. False recognition of the toward- and away-critical lures was analyzed separately for the list and the story conditions. For lists, there was a main effect of age for the toward-critical lures, $F(1, 60) = 9.69$, $p < .01$, $?_p^2 = .14$, where 11-year-olds had higher rates of false recognition for the toward-critical lures compared to the 7-year-olds (see Table 1). There were no other main effects or interaction. As expected for DRM lists, there were no significant main effects or interactions from the ANOVA conducted for false recognition of the away-critical lures. Thus, for the standard DRM list conditions, the expected age effects for true and false memory rates were present – older children had higher true and false memory rates than younger children.

For stories, the results of the ANOVA for the toward-critical lures revealed a main effect of age, $F(1, 60) = 9.09$, $p < .01$, $?_p^2 = .13$, where 11-years-olds falsely recognized more toward-critical lures than the 7-year-olds. In addition, there was a main effect of bias, $F(1, 60) = 37.96$, $p < .01$, $?_p^2 = .39$, where there were more false memories for the toward-critical lures in the bias-toward condition than in the bias-away condition (see Table 1). There was no interaction. Finally, the results of the ANOVA for the away-critical lures revealed a main effect of bias, $F(1, 60) = 186.75$, $p < .01$, $?_p^2 = .76$, where biasing the stories away from the original critical lures and toward the unrelated "away" lures resulted in a higher incidence of false recognition of the away-critical lures when the stories were biased toward those critical lures. No other main effects or interaction were significant.

Signal detection analyses. Again d(and C were analyzed for false recognition of the toward- and away-critical lures separately for the list and the story conditions. For d(on lists, there was a main effect of age for the toward-critical lures, $F(1, 60) = 4.48$, $p = .038$, $?_p^2 = .070$, where, like the raw score analyses, 11-year-olds had higher d(scores for the toward-critical lures compared to the 7-year-olds (see Table 2). There was also a main effect for bias, $F(1, 60) = 4.66$, $p = .035$, $?_p^2 = .072$, where participants who were exposed to bias-toward stories had higher d(scores than the participants who were exposed to bias-away stories (see Table 2). The interaction was not significant. For C, there was a main effect for age, $F(1, 60) = 9.48$, $p = .003$, $?_p^2 = .136$, where 11-year-olds had much lower response bias than 7-year-olds (see Table 2).

For false recognition of the away-critical lures, d(analyses revealed only a main effect for bias, $F(1, 60) = 5.41$, $p = .023$, $?_p^2 = .083$, where participants who were exposed to bias-away stories had higher d(scores than the participants who were exposed to bias-toward stories (see

Table 2). For C, there was a main effect for bias, $F(1, 60) = 6.70$, $p = .012$, ?$_{p}^{2} = .100$, where participants who were exposed to bias-toward stories exhibited greater response bias than the participants who were exposed to bias-away stories (see Table 2).

For stories, the results of the d(ANOVA for the toward-critical lures revealed a main effect of bias, $F(1, 60) = 28.55$, $p < .001$, ?$^{2} = .322$, where d(was higher for the toward-critical lures in the bias-toward condition than in the bias-away condition (see Table 2). There were no other main effects or interaction. For C, the results of the ANOVA for the toward-critical lures revealed a main effect of age, $F(1, 60) = 8.96$, $p = .004$, ?$_{p}^{2} = .130$, where 11-years-olds had lower response bias for the toward-critical lures than the 7-year-olds. In addition, there was a main effect of bias, $F(1, 60) = 31.60$, $p < .001$, ?$^{2} = .345$, where C was lower for the toward-critical lures in the bias-toward condition than in the bias-away condition (see Table 2).

Finally, the results of the ANOVAs for the away-critical lures revealed a main effect of bias for d(, $F(1, 60) = 68.86$, $p < .001$, ?$^{2} = .534$, and for C, $F(1, 60) = 54.59$, $p < .001$, ?$^{2} = .476$, where biasing the stories away from the original critical lures and toward the unrelated "away" lures resulted in a higher d(scores and lower response bias for the away-critical lures when the stories were biased toward those critical lures (see Table 2). No other main effects or interaction were significant.

Overall, the results of these different sets of analyses are quite similar and are in line with our predictions. That is, children were more likely to falsely recognize the critical lures associated with the theme of the list regardless of whether the theme was the original one or the one that was consistent with the bias in the story. This was true for the raw score analyses as well as those computed using signal detection statistics. These latter analyses showed that memory discrimination (d() increased, and response bias (C) decreased, monotonically as a function of story bias. These findings illustrate the importance of thematic cuing in children's false memory development. Indeed, although there were no age differences in true recognition for stories, older children were still more likely than younger children to falsely recognize critical lures that were consistent with the story's bias. We return to this discrepancy in developmental trends between true and false recognition after we consider these same story findings when we control for rates of true and false recognition from standard DRM word lists.

Story Bias Analyses Controlling for Standard DRM List Performance

Before turning to the ANCOVA, we examined whether stories altered patterns of true and false recognition rates. For true recognition, regardless of whether stories biased interpretation of DRM lists toward or away from the original list theme, there were no significant changes in correct recognition rates over standard DRM word lists for either 7- or 11-year-olds [all $ts(31) < 1$, not significant]. For false recognition rates for stories that biased interpretation toward the original DRM list meaning, increases in false memory illusions over standard DRM word lists were observed for all children regardless of age although these differences were not significant [all $ts(31) < 1$, not significant]. For false recognition rates for stories that biased interpretation away from the original DRM list meaning, decreases in false memory illusions over standard DRM word lists were observed for all children regardless of age although these differences were only significant for 7-year-olds [$t(31) = 2.17$, $p < .05$] not 11-year-olds [$t(31) < 1$]. Thus, when directly compared to an appropriate control condition, story bias did not affect true recognition rates. For false recognition, biasing stories toward the theme did not significantly increase false memories for children, although biasing stories away from the original list theme decreased false memories, particularly for 7-year-olds.

Raw Score ANCOVA

We conducted two additional sets of analyses to examine exactly how stories altered patterns of true and false recognition relative to the standard DRM list presentation paradigm. In the first of these, we conducted an ANCOVA where each individual's performance on DRM lists was used as a baseline or control (covariate) for their performance on the stories (dependent variable) (see Table 3). For true recognition, the covariate was significant, $F(1, 59) = 6.78$, $p = .012$, ?² = .103, and there was a main effect for bias, $F(1, 59) = 36.70$, $p < .001$, ?² = .384. This main effect revealed that higher rates of true recognition in the bias-toward condition than in the bias-away condition.

The ANCOVAs conducted for false recognition of the toward-critical lures revealed a main effect of bias, $F(1, 59) = 36.50$, $p < .001$, $?_p^2 = .382$, such that false recognition rates for the toward-critical lures were higher in the bias-toward condition compared to the bias-away condition (see Table 3). No other main effects or interaction were significant. Finally, the ANCOVA conducted for false recognition of the away-critical lures also showed a main effect of bias, $F(1, 59) = 186.53$, $p < .001$, $?_p^2 = .760$, where there were higher rates of false recognition for the away-critical lures in the bias-away condition than in the bias-toward condition. No other main effects or interaction were significant.

Signal Detection ANCOVAs

First, we conducted an ANCOVA where d(for each individual's performance on DRM lists was used as a control (covariate) for their d(on the stories (dependent variable). For true recognition, there was a significant main effect for bias, $F(1, 59) = 7.02$, $p = .01$, ?² = .105, where higher memory discrimination rates were seen in the bias-toward condition than in the bias-away condition (see Table 4). When the response bias statistic C was analyzed, the ANCOVA revealed that the covariate was significant, $F(1, 59) = 4.35$, $p = .041$, ?² = .069, as was the main effect for bias, $F(1, 59) = 8.58$, $p = .005$, ?² = .127. Again, this main effect revealed that lower response bias for true recognition was seen in the bias-toward condition than in the bias-away condition.

The ANCOVAs conducted on d(for false recognition of the toward-critical lures revealed a main effect of bias, $F(1, 59) = 67.46$, $p < .001$, $?_p^2 = .533$, such that d(for the toward-critical lures, like previous analyses, was higher in the bias-toward condition compared to the bias-away condition (see Table 4). No other main effects or interaction were significant. For the ANCOVA conducted on d(for false recognition of the away-critical lures also showed a main effect of bias, $F(1, 59) = 26.32$, $p < .001$, $?_p^2 = .308$, where again like previous analyses, d(was higher for the away-critical lures in the bias-away condition than in the bias-toward condition. No other main effects or interaction were significant.

Finally, the ANCOVAs conducted on C for false recognition of the toward-critical lures revealed a main effect of age, $F(1, 59) = 5.58$, $p = .021$, $?_p^2 = .085$, where 7-year-olds' response bias was greater than 11-year-olds. There was also a main effect for bias, $F(1, 59) = 33.11$, $p < .001$, $?_p^2 = .359$, such that C for the toward-critical lures was lower in the bias-toward condition compared to the bias-away condition (see Table 5). No other effects were significant. For the ANCOVA conducted on C for false recognition of the away-critical lures also showed a main effect of bias, $F(1, 59) = 50.01$, $p < .001$, $?_p^2 = .459$, where C was lower for the away-critical lures in the bias-away condition than in the bias-toward condition. No other main effects or interaction were significant.

Thus, regardless of which statistic is calculated (raw recognition scores or the signal detection statistics d(and C), the results were similar. That is, when performance on DRM lists was used as a neutral baseline to compare thematic bias in memory for stories, children's false recognition rates (raw scores and d() consistently increased, and response bias (C) consistently decreased, as a function of the direction of the bias in the story. Moreover, these patterns were observed regardless of age.

Discussion

The question addressed in this research concerned the effects of thematic biasing on children's true and false memories. In particular, we wondered whether biasing associative material (items on DRM lists) using a story format would increase children's false recognition rates relative to the more standard DRM list learning procedure. Like previous research that has used standard DRM list learning procedures, our results showed that for true recognition, older children (11-year-olds) correctly recognized more presented items than younger children (7-year-olds). Similarly, for false recognition in the standard DRM list condition, 11-year-olds falsely recognized critical lures at a significantly higher rate than the 7-year-olds.

When DRM lists were embedded in stories, true recognition rates, although not differing with age, were higher when stories had been biased toward the overall themes of the DRM lists than when the stories had been biased away from the overall themes. It would seem that embedding associated items within a story context increases younger children's true recollection to levels comparable to that of older children. Stories perhaps allow greater elaboration and integration of presented information for younger children, something that is known to increase correct memory performance.

For false recognition, age differences did not disappear for all story conditions. That is, 11-year-olds falsely recognized toward-critical lures at a significantly greater rate than the 7-year-olds. Hence, the hallmark age effect associated with the standard DRM illusion also occurs in our thematically modified version of the DRM procedure. This finding stands in contrast to some prior research that has embedded DRM lists within stories (Dewhurst et al., 2007). Recall that Dewhurst et al. (2007) found that 5-year-olds false recognition rates for critical lures increased when lists were presented as stories but there was no increase for 8- and 11-year-olds. They argued that this was because older but not younger children could retrieve verbatim traces in the story condition and therefore were better able to reject the critical lures during retrieval. The difference between our study and that by Dewhurst et al. (2007) may have to do with the different aged children being tested (we did not include a group of 5-year-olds) or that our story and list manipulations were conducted within participant whereas Dewhurst et al. (2007) varied this between participants. Regardless, our results clearly show that when DRM lists are embedded in stories that were biased toward the overall theme of that DRM list, age effects did not disappear and were similar to those found using standard DRM lists.

Embedding DRM lists in stories that were biased away from the original list theme and toward an unrelated concept eliminated age differences in false recognition and reduced false memory rates for all children, regardless of age. That is, false recognition of the toward-critical lure was lower than on the standard DRM lists when the story bias was away from the original list theme. Thus, although 11-year-olds had significantly higher false recognition rates for the toward-critical lures than 7-year-olds, the performance of 7-year-olds was altered by the story context and this alteration saw their performance move in the expected direction – that is, one that was consistent with the theme of the story. Thus, even young children's false memories can be biased by the context in which the items have been presented.

Importantly, there was more false recognition of the toward-critical lures in the bias-toward condition than in the bias-away condition. This finding supports our predictions and is consistent with findings from previous research that used a gist-cuing manipulation (Odegard et al., 2008). Recall that despite the absence of a control condition or group against which to assess the effects of bias, when DRM lists were paired with words that served to bias the items' meaning toward the overall themes of the corresponding DRM lists (bias-toward) or away from the overall themes (bias-away), there was a higher rate of false memories for the critical lures in the bias-toward than the bias-away condition. These findings, as well as our current results, are consistent with predictions from both fuzzy-trace theory and associative-activation theory. Fuzzy-trace theory contends that manipulations that increase the likelihood of gist extraction and reliance on gist traces also increase the likelihood of false memories. Therefore, by embedding DRM lists in stories that emphasize the overall theme or gist elevated false memory rates are inevitable. Associative-activation theory argues that spreading activation from presented concepts through interconnected pathways that include theme nodes is responsible for the occurrence of false memories (see Figure 1). By emphasizing the overall theme of a DRM list by placing it into a story format will lead to a greater amount of activation in the knowledge base and elevate the probability that the memory representation corresponding to the critical lure will become activated. In addition, consistent with both fuzzy-trace theory's and associative-activation theory's assumptions that under certain circumstances true and false memories rates can be monotonically related, positive correlations were obtained between true and false memory rates for both the DRM lists [$r(N = 64) = .32$, $p = .011$] and the stories [$r(N = 64) = .68$, $p < .001$] in this experiment.

What may not be as easily accommodated by fuzzy-trace theory is the finding that there were larger differences between the 7- and 11-year-olds' false recognition of the toward-critical lures in the bias-away story condition. Here, 7-year-olds false recognition was lower to the toward-critical lures than that of 11-year-olds. This suggests that pushing the story towards an unrelated concept reduced 7-year-olds' false memory rates for the original themes due perhaps to the overall theme not being as obvious. Importantly, 11-year-olds still showed elevated false recognition to the toward-critical lures when the overall gist was pushed toward an unrelated theme. Fuzzy-trace theory might have predicted that gist cuing effects should be stronger in older than younger children and that older children should have had higher false recognition rates for away- than toward-critical lures; that is, older children should have been more susceptible to the gist manipulation than younger children. Although other interpretations from fuzzy-trace theory are of course possible, what this finding suggests is that mechanisms in addition to gist might be contributing to the recollection of associative information. For associative-activation theory, on the other hand, there is a relatively straightforward explanation for why 11-year-olds still falsely recognized the toward-critical lures in the bias-away condition. That is, because memory representations corresponding to the embedded items were activated on presentation of the bias-away story, these theme congruent items were active in memory and their activation still spread to related but unpresented concepts (i.e., the critical lure; see Figure 1).

The findings relating to false recognition of the away-critical lure, like false recognition of the toward-critical lures, revealed a greater rate of false recognition for the away-critical lures in the bias-away condition than in the bias-toward condition. This finding was expected because the bias-away stories emphasized the away theme as opposed to the original theme of the DRM list. Interestingly, this effect was age invariant with 7-year-olds falsely recognizing the away-critical lures as often as the 11-year-olds.

However, to really answer our questions concerning the effects of thematic bias on true and false memories, we need to compare children's performance when DRM lists are presented as stories relative to when they are presented in the usual list-learning format. This control has been absent in some previous research (e.g., Odegard et al., 2008) and so it is not clear whether thematic bias toward list themes increases true or false memory rates, thematic bias away from list themes decreases true and false memory rates, or both. To examine this we first directly compared true and false recognition rates between stories and lists. The results of these analyses showed that there was no change in true recognition rates regardless of age. For false recognition, although both 7- and 11-year-olds exhibited some increase in false memory illusions when stories were biased toward the theme, these increments were not significant. For false recognition when the story biased interpretation away from the original theme, although both 7- and 11-year-olds' false memory illusions declined these effects were reliable only for the 7-year-olds. Thus, when the appropriate controls are in place, thematic biasing in stories does not reliably increase true or false memories in children although biasing the interpretation away from the original theme does reduce false recognition rates, particularly for younger (7-year-olds) children.

In addition, we conducted a series of analyses on the story DRM recognition rates once children's baseline rates of DRM performance on standard words lists were removed. Regardless of whether these analyses of covariance were computed using raw recognition scores or the signal detection statistics d(and C, what we found was a clear bias effect. That is, true and false recognition for the toward critical lures were both higher in the bias-toward condition than the bias-away condition. Because false recognition of the away critical lures was higher in the bias-away condition, together these results show that the overall story theme can influence both younger and older children's false recognition of thematic lures. These analyses also showed that 7- and 11-year olds exhibited similar true and false recognition rates when the DRM lists had been embedded into stories and their baseline DRM performance had been controlled for statistically. This finding contrasts previous research findings (e.g., Dewhurst et al., 2007) and clearly demonstrates that when story themes are presented to children, developmental differences in corrected recognition rates disappear. Interestingly, when true and false recognition rates for DRM lists embedded in stories were corrected for baseline rates in the standard DRM list procedure, age differences in true recognition disappeared but age differences in false memories were preserved.

The results of this study can be interpreted in terms of a spreading activation model like associative-activation theory or the related model proposed by Reder and her colleagues (Arndt & Reder, 2003; Reder et al., 2009). As noted earlier, in this model individuals have a mental lexicon (knowledge base) that is constructed of nodes (memory representations) that correspond to previously encountered concepts. Spreading activation also occurs in the lexicon and like a recent implementation of associative-activation theory (see Howe & Derbish, 2010) there exist *theme nodes* within the lexicon or knowledge base (see Figure 1). Theme nodes are created when an individual encounters related stimuli, for example several sentences or a story that revolves around a specific theme, or may already exist in memory as a byproduct of the activation of a related subset of concepts linked to that theme.

This explanation can account for the standard finding that younger children (7-year-olds) are less vulnerable to false memories than older children and adults in the DRM list condition because they do not have an advanced lexicon that can automatically activate the theme nodes. However, when help is given to activate related nodes, as in the story condition, the theme nodes may be more easily activated and there is the potential for an increase in false memory rates. Indeed, this increased activation of theme nodes can attenuate age differences in false recognition rates between 7-year-olds and 11-year-olds. However, like research using child-friendly DRM lists to reduce age differences in false memories (e.g., Anastasi & Rhodes, 2008; Carneiro, Albuquerque, Fernandez, & Esteves, 2007; Metzger et al., 2008), developmental differences are not completely eliminated. Indeed, the current study showed that 11-year-olds still exhibited significantly higher levels of false recognition for the toward-critical lures than 7-year-olds. Thus, although children can and do activate theme nodes regardless of age, 7-year-olds still have fewer false memories than 11-year-olds even in the presence of externally presented themes.

Of course, it could be argued that the addition of theme nodes to associative-activation theory simply amounts to a less parsimonious version of fuzzy-trace theory's assumption concerning the role of gist. Obviously, theme nodes have been around for some time in spreading activation models and as such their inclusion in associative-activation theory requires different assumptions than those contained in fuzzy-trace theory. Specifically, theme nodes, like other nodes in children's knowledge base, are subject to the same spreading activation rules as other concepts in memory networks. Moreover, themes, like the individual concepts themselves, emerge in children's knowledge base as a function of both experience and learning. Thus, depending on the material being memorized, we should still expect to see age differences in true and false memory rates even when themes are cued in a gist-cuing paradigm (Odegard et al., 2008) or when associative information is embedded in stories that emphasize a specific theme. Indeed, this is exactly what we saw in the current experiment.

Regardless of which theory provides the best account of these findings, the current research has shown that older children (11-year-olds) not only correctly recognize more items than younger children (7-year-olds), they are also more susceptible to the standard DRM illusion. Importantly, these developmental trends in true and false memory change when associative information is embedded in a story context that emphasizes the thematic nature of the to-be-remembered information. Specifically, whereas developmental differences in true recognition rates disappeared, age differences in false recognition rates remained. Although embedding associative material in a thematically relevant story context does alter children's false memory rates, albeit only modestly, developmental differences in children's susceptibility to false memory illusions do not disappear. Thus, when appropriate controls are in place, thematic cues do not significantly increase children's false memory rates, even for the youngest children, nor do they eliminate age differences in children's susceptibility to false memory illusions.

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Appendix

The eight DRM lists chosen from Stadler, Roediger, and McDermott (1999) and the corresponding bias-toward and bias-away stories (the 14 semantic associated from each DRM list are underlined in the corresponding bias-toward and bias-away stories).

Cold

- **DRM List**: hot, snow, warm, winter, ice, wet, frigid, chilly, weather, freeze, air, shiver, artic, frost
- **Bias-toward story**: It was hot inside Tom's house. Outside snow covered the grass and the trees. Tom didn't want to leave his warm house but if he didn't he would be late. It was the middle of winter and ice covered the wet ground. Tom stepped out into the frigid air. He didn't like the chilly weather and he was scared that he would fall on the slippery ground. Tom was sure that he was going to freeze so he had wrapped up. He wore a scarf and some gloves and a woolly hat. The air made Tom shiver and his teeth began to chatter. Tom thought that he was in the arctic because of all the frost that surrounded him.
- **Bias-away story**: Tom's mum put the cakes into the hot oven to bake. Flour that looked like snow covered the work top so Tom cleaned it up. The cakes were ready but they were still too warm to decorate. Tom and his mum baked lots of cakes especially in winter. The cakes had finally cooled and it was time to ice them. The mixture was wet and frigid. It reminded Tom of the chilly weather. Tom put ice cream on the cakes which made the chocolate sauce freeze. The smell of the cakes filled the air. The ice cream made him shiver. Tomorrow Tom was making arctic roll and giving some to Mr. Frost who lived next door.
- (Critical lures: toward = cold; away = cook).

Doctor

- **DRM List**: nurse, sick, lawyer, medicine, health, hospital, dentist, physician, ill, office, stethoscope, surgeon, clinic, cure.
- **Bias-toward story**: The nurse had written a prescription for Sarah because she was sick. Sarah's mum was a lawyer and she told Sarah that she had to take the medicine because it would make her better and improve her health. She said that if Sarah did not take it then she would have to go to the hospital. Sarah didn't want to have to go there as she hated it there more than she hated going to the dentist. Sarah saw a physician the last time that she was ill. She went into his office and he listened to her heart with a stethoscope. She then went to see a surgeon in a different clinic who gave her the treatment that she needed to cure her illness and make her well again.
- **Bias-away story**: During drama class Sarah dressed up as a nurse. She helped the sick children. Tom dressed up as a lawyer. Tom wouldn't take the medicine that Sarah offered him. After drama the teacher talked to the children about good health. Tom interrupted and told the class how he once had to go to hospital because his dentist said that he needed some teeth taken out. Sarah told the class that her dad was a physician who helped ill people. He had his own office and a stethoscope. The teacher asked the children what they wanted to be when they grew up and Tom said a surgeon. He wanted his own clinic where he could cure people.
- (Critical lures: toward = doctor; away = school).

Lion

- **DRM List**: Tiger, circus, jungle, tamer, den, cub, Africa, mane, cage, roar, fierce, bears, hunt, pride.
- **Bias-toward story**: Tom and his family had gone out for the day. They saw a tiger and lots of other animals at the circus. Tom knew that they didn't belong there because they belonged in the jungle. The animals don't need a tamer to look after them because they can look after themselves. Tom had learnt that they should live in a den with their cubs. He also learnt that they come from Africa which is far away. Tom saw another animal with a mane and it was also locked in a cage. This animal gave out a roar that was fierce and it reminded Tom of the scary bears that he had seen earlier. Tom thought of how they would hunt with the rest of their pride.
- **Bias-away story**: Tom dressed up as a tiger at his fancy dress party. His sister was a clown because she liked the circus. Tom's yard was made into a jungle. Tom's dad was the animal tamer. When Tom's friends arrived he showed them his den. Tom received lots of presents including a teddy bear in the shape of a tiger cub, a book about Africa, and a fancy dress mask that had a mane. Tom climbed into a cage and gave out a roar that was loud and fierce. After tea they played a game where they had to find bears hidden around the house. They had to hunt high and low and the person who found the most won a medal. Tom won and he wore his medal with pride.
- (Critical lures: toward = lion; away = birthday).

Sleep

- **DRM List**: bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, peace, yawn, drowsy.
- **Bias-toward story**: It was late and it was time for Sarah to go to bed because she needed to rest. Sarah was still wide awake even though she felt so tired. Whilst Sarah lay down her mum read her a story and she started to nod off. She began to have a dream. Suddenly a loud bang made Sarah wake up. It was the window and the strong wind had made it shut quickly. Sarah settled down and began to snooze again. She had her blanket wrapped tightly around her and was snuggled up. Sarah quickly fell from a doze into a deep slumber. She started to snore loudly. Sarah lay there in peace until she woke up the next morning and let out a big yawn. She was still drowsy but she got up and started her day.
- **Bias-away story**: Sarah and her mum were planting seeds in the flower bed. Sarah wanted to stay outside for the rest of the day. She felt wide awake and she was not tired anymore. Sarah's dog seemed to be having a dream. Even the sound of the bees did not wake him, he continued to snooze. A blanket of blossom petals covered the soil. Sarah wondered how her cat could also doze on such a beautiful day. Sarah's mum mowed the lawn but the noise didn't disturb her grandad's deep slumber. Sarah could hear him snore which disturbed the peace outside. Sarah went to have a look at the fish in the pond. She didn't yawn or feel drowsy, she was just happy to be outside.
- (Critical lures: toward = sleep; away = garden).

Smell

- **DRM List**: nose, breathe, sniff, hear, see, nostril, whiff, scent, reek, stench, fragrance, perfume, salts, rose.

- **Bias-toward story**: Tom went to visit the farm with his dad. Tom had to help clean out the pig pen. He held his nose so tightly that he couldn't breathe. He wanted to make sure that he didn't sniff in the foul air. He could still hear the pigs oink and see the other children who were also helping to clean up. Tom had covered his nostrils so that the whiff did not affect him as he worked. He tried to think of a nice scent to help him forget about the reek and disgusting stench of the pig pen. Tom thought of a sweet fragrance, like his mum's perfume, the bath salts that he used when having a bath and a rose from his garden. These all helped him to forget about the awful pong of the farm.
- **Bias-away story**: Tom's nose kept running and he couldn't breathe properly. It hurt him every time he tried to sniff. The nurse listened to Tom's chest and she could hear that he wasn't very well. Tom had to wait and see if the medicine made him better. His mum also gave him some cream to rub on his nostrils because they were sore. After a few days Tom felt better. The whiff and scent of flowers in the garden helped him to forget about the reek and stench of his medicine. He hated the medicine because it reminded him of his grandma's fragrance and he didn't like her perfume. Tom had to take a bath with special salts because his temperature rose and he began to feel poorly again.
- (Critical lures: toward = smell; away = ill).

Bread

- **DRM List**: butter, food, eat, sandwich, jam, milk, flour, jelly, dough, crust, slice, wine, loaf, toast.
- **Bias-toward story**: Sarah helped her mum butter some croissants for their breakfast. The food looked delicious and Sarah sat down at the table to eat it. Sarah's mum had made her dad a sandwich for his dinner. It was time to bake so Sarah got out the list of ingredients that they needed. There was jam, milk, and flour on the list. Sarah made jelly last time she baked with her mum. Sarah mixed the ingredients together and kneaded the dough. The mixture was put into the oven to bake and it came out with a large brown crust. Sarah helped her mum to slice it. Sarah's mum was drinking a glass of wine. They had made the perfect loaf. Sarah looked forward to eating it as toast the next morning.
- **Bias-away story**: Sarah had a bridesmaid dress that was yellow like butter. Sarah's grandma made them some food for breakfast. They had to eat it quickly so they arrived at the church on time. Sarah had a sandwich with jam and a glass of milk. Sarah's sister had a dress that was white like flour. She was nervous and her legs shook like jelly. In the church Sarah sat in her seat which was soft like dough. Later for dinner Sarah ate a pie which had a big pastry crust. Sarah's sister and her new husband had to slice the cake. Everyone celebrated and drank wine except Sarah because she was too young. They all had malt loaf for desert and made a toast to the newly married couple.
- (Critical lures: toward = bread; away = wedding).

Music

- **DRM List**: note, sound, piano, sing, radio, band, melody, horn, concert, instrument, symphony, jazz, art, rhythm.
- **Bias-toward story**: Tom's dad had taken him to his lesson. Tom played a note and listened to the sound that came from the piano. He began to sing along. He enjoyed his lessons very much. On the way home Tom listened to the radio in the car and he heard a

brass band. The group were playing a famous melody and Tom could hear the French horn playing the loudest. Tom hoped that one day he would play in a concert in front of a large audience. He wanted to play his favourite instrument which was the trumpet and maybe play a famous symphony. Tom also dreamt of playing in a jazz group. His conductor always told him that it was an art and that he should feel the rhythm.

- **Bias-away story**: Tom read the note that his mum had left for him and he listened out for the sound of her car. Tom's sister had gone for her piano lesson. His mum picked him up and they had a sing along to the radio. They arrived and bought a band that allowed them to go on all the rides. The carousel played a cheerful melody and Tom rode the unicorn which had a silver horn. Next they watched a concert by a group of toy monkeys and later they won a toy from a machine using an instrument shaped like a claw. The machine played a victory symphony. Tom rode the rollercoaster in a cart called Jazz which was decorated with colourful art. The rhythm of the ride made Tom feel sick.
- (Critical lures: toward = music; away = fairground).

Fruit

- **DRM List**: vegetable, orange, kiwi, citrus, ripe, pear, banana, berry, cherry, basket, juice, salad, bowl, cocktail.
- **Bias-toward story**: Sarah was out with her dad. Her mum had given them a list of things that they needed to buy. They had already picked up lots of vegetables. Sarah didn't like the taste of them but she ate them because they were healthy. Sarah decided to pick all the things from the supermarket that she liked. First, she picked up an orange and a kiwi. Her dad had told her that they were citrus. Next Sarah chose a ripe pear and a banana that was yellow. Sarah also chose a berry and a cherry and put them in the basket. Her dad said that one of everything would be enough to make some juice for the family and fill the salad bowl with a cocktail for after their tea.
- **Bias-away story**: Sarah had finished her chicken and vegetables. Last time Sarah went to the mall her mum bought her an orange t-shirt and some kiwi green shorts. Today Sarah wanted some citrus yellow flip flops. Sarah's favourite store was called ripe valley. Sarah's mum had once bought some pear green earrings and a bag in the shape of a banana from there. First they bought Sarah's dad some shorts which were red like a berry or a cherry. They then bought a picnic basket. Sarah had some juice. Her mum told her about the exciting things they were going to do on their holiday. She said there would be lots of salad and bowls of ice cream to eat and a cocktail for her mum and dad.
- (Critical lures: toward = fruit; away = shopping).

Table 1

Mean proportion (standard deviations) of true recognition, false recognition, related distractor acceptance, and unrelated distractor acceptance for DRM lists and stories as a function of age and bias.

Condition			Bias		
	Toward			Away	
	7-year-olds	11-year-olds		7-year-olds	11-year-olds
Lists					
True	.61 (.20)	.70 (.12)		.56 (.15)	.68 (.14)
False	.67 (.22)	.86 (.18)		.66 (.24)	.80 (.21)
toward					
False away	.03 (.09)	.00 (.00)		.03 (.09)	.02 (.06)
Related	.36 (.21)	.44 (.20)		.20 (.12)	.48 (.19)
Unrelated	.04 (.01)	.03 (.01)		.09 (.02)	.09 (.02)
Stories					
True	.72 (.15)	.76 (.16)		.43 (.17)	.55 (.19)
False	.89 (.20)	.95 (.19)		.41 (.30)	.70 (.25)
toward					
False away	.16 (.18)	.13 (.16)		.72 (.20)	.83 (.20)
Related	.34(.14)	.44 (.17)		.16 (.07)	.20 (.09)
Unrelated	.04 (.01)	.06 (.02)		.06 (.01)	.07 (.02)

Table 2

Mean d((and C) values as a function of age and bias.

Condition			Bias		
	Toward			Away	
	7-year-olds	11-year-olds		7-year-olds	11-year-olds
Lists					
True	2.92 (1.15)	3.15 (1.02)		2.17 (.92)	2.24 (.59)
False	3.29 (.96)	4.55 (.33)		2.75 (.63)	3.28 (.08)
toward					
False away	-.22 (2.68)	-.49 (2.85)		-.79 (2.39)	-1.23 (2.33)
Stories					
True	3.13 (.91)	3.05 (.71)		2.23 (1.28)	2.43 (1.06)
False	4.73 (.11)	5.09 (.31)		1.93 (1.43)	3.26 (.65)
toward					
False away	.68 (2.14)	.24 (2.11)		3.42 (.69)	4.03 (.26)

Table 3

Raw score means (standard deviations) for proportion of true and false story recognition controlling for DRM performance using ANCOVA as a function of age and bias.

Condition and Score			Bias		
	Towards 7-year-olds	11-year-olds		Away 7-year-olds	11-year-olds
True	.73 (.04)	.74 (.03)		.46 (.03)	.53 (.03)
False:					
Toward	.90 (.06)	.94 (.05)		.42 (.05)	.70 (.06)
Away	.16 (.04)	.12 (.04)		.72 (.05)	.83 (.05)

Table 4

Mean d((and C) values for true and false story recognition controlling for DRM performance using ANCOVA as a function of age and bias.

Condition and Score	Bias			
	Towards		Away	
	7-year-olds	11-year-olds	7-year-olds	11-year-olds
True	3.13 (.84)	3.05 (.68)	2.23 (1.29)	2.43 (1.16)
False:				
Toward	4.73 (.04)	5.10 (.29)	1.92 (1.41)	3.26 (.71)
Away	.60 (2.15)	.21 (2.13)	3.44 (.67)	4.12 (.24)

Figure Caption

Figure 1. Hypothetical knowledge base network containing individual concepts, theme nodes, and a subset of potential activation pathways.