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Developmentally Invariant Dissociations in Children's True and False Memories: Not All Relatedness Is Created Equal

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The role of categorical versus associative relations in 5-, 7-, and 11-year-old children's true and false memories was examined using the Deese – Roediger – McDermott (DRM) paradigm and categorized lists of pictures or words with or without category labels as primes. For true items, recall increased with age and categorized lists were better recalled than DRM lists. For false items, recall increased with age except for picture lists, there were no differences between categorized and DRM lists and no effect of priming, and there were fewer false memories for pictures than words. Like adults, children's false memories are based on associative not thematic relations, whereas their veridical memories depend on both. This new, developmentally invariant dissociation is consistent with knowledge- and resource-based models of memory development.

Research on children's memory has examined developmental changes in not only memory for real events and materials but also false memory. One useful task used recently to study children's memory illusions is the Deese – Roediger – McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). Research with this paradigm has routinely shown that older children produce more false memories than younger children (Brainerd, Reyna, & Forrest, 2002; Dewhurst & Robinson, 2004; Howe, 2005; Howe, Cicchetti, Toth, & Cerrito, 2004; Price, Metzger, Williams, Phelps, & Phelps, 2001). In this procedure, children study word (or picture) lists whose members are associatively linked (e.g., Sour, Candy, Sugar, Bitter, Good, Taste, Tooth, Nice, Honey, Soda, Chocolate, Heart, Cake, Tart, and Pie are all semantic associates of Sweet). Children are then asked to recall as many words as they can from the just presented list. The key outcome is that in addition to correctly recalling the words that were actually on the list (e.g., SOUR, CANDY, etc.), the associated, unpresented item (the so-called critical lure, SWEET) is also falsely recalled.

Although false memory illusions are robust using the DRM paradigm, there is disagreement as to the theoretical mechanism(s) that could account for the creation of false memories as well as why younger children should be less susceptible to the DRM illusion than older children. Most theorists do agree that items on the DRM list activate (semantically, associatively, etc.) related but unpresented concepts that are consistent with the items presented during study. In fact, most if not all explanations rely on this activation happening during study and for adults at least, this activation occurs automatically and unconsciously (Roediger, Balota, & Watson, 2001; Seamon, Luo, & Gallo, 1998; Seamon et al., 2002). Later, these unpresented but activated concepts are erroneously produced during recall or recognition because participants cannot discriminate them from other members of the original list.

What is not clear is whether false memories are the result of associative connections or the activation of higher order semantic and thematic relations across list items. That is, are critical lures falsely recalled and recognized because they share semantic features with list members or because they share varying degrees of associative strength with different list members? Although association norms usually consist of a multiplicity of relations between concepts (synonyms, antonyms, property relations, functional relations), semantic relations are usually restricted to thematic or categorical relations between concepts (category membership, superordinate relations, subordinate relations) (see Hutchison, 2003). For example, *dog* and *bark* share an associative property relation whereas *dog* and *rabbit* share a semantic categorical relation.

Although some theories place importance on across-item thematic or semantic relations in the generation of false memories (e.g., Brainerd &

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Reyna's, 2005, fuzzy-trace theory), others have stressed the importance of associative relations (e.g., McEvoy, Nelson, & Komatsu, 1999; Roediger, Balota et al., 2001; Roediger, Watson, McDermott, & Gallo, 2001). The growing consensus is that associative strength is primarily responsible for false memory production in the DRM paradigm, a consensus that has been bolstered by the finding that the strongest predictor of false memories is backward (from the presented list item back to the unpresented critical lure) associative strength (Roediger, Watson et al., 2001).

Hutchison and Balota (2005; also see Hutchison, 2003) have also argued that for adults, false memories that arise in the DRM paradigm are driven by associative connections between list items and the critical lure and not by higher order thematic links across list members. Consistent with this idea, four experiments showed that adults' false recall was related to measures of associative strength between list items and the critical lure and not the thematic coherence of list members (Hutchison & Balota, 2005). More importantly, this research also revealed a dissociation between true and false recall. That is, although relational processing did not affect false recall, it was related to true recall. Specifically, thematic consistency increased correct recall but had no effect on false recall.

To clarify, it is well known that for adults at least, the DRM illusion is due to variability in the strength of backward associations between studied items and the critical lure (Deese, 1959; Hutchison & Balota, 2005; McEvoy et al., 1999; Park, Shobe, & Kihlstrom, 2005). Indeed, multiple regression analyses have routinely confirmed that backward associative strength between studied items and critical lures accounts for the majority of the variance in the DRM illusion (Roediger, Watson et al., 2001). It is equally well known that most associative norms contain what might be termed undifferentiated links between items, ones based primarily on contiguity and similarity. However, following Mandler (1979), it is possible to distinguish among three different types of association: *coordinate* or horizontal in which items are linked by similarity (e.g., both dogs and cats have fur); *subordinate* or vertical in which terms are linked because they belong to the same category (e.g., dogs and whales are both mammals); and *proordinate* or temporal in which terms are linked by space or time (e.g., as the sun sets, it becomes dark). As it turns out, lists yielding high rates of false memory contain associations primarily of the coordinate variety (also see Park et al., 2005). Thus, across-item relations, especially those containing subordinate or hierarchical information, do not appear to be related to false memory production in the DRM paradigm, at least not for adults. Indeed, unlike true recall, false recall seems to be controlled by coordinate, backward associations between individual targets and the critical lure.

That associative relations trump across-item thematic relations in adults' false memories using the DRM procedure is inconsistent with models of false recall that rely on across-item gist processing mechanisms to explain the DRM illusion. For example, Brainerd and Reyna's (2005; also see Brainerd, Forrest, & Karibian, in press) fuzzy-trace theory (FTT) explicitly predicts that false memory illusions in the DRM paradigm are due to ''. . . the processing of gist memories that *connect meaning across different words*.'' (pp. 3–4). Indeed, FTT anticipates developmental increases in false memories because children's ability to connect meanings across list items improves with age. Although FTT makes no assumptions concerning the automaticity with which these connections are made (Brainerd et al., in press; but see Howe, 2005), because the ability to make such connections improves with age (due in part to correlated changes in knowledge base through learning and experience) so too should the magnitude of the DRM illusion.

FTT's explanation is compelling and appears to be consistent with the developmental trends found in research on children's DRM illusions as well as earlier research examining children's spontaneous clustering of categorizable lists in free recall (e.g., Bjorklund & Hock, 1982). However, it is also possible that children can and do use associative relations between individual items and the critical lure in much the same manner as adults (although they probably do so more slowly than adults using a more labor-intensive and less automatic processing strategy; see Howe, 2005). First, concerning associative processing, it is well known that even young children use associative relations when remembering lists of concepts and that such relations represent an early form of semantic representation that changes minimally with development (e.g., Bjorklund & Jacobs, 1985). Indeed, Bjorklund and de Marchena (1984) demonstrated that young children's recall of categorized lists was mediated by associative relations (e.g., dog, cat) and not categorical relations (e.g., dog, rabbit) (also see Bjorklund & Zeman, 1982, 1983; Lange, 1978).

With development, children become better able to spontaneously use categorical relations to mediate recall (e.g., Bjorklund & de Marchena, 1984) but can do so even at a relatively young age given that category relations are made salient (e.g., Howe, Brainerd, & Kingma, 1985). That is, young children can use categorical relations when within-category items are blocked within a list. Under these conditions, even young children can utilize categorical relations to improve recall over unrelated lists. If children are able to use categorical relations to benefit recall when relations are made salient, then they should also be capable of extracting meaningful relations across DRM list items. This is because blocking items by category is similar to the DRM procedure in that all of the items on a DRM list share a single semantic or associative meaning. Consistent with the idea that even young children process category information is the finding that when recognition measures are used instead of recall, false memories following study of categorized lists are no less likely in younger than older children (Seamon, Luo, Schlegel, Greene, & Goldenberg, 2000). Thus, at least for recognition memory, young children can and do process the meaning of individual items as well as across-item themes, especially when items that are alike are blocked at presentation.

The purpose of the current series of experiments was to examine whether children, like adults, (1) use associative relations when generating false memories even though across-item (categorical) relations are also available and (2) show a dissociation such that true recall is affected by both inter-item associations and across-item relational information but false recall is affected solely by inter-item associations. The finding that true memories are affected by both associative and categorical relations would be anticipated by most theories of memory development, including FTT. However, what would not be anticipated by FTT is the failure of across-item relational (categorical or vertical) links to increase children's false memory production, particularly as it is this very mechanism that is said to be the key to developmental trends in children's false memories. In the first experiment, children's recall performance was compared across categorized lists and standard associative DRM lists. Like Seamon et al. (2000), the critical (unpresented) lure for the categorized lists was the top exemplar for that list. If children's performance is consistent with Hutchison and Balota (2005) adults' performance, then true recall should be better for lists with additional relational information (categorized lists) than standard associative DRM lists. However, there should be no differences in false recall if the DRM illusion is driven by associative rather than relational information.

Experiment 1

To date, no study has directly compared the tendency of categorical and standard associative DRM lists to induce false memories in children. As noted earlier, Seamon et al. (2000) did administer categorized lists to children and measured the DRM illusion on these lists using recognition scores. In the present experiment, categorized and traditional associative DRM lists were administered to children of different ages, followed by tests of recall rather than recognition. The reason recall was used rather than recognition is important because recall tests have traditionally been found to be more sensitive than recognition tests to developmental differences in memory. Also, recall tests rely more on gist processing than recognition tests (e.g., Brainerd & Reyna, 2005) and thus provide a stronger test of the associative versus relational processing hypotheses.

Method

Participants. There were 180 children (95 males, 85 females): 60 from Kindergarten (5-year-olds; $M = 5$ years 3 months), 60 from grade 2 (7-year-olds; $M = 7$ years 2 months), and 60 from grade 6 (11-year-olds; $M = 11$ years 2 months). This age range was selected to match that used in prior studies investigating the DRM illusion in children. All of the children (predominantly White and middle class) who were tested had parental consent and had themselves assented to the procedure.

Design, materials, and procedure. A 2 (list: standard DRM vs. category) $\times$ 3 (age: 5 vs. 7 vs. 11) between-subjects design was used. Children were presented with either 8, 14-item DRM word lists one at a time or 8, 14-item category word lists (with the top exemplar excluded from presentation as it served as the critical lure) one at a time. All items were printed on index cards and read out loud by the experimenter one at a time at a 5-s rate. Examples of the DRM lists include "sweet" (critical lure = sweet; list members presented = sour, candy, sugar, bitter, good, taste, tooth, nice, honey, soda, chocolate, cake, tart, pie) and "needle" (critical lure = needle; list member presented = thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection, syringe, knitting). Examples of the category lists include "four-footed animals" (critical lure = dog; list members presented = cat, horse, tiger, cow, elephant, deer, mouse, pig, rat, giraffe, squirrel, rabbit, goat, zebra) and "part of the human body" (critical lure = leg; list members presented = arm, foot, fingers, head, toe, hair, hands, nose, ear, mouth, heart, knee, neck, elbows). All of the DRM lists (drawn from Stadler, Roediger, & McDermott, 1999) and all of the category lists (drawn from Van Overschelde, Rawson, & Dunlosky, 2004) used in the experiments in this article have been used previously with children in these age ranges (e.g., Brainerd et al., 2002; Howe, 2004; Howe et al., 2004).

Children were randomly assigned to the DRM and category list conditions. Each child was instructed to try to remember the concepts presented on the list. After the presentation of the last item in a list, children were given a distractor task (circling pairs of letters) for 30 s before being asked to recall the items from the list. After recall of that list was completed, the procedure was repeated for the seven remaining DRM or category lists, depending on the condition the child was in. List order was randomized across children within each age group.

Results and Discussion

Because there were no effects due to gender, this variable was eliminated from subsequent analyses. The mean proportion of targets (items presented) correctly recalled and critical lures (items not presented) falsely recalled for the DRM and category lists are shown in panels a and b of Figure 1, respectively. To test the main hypotheses associated with this study, analyses for true recall will be presented first, followed by analyses for false recall.

The proportion of targets correctly recalled (panel a) were analyzed using a 2 (list: DRM vs. category) × 3 (age: 5 vs. 7 vs. 11) between-subjects analysis of variance (ANOVA). The analyses revealed two main effects, one for list, $F(1, 174) = 137.58$, $p < .001$, $\eta^2 = .49$, where fewer items were recalled on the DRM lists (.283) than the category lists (.497), and one for age, $F(2, 174) = 62.01$, $p < .001$, $\eta^2 = .47$, where post hoc Newman–Keuls analyses indicated that 5-year-olds (.27) recalled less than 7-year-olds (.39), who recalled less than 11-year-olds (.51). There was a first-order interaction, List × Age, $F(2, 174) = 3.38$, $p < .05$, $\eta^2 = .046$. As can be seen in Figure 1 (panel a) and confirmed by post hoc tests, the difference between DRM and category lists was significantly smaller for the 5-year-olds than for 7- and 11-year-olds, where these same differences for the latter two groups did not vary significantly. Thus, although the difference was smaller for the youngest children, it is clear that true recall was better for categorized than standard DRM lists.

Next, tests concerning the false recall of critical lures were conducted (panel b). Recall that critical lures for the DRM lists were those unpresented items that are associated with each of the items in the presented list. For the categorized lists, the critical lures were the unpresented top exemplars for each of the categories (consistent with Seamon et al., 2000). Critical lures were analyzed using a 2 (list: DRM vs. category) × 3 (age: 5 vs. 7 vs. 11) between-subjects ANOVA.

The analysis revealed a main effect for age, $F(2, 174) = 7.53$, $p < .001$, $\eta^2 = .10$, where post hoc tests showed that 5-year-olds (.16) falsely recalled fewer critical lures than 7-year-olds (.27), who in turn falsely recalled fewer critical lures than 11-year-olds (.32). No other significant effects emerged. Thus, consistent with Hutchison and Balota (2005) adults' performance, relational (categorical) information did not increase the frequency of children's false memories regardless of age.

Experiment 2

The results of Experiment 1 are clear. Relational (categorical) processing enhanced children's true recall but had no impact on children's false recall. This finding is consistent with the dissociation found with adults (Hutchison & Balota, 2005) and is inconsistent with FTT's claim that developmental increases in the DRM false memory illusion are due to children's growing use of across-item relational (categorical) information.

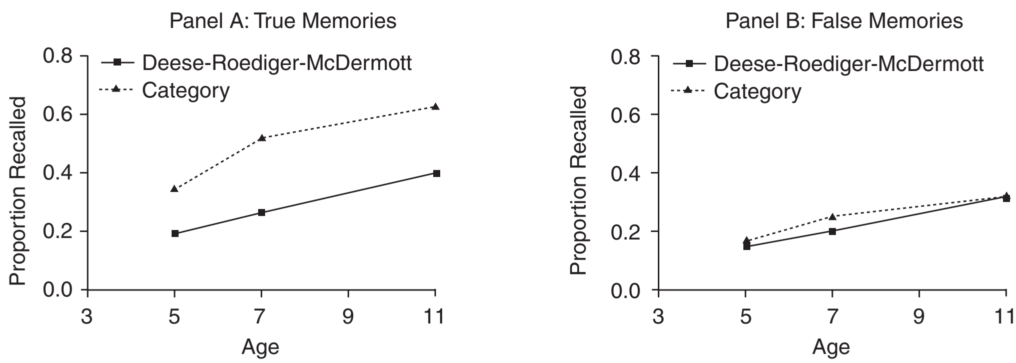

Figure 1. Children's true (panel a) and false (panel b) recall of standard Deese–Roediger–McDermott (DRM) and categorized word lists.

It could be argued that perhaps children, especially the younger ones, did not spontaneously extract the relational theme embedded in the categorized lists. That is, although items in each of the lists came from a single category, the blocking of items in this manner might not have ensured that children were conscious of these categorical relations. Although awareness of these categorical relations may not be necessary for improving true recall, it might be argued that this awareness is necessary for the production of false memories. For example, Howe (2005) found that unlike adults, children's false memories involve effortful, conscious processing.

In order to insure that children were consciously aware of the relational properties of the categorized lists, half of the children in the second experiment were provided with category labels before list presentation in order to insure that the categorical relations were properly primed. If children were not spontaneously using the category relations in the previous experiment, and relational processing is important for false memories, then those children receiving the prime before list presentation should not only exhibit higher true recall than those not receiving the prime, but should also be more susceptible to false memory illusions.

Method

Participants. A new sample of 180 children (93 males, 87 females), 60 from Kindergarten (5-year-olds; $M = 5$ years 4 months), 60 from grade 2 (7-year-olds; $M = 7$ years 4 months), and 60 from grade 6 (11-year-olds; $M = 11$ years 5 months), participated in this experiment. All of the children (predominantly White and middle class) who were tested had parental consent and had themselves assented to the procedure.

Design, materials, and procedure. A 2 (label: No-label vs. Label) $\times$ 3(age: 5 vs. 7 vs. 11) between-subjects design was used. Children were presented with 8, 14-item category word lists (without the top exemplar) one at a time (again drawn from Van Overschelde et al., 2004). Both the items and the category labels are familiar to, and used by, children as they also appear in child-relevant norms (i.e., these lists were cross-referenced with category norms established for children; see Posnansky, 1978). Words were printed on index cards and pronounced by the experimenter at a 5-s presentation rate. Children were randomly assigned to the No-label and Label conditions. Each child was instructed to try to remember the concepts presented on the list. For half of the children, lists were presented without a category label as they had been in Experiment 1. For the other half of the children, a category label was provided before list presentation. For example, for the animal category, children were told "all of the words on this list are names of animals."

As before, after the presentation of the last item in a list, children were given a distractor task (circling pairs of letters) for 30 s before being asked to recall the items from the list. After recall of that list was completed, the procedure was repeated for the seven remaining category lists. List order was randomized across children within each age group.

Results and Discussion

Once again, because there were no effects due to gender, this variable was eliminated from subsequent analyses. The mean proportion of targets correctly recalled and critical lures falsely recalled for the No-label and Label category lists are shown in panels a and b of Figure 2, respectively. As before, the main hypotheses associated with this study were tested by separately analyzing true recall and false recall.

The proportion of targets correctly recalled (panel a) were analyzed using a 2 (label: No-label vs. Label) $\times$ 3 (age: 5 vs. 7 vs. 11) between-subjects ANOVA. The analyses revealed a main effect for age, $F(2, 174) = 40.06$, $p < .001$, $\eta^2 = .49$, where post hoc

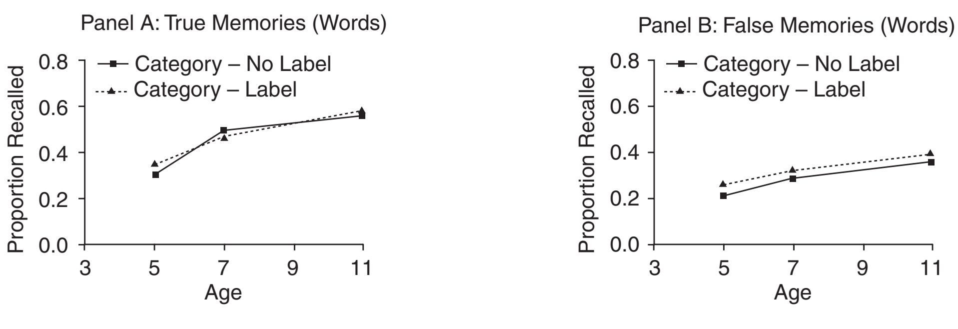

Figure 2. Children's true (panel a) and false (panel b) recall of categorized word lists with and without the presence of category labels at study.

Newman–Keuls analyses indicated that 5-year-olds (.32) recalled less than 7-year-olds (.48), who recalled less than 11-year-olds (.58). As can be seen in Figure 2 (panel a), although correct recall increased with age, it did not vary as a function of the category cuing manipulation. Thus, consistent with the extant literature on children's free recall of categorized lists (e.g., Bjorklund, 2004; Howe et al., 1985), it would seem that even children as young as 5-years-old can spontaneously use category information when items are blocked during presentation. Indeed, given the known strength of the blocking manipulation on even young children's recall (Lange, 1978; Moely, 1977; Schneider & Pressley, 1997), it would have been surprising to see any additional effects due to labeling. Hence, the differences between children's performance on DRM lists and category lists that were observed in Experiment 1 are most likely attributable to children's spontaneous use of category information and not spurious between-list item differences. That is, categorized lists were better remembered than DRM lists because they contain not just associative information but also categorical information that children can use to improve storage and retrieval of information (see Howe, 2000).

Next, tests concerning the false recall of critical lures were conducted (panel b). Again, the critical lures for the categorized lists are the unpresented top exemplars for each of the categories (consistent with Seamon et al., 2000). Critical lures were analyzed using a 2 (label: No-label vs. Label) × 3 (age: 5 vs. 7 vs. 11) between-subjects ANOVA.

The analysis revealed a main effect for age, $F(2, 174) = 8.59$, $p < .001$, $\eta^2 = .17$, where post hoc tests showed that 5-year-olds (.17) falsely recalled fewer critical lures than 7-year-olds (.30), who in turn falsely recalled fewer critical lures than 11-year-olds (.38). No other significant effects emerged. Thus, although false memories increased with age, this effect was no stronger when children were explicitly primed as to the category relations present in the list. Again, like the result of Experiment 1, it would seem that false memories in children, like those of adults, are based on inter-item associations and not across-item relational information.

Experiment 3

What the first two experiments have shown is that like adults (Hutchison & Balota, 2005), there exists a dissociation between children's true and false memories. Specifically, relational processing influences true but not false memory in the DRM paradigm. In order to provide additional, converging evidence concerning the importance of inter-item associations as opposed to across-item thematic information in children's false memories, a tact opposite to that of the first two experiments was taken. That is, rather than attempting to enhance thematic processing, Experiment 3 was designed to reduce associative processing. If the current hypothesis is correct, when associative processing is reduced, false memory rates should decline overall and developmental differences in the DRM illusion should vanish.

In order to selectively reduce associative but not overall thematic processing, Experiment 3 relied on another finding in the adult (and child) literatures concerning the DRM illusion, namely, the use of pictures rather than words. It is well known that pictorial presentation of DRM lists results in decreased false memory production (for a review, see Brainerd & Reyna, 2005). This is true for adults' false recognition rates (e.g., Schacter, Cendan, Dodson, & Clifford, 2001; Schacter, Israel, & Racine, 1999) as well as recall rates (e.g., Hege & Dodson, 2004). Indeed, Hege and Dodson (2004) found that adults who studied DRM word lists reported nearly twice as many critical lures on a recall test as did those who studied pictures. Similar effects have been observed for children's false recall and recognition rates (e.g., Ghetti, Qin, & Goodman, 2002). In fact, when pictures are used, the typical age increments in children's false memory rates disappear.

A leading explanation for this effect relies on the literature concerning adults' (e.g., Hunt & McDaniel, 1993) and children's (e.g., Howe, 2000, in press) distinctiveness effects in memory. Here, it is argued that reductions in false memory production with pictorial presentation are due to the distinctive processing that pictures receive during encoding. When participants study distinctive information (or process information in a distinctive manner), there is an increase in the encoding of item-specific information at the expense of memory for associative information (see also Arndt & Reder, 2003; Hunt & McDaniel, 1993; Smith & Hunt, 1998). As the critical lure is associatively related to each of the presented items, decreased associative processing would decrease responses to the critical lure (see also McEvoy et al., 1999; Roediger, Balota et al., 2001; Roediger, Watson et al., 2001). Interestingly, although pictorial presentation reduces associative processing, it does not impair other semantic (e.g., categorical) processing (Hutchison, 2003; Hutchison & Balota, 2005). Indeed, it has been found that semantic (as opposed to associative) relations play a greater role in picture encoding than in word encoding (Chiarello, 1998; Lupker, 1984, 1988).

Following this theoretical reasoning, it was hypothesized that presenting items as pictures rather than words would reduce associative processing, which in turn should reduce false recall if such false recall is based on associative rather than categorical relations. That is, like children's performance on DRM lists (e.g., Ghetti et al., 2002), false memories should be reduced on a recall test when pictures rather than words are presented on categorized lists because of impoverished encoding of associative (but not categorical) information. Like Experiment 2, in order to insure that children were aware of the relational (categorical) information, half of the children were primed with the category label before list presentation and the remaining half were not primed.

Method

Participants. A new sample of 180 children (94 males, 86 females), 60 from Kindergarten (5-year-olds; $M = 5$ years 5 months), 60 from grade 2 (7-year-olds; $M = 7$ years 3 months), and 60 from grade 6 (11-year-olds; $M = 11$ years 4 months), participated in this experiment. All of the children (predominantly White and middle class) who were tested had parental consent and had themselves assented to the procedure.

Design, materials, and procedure. A 2 (label: No-label vs. Label) $\times$ 3 (age: 5 vs. 7 vs. 11) between-subjects design was used. Children were presented with the same 8, 14-item category lists (without the top exemplar) that were used in Experiment 2, except that the items were presented pictorially, one at a time. The pictures themselves were taken from norms developed for children (Cycowicz, Friedman, Rothstein, & Snodgrass, 1997) and have been used before in memory experiments with children (e.g., Howe, in press). Pictures were affixed individually to index cards and were shown to the children at a 5-s rate while the experimenter named the picture. As before, children were randomly assigned to the No-label and Label conditions. Each child was instructed to try to remember the concepts presented on the list. For half of the children, lists were presented without a category label, and for the other half of the children, a category label was provided before list presentation.

As before, after the presentation of the last item in a list, children were given a distractor task (circling pairs of letters) for 30 s before being asked to recall the items from the list. After recall of that list was completed, the procedure was repeated for the seven remaining category lists. List order was randomized across children within each age group.

Results and Discussion

Again, there were no effects due to gender and this variable was eliminated from subsequent analyses. The mean proportion of targets correctly recalled and critical lures falsely recalled for the No-label and Label category lists are shown in panels a and b of Figure 3, respectively. As before, the main hypotheses associated with this study were tested by separately analyzing true recall and false recall.

The proportion of targets correctly recalled (panel a) were analyzed using a 2 (label: No-label vs. Label) $\times$ 3 (age: 5 vs. 7 vs. 11) between-subjects ANOVA. The analyses revealed a main effect for age, $F(2, 174) = 68.91$, $p < .001$, $\eta^2 = .624$, where post hoc Newman–Keuls analyses indicated that 5-year-olds (.31) recalled less than 7-year-olds (.54), who recalled less than 11-year-olds (.64). As can be seen in Figure 3 (panel a), although correct recall increased with age, it once again did not vary as a function of the category cuing manipulation. Thus, consistent with the extant literature on children's free recall of categorized lists (e.g., Bjorklund, 2004; Howe et al., 1985), category information can be extracted spontaneously even by 5-years-olds when items are blocked during

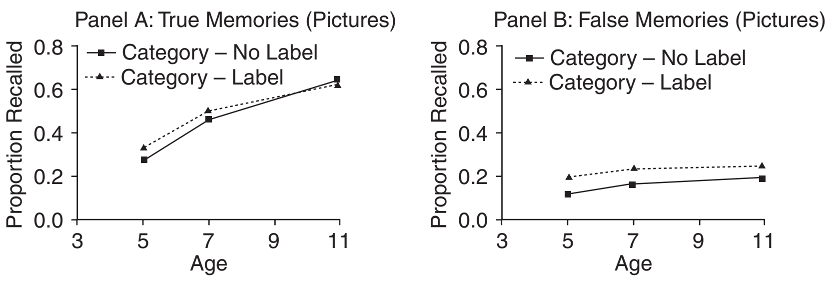

Figure 3. Children's true (panel a) and false (panel b) recall of categorized picture lists with and without the presence of category labels at study.

presentation and when the information is presented pictorially. Interestingly, a comparison of panel a in Figures 2 and 3 reveals no advantage of pictorial presentation over word presentation. This absence of a picture superiority effect (e.g., Paivio, 1986) is consistent with the fact that pictures and words were manipulated between subjects. That is, picture superiority effects typically emerge in a mixed-list, within-subject design (see also Dodson & Schacter, 2002).

Next, tests concerning the false recall of critical lures were conducted (panel b). Again, the critical lures for the categorized lists are the unpresented top exemplars for each of the categories (consistent with Seamon et al., 2000). Critical lures were analyzed using a 2 (label: No-label vs. Label) × 3 (age: 5-year-olds vs. 7-year-olds vs. 11-year-olds) between-subjects ANOVA. The analysis revealed no main effects or interactions.

That false recall was relatively minimal and did not vary with age or category cuing is consistent with the idea that the use of pictorial information reduces associative processing but not semantic processing (Chiarello, 1998; Hege & Dodson, 2004; Hutchison & Balota, 2005). That is, the associative processing necessary to produce false memories was minimized using pictorial information and these effects were seen in the reduction of false recall. Indeed, when compared with false memory rates for the same lists presented verbally (Experiment 2), false memories for pictorially presented items were reliably lower. Specifically, because the only difference between Experiments 2 and 3 was presentation mode (remembering that the lists and procedure were otherwise identical), a 2 (experiment: 2 vs. 3) × 3 (age: 5- vs. 7- vs. 11-year-olds) ANOVA was conducted with the result that: there was a main effect for experiment, $F(1, 348) = 10.23$, $p < .01$, $\eta^2 = .06$, such that there were fewer false memories in Experiment 3 ($M = .16$) than Experiment 2 ($M = .28$) and an Experiment × Age interaction, $F(2, 348) = 4.00$, $p < .01$, $\eta^2 = .045$. Post hoc Newman–Keuls tests confirmed that, regardless of age, there were fewer false memories in Experiment 3 than Experiment 2 and that, although false memories increased with age in Experiment 2, there were no age-related trends in Experiment 3 (compare panel b in Figures 2 and 3). Importantly, despite these differences between experiments (modality) with regard to false memories, patterns of veridical memory were reasonably similar. What this means is that, regardless of modality, semantic information was still being processed as indicated by similar levels of true recall for both pictures (Experiment 3) and words (Experiment 2) as well as nearly identical age effects.

General Discussion

The issue addressed in the current series of experiments was whether children, like adults, exhibit a dissociation between inter-item associative links and across-item thematic (semantic) links when generating true and false recall. That is, like adults, are inter-item associative links primarily responsible for children's false recall in the DRM paradigm whereas both inter-item associations and thematic coherence are critical for true recall? This issue was examined in three experiments, two of which varied (enhanced) across-item thematic relations (Experiments 1 and 2) and one of which varied (reduced) inter-item associative relations (Experiment 3).

The results of the current set of experiments are consistent with prior research inasmuch as they showed that children from all three age groups produced true and false memories and that, with one exception (Experiment 3), the numbers of both increased significantly with age (e.g., Brainerd et al., 2002; Howe et al., 2004). More importantly, the present research also showed some hitherto unreported trends in children's DRM illusions, ones that are consistent with those found in the adult DRM literature (e.g., Hege & Dodson, 2004; Hutchison & Balota, 2005). That is, regardless of age, children's (1) true but not false recall was enhanced by the addition of across-item thematic (semantic) relations (Experiments 1 and 2) and (2) false but not true recall was reduced when inter-item associative relational processing was minimized (Experiment 3).

These findings are compatible with models of false memory production that rely on associative mechanisms (e.g., Hutchison & Balota, 2005; Underwood, 1965) but not with models that rely on thematic mechanisms (e.g., Brainerd & Reyna, 2005). In particular, it is difficult to see how FTT can account for the current developmentally invariant pattern of dissociations. According to FTT, recall of false memories is said to be primarily the result of gist-based across-item processing. What this means is that the addition of categorical relations (with or without the associated labels) in list structures should have resulted in increased false memories relative to the standard associative DRM lists. However, although the addition of strong across-item semantic relations enhanced children's true recall, it had no effect on children's false recall.

Similarly, it is not clear how FTT can accommodate the findings from Experiment 3 in which associative processing was minimized but across-item semantic relations were left intact. Here, not only was children's false recall lower overall than in the other experiments where both semantic and associative relations were intact, but developmental trends in false memories disappeared. Thus, although gist processing is certainly involved in the generation of children's false memories in the DRM paradigm, the meanings being processed appear to be associative and not necessarily semantic.

As noted earlier, this finding, that the false memory illusion in the DRM paradigm is driven by inter-item associative relations but veridical recall is driven by both associative and semantic processing, is well established in the adult memory literature (e.g., Hege & Dodson, 2004; Hutchison, 2003; Hutchison & Balota, 2005; Park et al., 2005). The present experiments have established the developmental invariance of this dissociation in children's DRM illusions. Given that the dominant explanation of the growth of children's DRM illusions across development, FTT (Brainerd & Reyna, 2005), has difficulty accounting for the present findings, what theoretical explanations remain? In what follows, theoretical explanations of this dissociation are presented. This is followed by a discussion of how these theories can account for the developmental invariance of this dissociation as well as how they can accommodate developmental increases in the DRM illusion in childhood.

Turning to the adult literature, the primary explanation for this dissociation relies on earlier models of associative learning. Prominent among these is Underwood's (1965) implicit associative response (IAR) view of false memory in which false associative information is generated during study and becomes part of the person's conscious, episodic list experience. More recent theories suggest that for adults, at least, this activation may be implicit, occurring automatically, and that this activation summates over associations to increase the level of activation of an associated (false) lure's representation in memory (e.g., Balota & Paul, 1996; see also Hutchison, 2003).

A related theory is similar to that proposed by Anderson and Bower (1973, 1974) in their original FRAN and HAM models (see Hutchison & Balota, 2005). Here, concepts that are activated during study are "marked" as having occurred on an episodic list and their associative pathways to other, unpresented items are also marked, possibly erroneously connecting them to the same episodic list. Later, during retrieval, this network of marked concepts and connections is searched for items to output. If strongly associated but unpresented items have multiple pathways that are marked, then such an item might be falsely output as having occurred on the list itself. That is, as the pathways linking "sour" and "sugar" become marked, so too could the pathways between these concepts and the critical unpresented lure "sweet." Over the entire list, the critical lure "sweet" may have been activated multiple times, giving it more strength or support in the associative network making up the episodic list representation in memory. Indeed, the critical unpresented lure could receive more activation than the presented items, something that in turn might lead not only to that item being falsely recalled but also to it being retained in episodic memory longer than the items actually presented. Importantly, both of these speculations have received empirical support in the literature. That is, false memories are more enduring than veridical memories for both adults (e.g., Seamon et al., 2002; Thapar & McDermott, 2001) and children (e.g., Brainerd, Reyna, & Brandse, 1995) and critical lures that are more strongly (backwardly) associated with the episodically presented list items are more likely to be falsely recalled for both adults (e.g., Roediger & McDermott, 1995) and children (e.g., Howe et al., 2004).

If inter-item associative processing is controlling the magnitude of the DRM illusion in children and adults, and associative connectivity between items is available early in childhood (e.g., Bjorklund, 2004), then how can we explain the observed developmental increases in the magnitude of this illusion? First, although associations are available early in childhood that does not mean that they do not undergo any development. Many concepts, although represented in memory, are not well linked to other concepts early in development. Continued experience with items and objects not only increases their representational strength in memory but also leads to increases in the number and strength of inter-item associations in memory (e.g., Bjorklund, 1987). Indeed, much of the research conducted over the past three decades has shown that increases in the frequency of occurrence of particular items lead to a number of important changes in children's knowledge base, including ease with which items are activated and the strength of inter-item associations (e.g., Howe, 2000). In addition, as items become experienced in different contexts, the number and strength of their connections to other items increases. As Bjorklund (1987) pointed out, it is these latter changes that are the single most important factor responsible for age changes in the speed of activation of concepts and their interconnections in memory.

Second, in addition to growth in the quantity and quality of associations in children's memory, the automaticity with which concepts and their associative links are activated also changes (e.g., see Dempster & Brainerd, 1995). Although the activation of concepts and their pathways to related items in memory is relatively automatic for adults, such processing is more effortful for children (e.g., Bjorklund, 1987, 2004). Although it is well known that children's automatic processing develops at different rates depending on the type of memory task being administered, it is known that their performance on the DRM paradigm is not automatic. Using the DRM paradigm with children of the same ages as those tested here, Howe (2005) found that children's performance, particularly their production of false memories, was generated using effortful, not automatic, processing. Such effortful, conscious processing is the hallmark of children's false memory production in the DRM task and is one of the factors that separates them from adults whose processing is relatively automatic. This does not imply that children are aware that the memories they are generating are false. Rather, it means that once generated, such items become part of conscious awareness and are treated as part of the episodically studied material. Thus, although children can and do extract the meaning of items and activate their inter-item associative links, they do so with greater cognitive effort than adults.

The current proposal, then, is that contrary to FTT, age increases in spontaneous false memories in the DRM paradigm are not driven by developmental advances in the ability to generate across-item gist per se, but rather by increased representational strength of individual concepts and the automaticity with which inter-item associations are activated. As associative strength and automaticity increase, so too do the number of associations potentially activated between list items and the critical lure, something that in turn increases the summative activation of critical unpresented items, leading to their erroneous output during recall. These assumptions are consistent with more global models of memory development (e.g., the trace-integrity theory; see Howe, 2000) in which changes in children's ability to represent concepts and their inter-item associative links in storage lead to age-related improvements in memory performance. More generally, these ideas are consistent with models of memory development that rely on changes in the dynamics of children's storage abilities (e.g., Bauer, 2005; Howe, 2000).

Overall, these findings show that 5-, 7-, and 11-year-old children do generate false memories when studying DRM lists and that they increase with age. More importantly, like adults, false memories are controlled more by inter-item associations than across-list thematic or semantic relations. Indeed, the present results duplicate the dissociation found in the adult literature (e.g., Hutchison & Balota, 2005) in which veridical recall depends on both associative and semantic relations, but false recall is driven by associative links. In addition, like adults (e.g., Hege & Dodson, 2004), when associative information is diminished but across-item semantic (categorical) information remains intact, veridical memories are robust but false memories decrease. These results are consistent with theories that localize the DRM illusion in terms of associative mechanisms (e.g., Hutchison & Balota, 2005) rather than across-item thematic relations (e.g., Brainerd & Reyna, 2005). The newly discovered developmental invariance in this mechanism that was seen across the three experiments in this article argues for a single, associative mechanism that drives false memories in the DRM paradigm. Such a mechanism is well known in the literature on children's memory and is consistent with models of development that emphasize changes in how information is stored in memory and increases in the automaticity of children's processing.

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