Available online at www.sciencedirect.com
ScienceDirect
Cognitive Development 23 (2008) 67–78
COGNITIVE DEVELOPMENT

Recall of details never experienced: Effects of age, repetition, and semantic cues

Robyn E. Holliday [a,*], Valerie F. Reyna [b], Charles J. Brainerd [b]

[a] *Department of Psychology, University of Kent at Canterbury, Canterbury CT2 7NP, United Kingdom*
[b] *Department of Human Development, Cornell University, Ithaca, NY, United States*

Abstract

To test theoretical predictions about the role of meaning connections in false memory, the effects of semantic cues and list repetition on children's false memories were evaluated across early childhood to mid-adolescence using the Deese–Roediger–McDermott (DRM) paradigm. True recall and false recall increased from 7 to 13 years. Study list repetition increased true recall of list words with the magnitude of this effect largest in the older children and adolescents. Repetition reduced false recall of critical lures in all age groups. Consistent with theoretical predictions, false recall of critical lures increased when children were informed of the thematic gist of each list prior to study.

Keywords: Memory; Pre-school children; Primary/junior school children; Adolescents; Memory illusions; Memory development

1. Introduction

False memory illusions have been studied extensively in the adult literature using the Deese–Roediger–McDermott (DRM) converging associates task – first published by Deese (1959) and later revived by Roediger and McDermott (1995) and Read (1996) – largely because robust levels of false memory illusions can be produced under controlled conditions. There are multiple theories of the DRM Illusion in adults. Two prominent theories are fuzzy-trace theory (FTT) and activation-monitoring theory (AMT). FTT explains the illusion like this: Memory illusions are based on the meaning or gist of the experienced event (Reyna & Lloyd, 1997) combined with

* Corresponding author. Fax: +44 1227827030.
E-mail address: R.Holliday@kent.ac.uk (R.E. Holliday).

0885-2014/$ – see front matter
doi:10.1016/j.cogdev.2007.05.002

inability to retrieve verbatim traces of list words. AMT explains the illusion like this: Memory illusions are based on implicit activation and failures of source-monitoring (Roediger & McDermott, 2000). Of these adult theories, FTT is the only one that can explain the robust findings in the developmental literature because it predicts age increases in reporting of memory illusions.

In a typical DRM task, children study several lists of semantically related words. Each list contains words, which are all meaning associates of an unpresented but thematically related word, the critical lure. For example, the words *door*, *glass*, *pane*, *shade*, *ledge*, *sill*, *house*, *open*, *curtain*, *frame*, are related in meaning to the critical lure *window*. The list words are presented in the order of strongest to weakest associate of the critical lure for that list—*door* is more strongly associated to *window* than *glass* is to *window*. Each list word does to some degree repeatedly cue or activate the meaning for that list and the strongest associate to those list words, the critical lure. Brainerd, Forrest, Karibian and Reyna (2006) and Brainerd, Reyna, and Forrest (2002) reported that false recognition and false recall increased from 5–6 years to 11–12 years, and Brainerd, Holliday and Reyna (2004) and Holliday and Weekes (2006) replicated that trend for false recognition. Similarly, Price, Metzger, Williams, Phelps, and Phelps (2001) found that college students falsely recalled more critical lures than 7-year-old children. Warren, Reed, Mangan and Metzger (2003) and Howe, Cicchetti, Toth, and Cerrito (2004) reported increases in false recall and false recognition from 7 years to young adulthood and from 5 to 12 years, respectively. Brainerd et al. (2002, 2004) and Howe et al. (2004) used word lists that were developed for and normed on adults. Nonetheless, Metzger et al. (2004) reported similar developmental increases when they used word lists generated by the children themselves. Holliday and Weekes (2006) and Brainerd and Reyna (in press) showed that this pattern is specific to lists of *semantically* related words and does not occur for lists of phonologically related words.

Next, we outline the process assumptions of two popular accounts of false memory illusions, activation-monitoring theory (AMT) and fuzzy-trace theory (FTT). We then discuss these two theories in relation to the extant empirical evidence for children.

1.1. Theoretical accounts of the DRM iIllusion

Roediger & McDermott, 2000 expanded Underwood's (1965) implicit associative response (IAR) hypothesis about false memory into a two-process account of memory illusions (false memories), known as AMT. Activation is a fast-acting, automatic process (Anderson & Pirolli, 1984; Collins & Loftus, 1975). False memories in the DRM task are due to the rapid and automatic spread of activation at encoding between representations of list words and the semantically associated but unstudied word, the critical lure (Roediger & McDermott, 2000). In other words, studying a list of words all of which are strong semantic associates of a critical lure activates the critical lure for that list as well as a network of connecting nodes. For example, studying the words *sour*, *candy*, *sugar*, *bitter*, *good*, *taste*, *tooth*, *nice*, *honey*, *soda*, *chocolate*, *heart*, *cake*, *tart*, *pie*, activates the critical lure for this list, *sweet*. Hence, the expectation is that high levels of activation will increase both true and false recall (Arndt, 2006). Indeed, in adult (but not child) participants, the rate of critical lure intrusion in recall is sometimes close to recall of list words (Reyna, Mills, Estrada, & Brainerd, 2006; Robinson & Roediger, 1997). The second process, memory source-monitoring (Johnson, Hashtroudi, & Lindsay, 1993), is a slower, more strategic process that serves to reduce false memories. At retrieval, a participant must make a source-monitoring judgment about the activation; that is he/she must decide whether a recollected word was actually presented on the studied list. Source decisions are made on the basis of the qualities (e.g., perceptual, contextual) of the available memories (Gallo & Roediger, 2002). Accurate source-monitoring should increase true recall by correctly identifying the studied list as the source and reduce false recall by correctly identifying that the critical lure was not on the studied list.

With regard to activation of associated words, well established findings from research on memory strategy use in childhood are informative. Bjorklund and his colleagues have reported that children as young as six years show evidence that associative relations between meaning-related words are activated automatically (Bjorklund & Zeman, 1982; Lange, 1978) and are a precursor of semantic organization (Bjorklund & Hock, 1982; Bjorklund, & Jacobs, 1985). Patterns of associative activation are generally stable between 6 and 12 years (Bjorklund & de Marchena, 1984). It is also the case that *spontaneous* implementation of an organization strategy (e.g., clustering) that increases recall of semantically related words is not evident until around 13 years of age (Bjorklund, Coyle, & Gaultney, 1992; Bjorklund & Jacobs, 1985; DeMarie-Dreblow, 1991). Bjorklund et al. (1992), for example, found that despite the 9-year-olds in their study displaying some evidence of organizational strategy use, it was not until 13-years that such usage led to improvements in recall.

With regard to monitoring, it is well established that source-monitoring errors decline from early childhood to young adulthood due to improvements in correct source discriminations (Ackil & Zaragoza, 1995; Foley & Johnson, 1985; Lindsay, Johnson, & Kwon, 1991). Lindsay et al., for example, reported that 4–6-year-old children were particularly susceptible to the effects of source similarity and were more likely to make source-monitoring errors than older children and adults. Ackil and Zaragoza replicated this developmental trend in 7, 9, and 11-year-olds and college students (see Roberts & Blade, 2000, for a comprehensive review of source-monitoring in children). It is also well established that spontaneous implementation of memory strategies during memory recall is quite limited in young children and develops slowly across early to late childhood (Bjorklund, 2005). Given that accurate source-monitoring increases with age while associative activation is age invariant, the prediction is that false memories should *decrease* with age (see also Ghetti, Qin, & Goodman, 2002).

FTT is an opponent process theory of false memory that preceded AMT (Reyna & Brainerd, 1995). In FTT, information (e.g., studied word lists, witnessed events) is stored in two independent memory traces, *verbatim* – integrated representations of the surface form and item-specific details (e.g., *ate pancakes*) and *gist* – meaning, interpretation, and elaboration of an experience (e.g., *ate breakfast*). For true recall of studied list words, verbatim and gist traces work together; retrieval of vivid verbatim traces of true events suppresses false but gist-consistent details via a memory editing process called *recollection-rejection* (e.g., *I could not have eaten fried eggs because I remember eating pancakes*). (For further details, see Brainerd & Reyna, 2002; Brainerd, Reyna, Wright, & Mojardin, 2003.) For false recall, verbatim and gist traces oppose each other; retrieval of vivid verbatim traces of true events supports suppression of false gist-consistent events, and retrieval of false gist traces supports recall of false meaning consistent events (e.g., *ate fried eggs*) (Brainerd & Reyna, 2001, 2005).

According to FTT, spontaneously connecting meaning across list words is crucial to the DRM illusion, and this ability develops slowly (Brainerd et al., 2006; Reyna et al., 2006). For instance, evidence that young children process surface features rather than semantic features of an event or word list is demonstrated in a recent study which compared children's recollections in the typical semantic DRM task with a phonological DRM task (Holliday & Weekes, 2006). A developmental dissociation between phonological and semantic false memory was found; false memories increased with age for semantic relatedness and decreased with age for phonological relatedness (see also Brainerd & Reyna, in press).

In late childhood and early adolescence, children are more adept at extracting and retaining the gist of semantically related words than young children (Brainerd & Reyna, 2005). Hence, the predicted developmental trend according to FTT is that young children should be less likely than older children and adolescents to falsely recall critical lures because they are less likely to notice the gist theme and hence less likely to accumulate the impact of multiple cues to the same gist (Brainerd et al., 2006; Reyna et al., 2006).

Although the age increase prediction has been confirmed in numerous experiments, this confirmation is not the same thing as a test of the process mechanisms. Indeed, there could be other mechanisms that might be producing this age increase. Hence, in order to test the FTT process mechanisms, we implemented an experimental design in which the mechanisms were manipulated to see if doing so would increase false memory in children. There are many ways to manipulate these mechanisms, but the obvious way is to help children connect the gist of the lists. In this experiment, we achieved this with a cuing manipulation that does two things: First, it alerts children that there are going to be meaning relations in the list and, second, it tells children what the meaning relation is for each specific list.

Children in a semantic cue condition were given meaning instructions, which informed them of the theme of each DRM list just before it was presented. The remaining children received no advance information about list themes. We reasoned that if children fail to connect the gist of semantically related words, then providing a gist cue before studying each list would facilitate gist extraction. This manipulation resembles the category-cuing instructions that were used in classic developmental studies of categorized recall (for a review, see Bjorklund, 1987). If FTT is correct, providing children with list themes before list presentation (e.g., *the words you will hear are all related in meaning, they are all medical words*) should increase false recall of critical lures by compensating to some extent for young children's limitations in meaning connection. Only two developmental studies have investigated the effects of meaning instructions on false recall and these have reported opposite effects. In Brainerd et al's (2006) study with 7, 11, and 14-year-olds, meaning instructions (i.e., *each list will contain words with similar meanings*) increased false recall of critical lures relative to a control condition, but only in the 7- and 11-year-olds. Howe (2006), on the other hand, found no increase in false recall when 5, 7, and 11-year-old children were provided with a category label (i.e., *all of the words on this list are names of animals*) immediately before a word list presentation. FFT predicts that the effects of the semantic cue instructions should only be found in false recall of critical lures because true recall of list words can be based on verbatim traces (Brainerd et al., 2006).

A second manipulation was implemented to test another process mechanism of FTT. Children's false recall was compared for two levels of study list presentation: some lists were administered once and others three times. FTT predicts that list repetition strengthens verbatim traces of list words (Brainerd et al., 2003). These verbatim traces are used to suppress false but gist-consistent words via the editing process noted earlier, *recollection-rejection* (Brainerd et al., 2003): Retrieving vivid, realistic traces of the prior presentation of list words serves to neutralize the meaning familiarity of unpresented critical lures (Brainerd & Reyna, 2005). Hence, if FTT is correct, list repetition should result in better discrimination between verbatim traces (support true recall) and gist traces (support false recall) at retrieval (Brainerd et al., 2003; Seamon et al., 2002). The predicted developmental trend is that the tendency of list repetition to suppress false recall should increase with age, as children become more proficient at forming the gist memories that support false recall.

2. Method

2.1. Participants

The participants were 80: 7-year olds (M = 7–4; range 6–9 to 7–6), 86: 9–year-olds (M = 9–6; range 8–11 to 9–7), 78: 11-year-olds (M = 11–3; range 10–10 to 11–6), 78: 13-year-olds (M = 13–3; range 12–10 to 13–5), and 78: 15-year-olds (M = 15–6; range 14–10 to 15–7). There were approximately equal numbers of males and females in each age group. Ninety-eight percent of the children were white British and 2% non-white British. All attended schools in middle-class areas and only participated if prior parental and child consent had been granted.

2.2. Design

A 5 (age) × 2 (meaning condition: semantic cue, no semantic cue) × 2 (list repetition: one presentation, three presentations) mixed design was used, with age and meaning condition between subjects-variables and list repetition within-subjects variable.

2.3. Materials

The Stadler, Roediger and McDermott (1999) word lists provided a pool of words from which materials were taken.[1] The first 14 words from 10 lists rated as producing high levels of false recall served as list words presented in the study phase. Each child heard six lists randomly selected from these 10 Stadler et al. lists presented in random order.

2.4. Procedure

All testing took place in a quiet room at the children's schools. At each age level, a child was randomly assigned to either a semantic cue or a no semantic cue condition (control). Children were told that they would hear several lists of words, that some lists would be heard once and the remainder three times, and that they would be asked to remember the words after hearing each list. Children in the semantic cue condition were then given a meaning instruction before each list; for example – before the presentation of the *doctor* list children were told, *"The words you are about to hear all have similar meanings. They are all very closely related to each other. All the words are medical words*." The first list of 14 words (strongest-to-weakest meaning associates of the critical lure) was then played on audiotape at the rate of 3 s per word. Next, a 60 s distractor task (coloring shapes) was given, followed by written recall of list words (2 min).[2] This procedure was repeated until all six lists (three presented once and three presented three times) had been studied and recalled. No meaning cues were given before recall of a list.

A final recognition test was given after all lists had been studied and recalled. Children in the semantic cue condition were first reminded that the words on each list they had heard were related in meaning, for example, *"The first list was about medical words, the second list was about furniture word*s, etc." Control condition participants received no cues. All children then

[1] These lists were selected in order that comparisons could be made with published adult and child studies.

[2] We allowed 2 min for recall after each 14-word study list. During this time, children in all age groups spoke aloud and then wrote down each recalled word. In the event that a child displayed difficulty with the written aspect of the task, the experimenter wrote down a word for him/her. Four 7-year-olds (two males and two females) needed such assistance.

responded *yes* or *no* on a recognition test for 38 words presented on audiotape. Eighteen of the words were studied list words (targets) (i.e., 3 × 6 lists), another six the critical lures and another six the unpresented associates for these lists (the 15th word on list). Also included were eight new words (from 24 other Stadler et al., 1999 lists).

3. Results

The mean proportions of targets (studied words) and critical lures recalled by experimental conditions were calculated. True recall of targets and false recall of critical lures were analyzed separately in two mixed ANOVAs. For true recall of target words, a 5 (age) × 2 (meaning condition: semantic cue, no semantic cue) × 2 (list repetition: one presentation, three presentations) mixed ANOVA with repeated measures on the last factor was performed using yes response proportions as the dependent variable. Post hoc analyses (Tukey HSD $p < .05$) were performed on all significant interactions.

Robust main effects were found for repetition, $F(1, 390) = 454.30$, MSE = .005, $p < .001$, $\eta_p^2 = .538$, and for age, $F(4, 390) = 175.42$, MSE = .015, $p < .001$, $\eta_p^2 = .643$. Concerning the former effect, repetition of study lists increased target recall ($M_1 = .38$, $M_3 = .49$). For the age main effect, the following developmental increase from 7 to 13 years was observed: 7-year-olds (M = .22) recalled fewer targets than 9-year-olds (M = .45) and 11-year-olds (M = .43) who recalled fewer targets than 13-year-olds (M = .54) and 15-year-olds (M = .53). These main effects were qualified by a significant age × repetition interaction, $F(4, 390) = 15.90$, MSE = .001, $p < .001$, $\eta_p^2 = .140$. As can be seen in Fig. 1, true recall of studied words (targets) was increased by list repetition in the older children (11, 13, 15 years).

False recall of critical lures was analyzed using a 5 (age) × 2 (meaning condition: semantic cue, no semantic cue) × 2 (list repetition: one presentation, three presentations) mixed ANOVA with repeated measures on the last factor using yes response proportions as the dependent variable.

Main effects were found for repetition (one list versus three list presentations), $F(1, 390) = 19.41$, MSE = .073, $p < .001$, $\eta_p^2 = .047$, meaning condition (semantic cue versus no

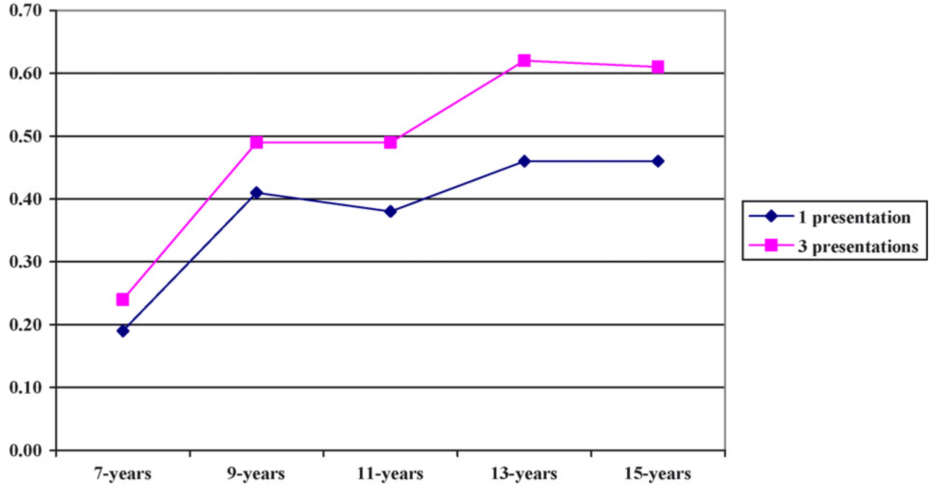

Fig. 1. Proportions of DRM list words (targets) recalled by age and the number of list presentations.

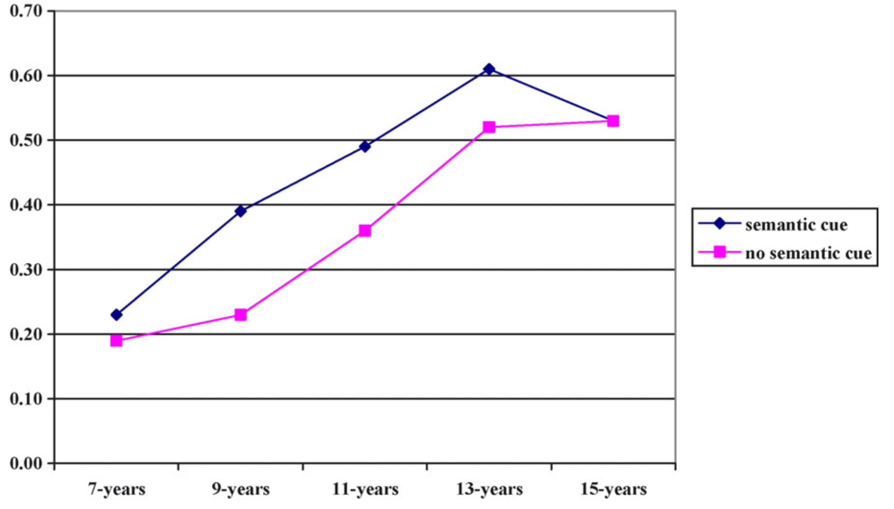

Fig. 2. Proportions of false recall of critical lures by age and cue conditions.

semantic cue), $F(1, 390) = 12.83$, MSE = .112, $p < .001$, $\eta_p^2 = .032$, and age, $F(4, 390) = 31.18$, MSE = .112, $p < .001$, $\eta_p^2 = .017$. Repetition of studied lists reduced false recall of critical lures ($M_1 = .45$, $M_3 = .36$) in all age groups. Semantic cues increased false recall of critical lures ($M_{cue} = .45$, $M_{no\ cue} = .36$) in all age groups. For the age main effect, the developmental trajectory was one of age increases in false recall of critical lures between 7 and 13 years; 7-year-olds recalled fewer critical lures (M = .21) than 9-year-olds (M = .31) who recalled fewer critical lures than 11-year-olds (M = .42) who recalled fewer critical lures than 13-year-olds (M = .57) and 15-year-olds (M = .53). Simple effects confirmed that these differences were reliable. Fig. 2 displays the mean proportions of critical lures recalled by meaning conditions. Even though there was a trend for more critical lures to be recalled in the semantic cue than in the no cue condition, the age × meaning condition interaction did not reached significance, $F(4, 390) = 1.72$, MSE = .112, $p = .115$, $\eta_p^2 = .017$; semantic cues increased false recall in all age groups.

The mean proportions of semantically related intrusions by cue condition and age are presented in Fig. 3. A recalled word was coded as a *semantically related intrusion* if it was unpresented but related in meaning to the studied words for that list (e.g., *yawn* from the *sleep* list). We also coded earlier list and unrelated intrusions—an *earlier list intrusion* if it appeared on a previously studied list (e.g., *table* reported during recall of the *sleep* list when the CHAIR list was presented earlier), and an *unrelated intrusion* if it was previously unpresented and semantically unrelated to studied list targets (e.g., *small*). Because these were rarely recalled (i.e., <1% of reported intrusions), they are not discussed further. Semantically related intrusions, on the other hand, comprised 25.7% of all reported intrusions. These items were identified by two independent coders. We report reliability measures for the semantically related (but unpresented) distractors on which we performed ANOVA. The intraclass correlation co-efficient = .993, $p < .001$, and Cronbach's Alpha = .996.

A 5 (age) × 2 (meaning condition: semantic cue, no semantic cue) × 2 (list repetition: one presentation, three presentations) ANOVA on the number of semantically related intrusions recalled revealed a main effect for meaning condition, $F(1, 390) = 16.94$, MSE = 1.28, $p < .05$, $\eta_p^2 = .033$;

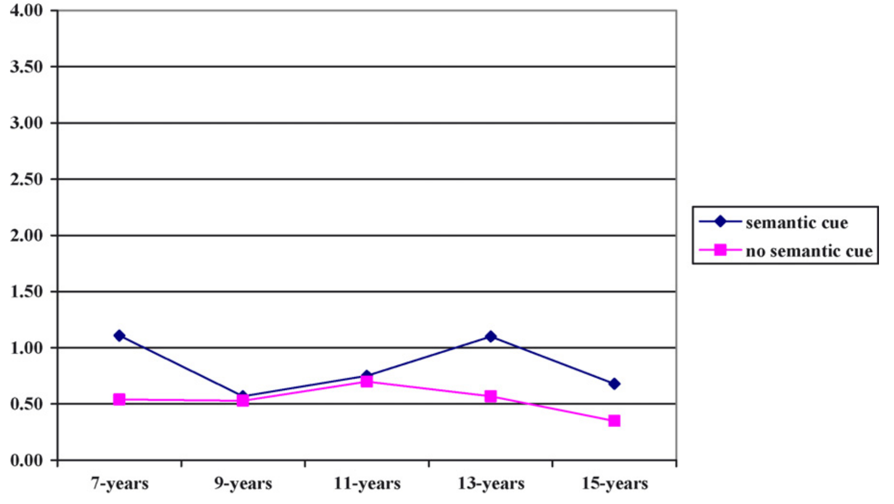

Fig. 3. Mean numbers of semantically related (to DRM list words) intrusions recalled by age and cue conditions.

not surprisingly, more semantically related intrusions were reported in the semantic cue condition (M = .84) than in the no semantic cue condition (M = .54).

3.1. Are true recall and false recall independent?

The following analyses were motivated by source-monitoring theory (Johnson et al., 1993) in which it is predicted that the relationship between studied list words (e.g., *sour*, *candy*, *sugar*, *bitter*, *good* etc.) and critical lure (e.g., *sweet*) is one of positive dependency because both are related to the meaning of the studied list (Reyna et al., 2006). In other words, it is argued that source discriminations are based on qualities of memories for the studied list (e.g., shared semantic features) (e.g., *sour*, *candy*, *sugar*, *bitter*, *good etc*). Pearson bivariate correlations (2-tailed) on the proportions of true recall and proportions of false recall were computed for each age group. True recall of list words and false recall of critical lures were unrelated for the 7-year-olds, $r = -.01$, 11-year-olds, $r = .10$, 13-year-olds, $r = .09$, and 15-year-olds, $r = .10$. For the 9-year-olds, however, true recall and false recall were positively related, $r = .28$, $p < .01$, although not strongly (Stadler et al., 1999). Hence, with the exception of the 9-year-olds, true recall and false recall were independent, which supports a dual process account of false memory such as FTT, and not a source-monitoring account of dependency of true and false recall.

3.2. Are true and false recall related to true and false recognition?

We investigated the relationships between true recall and recognition and between false recall and recognition across participants. We reasoned that if each list word in a list of meaning associates activates other meaning associates including the critical lure, false recall of list words and critical lures are necessarily semantically related. Results of our analysis replicated Stadler et al.'s (1999) and Gallo and Roediger's (2002) findings with adults and extended them to children and adolescents across a wide age range. A strong positive relationship between true recall and recognition was found, $r = +.36$, $p < .01$. Similarly, a positive relationship between false recall and false recognition was found, $r = .16$, $p < .01$, although the size of this effect was smaller. As noted by Stadler et al. (1999) and Gallo and Roediger (2002), caution must be taken in interpreting such findings given that the recognition test always followed free recall of all the studied lists.

4. Discussion

Repetition of studied lists we found reduced false recall of critical lures. As expected, children were less likely to falsely recall critical lures following three presentations of study lists than one presentation. These results parallel those reported in the adult literature (e.g., Benjamin, 2001) and are consistent with FTT's opponent processes account of false recall such that verbatim repetition of DRM list words strengthens verbatim memory traces which are then used to suppress false but gist-consistent critical lures via a recollection-rejection editing process (Brainerd et al., 2003). Repetition also affected true recall in a manner analogous to previously reported findings with adults (e.g., Seamon et al., 2002). Children were more likely to correctly recall studied words as having been presented on DRM lists following three presentations rather than one presentation.

Semantic cue instructions elevated false recall at all age levels. False recall of critical lures was higher if children were given meaning instructions (e.g., *all the words are medical words*) just before presentation of a DRM list (Brainerd et al., 2006), as predicted by FTT. This result is particularly important because this manipulation tested FTT's assumptions about the memorial bases for DRM false memories, namely, that storage and retrieval of gist memories that connect the meanings of DRM list words increase the incidence of false recall of critical lures (Brainerd et al., 2002). Note that the meaning instructions manipulation did not affect true recall, which lends support to the FTT view that true memories are, for the most part, verbatim based. Meaning instructions should only affect false recall of critical lures because they originate from gist memories (Brainerd et al., 2006).

As expected, false recall of critical lures increased from 7 to 13 years as reported by others (e.g., Brainerd et al., 2002; Dewhurst & Robinson, 2004; Howe et al., 2004; Price et al., 2001; Warren et al., 2003). Indeed, false recall at 13- and 15-years reached levels similar to those reported in the adult DRM literature (e.g., Roediger & McDermott, 1995). This developmental pattern is predicted by FTT on the basis of age increases in gist extraction between early childhood and early adolescence (Brainerd et al., 2004). FTT holds that false recall will increase with age if a paradigm satisfies two conditions: (1) the skills (e.g., meaning extraction and connection) that support gist-based memory reports improve slowly with age, and (2) retrieval of verbatim memory traces to suppress false but gist consistent traces is made difficult by the particular paradigm (Brainerd et al., 2006). The DRM paradigm satisfies both these conditions (Brainerd et al., 2002). First, we know from the literature on recall of categorized word lists that young children do not spontaneously connect meaning related words during encoding or recall (Bjorklund, 1987; Bjorklund & Hock, 1982; Bjorklund & Jacobs, 1985). The ability to use such strategies without specific instructions to do so develops slowly between early childhood and early adolescence (Bjorklund, 2005; Bjorklund, Schneider, Cassel, & Ashley, 1994). Second, it is difficult to reject the critical lure *sweet* following presentation of the DRM list words *sour*, *candy*, *sugar*, *bitter*, *good*, *taste*, *tooth*, *nice*, *honey*, *soda*, *chocolate*, *heart*, *cake*, *tart*, *pie* because each list word strongly instantiates and repeatedly cues or activates the false but meaning consistent critical lure *sweet*.

It was expected that the older children would be more competent than young children in using the meaning instructions to connect the meaning relations of the list words. Instead, we found that all children could use these cues. Even the youngest children, who have been shown in numerous studies of memory strategy use to not spontaneously connect the meaning of a list of words during recall, could use those cues if given meaning instructions. These results can be explained by the research of Bjorklund and colleagues on memory strategies. The typical finding in these studies is that children do not *spontaneously* cluster meaning related words or pictures during encoding and recall until early to mid-adolescence (Bjorklund, 1987; Bjorklund & de Marchena, 1984; Bjorklund & Hock, 1982; Bjorklund & Jacobs, 1985). Indeed, training in clustering techniques typically does not improve recall accuracy in children below this age (Bjorklund et al., 1994).

True recall of list words increased steadily from childhood to adolescence, as others have reported (Brainerd et al., 2004; Holliday & Weekes, 2006; Price et al., 2001). Moreover, as expected, three list presentations increased true recall across age groups, and the magnitude of this effect was greatest in the 11, 13, and 15-year-olds. These findings are consistent with the FTT assumption that older children's superior verbatim memory abilities make it easier for them to benefit from manipulations that support verbatim memory (Brainerd et al., 2003; Seamon et al., 2002).

4.1. Future directions and applications

False memories induced by meaning related information embody several features of forensically relevant memories. For child witnesses of domestic violence, for example, such violence is not usually a single episode but rather a series of repeated events that are substantially similar but not exactly the same (Reyna et al., 2006). Likewise, in cases of repeated experiences of sexual abuse, young children because of limited gist-extraction abilities, will be less likely than older children and adults to incorporate gist-consistent events (that did not take place) in their memory reports (Brainerd & Reyna, 1998; Reyna et al., 2006).

After long delays gist memories are used to remember both experienced events and non-experienced but meaning consistent events (Holliday & Hayes, 2000; Reyna et al., 2006). Further work is planned to test whether memory illusions persist over retention intervals of varying length. At the present time, extant research has typically tested recall and recognition of DRM lists immediately after list presentation. If it is demonstrated that children's memories for critical lures persist over time (consistent with memory for gist) as opposed to decreasing due to forgetting (similar to list words) this would lend support to the notion that gist memories are critical to the DRM illusion (Reyna, Holliday, & Marche, 2002; Reyna et al., 2006). Of course, not all questions about the reliability and accuracy of children's testimony can be resolved by empirical studies. Nonetheless, such studies can inform best practices in gathering evidence from children and other vulnerable witnesses (Holliday, 2003; Reyna et al., 2006).

References

Ackil, J. K., & Zaragoza, M. S. (1995). Developmental differences in eyewitness suggestibility and memory for source. *Journal of Experimental Child Psychology*, *60*, 57–83.

Anderson, J. R., & Pirolli, P. L. (1984). Spreading activation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*, 791–798.

Arndt, J. (2006). Distinctive information and false recognition: The contribution of encoding and retrieval factors. *Journal of Memory and Language*, *54*, 113–130.

Benjamin, A. S. (2001). On the dual effects of repetition on false recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 941–947.

Bjorklund, D. F. (1987). How age changes in knowledge base contribute to the development of children's memory: An interpretive review. *Developmental Review*, *7*, 93–130.

Bjorklund, D. F. (2005). *Children's thinking: Cognitive development and individual differences* (4th ed.). Belmont, CA: Wadsworth/Thomson Learning.

Bjorklund, D. F., Coyle, T. R., & Gaultney, J. F. (1992). Developmental differences in the acquisition of an organizational strategy: Evidence for the utilization deficiency hypothesis. *Journal of Experimental Child Psychology*, *54*, 434–448.

Bjorklund, D. S., & de Marchena, M. R. (1984). Developmental shifts in the basis of organization in memory: The role of associative versus categorical relatedness in children's free recall. *Child Development*, *55*, 952–962.

Bjorklund, D. F., & Hock, H. S. (1982). Age differences in the temporal locus of memory organization in children's recall. *Journal of Experimental Child Psychology*, *33*, 347–362.

Bjorklund, D. F., & Jacobs, J. W. (1985). Associative and categorical processes in children's memory: The role of automaticity in the development of free recall. *Journal of Experimental Child Psychology*, *39*, 599–617.

Bjorklund, D. F., Schneider, W., Cassel, W. S., & Ashley, E. (1994). Training and extension of a memory strategy: Evidence for utilization deficiencies in the acquisition of an organizational strategy in high- and low-IQ children. *Child Development*, *65*, 951–965.

Bjorklund, D. F., & Zeman, B. R. (1982). Children's organization and metamemory awareness in their recall of familiar information. *Child Development*, *53*, 799–810.

Brainerd, C. J., Forrest, T. J., Karibian, D., & Reyna, V. F. (2006). Development of the false memory illusion. *Developmental Psychology*, *42*, 962–979.

Brainerd, C. J., Holliday, R. E., & Reyna, V. F. (2004). Behavioral measurement of remembering phenomenology: So simple a child can do it. *Child Development*, *75*, 505–522.

Brainerd, C. J., & Reyna, V. F. (1998). Fuzzy-trace theory and children's false memories. *Journal of Experimental Child Psychology*, *71*, 81–129.

Brainerd, C. J., & Reyna, V. F. (2001). Fuzzy-trace theory: Dual processes in reasoning, memory, and cognitive neuroscience. *Advances in Child Development and Behavior*, *28*, 49–100.

Brainerd, C. J., & Reyna, V. F. (2002). Recollection rejection: How children edit their false memories. *Developmental Psychology*, *38*, 156–172.

Brainerd, C. J., & Reyna, V. F. (2005). *The science of false memory*. New York: Oxford University Press.

Brainerd, C. J., Reyna, V. F., & Forrest, T. J. (2002). Are young children susceptible to the false-memory illusion? *Child Development*, *73*, 1363–1377.

Brainerd, C. J., Reyna, V. F., Wright, R., & Mojardin, A. H. (2003). Recollection rejection: False-memory editing in children and adults. *Psychological Review*, *110*, 762–784.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*, 407–428.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology*, *58*, 17–22.

DeMarie-Dreblow, D. (1991). Relation between knowledge and memory: A reminder that correlation does not imply causality. *Child Development*, *62*, 484–498.

Dewhurst, S. A., & Robinson, C. A. (2004). False memories in children: Evidence for a shift from phonological to semantic associations. *Psychological Science*, *15*, 782–786.

Foley, M. A., & Johnson, M. K. (1985). Confusions between memories for performed and imagined actions: A developmental comparison. *Child Development*, *56*, 1145–1155.

Gallo, D., & Roediger, H. L. (2002). Variability among word lists in eliciting memory illusions: Evidence for associative activation and monitoring. *Journal of Memory and Language*, *47*, 469–497.

Ghetti, S., Qin, J., & Goodman, G. S. (2002). False memories in children and adults: Age, distinctiveness, and subjective experience. *Developmental Psychology*, *38*, 705–718.

Holliday, R. E. (2003). Reducing misinformation effects in children with cognitive interviews. *Child Development*, *74*, 728–751.

Holliday, R. E., & Hayes, B. K. (2000). Dissociating automatic and intentional processes in children's eyewitness memory. *Journal of Experimental Child Psychology*, *75*, 1–42.

Holliday, R. E., & Weekes, B. S. (2006). Dissociated developmental trajectories for semantic and phonological false memories. *Memory*, *14*, 624–636.

Howe, M. L. (2006). Developmentally invariant dissociations in children's true and false memories: Not all relatedness is created equal. *Child Development*, *77*, 1112–1123.

Howe, M. L., Cicchetti, D., Toth, S. L., & Cerrito, B. M. (2004). True and false memories in maltreated children. *Child Development*, *75*, 1402–1417.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, *114*, 3–28.

Lange, G. W. (1978). Organization-related processes in children's recall. In P. A. Ornstein (Ed.), *Memory development in children*. Hillsdale, NJ: Erlbaum.

Lindsay, D. S., Johnson, M., & Kwon, P. (1991). Developmental changes in memory source-monitoring. *Journal of Experimental Child Psychology*, *52*, 297–318.

Metzger, R.L., Warren, A.R., Shelton, J., Reed, A., Price, J., & Williams, D. (2004). *Do Children "D/R-M" like adults: False memory production in children*, in press.

Price, J. L., Metzger, R. L., Williams, D., Phelps, N. Z., & Phelps, A. M. (2001, April). *Children produce as many false memories as adults (sometimes!).* Poster presented at Biennial Meeting of the Society for Research in Child Development, Minneapolis, MN.

Read, D. R. (1996). From a passing thought to a false memory in 2 minutes: Confusing real and illusory events. *Psychonomic Bulletin & Review*, *3*, 105–111.

Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences*, *7*, 1–75.

Reyna, V. F., Holliday, R. E., & Marche, T. (2002). Explaining the development of false memories. *Developmental Review*, *22*, 436–489.

Reyna, V. F., & Lloyd, F. (1997). Theories of false memory in children and adults. *Learning and Individual Differences*, *9*, 95–123.

Reyna, V. F., Mills, B., Estrada, S., & Brainerd, C. J. (2006). False memory in children: Data, theory, and legal implications. In M. P. Toglia, J. D. Read, D. F. Ross, & R. C. L. Lindsay (Eds.), *Handbook of eyewitness psychology*. Mahwah, NJ: Erlbaum.

Roberts, K. P., & Blades, M. (2000). *Children's source monitoring*. Mahwah, NJ: Erlbaum.

Robinson, & Roediger. (1997). Associative processes in false recall and false recognition. *Psychological Science*, *8*, 231–237.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented on lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 803–814.

Roediger, H. L., & McDermott, K. B. (2000). Tricks of memory. *Current Directions in Psychological Science*, *9*, 123–127.

Seamon, J. G., Luo, C. R., Schwartz, M. A., Jones, K., Lee, D. M., & Jones, S. J. (2002). Repetition can have similar and different effects on accurate and false recognition. *Journal of Memory and Language*, *46*, 323–340.

Stadler, M. A., Roediger, H. L., & McDermott, K. B. (1999). Norms for words that create false memories. *Memory and Cognition*, *27*, 494–500.

Underwood, B. J. (1965). False recognition produced by implicit verbal responses. *Journal of Experimental Psychology*, *70*, 122–129.

Warren, A. R., Reed, A. W., Mangan, B. R., & Metzger, R. L. (2003, May). *Growth of false and accurate memories during the school years.* Paper presented at 15th Annual Convention, American Psychological Society, Atlanta, GA.