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Developmental Trends in False Memory Across Adolescence and Young Adulthood: A Comparison of DRM and Memory Conformity Paradigms

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Summary: Little is known about the reliability of eyewitness memory among adolescents as most memory research has focused primarily on adults and young children. A number of studies recently have emerged outlining conditions where memory suggestibility increases from early childhood to adulthood. These developmental reversals are found in semantic association tasks such as the Deese–Roediger–McDermott (DRM) paradigm and have not yet been thoroughly investigated among adolescents. In the current study, we examined DRM performance among 11–21 year olds (N = 245). Extending the work comparing children and adults, false memory on the DRM task increased with age. False memory on the DRM task was not associated with false memory on a memory conformity task. The different memory processes involved with the tasks and the implications for legal psychology are discussed. Copyright © 2015 John Wiley & Sons, Ltd.

Adolescents have been almost wholly ignored in the eyewitness testimony literature (McGuire, London, & Wright, 2011), with scores of developmental studies instead focusing on young children. Up until the 1980s, child competence statutes generally excluded the testimony of youth on the grounds that young children's testimony is unreliable (Brainerd & Reyna, 2012; Bruck & Ceci, 1999; Goodman, 1984). Many developmental studies provided empirical support for this legal practice, showing preschoolers to be much more suggestible than grade school-aged children (e.g., Goodman & Reed, 1986; Robinson & Briggs, 1997). However, the notion that young children are incompetent witnesses is an oversimplification. Forensic developmental research has shown that young children can sometimes very accurately recount events (Peterson, 2012), while at times even adults err on eyewitness tasks (Loftus, 2005).

An interesting and robust developmental finding has recently emerged showing that under certain circumstances, younger children are less susceptible to false memories than older children or adults, a concept now known as developmental reversals (for reviews, see Brainerd, Reyna, & Ceci, 2008; Brainerd & Reyna, 2012). Developmental reversals in false memory have been receiving much attention because of their counterintuitive nature and because there is potential to predict contexts in which individuals become increasingly prone to false memories with development. In addition, developmental reversals have obvious forensic significance.

The primary paradigm used to show developmental reversals in false memory has been the Deese–Roediger–McDermott (DRM) list-learning paradigm (Roediger & McDermott, 1995). However, the trajectory of developmental reversals across adolescence has yet to be established. The first major goal of the present study, therefore, was to explore developmental trends in false memory across adolescence and young adulthood. In addition, because data showing developmental reversals in false memory susceptibility are just emerging, it has been met with considerable skepticism because of decades of previous suggestibility and misinformation studies indicating that false memory declines with age (for reviews, see Bruck & Ceci, 1999; Ceci & Bruck, 1993). The discrepant findings have led some researchers to question the ecological validity of the DRM paradigm findings (e.g., Pezdek & Lam, 2007). Because the few studies comparing the relationship between false memories for occurrences (e.g., DRM-based false memories) and false memories for sources (misinformation-based false memories) have yielded inconsistent results, an additional goal was to compare the DRM paradigm with another method of false memory induction (i.e., a memory conformity paradigm). In the first section as follows, we review the literature on developmental reversals in DRM-based false memories. In the second section, we review the literature that has examined whether DRM-based and misinformation-based false memories are associated. Finally, we review the developmental memory conformity literature.

DEVELOPMENTAL REVERSALS IN FALSE MEMORIES GENERATED BY THE DEESE–ROEDIGER–MCDERMOTT PARADIGM

The DRM paradigm is a popular semantic association task used to elicit false memory (Gallo, 2006). In the paradigm, participants read or listen to word lists that are semantically associated to a specific familiar word that is not presented in the lists. These nonpresented words are referred to as critical lures. For example, a word list may include the words 'bed', 'tired', and 'rest', which are semantic associates of the critical nonpresented lure, 'sleep'. The DRM paradigm has been extensively used by memory researchers and has been shown in adults to reliably produce false memories for words that were not presented. For example, the mean level of false memory in young adults for strong associate lists is 54% in recall tasks and 76% in recognition tasks (Brainerd & Reyna, 2012).

More recently, researchers have begun to explore developmental trends in false memories generated by the DRM task. Brainerd and Reyna (2012) summarized 38 DRM articles exploring age-related DRM findings. Findings from these

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studies show that research using the DRM paradigm has consistently produced reverse developmental trends. Other studies have demonstrated this finding as well (Knott, Howe, Wimmer, & Dewhurst, 2011; Wimmer & Howe, 2010). Overall, a majority of these articles (92%) produced at least one study showing that errors are made more often by older than by younger individuals. This finding is striking given that previous developmental studies of false memory almost universally show a reduction in errors with age. Furthermore, this finding has been replicated in different cultural contexts in both recall and recognition tests (e.g., Bouwmeester & Verkoeijen, 2010; Carneiro, Albuquerque, & Fernandez, 2009; Carneiro & Fernandez, 2010; Carneiro, Fernandez, & Dias, 2009; Howe, Candel, Otgaar, Malone, & Wimmer, 2010; Howe, Gagnon, & Thouas, 2008; Wimmer & Howe, 2010).

While studies show that developmental reversals in false memory are reliable, adolescents (specifically 13–17 year olds) are rarely included in these studies; most include a comparison of adults and young or preadolescent (i.e., 11–12 year olds) children. Across 54 studies summarized in the articles discussed previously, only six [Brainerd, Forrest, Karibian, & Reyna, 2006 (study 3); Holliday, Reyna, & Brainerd, 2008; Holliday & Weekes, 2006; Howe, 2007; Metzger, Warren, Shelton, Price, & Reed, 2008 (studies 1 and 3)] included subjects beyond age 12 but younger than the adult groups (usually college age). Of these, only two studies (Brainerd et al., 2006; Holliday et al., 2008) included 14 or 15 year olds, and none include 16 year olds. Furthermore, none have explored age continuously. Of the few studies that have included adolescent-aged subjects, two studies [Holliday et al., 2008; Metzger et al., 2008 (study 3)] found that adolescents were similar to adults in false memory production. An additional four studies [Knott et al., 2011 (studies 2 and 3); Wimmer & Howe, 2009 (studies 1 and 2)] found false memory trends suggesting that preadolescents are also similar to adults. However, these findings provide a before and after snapshot of DRM-based false memory development, and it is unclear what we would find over a more complete course of development that includes the middle piece of the puzzle, adolescence. Further exploration of this age group may provide insight regarding whether we should expect a more continuous or discontinuous explanation of reversals.

Should adolescents be expected to show developmental reversals in false memory?

One reason to suspect that adolescents will continue to display developmental reversals in comparison with adults comes from studies examining neurobiological development. Adolescents' brains are different from adults' brains in ways that affect various aspects of cognition such as inhibition, working memory, processing speeds, decision making, and perspective taking (see Blakemore & Choudhury, 2006; Choudhury, Blakemore, & Charman, 2006). These differences may correspond to performance differences on tasks that require concept and category activation (Dennis, Kim, & Cabeza, 2007; Gaillard et al., 2000; Kim & Cabeza, 2007; McDermott, Watson, & Ojemann, 2005).

Category formation also improves with development. Bjorklund and Hock (1982) found that categorical association before age 12 was more likely to occur during retrieval than encoding and that children 9 years old and younger are unlikely to spontaneously generate categorical relationships during encoding, and even when cued to do so, 9 year olds are still not as proficient as 13 year olds. Extending this finding, Bjorklund, Miller, Coyle, and Slawinski (1997) found that memory deficits continue to exist in young children even when warnings or instructions are given to young children to pay attention to certain categorical relationships among list items. Bjorklund and Jacobs (1985) explained that during early adolescence, there is a shift to begin using categorical and semantically related information (as opposed to information that is based on more simple associations, such as rhyming associates, which does not undergo much developmental change) and that this use of categorical information occurs automatically by adulthood.

According to Bjorklund (1987), this increased use of categorical information is the result of developmental increases in knowledge base, which includes the ability to make semantic connections, allowing new memory strategies through improved processing ability that allows for automaticity. Overall, work from Bjorklund and colleagues demonstrates that the developmental differences that exist in the ability to organize information taxonomically and recognize semantic relationships affect the ability to retrieve information from memory. Specifically, these developmental differences are accompanied by cognitive improvements in efficiency and are consistent with the developmental reversal trends in false memory. That is, increases in false memory on the DRM may be due to increases in knowledge base, which cause activation of concepts that are semantically related. Findings from Bjorklund and colleagues are especially interesting because category formation is activated in processing DRM-type tasks but not always in misinformation tasks. In the following section, we further discuss differences between memory processes in DRM-type tasks versus misinformation paradigms.

DIFFERENCES BETWEEN MEMORY PROCESSES INVOLVED WITH DEESE–ROEDIGER–MCDERMOTT AND MISINFORMATION PARADIGMS

Studies examining developmental trends in false memories

While the age findings from the DRM paradigm are reliable, some researchers are concerned about their ecological validity when applied to the forensic setting. Pezdek and Lam (2007) reviewed false memory research and found that most false memory studies do not include false memories resulting from misinformation provided from an outside source but are rather semantic in nature and based on an occurrence (e.g., list-learning tasks such as the DRM paradigm). Pezdek and Lam (2007) raised the concern that underlying processes that result in false memories for an entire event may differ from false memories produced from misremembering an occurrence (see also Banaji & Crowder, 1989; DePrince, Allard, Oh, & Freyd, 2004; Wade et al., 2007).

A few studies have examined the relationship between DRM performance and other types of false memories. In a recent study by Zhu, Chen, Loftus, and Dong (2013), a relationship was found between performance on the DRM paradigm and performance on a task using a misinformation paradigm. However, the relationship was weak, and the authors suggested after further analyses that, while there may be a shared mechanism, it is likely that some mechanisms differ in the production of false memories for each of the two tasks. Findings from other studies have been equivocal. Some studies found no relationship (e.g., Ost et al., 2013; Otgaar & Candel, 2011), and others found ambiguous relationships (e.g., Geraerts, Smeets, Jelicic, van Heerden, & Merckelbach, 2005; Otgaar, Howe, Peters, Sauerland, & Raymaekers, 2013; Qin, Ogle, & Goodman, 2008). However, for those finding ambiguous relationships (e.g., weak positive or negative correlations), the relationship between false memory elicited by the DRM paradigm and false memory elicited by other types of paradigms was not directly assessed, or trends were unrelated. For example, in a developmental study by Otgaar et al. (2013), age trends for DRM tasks demonstrated reversals, while suggestively induced memories from a video event demonstrated traditional age-related decreases in false memory.

Gallo (2010) reviewed the literature of both DRM false memory studies and those produced by other paradigms and found that while the DRM paradigm seems to be related to false memories produced outside of the laboratory (e.g., Eisen, Cardenas, Kistorian, Yu, & Tirtibudi, 1999; Geraerts et al., 2005; Meyersburg, Bogdan, Gallo, & McNally, 2009; Platt, Lacey, Iobst, & Finkelman, 1998), relationships between the DRM paradigm and other types of lab-induced false memories are inconsistent (e.g., Qin et al., 2008; Wilkinson & Hyman, 1998). Findings that the DRM paradigm was related to memories formed outside of the laboratory initially led to the assumption that shared factors (possibly source monitoring ability or working memory processes) are responsible for basic memory processes. However, the studies were insufficient to determine precisely what these factors are and when they should be expected to co-concur. In addition, the inability to produce a consistent relationship in a lab setting led to uncertainty about whether the two tasks were drawing on one underlying memory process and questioned the assumption that performance on the DRM paradigm and other false memory paradigms should overlap. Because of the serious nature of the forensic implications resulting from false memory research, investigators have become concerned about whether and when findings from the DRM paradigm can be generalized to other types of false memory found in eyewitness testimony.

The primary argument is that questions regarding children (or adults for that matter) as witnesses are centered on the individual's ability to recall an event accurately. Errors in memory often occur because individuals misattribute the source of a memory. In many paradigms, this misattributed source is provided through an external source, derived from post-event information usually provided by another person (e.g., a peer or an interviewer). The DRM paradigm differs from this context in two important ways. First, the source of the incorrect memory is self-generated. Second, because it is self-generated, social factors are less influential. Therefore, it is not surprising that developmental trends in memory performance differ relative to the false memory paradigm used. However, one would expect that there are similar underlying cognitive mechanisms that drive false memory effects for both lists and other types of events. In line with this assumption, developmental reversals have also been produced in non-DRM studies assessing false memories of events relying on both occurrence and misinformation errors (Connolly & Price, 2006; Odegard, Cooper, Lampinen, Reyna, & Brainerd, 2009; Principe, Guiliano, & Root, 2008; Ross et al., 2006). This demonstrates that it is not necessarily the lack of a complex event and social context that is driving reversals.

Fuzzy-trace theory and developmental reversals

The most developed explanation for age differences in false memory development is based on fuzzy-trace theory (FTT). According to Brainerd and Reyna (2012), it should be expected that age trends vary by task as they have in the previously described literature, but this variation is theoretically predictable based on FTT. This theory suggests that gist and verbatim memory are enhanced over the course of development. Therefore, tasks that trigger errors through gist-based memory will lead to more and richer false memories in older individuals, who have superior gist-based memory. Likewise, tasks that allow individuals to pull on verbatim traces of memory will show superior performance over the course of development, because verbatim memory continues to strengthen with development. Many standard false memory paradigms do not fit this model and so should not be expected to produce reversals (Brainerd, Reyna, & Zember, 2011). Theoretical framework, FTT in particular, explains the inconsistencies in age trends that are found in the literature. In fact, the theory actually predicts them (see Brainerd & Reyna, 1998 for more information on differences between false memory for occurrence versus misinformation sources).

The nature of the DRM task is clearly gist based with list items producing the 'gist' for a lure, while list length and similarities in words that compose list items simultaneously make it difficult to rely on verbatim traces. Further evidence for this is presented by studies using a variety of manipulations to interfere with verbatim (e.g., list length) and gist (e.g., association of semantic strength) memory that have produced changes in developmental trends, most of these consistent with FTT (Bouwmeester & Verkoeijen, 2010; Brainerd et al., 2006; Carneiro, Albuquerque, Fernandez, & Esteves, 2007; Dewhurst, Pursglove, & Lewis, 2007; Dewhurst & Robinson, 2004; Holliday, Brainerd, & Reyna, 2011; Holliday & Weekes, 2006; Holliday et al., 2008; Lampinen, Leding, Reed, & Odegard, 2006; Odegard, Holliday, Brainerd, & Reyna, 2008; Sugrue & Hayne, 2006).

The bottom line is that it is unknown whether false memory produced by the DRM paradigm can predict false memory that is generated by a misinformation paradigm constructed in the laboratory. However, predictions can be made based on FTT. Wade et al. (2007) stressed that, in order to understand the phenomenon of false memories, it is beneficial to gather data from several methods including those that just produce list item false memories. The present study directly explores the relationship between performance on the DRM and performance on another false memory paradigm that externally induces misinformation, the memory conformity paradigm.

MEMORY CONFORMITY AND DEVELOPMENT

In addition to the DRM work in the memory field over the past decade, an additional area of study known as memory conformity (Gabbert, Memon, & Allan, 2003; Gabbert, Memon, Allan, & Wright, 2004; Wright, Self, & Justice, 2000) or social contagion of memory (Roediger, Meade, & Bergman, 2001) has emerged. Like the DRM, memory conformity studies have a well-established experimental protocol to manipulate false memory production (for a review, see Wright, Memon, Skagerberg, & Gabbert, 2009). Moreover, this paradigm has been used to produce false memory effects in children, adolescents, and adults (e.g., Candel, Memon, & Al-Harazi, 2007; McGuire et al., 2011; Wright, London, & Waechter, 2010). Memory conformity research examines the effect of post-event information on event reports when peers are the source of post-event information, which sometimes includes misinformation. Peer influence is typically established through a co-witness, either another participant or a confederate, who witnesses the same event and engages in the same memory task as the participant. The general finding from this literature is that, even when memories originate from another source such as a co-witness, people often maintain that these memories are their own and have originated from their own experiences (e.g., Candel et al., 2007; Skagerberg & Wright, 2008; Wright & Schwartz, 2010).

To our knowledge, only a handful of studies have been conducted using a memory conformity paradigm with youth. However, developmental findings are equivocal, primarily because of the differing age groups that have been used. Candel et al. (2007) compared levels of memory conformity in young children (6–7 year olds) versus preadolescents (11–12 year olds). They found that the older group made more memory errors during a free recall test when they were provided with misinformation. However, the two groups did not differ on a cued recall measure. Thus, their findings partially supported developmental reversals. In another study, Wright et al. (2010) explored memory conformity across adolescents ranging from 11 to 18 years of age but found steady levels of memory conformity. However, the authors in these studies did not independently explore verbatim versus gist components of false memories, so it is impossible to tell whether trends supporting FTT existed. Similarly, McGuire et al. (2011) found no age trends in memory conformity among adolescents and young adults. One of the goals of McGuire et al. (2011) was to examine social motivations for false memory. However, these very same participants were also tested on a cognitive measure of false memory, the DRM. This paper presents findings from this study that focus on DRM and memory conformity performance within subjects and in relation to development.

THE PRESENT STUDY

The DRM paradigm is well suited for comparison because when using this paradigm, (i) findings (whether general or developmental) are often combined with those of other false memory studies, (ii) developmental reversal trends are reliable, and (iii) the false memory errors are self-generated and cognitively based. The memory conformity paradigm is also well suited for comparison because (i) like DRM studies, memory conformity studies have a well-established experimental protocol to manipulate false memory production, (ii) it is a misinformation paradigm that has been shown to produce false memories in children, adolescents, and adults from externally generated sources (e.g., Candel et al., 2007; McGuire et al., 2011; Wright et al., 2010), and (iii) some support for developmental reversals with this paradigm (e.g., Candel et al., 2007) has been documented.

The present study will (i) explore age trends among adolescents and young adults on the DRM paradigm, (ii) compare age trends using both the DRM and memory conformity paradigms, and (iii) determine whether performance on the DRM paradigm can predict performance on a memory conformity task.

Design overview

The variables of interest in this study included age of the participant and, for the memory conformity paradigm, the between subjects factor of co-witness information (CWI) type. There were three CWI conditions. In one condition, participants received no CWI. In two conditions, participants received CWI; approximately half of these were told that they would need to report their answers publicly, and the other half was not. No effect of public versus private reporting was detected, so data were collapsed for analyses. The dependent variables were the amount of correct and incorrect information reported in both the DRM and memory conformity tasks and the tendency to report the critical lure during the DRM task.

Hypotheses

Age

While previous developmental studies have shown developmental reversals using the DRM paradigm, it is unknown whether this trend continues through adolescence. However, given that a majority of existing developmental DRM studies suggest an increase in false memory with development, a linear increase in false memory using the DRM paradigm was predicted.

Task performance

The DRM and memory conformity tasks are different and may be relying on factors other than memory performance. In addition, few studies have tried to correlate performance between the DRM and another paradigm, and the findings from those that have are equivocal. We expected false memory on the DRM task to relate to false memory on the memory conformity task because (i) each requires the person to misattribute the source of information and (ii) developmental reversals have been found using both paradigms. In addition, individual differences in memory performance should lead to similarities on any type of memory performance task (Gallo, 2010). The within subjects component of this study should make this easier to detect.

Method

Participants

Participants included 252 11–21 year olds (M = 16.7 years; SD = 2.71). Participants' age in months was used to analyze data. Seven participants were excluded from analyses, bringing the final sample size to 245 participants (143 female was used in the original as some participants were 11 year olds). One participant was excluded from the analyses because he reported that he did not understand the instructions. Two were excluded because they indicated at debriefing that they were suspicious about the intent of this study. Four participants were excluded because there were audio difficulties with the DRM recordings during the experiment.

Participants under the age of 18 years were recruited from local summer camps and received either a $5 restaurant certificate or a 4-h time slot for their entire camp at the local university recreation center. Participants 18 years old and over were recruited from introductory psychology courses at a Midwestern University and received partial course credit for participation.

Materials

To provide an event for the memory conformity task, a short 40-s video clip was used. The video had no sound and depicted the theft of a cell phone in a busy shopping district (previously used in Skagerberg, 2007). For the memory test, participants were questioned about the theft using 14 questions with two forced-choice alternatives, one of which was the correct response. In the CWI condition, participants could see what they believed was their peer's responses to these questions. Questions were actually answered by the researcher. Nine of the responses given by the researcher were true, and five were false (for clarity, we refer to these responses as 'true' or 'false' in order to distinguish them from 'correct' and 'incorrect' responses from participants). A control group receiving no true or false information (i.e., peer responses were not given) was used to provide a baseline for correct and incorrect responding. Increases in incorrect responses for false items and increases in correct responses for true items were determined relative to the control group.

Next, participants completed a DRM task. Roediger and McDermott (1995) developed 24 word lists, which have been widely used in memory and suggestibility research. Six of these lists (i.e., Sleep, Anger, Chair, Needle, Sweet, and King) were chosen. The frequency of false recall associated with each word list is reported by Roediger and McDermott (1995) and Gallo and Roediger (2002). Participants listened to a tape recording of the six lists of words through headphones on a tape recorder. Each list consisted of 15 words. When participants recalled a critical lure, this increased their false recall scores. Higher scores were used as indicators for susceptibility to the creation of false memories. Each word in the DRM word lists was presented with a 1-s delay. Each list was presented with a 10-s delay. These delays are the standard delays used with this paradigm and were chosen based upon work by Gallo and Roediger (2002) who found that words presented with a delay longer than 1 s often fail to elicit false recall. All lists were audio recorded with a male voice at the same rate of speed.

Procedure

Parental and adult consent forms were signed in advance to testing. Adolescents' assent was obtained. Participants watched the video clip in age and gender matched pairs. If no age or gender match was available, participants were tested alone as control participants. Preliminary analyses revealed no differences between control participants who were tested alone versus control participants tested in pairs. Participants were asked to pay as much attention to the details and events in the video as possible because they would only see it once and would later be asked questions regarding the information in the video.

After the video, participants were taken to separate areas for the remainder of the experiment. Once separated, each participant was told that we only had one set of materials, so while one is working on the questionnaire, the other will have to work on the DRM task. Both participants, however, were actually working on the DRM task while under the assumption that their partner was working on the questionnaire. It was important for participants to assume that their partner had completed the video questionnaire while they were working on the DRM task so that we could provide them with perceived peer responses later. The instructions for the DRM task were then given orally to the participant by the researcher.

After this task, which took approximately 10 min, participants were asked to wait until the experimenter (fictitiously) took the DRM materials to their partner and retrieved a video questionnaire for them to complete. Upon returning, the experimenter told those in the CWI condition that there were no blank questionnaires available but one was available from their partner who was already finished with this part of the experiment. Participants were then asked if they would mind using the completed questionnaire. All participants agreed and were asked to put a star by their answer choice because their partner had circled an answer. Participants were told that we needed them to do this so that we could keep their responses separate. Both participants received the same prewritten questionnaire, and each assumed that their partner filled in the responses. This manipulation was intended to provide true and false information, which participants would assume was given by a peer. Participants in the control condition simply completed the questionnaire with no peer information provided when the experimenter returned.

Results

The results are divided into two sections. First, we examined the DRM results in relation to age and constructed a measure for each individual for critical lure recall. For these results, the entire sample (N = 245) was used. Second, we examined the memory conformity data and explored whether age or CWI related to performance on answering questions about the video. We then examined if DRM results were associated with memory conformity. For these results, only data from individuals who received misinformation in the memory conformity paradigm ($N = 134$) were used to compare performance. This paper presents findings from this study that focus on DRM and memory conformity performance within subjects and in relation to development. More details about participants' memory conformity performance are reported in McGuire et al. (2011).

There are several ways that can be used to analyze these data. We used several approaches, which led to the same conclusions. Next, we reported the methods that we believe are most appropriate and justified their use.

Deese–Roediger–McDermott and age

Participants listened to six 15-item DRM lists. Therefore, each had the opportunity to recall 90 words correctly, six critical lures, and an unlimited number of noncritical lures. The mean number of accurate items recalled per list was 6.16 (41%). False memories, as measured by recall of critical lures, were recalled by 89% of participants. On average, participants falsely recalled 39% of the critical lures. Participants recalled about 2.23 incorrect noncritical words on average (i.e., about the same mean rate as critical lures).

The first question was whether age predicts recall for any of these three categories of words. Because there are differences among the lists (Gallo & Roediger, 2001; Roediger & McDermott, 1995), the unit of analysis was the list, nested within the participant. A mixed/multilevel model was used (e.g., Goldstein, 2011; Wright & London, 2009). A multilevel model was used for accurate recall (assuming normally distributed residuals), for critical lure recall (assuming binomially distributed residuals), and for incorrect recall (assuming a Poisson distribution). These are all generalized linear multilevel models. We allowed both participant and list to be random variables and then used age in months to predict recall. We first included the untransformed age variable. To test if the relationship may be nonlinear, we then transformed the age variable with regression splines, first two straight lines meeting at the median and then two quadratic curves joined in a straight line at the median. Using these more complex curves did not improve the fit of any of the models (all ps $> .10$). The results showed that both accurate recall, $\chi^2(1) = 77.35$, $p < .001$, and recall of the critical lure, $\chi^2(1) = 14.47$, $p < .001$, increased with age but that other erroneous recalls decreased with age, $\chi^2(1) = 7.08$, $p = .008$. The amount of increase for recall was, on average, 31% (standard error = 0.03) more correctly recalled words per year. The estimate for lures was in different units. The log of the odds ratio between adjacent years was 11% (SE = 0.03). This equates with the predicted probability of 30% for a 15 year old recalling a lure and of 42% for a 20 year old recalling a lure.

Table 1. Proportion of true and false items reported by paradigm type

Paradigm type, $N = 134$	True		False	
	M(%)	*SD*(%)	*M*(%)	*SD*(%)
DRM (90 possible true items and 6 possible false items)	41	9	37	21
Memory conformity (nine possible true items and five possible false items)	67	19	54.5	23

DRM, Deese–Roediger–McDermott; SD, standard deviation.
Proportions for false items for the DRM are reported for critical words only. Proportions of noncritical false items for the DRM are not included in this table.
For false items, the proportions of items answered incorrectly (as opposed to correctly, as is reported for true items) are presented.

Simple correlations with age and correct recall, incorrect recall, and incorrect recall for critical words were conducted. Findings were consistent with the models described previously. Age in months was positively correlated with correct recall, $r = .51$, $p < .001$, positively correlated with the number of critical words given, $r = .22$, $p < .001$, and negatively correlated with the number of incorrect noncritical words given, $r = -.17$, $p < .01$. See Table 1 for raw percentages that correspond to the average amount of true and false information participants reported on the DRM and memory conformity items. See Table 2 for a breakdown of this performance by three different age categories. For ease of presentation, three categories of ages rather than each of the 11 age-in-year categories were used to present descriptive statistics. As noted, the inferential analyses were conducted using age as a continuous variable.

Predictors of memory conformity

The response variable was whether the participant was correct or incorrect for each of the 14 items. Because this is binary, a logistic regression was used, and because each participant had 14 of these trials, multilevel/mixed modeling was used (see Wright, Horry, & Skagerberg, 2009, for a

Table 2. Proportion of true and false items reported by age and paradigm type

Participant age (in years), $N = 134$	DRM (90 possible true items and 6 possible false items)				Memory conformity (nine possible true items and five possible false items)			
	True		False		True		False	
	M(%)	*SD*(%)	*M*(%)	*SD*(%)	*M*(%)	*SD*(%)	*M*(%)	*SD*(%)
11–14	34	12	33	27	61	17	57.5	23
15–18	42	10	40	22	70	18	54	24
19–21	47	8	43	24	68	21	49	21

DRM, Deese–Roediger–McDermott; SD, standard deviation.
Proportions for false items for the DRM are reported for critical words only. Proportions of noncritical false items for the DRM are not included in this table.
For false items, the proportions of items answered incorrectly (as opposed to correctly, as is reported for true items) are presented.

more detailed description of this model). We allowed variability both by items and by participants. The intercept was associated with accuracy, so this allowed for variability for how difficult each item was and for variability in the quality of each participant's memory. The main predictor variable was whether the participant received no information about the item, incorrect information about the item, or correct information about the item. This was coded as two dummy variables, correct and incorrect. The coefficients show whether memory conformity occurred for true and false post-event information. To test whether age and DRM lure score moderated the memory conformity effects, the main effect of the variable was included, and then the interaction between it and the two dummy variables was added to the model.

When no information was given, participants provided accurate information 57% of the time. This dropped to 46% when inaccurate information was given, $\chi^2(1) = 8.27$, $p = .004$. The value rose to 67% when accurate information was given, $\chi^2(1) = 17.55$, $p < .001$. The variable for age was included first as a main effect. It was positively associated with accuracy, $\chi^2(1) = 11.91$, $p < .001$. However, it did not moderate the memory conformity effects, $\chi^2(2) = 0.47$, $p = .79$. The age effects were removed from the model, and the DRM lure main effect was included. The main effect of the DRM variable was nonsignificant, $\chi^2(1) = 0.28$, $p = .60$, as was its interaction with the memory conformity variables, $\chi^2(2) = 2.44$, $p = .30$. Nonlinear effects and examining whether DRM moderated only accurate or inaccurate memory conformity were explored, but none of these effects were significant.

Correlations were also conducted for age, reporting of critical lures, and overall conformity. See Figure 1 for scatter plots depicting relationships among the three variables. These results demonstrated that age and DRM performance on reporting critical words are related but neither of these with conformity on its own and neither with conformity partial out the other. As Table 2 demonstrates, age was an unreliable predictor of the conformity measure, and DRM was correlated with age. This effect was similar when we partialled out age, and the DRM still did not predict memory conformity $r_p = .0108$.

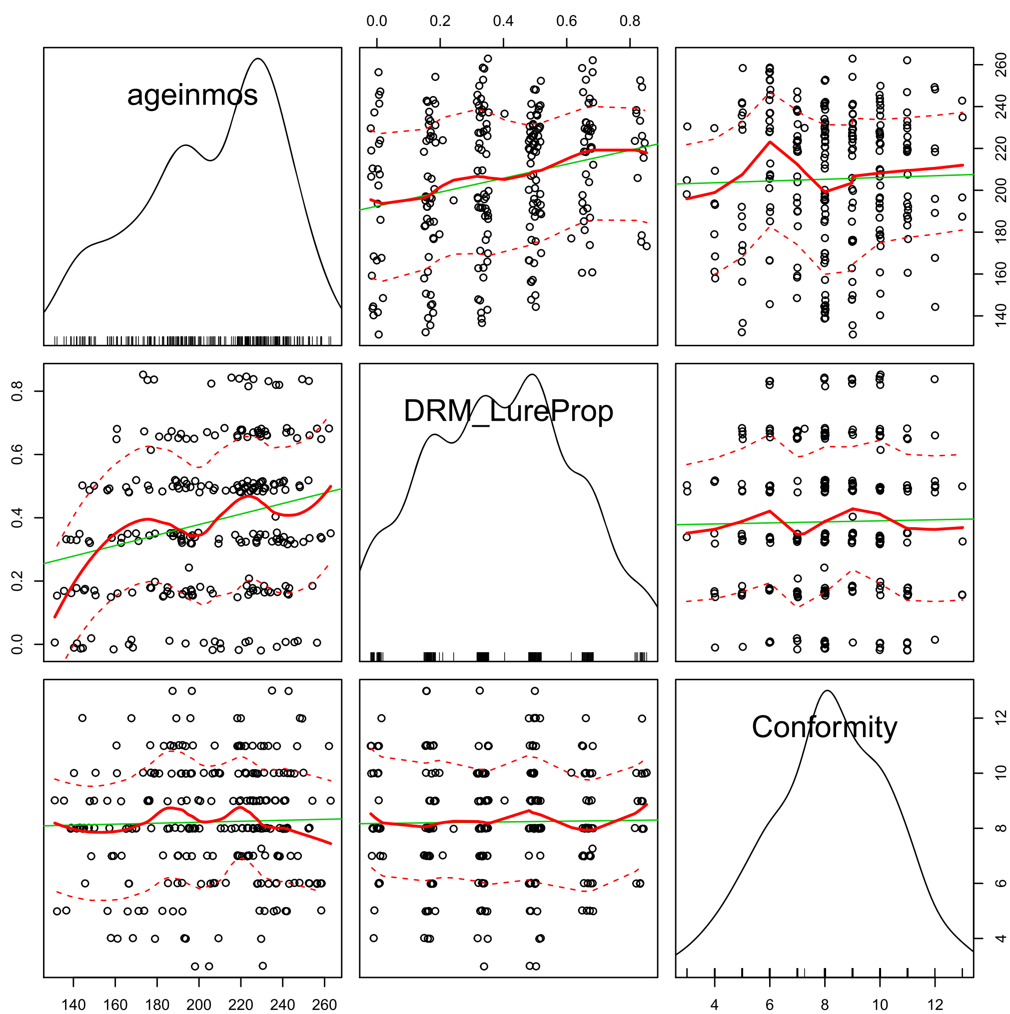

Figure 1. Scatterplots depicting the relationship among the three variables of age, Deese-Roediger-McDermott (DRM) critical lure performance, and overall memory conformity performance.

Discussion

We explored false memories generated by the DRM paradigm and a memory conformity task among 11–21 year olds. As predicted, false memory as measured by the DRM increased as a function of age. This finding is consistent with other studies exploring developmental trends but that have not included the entire span of adolescence. While younger individuals were less likely to report the critical false item on a list, they were also less likely to report the correct items actually heard. Exploring age continuously and including early to late adolescence have provided evidence that developmental reversals in false memory produce a linear trend in 11–21 year olds, at least as measured by the DRM paradigm.

Developmental DRM paradigm findings suggested that the underlying mechanisms responsible for these trends continue to develop slowly and continuously between preadolescence and late adolescence. This is consistent with the work from Bjorklund and colleagues discussed earlier. However, given that no developmental trends were found in the memory conformity paradigm, it seems that false memory development produced from this type of task is more stable from preadolescence to adulthood. Exploring memory development over the course of adolescence will likely require theory grounded experimentation using social, cognitive, and neuropsychological components to acquire a better understanding of developmental phenomena such as stability and continuity.

We also compared age trends on the DRM paradigm with those from a memory conformity task. The results from this study confirmed that both memory conformity and the DRM task produced false memory effects. However, while developmental reversals were found for the DRM as predicted, they were not found for memory conformity. Furthermore, performance on the two tasks was not related. This suggests that the processes producing errors through the DRM source monitoring tasks and memory conformity tasks are different. These results also suggest that the DRM and memory conformity procedures elicit different types of false memory and that care should be taken generalizing the findings from one method to the other. Research has shown that both children's and adult's memory reports can be influenced by both external and internal sources (e.g., Bruck, Ceci, & Melnyk, 1997; Davis & Loftus, 2007). However, in order to understand the false memory phenomenon, it is necessary to isolate the different processes involved in false memory that is externally generated in a social context from those in a DRM study (internally generated in a nonsocial context). This study was a first step in exploring the association between these two methods of studying false memory.

A variety of explanations are offered to explain the finding that the two paradigms produced different age trends. One explanation is that misinformation paradigms produce false memories differently than paradigms assessing an occurrence, such as the DRM paradigm (Ost et al., 2013). Salthouse and Siedlecki (2007) found that differing gist-based memory tasks (i.e., DRM recognition, face recognition, and dot pattern recognition) were not correlated with one another. In addition, the DRM effect is derived from internally generated errors, while the memory conformity paradigm is based on false memory from an externally generated source. However, as mentioned, the developmental reversal effect has been produced by other paradigms that use external sources of influence, so this is an unlikely explanation.

The best explanation for the differences in age trends found in this study and those reviewed in this paper lies within FTT. This theory works well to explain the developmental reversals found overall with the DRM paradigm and in this study. However, the memory conformity paradigm did not produce reversal effects in this study. Most likely, as explained by FTT, you would not expect to find reversals when memory for events in the paradigm relies heavily on verbatim traces (Brainerd et al., 2011).

While some components of the memory conformity paradigm used in this study relied upon gist processing (e.g., scripts for what usually happens during a theft), the paradigm also contained questions such as 'What did the victim look like?' and 'What color was the thief's hair', which clearly rely on verbatim memory given that it requires individuals to pay attention to and recall surface features. If the verbatim traces were strong enough, this could have essentially 'washed out' any age effects of errors produced through superior gist processing. Using FTT, traditional age decreases in false memory would actually be predicted in this scenario, as the ability to rely on verbatim traces increases with age. In addition, although individuals did not produce more memory errors because of social influence relative to age (i.e., traditional age decreases in suggestibility in the memory conformity paradigm were not found), younger individuals were less accurate overall. That is, while younger individuals were not more susceptible to memory conformity effects, they were still more likely to be incorrect. This is partial support for this explanation in that adults may have performed better because of superior verbatim processing. Furthermore, while this study adjusted for individual memory performance and still found no predictive power in one task for the other, the nature of the designs did not permit independent adjustment for verbatim versus gist memory. Specifically, the memory conformity task was not purely, or perhaps even mostly, reliant on gist processing. This study was a first attempt to relate the DRM paradigm to another false memory paradigm while simultaneously exploring age. Future studies should attempt to use theoretical framework such as FTT when formulating study designs and predictions.

CONCLUSION

The DRM paradigm continues to produce clear developmental reversals in false memory across adolescence. This finding adds further evidence to suggest that false memory does not consistently decrease with age. An important forensic implication of this finding includes considering the possibility of increased contamination in the reports of older youth and adults (versus children's) in certain contexts. Based on FTT, repeated events or events that could be affected by the formation of gist memory could be more adversely affected in older individuals.

These results have particular implications for expert testimony. Judges often prohibit expert testimony on memory primarily because it is assumed that the contributions of memory experts are not considered outside the ken of juror knowledge. However, developmental reversals found in this study and countless others contradict this assumption. For example, Nunez, Kehn, and Wright (2011) found that adults' believed children's honesty and cognitive abilities increase until around the age of eight. Similarly, Wright et al. (2010) found that adults believed the reliability of children's memory increased between the ages of 3–6 years. Likewise, McAuliff and Kovera (2007) examined the beliefs of jurors and found that a majority supported the notion that memory performance increases with age. While this is true even according to FTT, this study and others are providing evidence that there are certain contexts where enhanced memory performance actually leads to more memory errors. Given that it took decades of research to uncover these findings and that the topic of memory suggestibility is very controversial, it is highly unlikely that jurors would be aware of developmental reversals in false memory.

The lack of association between performance on the DRM task and a memory conformity task suggests that different processes drive false memories produced from the two tasks. Forensic implications from this finding include interpreting the results of false memory studies with consideration of the context and paradigm used. This is not only important in relation to developmental differences but also important in relation to the context overall, because performance on one false memory task may not provide any information on what we should expect in other contexts of false memory.

Future studies should compare the DRM paradigm with other types of false memory paradigms, especially those that are known to produce developmental reversals and that would predict developmental reversals based on a theoretical framework. This will increase our understanding of the developmental mechanisms that underlie false memory. In addition, the inclusion of adolescents in these studies will remain an important undertaking as we continue to explore the development of false memory, because important changes in neurobiology and memory development are taking place during this time.

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