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Effects of forewarnings on children's and adults' spontaneous false memories

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ABSTRACT
The current experiment examined the effect of forewarning on children's (11 to 12 years of age) and adults' spontaneous false memory creation by presenting participants with semantically related word lists that are often used to elicit false memories (i.e., Deese-Roediger-McDermott (DRM) paradigm). The forewarning consisted of an explanation of the false memory effect and a demonstration of a DRM word list and an associated recognition task. It was hypothesized that children would have fewer false memories than adults using the DRM paradigm and that forewarning would reduce the number of critical lures remembered by children and adults. We found a developmental reversal effect in that children had lower false memory levels than adults and that forewarning reduced, but did not eliminate, false memory propensity in both children and adults. Our findings further indicated that forewarning was more effective in reducing false memory levels in 11- to 12-year-old children than in adults. Finally, analyses revealed that participants were more accurate when they received a forewarning as compared to when they did not.

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KEYWORDS False memory; Deese-Roediger-McDermott paradigm; forewarning; children; adults

A widely used paradigm to study the creation of spontaneous false memory is the Deese-Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995). In this paradigm, participants are exposed to a list of words that are semantically related to a critical lure word, which is not included in the list. The words are arranged from the strongest to the weakest association; for example, for the lure word *sleep*, the list might be: *bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy*. After studying the word list a recognition or recall task follows. The lure word is often incorrectly recognized or recalled by

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participants as having been presented as part of the original list, thereby being a false memory. The principal goal of the current study was to examine whether this type of false memory formation can be inhibited by forewarnings about this phenomenon and whether there are development-related differences with regard to this inhibition.

Research on the accuracy of child eyewitness testimonies has repeatedly demonstrated an age-related decline in false memories (e.g., Bruck & Ceci, 1999; Eisen et al., 2002; Holliday & Hayes, 2000; Marche & Howe, 1995). More specifically, it was concluded that young children are more prone to false memories than older children or adults because they experience more difficulties in monitoring and rejecting faulty recollections. More recently, a number of studies showed a reversal of this trend, indicating that false-memory rates tend to increase with age (e.g., Brainerd et al., 2002, 2006; Howe, 2006; Odegard et al., 2008; Otgaar et al., 2018). The majority of these studies were conducted with the DRM paradigm.

There are several false memory theories that explain the occurrence of faulty recollections. Associative-Activation Theory (AAT) proposes that false memories are the product of associative activation in memory that then spreads across different related nodes or concepts (e.g., words) in one's knowledge base (Howe et al., 2009; Otgaar et al., 2019). According to AAT, false memories arise because the activation of one node leads to the activation of related nodes including those that were not actually experienced (Collins & Loftus, 1975). The number, strength, and speed of activation of these relations increases with age due to (in)formal learning and increased knowledge about the world (e.g., via experience). Throughout development, people acquire new information which will lead to a more elaborate and densely organized knowledge base. Practice and experience also lead to enhanced automaticity of associative activation. Thus, AAT predicts that children will have fewer false memories compared to adults because their knowledge base is less elaborate and the nodes relating to similar concepts are less interrelated and thus less easily activated (Howe, 2005, 2006).

An alternative explanation for false memories is Fuzzy-Trace Theory (FTT; Brainerd et al., 2008) which stipulates that when experiencing an event, two independent memory traces are formed, a gist and a verbatim trace. The gist trace encodes the overall meaning of experiences, whereas the verbatim trace encodes the more specific features of experiences. The gist trace is considered to be the main cause of false memories in the DRM paradigm (Brainerd et al., 2008). According to FTT, adults display a superior ability to extract gist traces as compared to children with the net consequence being that with increasing age, susceptibility to this type of false memory formation will also increase. Adults' higher rates of spontaneous false memories than children has been referred to as a developmental reversal effect (e.g., Brainerd et al., 2008; Otgaar et al., 2016).

Obviously, the developmental reversal effect can be explained by both AAT and FTT. According to AAT, adults' knowledge base is more elaborate compared to children leading to a predominantly automatic production of false memories (Howe et al., 2009), whereas FTT emphasizes the increasing reliance on gist traces throughout development (Brainerd et al., 2008).

To further understand false memories, the consideration of two opposing processes are needed: an error-inflating process that results in an increase in false memories and an error-editing process that counteracts false memories (Arndt & Gould, 2006). For example, high identifiable DRM word lists would activate the error-inflating effect (Brainerd & Wright, 2005) and hence yield increased spontaneous false memory rates in adults, while forewarning would prompt the error-editing process that mitigates false memory susceptibility. The balance between both processes would eventually determine the production of a false memory (Arndt & Gould, 2006).

Gallo (2006) further distinguished between two types of monitoring processes: diagnostic monitoring and disqualifying monitoring. Diagnostic monitoring occurs if a participant rejects an unpresented item based on not having a recollection of it. The underlying assumption would be 'if that item had occurred, I would have remembered it.' Using the DRM paradigm, diagnostic monitoring would tend to occur if critical lures have a salient characteristic such as word length (Madigan & Neuse, 2004) or emotionality (Pesta et al., 2001). If an unpresented word is rejected based on a true recollection of another word, then the process is referred to as disqualifying monitoring. This type of monitoring strategy has also been referred to as the recall-to-reject process and reflects conscious decision making. Participants applying this strategy identify the absence of a theme word from the presented words and use this knowledge to later reject the critical lure during a recognition test. The recall-to-reject strategy is sometimes used by adults (Gallo et al., 1997).

One way to inhibit the formation of spontaneous false memories is to warn people about the associative structure of DRM lists and their concomitant aftereffects (e.g., false memories). Such forewarning procedures might interfere with the formation of false memories during encoding, increase rejection rates of false memories during the retrieval process, or both. The question arises as to whether false memory rates can be effectively reduced by forewarnings and whether such intervention will be equally effective in children and adults. Because false memories occur relatively automatically during encoding, especially in adults, it might be difficult to reduce one's susceptibility to such spontaneous false memories.

Forewarning and false memories

A plethora of research has investigated the preventive effect of forewarning on the formation of spontaneous false memories in adults (e.g., Bixter & Daniel, 2013; Peters et al., 2008; Watson et al., 2004). Some studies reported that forewarning instructions do not reduce the DRM effect (Neuschatz, Payne, Lampinen, & Toglia, 2001), but the majority of this research indicates that providing adults with a warning prior to encoding DRM lists reduces the production of false memory (Gallo et al., 1997). For example, Gallo et al. (1997) attempted to reduce the number of spontaneous false memories in adults using forewarning instructions. Specifically, one group of participants in this study received a forewarning and a false memory recognition demonstration to understand the nature of the DRM paradigm. The other two groups received no forewarning (uninformed condition) or were told to be cautious in order to make as few mistakes as possible (cautious condition) but did not receive explicit preparatory instructions about the nature of the DRM paradigm. The results of this study indicated that during memory testing, participants in the forewarning condition falsely recognized fewer critical lure words than participants in the uninformed and cautious conditions. This finding suggests that forewarnings are moderately effective in reducing false memory rates in the DRM paradigm. Even though participants obtained extensive training in the forewarning condition, the forewarning only reduced false memory rates but did not entirely eliminate them.

Neuschatz et al. (2003) conjectured that participants who receive a forewarning may be prone to report false memories because they are struggling to identify the critical lure word of a DRM list. Therefore, these researchers investigated whether adult participants showed lower false memory rates when they received a forewarning and had to search for the critical lure word in a DRM list that was more easily identifiable. In this study, the level of identifiability of DRM lists was determined by the percentage of subjects that could identify the critical lure. Lure words that were detected by at least 67% of the subjects were defined as high identifiable, whereas lure words that were recognized by fewer than 40% of the participants were considered as low identifiable. Neuschatz et al. (2003) found that false recognition of critical lure words was not affected by the identifiability of the lists when participants did not receive a forewarning. However, when participants received a forewarning, the number of false memories was reduced but only for the high identifiable lists and not for the low identifiable lists. The explanation here is that with such lists, it is easy to identify the underlying theme of the DRM list and such identification might become even easier when participants are alerted about the associative nature of DRM lists. The results of Neuschatz et al. (2003) are interesting as they provide a possible explanation why in some previous studies, such as in McDermott and Roediger (1998) and Gallo et al. (1997), forewarning was **only moderately effective**. Neuschatz et al. (2003) concluded that presumably, both studies used low, not high, identifiable lists resulting in a diminished effect of forewarning.

Carneiro and Fernandez (2010, Experiment 1) were the first to take a developmental perspective by examining the effects of forewarning on false memories in young people. Specifically, younger (4- to 5-year-old) and older (11- to 12-year-old) children received a forewarning prior to listening to DRM lists. Younger children were told that they would participate in a memory game, whereas older children were notified that they would participate in a memory test. Both age groups in the forewarning condition were instructed to carefully listen to audiotaped word lists that were presented via a computer. Children were alerted that the intention was to trick them into remembering words that they did not hear. To further explain how the deception was conducted, the experimenters gave an example of a DRM list and highlighted how these words might make one think about words that were actually not presented.

The authors found that forewarning significantly reduced false memories in 11- to 12-year-olds but not in 4- to 5-year-olds. Because forewarning in this study had little effect on 4- to 5-year-olds, Carneiro and Fernandez (2010) suggested that perhaps participants need to have reached a certain (meta)cognitive level to deploy strategies that reduce false memory rates. However, this study had several important limitations, including the absence of an adult control group, so we cannot be sure that the level of reduction in false memories is larger in children than in adults. Furthermore, as noted above, the instructions between the two child groups were somewhat different and hence, such differences might have affected the efficacy of forewarning on children's false memory production.

Del Prete et al. (2014) also took a developmental perspective by examining the effects of forewarning on false memories in 7- to 13-year-old children and adults. Again, false memory rates were assessed by means of DRM lists. Two warning conditions were included, one in which participants received a warning with an example of a critical lure, and one in which they received a warning without an example of a critical lure. The third condition was the control condition in which participants did not receive a warning prior to the DRM task. The results showed that younger children (7- to 8-year-old) exhibited higher false memory rates in the warning-with-example condition compared to the control condition. The researchers argued that younger children did not engage in meta-cognitive processes that are needed to recognize the critical lure. Further, they suggested that a warning instruction helped younger children process the gist of each list, resulting in an increased false recognition rate.

No effect of warning was noted in 10- to 11- year-olds, but 12- to 13-year-olds and young adults were able to reduce their false memory rate in the warning-with-example condition. The researchers suggested that the processes promoting and inhibiting false memories were cancelling each other out at the age of 10- to 11- year-olds, therefore, resulted in a null effect. The 12- to 13-year-old children were, however, able to reduce their false memory rate because of advanced capacities to process semantic relationships.

The limitation with that study, however, was that it only corrected for yea saying, but not for the overall frequency of false memories. Since adults experience more false memories than children the same absolute reduction in the number of false memories represents a lower chance of preventing a given false memory. Correcting for the overall frequency of false memories is important to investigate whether false memory reduction is larger in children than in adults, which is a critical question in the current study.

The present experiment

In the present experiment, we examined the impact of forewarning on false memory production in 11- to 12-year-olds and adults. Acknowledging past findings, which showed that forewarning might be especially effective if high identifiable lists are used, we only included DRM lists for which the critical lure was well identified (see Neuschatz et al., 2003). Participants in the experimental group first received a forewarning, consisting of an explanation of the false memory effect and a demonstration using a DRM word list and an associated recognition task. Next, they listened to 8 audiotaped, high identifiable DRM word lists, followed by a recognition task. Participants in the control group were subjected to the same DRM procedure and assessment but did not receive any preparatory instructions beforehand. We hypothesized that forewarning, in both children and adults, would reduce their rates of false memories for semantically related but unpresented words in a DRM paradigm. Furthermore, children were predicted to have fewer false memories on the DRM paradigm compared to adults thereby evincing a developmental reversal effect (Brainerd et al., 2008; Otgaar et al., 2016). Further, we hypothesized that forewarning would be more effective in reducing false memories in children compared to adults. Our reasoning behind this is that in children false memories are not as automatically produced as in adults (Howe et al., 2009). This means that when children have to inhibit the production of false memories, the chance is higher that this inhibition will be successful leading to lower false memory rates. Indeed, in a study by Howe (2005), children listened to DRM word lists and were either instructed to remember the list, to forget the list, or received no instruction. The results showed that, compared to adults, the forgetting instruction only led to reduced false memories in children. Hence, we expected that forewarning would be more effective in lowering false memory rates in children compared to adults.

Method

Participants

An a priori power analysis G*Power (Faul et al., 2007) was used to determine how many participants were needed for the study. Thirty-three participants per condition were required to reach a power of 0.80 and an anticipated medium effect size (f) of 0.25. A total of 140 participants took part in this study of which only 133 were included in the final analysis (adults: n = 67, children: n = 66). The data of seven participants was not further analysed because they either did not follow the given instructions or clearly stated that they did not understand the forewarning intervention. Adult participants (age: M = 21.43 years, SD = 1.72, range: 18–26 years; 34 males, 33 females) were recruited at Maastricht University (n = 7) or the Rheinisch-Westfälische Technische Hochschule Aachen (n = 61). Children from the United World College Maastricht

(n = 14), Couven Gymnasium Aachen (n = 34), and AFNORTH International School in Brunssum (n = 18) also took part in the study. All children were 11 and 12 years of age (M = 11.49 years, SD = 0.49; 32 males, 34 females).

Ethical approval for the study was received from the Ethical Research Committee Psychology and Neuroscience at Maastricht University. All data and materials of the study can be accessed using the following link: https://osf.io/wbczq/. Participation was voluntary and participants were required to have a proficient level in English to be included in the research. Hence native speakers and bilinguals participated in the study. Written consent was obtained from university students prior to participation. Children also needed the approval of their parents or guardians before they could participate in the study. In agreement with the principle of the schools and the teachers, the study was scheduled in such a way that it did not interfere with scholastic activities. All children and students received a small gift for their participation.

Materials

Eight high identifiable DRM word lists (containing 15 words each) that were also used by Neuschatz et al. (2003) were employed for the current research. The lists that were used are provided in Appendix A. These 120 words were presented via an audio recorder. Each word was presented for approximately 0.75 seconds and was followed by a pause of approximately 1 second before the next word was presented. There was no additional pause between the word lists. The recognition task consisted of 64 words. The words were presented on a sheet of paper and included 24 of the presented words (serial positions 1, 8, and 10 in the original word lists), 8 critical lures, and 32 unrelated words (Gallo et al., 1997). The unrelated words were extracted from the Stadler et al. (1999) DRM lists and were not presented in the audio recording. On the subsequent recognition task participants had to indicate the words they remembered from the audiotape.

Participants in the experimental condition received an eight-word recognition task, after being warned about the nature of the DRM paradigm and before listening to the eight high identifiable DRM word lists. The critical lure word associated to the DRM list (*thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection, syringe, cloth, knitting*) in the eight-word recognition task was *needle*. The short recognition task consisted of 8 words which included 3 of the presented words (serial positions 1, 8, and 10 in the original word lists), 1 critical lure, and 4 unrelated words which were again extracted from Stadler et al. (1999).

Design and procedure

The current study used a 2 (Age group: children vs adults) x 2 (Experimental condition: forewarning-with-example vs. control condition: no-forewarning) between-subjects design. A total of four groups was created, namely an experimental condition for adults (adults forewarning, n = 34) and children (11- to 12-year-olds forewarning, n = 33) as well a control condition for adults (adults control, n = 33) and children (11- to 12-year-olds control, n = 33). Participants were randomly assigned to the experimental or control condition. Children conducted the experiment in a quiet classroom at their school. University students were tested at the university in a quiet room. In both conditions, the experiment lasted approximately 15 minutes and a maximum of six participants per group (Gallo et al., 1997) were tested at a time.

In the experimental condition, information about the nature of the DRM paradigm and its false recognition effect was provided to the participants (see Neuschatz et al., 2003). Participants in the experimental condition were alerted that each word list consisted of related words and that each word was associated with one common word which tied all other words together. They were also notified that this critical lure was not presented but would be shown in the recognition task. Furthermore, they were warned that the DRM lists often elicit false memories for the critical lure because it was associatively related to the other words from the word list. Participants were instructed to be cautious in order to avoid remembering the related but unpresented critical lure during the recognition task. The full instructions that were read to the participants can be found in Appendix B.

After explaining the nature of the DRM paradigm, the participants received a demonstration of a DRM list. Prior to this demonstration, participants listened to a recording of a DRM list consisting of 15 words, which was followed by a short recognition task. After filling out the recognition task, the experimenter pointed out which word was the critical lure and cautioned participants not to become prone to this false memory effect. Next, the eight DRM lists were presented to the participants. Each DRM word list was presented directly after one another. The lists were presented through a recording of a neutral, female voice.

After the presentation of the eight words lists, all participants received a paper-and-pencil recognition task, which they could fill in at their own pace. At the end, all participants were debriefed about the experiment and thanked for their participation.

In the control condition, participants did not receive a forewarning, which means that they were not given any explanation about the DRM paradigm and its false memory effect nor did they receive a short recognition task. Instead, participants were only instructed to listen carefully to all eight word lists and try to remember as many words as possible, as they would be tested by a subsequent recognition task. Afterwards, participants received the same paper-and-pencil recognition task as the experimental condition. The full instructions that were read to the participants in the control condition can be found in Appendix B.

Results

Response bias-corrected true and false memory scores

Table 1 displays the proportion of studied words remembered by adults and children without correction for yea saying. Children are more prone to yea saying in general (Snodgrass & Corwin, 1988). It is assumed that children's total lure words score represents both their false memories plus their higher propensity for yea saying, while children's recognition of unrelated words score only represents their propensity for yea saying. In order to obtain an estimate of children's corrected false memory rate, we subtracted the proportion of 'yea' responses to unrelated words from the proportion of 'yea' responses to critical lures (e.g., Brainerd & Reyna, 2007; Carneiro & Fernandez, 2010; Del Prete et al., 2014). The corrected true memory rate is calculated similarly by subtracting the proportion of 'yea' responses to unrelated words from the proportion of "yea" responses to presented words.

To examine the effect of age and forewarning on children's memory performance, two separate two-way between-subjects analysis of

Table 1. Mean recognized proportion of studied words and critical lures for bias uncorrected data.

	11 – and 12-year-olds				Adults			
	Control		Forewarning		Control		Forewarning	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Studied words	0.62	0.15	0.58	0.14	0.68	0.14	0.66	0.14
Critical lures	0.56	0.23	0.49	0.23	0.63	0.20	0.49	0.20

variance (ANOVA) were conducted with corrected true memory rate and corrected false memory rate as the dependent measure. For corrected true rate, results showed that adults had statistically significantly higher corrected true memory rates as compared to children [$F(1,129) = 23.15$, $p < .001$, $\eta 2 = .15$; see Table 2]. Experimental condition had little effect on corrected true memory rates [$F(1,129) = 0.18$, $p = .673$, $\eta 2 = .005$] and had no differential impact on these scores between the two age groups [$F(1,129) = 2.59$, $p = .11$, $\eta 2 = .02$].

The two-way ANOVA conducted on the corrected false memory rate yielded a statistically significant main effect of experimental condition [$F(1,129) = 4.50$, $p = .036$, $\eta 2 = .03$], indicating that participants in the forewarning condition displayed lower levels of false memories than participants in the control condition. Furthermore, a statistically significant main effect of age group was found [$F(1,129) = 5.77$, $p = .018$, $\eta 2 = .04$]: as can be seen in Table 2, adults had higher corrected false memory rates than children, which is indicative of a developmental reversal effect. The interaction effect of age group and experimental condition was not statistically significant [$F(1,129) = 0.034$, $p = .854$, $\eta 2 = .0002$], which is consistent with an equal reduction of corrected false memory rates in children and adults.

Exploratory *analysis*

Net accuracy

One potential concern is that the decrease in false memories following forewarning is due to participants being more conservative and not actually becoming better in suppressing false memories. This was addressed by calculating net accuracy, which is the ratio of true memory to total memory (i.e., true/(true + false); Brainerd et al., 2010). A two-way ANOVA was performed on these net accuracy scores and yielded no statistically significant interaction effect between experimental condition and age group. There was no statistically significant main effect for

Table 2. Mean recognized proportion of studied words and critical lures for bias corrected data.

	11 – and 12-year-olds				Adults			
	Control		Forewarning		Control		Forewarning	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Studied words	.43	.20	.37	.13	.52	.20	.55	.13
Critical lures	.37	.29	.27	.20	.47	.28	.39	.21

experimental condition [$F(1,129) = 0.93$, $p = .337$, $\eta 2 = .006$] nor a significant main effect of age group [$F(1,129) = 0.587$, $p = .445$, $\eta 2 = .005$]. However, a statistically significant effect of experimental condition (forewarning) was obtained [$F(1,129) = 5.19$, $p = .024$, $\eta 2 = .39$]: forewarning increased net accuracy and did not simply suppress memory formation. Net accuracy was significantly higher for participants who received a forewarning (forewarning: $M = 0.79$, $SD = 0.07$) compared to those who did not receive a forewarning (no forewarning: $M = 0.77$, $SD = 0.06$).

Proportion-corrected accuracy

The above described two-way ANOVA on corrected false memories found no statistically significant difference in false memory rate reduction due to forewarning between children and adults. However, this analysis looked at absolute differences and did not take baseline differences concerning false memory creation into account. That is, children had lower false memory rates than adults in the control condition.

One problem with the above analysis is that it measures the effectiveness of forewarning by looking at the reduction in the absolute number of false memories. However, since adults had more false memories than children, forewarning has to reduce false memories in children by a much larger proportion to achieve the same absolute difference in false memories. To take baseline differences into account, we focused on the proportional reduction in false memories, which we calculated for participants in the experimental condition by first taking the difference between their false memory rate and the average false memory rate of the control condition and then dividing that by the average false memory rate of the control condition.

An independent sample *t*-test was performed between children's and adults' false memory rates while considering these baseline differences. For this purpose, we computed pcFM(A,i) = cFM(A,i)/cFM, which represents the proportion corrected false memory rate of each individual adult participant. To obtain the proportion corrected false memory rate (pcFM) of a participant 'i' in the adult group who received forewarning (A,i), the corrected false memory rate (cFM) of participant 'i' in the adult group who has received forewarning (A,i) was divided by the average corrected false memory rate (cFM) of participants in the adult group who did *not* receive forewarning. The test statistic used for children was similar to that of the adults pcFM(C,i) = cFM(C,i)/cFM. Using these test statistics, a *t*-test could be performed comparing the ratio between false memory rates in the experimental condition to false memory rates in the control condition between children and adults. A *t*-test revealed a statistically significant difference between children's and adults' proportion-corrected false memory rates, $t(65) = -2.65$, $p = .01$, $d = 0.65$, indicating that forewarning was proportionally more effective in reducing false memories in children ($M = 0.98$, $SD = 0.35$) than in adults ($M = 1.18$, $SD = 0.28$). More precisely, we found that the effect of forewarning on false memories was nearly twice as large for children (27%) than for adults (17%). In other words, in children 27% of their false memories could be prevented through a forewarning intervention, whereas this percentage was only 17% in adults.

Discussion

In the present experiment, the effect of forewarning on 11- to 12-year-old children's and adults' false memory production was examined. Half of the participants were forewarned about the nature of the DRM paradigm and received a demonstration of the DRM effect before subjecting them to this false memory procedure. The current experiment yielded several key findings. First, we found that forewarning reduced false memories in both children and adults. Second, we showed that adults were more prone to false memories when using response bias-corrected data, which is consistent with what has been described in the literature as the developmental reversal effect (Brainerd et al., 2008). Third, forewarning was proportionally more effective in reducing false memories in children than adults. Finally, we found that forewarning did not affect true memory. We even found that net accuracy was higher for participants that received a forewarning. We will now address the relevance of these findings.

Interestingly, we found that forewarning was proportionally more effective in reducing the rate of false memories in children than in adults. The reduction in false memory rate was nearly twice as large for children compared to adults. The observed effect was expected because previous studies (e.g., Howe, 2005) indicated that children of this age are capable of extracting the overall theme of a word list. However, the meaning-related processes that foment false memories in children are weaker compared to adults and therefore, easier to disrupt spontaneous false memory production e.g., through forewarning. The reduced rate of false memories in 11- to 12-year-olds who had received a forewarning is in line with Carneiro and Fernandez (2010, Experiment 1). The current findings are also in line with our hypothesis namely that adults and children will have fewer false memories on the DRM paradigm if they receive a forewarning. The reduction of false memories after receiving a forewarning can be explained from the perspectives of both FTT and AAT. For example, it has been observed, that by the age of 11 children start to use similar semantic processing strategies as adults do (Brainerd et al., 2002). Thus, children also employ strategies, such as elaboration and organization, which enable them to recognize the theme of a word within a word list. If 11- to 12-year-olds start to rely on semantic processing strategies as adults do, it might be that they already begin to understand the gist of the DRM word lists. Since forewarning is an intervention to understand the nature (theme/gist) of the DRM paradigm, this might explain why it is not effective in younger children (e.g., 4- to 5-year-olds; Carneiro & Fernandez, 2010) but does have a false memory reducing effect in 11- to 12-year-olds and adults.

According to AAT, the decreased rate of false memories in children who received a forewarning could be explained as well. In the previously mentioned study by Howe (2005), young children could inhibit their rates of false memories when they were instructed to forget word lists. He found that children (5-, 7-, and 11-year-olds) were able to inhibit false memory formation which supports the assumption that spreading activation is not as automatic in children as it is in adults. Since associative activation is less automatic with children than adults, one might expect that children can effectively reduce their false memory rates through forewarning whereas this would be more difficult for adults. However, our results indicate that children and adults do equally well in inhibiting their false memories when they receive an extensive forewarning concerning the DRM paradigm and when highly identifiable lists are used. It remains possible that age differences would be evident when more typical DRM lists had been administered, ones that have lower levels of identifiability, which is, of course, a topic of further inquiry.

As mentioned earlier, our second finding was that children had fewer false memories than adults, thereby showing a developmental reversal effect, which is in line with prior research (Brainerd et al., 2002). The data to support this hypothesis was obtained after correcting for the response bias in children. The developmental reversal effect is often found with corrected data because the procedure adjusts for the response bias typically displayed by children, namely higher rates of yea-saying (Brainerd et al., 2008). If no correction for response bias would be applied, then the higher yea-saying in children and the higher rates of false memories in adults cancels out the effect of age on false memory creation.

Importantly, the decrease in false memories due to forewarning did not go hand in hand with reductions in true memory. On the contrary, when we explored net accuracy scores, we found that participants had higher net accuracy scores in the forewarning condition. This finding suggests that forewarning can exert two positive effects on memory: 1) it can decrease false memory formation, and 2) it can increase accuracy. This, together with related research showing that forewarning is effective in reducing other types of false memories (i.e., due to suggestive influence; Blank & Launay, 2014), demonstrates that forewarning is an effective strategy to edit (partly) out false memory creation without affecting true memories.

In general, research investigating false memory production is relevant to the legal field since it impacts the reliability of eyewitness testimonies. First, when children and adults are, for example, interviewed by the police, it is of utmost relevance that what is reported is accurate. The current study suggests that warning might be an efficient way to make sure that the production of spontaneous memory errors is minimized without affecting true memory reports. Second, past research has shown that child memory reports are often tainted and more sensitive to suggestive interviewing styles compared to adults (Goodman & Melinder, 2007). It is often believed within legal settings (e.g., police, lawyers, judges) that adult memory reports are more reliable than those of children, which is not necessarily true and depends on the case and situation. Children are more susceptible to external influences such as suggestive interviewing, whereas adults are more susceptible to spontaneous false memories, which are caused by internal mechanisms such as associative activation (Otgaar et al., 2018). If adults are surrounded by associatively related cues, this could threaten the accuracy of their memory report. Indeed, eyewitness testimonies often involve highly interrelated information, and, in such cases, child memory reports might have fewer false memories as compared to those of adults. Otgaar et al. (2016) further emphasized that children are not always more susceptible to suggestion-induced false memories. In their first experiment, they exposed younger children (6- to 7-year-old), older children (11- to 12-year-old), and adults to a video with a mock crime and exposed them afterwards to misinformation about details not presented in the original video. Results showed higher misinformation acceptance rates in older children and adults compared to younger children. These findings further underline the assumption that adult memory reports are more susceptible to interrelated information than those of younger children. The current study supports the argument that child memory reports are not necessarily of poorer quality than those of adults. The obtained results indicate that regardless of whether children are in the forewarning or no forewarning condition, they have fewer false memories than adults.

Limitations

Nonetheless, our results should be treated with a degree of caution. Spontaneous false memories are one specific type of false memory and not necessarily applicable in every court hearing. In legal settings, perhaps other types of false memories such as those caused by suggestion might be more relevant. For example, suggestive questioning and suggestive line-ups (Wells & Loftus, 2003) might have a greater impact on testimonies of eyewitnesses compared to spontaneous false memories. Therefore, future research should aim to further examine the effects of spontaneous false memories in more realistic settings to draw further conclusions about its impact on the criminal justice system.

It should further be noted that high identifiable word lists, which were used in the current study, have been shown to yield opposite effects on adults' and children's false memory production (Carneiro et al., 2009). More specifically, if the theme of a list is easily identifiable, adults show a reduced level of false memories, while children display an increased false memory rate. Carneiro et al. (2009) hypothesized that adults are able to reduce their false memory rate when exposed to high identifiable word lists because they presumably apply the identify-to-reject strategy. This identify-to-reject strategy requires a higher level of cognitive operations, which is why this strategy is probably too complex for children. The application of only high identifiable word lists hence somewhat limits the comparability of the present results to previous findings.

Following the procedure by Gallo et al. (1997), the present study contrasted a forewarning condition with a control condition. A potential drawback of this procedure might be that the forewarning condition received additional training because of the practice list, which the control condition did not receive such training. As a result the observed reduction in false memory rates in the current study might be due to a practice effect instead of a forewarning effect.

Despite these limitations, the current study showed that both true and false recognition increased with age, which is consistent with previous developmental research (e.g., Brainerd et al., 2002). The novel finding of the current study was that forewarning before administrating DRM word lists significantly reduced false memories and that this was not only true in adults but also in children. In the current study, it was also observed that children had fewer false memories compared to adults regardless whether they were in the forewarning or control condition.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix A DRM word lists

Critical Targets With List Items 1 to 15

*SLEEP: bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy

*SPIDER: web, insect, bug, fright, fly, arachnid, crawl, tarantula, poison, bite, creepy, animal, ugly, feelers, small

*WINDOW: door, glass, pane, shade, ledge, sill, house, open, curtain, frame, view, breeze, sash, screen, shutter

*RIVER: water, stream, lake, mississippi, boat, tide, swim, flow, run, barge, creek, brook, fish, bridge, winding

*MUSIC: note, sound, piano, sing, radio, band, melody, horn, concert, instrument, symphony, jazz, orchestra, art, rhythm

*FRUIT: apple, vegetable, orange, kiwi, citrus, ripe, pear, banana, berry, cherry, basket, juice, salad, bowl, cocktail

*SMOKE: cigarette, addiction, cancer, harmful, lung, drug, horrible, cigar, cough, nicotine, marijuana, ash, lighter, swallow, tobacco

*FLAG: banner, american, symbol, stars, anthem, stripes, pole, wave, raised, national, checkered, emblem, sign, freedom, pendant

* HI lists according to Neuschatz et al. (2003)

Appendix B Forewarning instructions

I will give you word lists which are comprised of several similar words. You will listen to these lists once through a recording. All words in a list are related to one common word which is not named in the recording but in the following recognition task. In every word list, you should try to discover the common word which ties all other words together and then try to avoid it in the recognition task.

Control instructions

I will give you word lists which you will listen once through a recording. Afterwards I will give you a recognition task. Try to remember as many words as possible from the recording.