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Developmental Reversals in False Memory: Effects of Emotional Valence and Arousal

C. J. Brainerd,
Department of Human Development, Cornell University

R. E. Holliday,
Department of Psychology, University of Leicester

V. F. Reyna,
Department of Human Development, Cornell University

Y. Yang, and
Department of Human Development, Cornell University

M. P. Toglia
Department of Psychology, University of North Florida

Abstract

Do the emotional valence and arousal of events distort children's memories? Do valence and arousal modulate counterintuitive age increases in false memory? We investigated those questions in children, adolescents, and adults using the Cornell/Cortland Emotion Lists, a word list pool that induces false memories and in which valence and arousal can be manipulated factorially. False memories increased with age for unpresented semantic associates of word lists, and net accuracy (the ratio of true memory to total memory) decreased with age. These surprising developmental trends were more pronounced for negatively-valenced materials than for positively-valenced materials, they were more pronounced for high-arousal materials than for low-arousal materials, and developmental increases in the effects of arousal were small in comparison to developmental increases in the effects of valence. These findings have ramifications for legal applications of false-memory research: Materials that share the emotional hallmark of crimes (events that are negatively valenced and arousing) produced the largest age increases in false memory and the largest age declines in net accuracy.

Keywords

memory development; fuzzy-trace theory; false memory; emotion; valence; arousal

Developmental reversals in false memory are surprising age increases in children's tendency to remember things that did not happen to them. Such increases are remarkable because it has been thought for over a century that false memory declines sharply between early childhood and young adulthood (e.g., Binet, 1900; Small, 1896; Stern, 1910; Whipple, 1909). There is a

Correspondence concerning this article should be addressed to C. J. Brainerd, Department of Human Development, Cornell University, Ithaca, NY 14853. cb299@cornell.edu.

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large literature of recent vintage that supports this long-standing belief (for reviews, see Bruck & Ceci, 1999; Ceci & Bruck, 1993, 1995; Goodman, 2006; Goodman & Schaaf, 1997; Poole & Lamb, 1998; Quas, Qin, Schaaf, & Goodman, 1997; Reyna, Mills, Estrada, & Brainerd, 2007). For instance, age declines in false memory have been reported in many studies of memory suggestion, a paradigm that is designed to parallel the coercive forensic interviewing techniques that first focused scientific attention on children's false memories (e.g., Bjorklund, Bjorklund, & Brown, 1998; Bjorklund et al., 2000; Eisen, Qin, Goodman, & Davis, 2002; Goodman, Quas, Batterman-Faunce, Riddlesberger, & Kuhn, 1994; Holliday, & Hayes, 2000, 2001; Marche, 1999; Marche & Howe, 1995). Likewise, age declines have been detected with false-memory paradigms that do not provide children with memory suggestions. Examples include free and cued recall of live events (e.g., Pipe, Gee, Wilson, & Egerton, 1999; Poole & White, 1991), free and cued recall of word lists (e.g., Bjorklund & Muir, 1988), memory for mathematical propositions (Brainerd & Reyna, 1995), memory for narratives (e.g., Ackerman, 1992, 1994), sentence recognition (e.g., Reyna & Kiernan, 1994, 1995), and word recognition (e.g., Brainerd, Reyna, & Kneer, 1995).

However, Brainerd, Reyna, and Ceci (2008a) recently concluded that despite extensive documentation of age declines in false memory, there is mounting evidence of reversals of that pattern under conditions that are both theoretically and pragmatically important. Brainerd et al. reviewed over 30 experiments in which such reversals were identified. In some, age increases in false memory were more pronounced than corresponding increases in true memory, so that the net accuracy of memory (the ratio of true memory to total memory) actually declined between childhood and adulthood (e.g., Metzger et al., 2008). Brainerd et al. noted that although such findings are surprising, the developmental reversal effect is not a serendipitous discovery because it was predicted on theoretical grounds some years before relevant studies were conducted. Specifically, the effect was predicted by fuzzy-trace theory (FTT; see Brainerd & Reyna, 1998; Ceci & Bruck, 1998), which posits that age increases in false memory are apt to occur in situations that have two features: (a) False memories arise from people's propensity to connect meaning across distinct events that share meaning, and (b) it is difficult to use verbatim traces of actual events to suppress those distortions.

In the developmental studies that Brainerd et al. (2008a) reviewed, Deese/Roediger/McDermott (DRM; Deese, 1959; Roediger & McDermott, 1995) lists were the most frequently used example of a task that exhibits both of these properties. With respect to the first property, a DRM list consists of a series of familiar words that share meaning with each other (e.g., *nurse*, *sick*, *ill*, *hospital*, *medicine*,…), and for which there is a missing word that is a semantic associate of all the list words (*doctor* in this instance). When adults are exposed to such lists and respond to immediate recognition or recall tests, missing words (usually called critical distractors or critical lures) are falsely recognized more than 70% of the time and falsely recalled more than 20% of the time, on average. Concerning the second property, after being exposed to such a list, it is difficult to suppress false memories of unpresented words such as *doctor* by recalling presented words such as *ill*, *hospital*, or *nurse* because participants are well aware that there are many other presented medical words that they cannot recall, and *doctor* could easily be one of them (Brainerd, Reyna, Wright, & Mojardin, 2003).

Several experiments have confirmed FTT's prediction that false memories of DRM critical distractors should increase during child-to-adult development. In the initial confirmation, Brainerd, Reyna, and Forrest (2002) found that both false recall and false recognition of critical distractors increased between early childhood and young adulthood, with floor levels of false recall being observed below age 7. In their literature review, Brainerd et al. (2008a) surveyed 26 published experiments in which DRM lists had been administered to participants who ranged in age from young children to young adults, 25 of which detected reliable age increases in false memory. Brainerd et al. also found that the accumulated literature showed that the formation of meaning connections between list words is both necessary and sufficient to produce age increases in DRM false memory. Regarding necessity, manipulations that interfere with older participants' greater ability to form meaning connections have been found to reduce or eliminate age increases (e.g., Connolly & Price, 2006; Holliday & Weekes, 2006). Regarding sufficiency, manipulations that enhance younger participants' lesser ability to form such connections have likewise been shown to reduce or eliminate age increases (e.g., Brainerd, Forrest, Karibian, & Reyna, 2006; Brainerd, Reyna, Ceci, & Holliday, 2008b; Lampinen, Leding, Reed, & Odegard, 2006; Odegard, Holliday, Brainerd, & Reyna, 2008). Of course, the fact that meaning connection is necessary and sufficient for age increases in false memory does not rule out the possibility that there are other mechanisms that contribute to such increases (Ghetti, 2008; Howe, 2008).

Several key questions about the developmental reversal effect remain unanswered. In their review, Brainerd et al. (2008a) concluded that a prominent one concerns the effects of emotion on developmental reversals. In the forensic situations that originally sparked interest in children's false memories (for a review, see Ceci & Friedman, 2000), an inherent feature of the events that children are asked to remember is that the events are emotionally charged. Consequently, knowing how levels of false memory and developmental trends in false memory are influenced by the presence of emotion is an urgent priority in applications of basic memory research to the law (Brainerd & Reyna, 2005). In that connection, certain adult theories posit that negative emotional events result in lower levels of false memory than positive emotional events because adults pay especially close attention to the surface details of negative experiences, while they place more emphasis on processing the semantic content of positive experiences. The distinction between the processing consequences of negative versus positive emotion is known as the affect-as-information hypothesis (for overviews, see Corson & Verrier, 2007; Storbeck & Clore, 2005). Research by Isen (1987) provides an early illustration of this hypothesis, whereas the socioemotional selectivity theory of Carstensen and associates (e.g., Carstensen & Mikels, 2005) provides a more recent illustration. For instance, socioemotional selectivity theory assumes that adults pay especially close attention to the details of negative experiences because they have higher informational content than the details of positive experiences (for any early example, see Smoke, 1933). Because attending to the surface details of experiences has been found to reduce false memories (Brainerd & Reyna, 2005), it follows that the developmental reversal effect should be more pronounced when participants are remembering positively-valenced events than when they are remembering negatively-valenced ones and that the effect may even disappear with negatively-valenced events (Brainerd et al., 2008a).

Although research on how levels of false memory and developmental trends in false memory are influenced by emotion is an urgent priority in the legal arena, there are obvious ethical concerns about exposing children to events that have the intense emotional qualities of crimes. It is therefore essential to begin with mild emotional manipulations in order to determine, first, whether children's memories are distorted by manipulations that do not raise such concerns. Here, an attractive methodology for investigating how emotion influences DRM false memory has already been devised by Budson et al. (2006). Although this procedure involves mild levels of emotion, it is reminiscent of everyday situations in which people experience a series of events that are meaningfully related by virtue of being emotionally charged (e.g., the events of a crime). As mentioned, a DRM list consists of a series of familiar words that are semantically related to one another and that are semantic associates of the critical distractor. Budson et al. created two sets of such lists: (a) a neutral set in which the critical distractors that generated the lists were non-emotional words (e.g., *chair, foot, fruit, teacher*) and (b) another set in which the critical distractors were emotional words (e.g., *anger, cry, lie, sick*). They administered those lists to younger and older adults, followed by recognition tests that included list words (targets), critical distractors, and unrelated distractors. They found that true memory (the target hit rate) was higher for the emotional lists, which is inconsistent with the aforementioned adult theories. They also found that false memory (the false-alarm rate for critical distractors) was the same for the two types of lists, which is inconsistent with those theories. Finally, they found that developmental trends in true and false memory were the same for the two types of lists.

The only other published developmental studies that implemented this procedure were reported by Howe (2007) and by Howe, Candel, Otgaar, Malone, and Wimmer (2010), and their results differed from Budson et al.'s (2006). Howe administered some of Budson et al.'s (2006) lists to 5-, 7-, and 11-year-old children. Contrary to the hypothesis that emotional lists should yield low levels of false memory and smaller developmental increases in false memory, recognition tests revealed that the false-alarm rate for critical distractors was higher for emotional than for neutral lists and that age increases in such errors were not suppressed by emotional lists. In the Howe et al. research, it was again found, with a sample of 8- and 11-year-old children, that false-alarm rates were higher for emotional lists and that developmental increases in false memory were comparable for emotional and neutral lists. Important additional findings were obtained about the persistence of emotional false memories over long-term retention intervals. Howe et al. reported two developmental studies of persistence, one with 5- and 7-year-olds and the other with 7- and 11-year-olds. In both, true and false recognition for emotional and neutral lists were either tested shortly after list presentation (for half the participants) or one week later (the other half of the participants). In the first study, it was found that (a) target hit rates declined over the retention interval but critical distractor false-alarm rates did not, (b) critical distractor false-alarm rates were higher for emotional than for neutral lists after a week, (c) the spread between the two false-alarm rates was greater after a week because errors to critical distractors increased over the delay for emotional but not neutral lists, and (d) and developmental trends in false memory were comparable for emotional and neutral lists. Similar patterns were obtained in the second study. Thus, in addition to providing support for prior studies showing that children's false memories can be more stable than their true memories (Brainerd, Reyna, & Brandse, 1995), Howe et al.'s data suggest that this finding may especially robust with emotional memories.

Budson et al.'s (2006) methodology is an important tool for securing baseline findings about how emotion influences developmental trends in false memory, but it has a key limitation. Brainerd, Stein, Silveira, Rohenkohl, and Reyna (2008c) pointed out that it is important to separate the effects of two components of emotional experience on false memory, arousal and valence (e.g., Bradley & Lang, 1999), which are not separated in Budson et al.'s methodology. In that methodology, emotional and neutral lists differ in valence (emotional lists are negative while neutral lists are not), but emotional lists are also more arousing than the neutral lists. Valence and arousal are confounded, in other words. Brainerd et al. used the Affective Norms for English Words (ANEW; Bradley & Lang, 1999) to compute mean valence and arousal scores for the critical distractors of the two sets of lists. The mean valence scores (on a 9-point scale) for the emotional and neutral critical distractors were 2.73 and 5.75, respectively, while the mean arousal scores (on a 9-point scale) for the emotional and neutral critical distractors were 6.81 and 3.92, respectively. This means that it is impossible to tell whether differences in false memory between emotional and neutral lists are due to the fact that the former are negatively valenced, or to the fact that they are more arousing, or both. Also, note that "neutral" critical distractors are actually positive on average: The mid-point of the ANEW valence scale is 5, and mean valence of the "neutral" critical distractors is well above that value.

Thus, in the studies of Budson et al. (2006) and Howe and associates (2007; Howe et al., 2010), the disconfirmations of the predictions of the affect-as-information-hypothesis may be due to the influence of arousal. The findings might be different if the effects of valence were separated from those of arousal. It is important to note in this connection that adult research on valence and arousal shows that these two factors have different behavioral and neuro-physiological effects (for a review, see Kensinger, 2004). For instance, brain imaging studies have revealed that variations in the arousal level of target materials produce changes in amygdala activation, whereas variations in valence produce changes in prefrontal cortical activation. It is possible, then, that the predictions of the affect-as-information hypothesis would be borne out with unconfounded manipulations of valence.

To resolve this uncertainty, we conducted an experiment that disentangled the effects of valence and arousal on the development of true and false memory. This was accomplished by administering emotional DRM lists drawn from a new pool of normed materials, the Cornell/Cortland Emotion Lists (CEL; Brainerd, Yang, Toglia, Reyna, & Stahl, 2008e), in which words' valence and arousal are varied factorially. The CEL is composed of 32 DRM lists, which are divided into 4 subsets: 8 negative valence/high arousal lists, 8 positive valence/high arousal lists, 8 negative valence/low arousal lists, and 8 positive valence/low arousal lists. By administering lists from each group in a 2 × 2 design, the effects of valence, arousal, and their interaction can be separated, and developmental trends in the effects of valence can be determined without the correlated influence of arousal.

A second feature of our experiment is that it pitted two types of theoretical predictions about emotion against each other: (a) FTT's predictions about developmental trends in the memory effects of emotional valence versus (b) the aforementioned predictions that memory falsification (and, therefore, age increases in false memory) will be lower for negatively-valenced materials than for positively-valenced materials. Concerning a, Rivers, Reyna, and Mills (2008) noted that FTT expects that once valence and arousal have been disentangled, the effects of valence on both true and false memory will increase between early childhood and young adulthood, for two reasons. First, valence is a conceptual property that people use to organize and understand their experience; that is, it is a gist that connects events that are quite distinct from one another. It is well known from developmental studies of semantic clustering and semantic organization (e.g., Bjorklund & Hock, 1982; Bjorklund & Jacobs, 1985) that the tendency to spontaneously connect conceptual gist across distinct events increases during childhood and adolescence and, hence, so should the effects of particular gists (e.g., valence) on true and false memory. Second, brain-imaging research with adults has shown that variations in the valence of target materials are associated with activation differences in later-maturing brain regions (e.g., the prefrontal cortex; Kensinger, 2004; Lieberman, Eisenberger, Crockett, Tom, Pfeifer, & Way, 2007). With the CEL, FTT's prediction that the memory effects of emotional valence will wax with age can be evaluated by examining age trends in true and false memory for materials that differ in valence but not in arousal. Concerning b, we have already noted that certain adult theories forecast that memory for negatively-valenced materials will be more accurate than memory for positively-valenced materials, from which it follows that the developmental reversal effect will be more marked for positively-valenced materials. With the CEL, such predictions can be evaluated by examining age trends in true and false memory for negative versus positive lists, with arousal controlled.

Method

Participants

The participants were 53 7-year-old children (*M* = 7.90 years; range = 7.50–8.33 years), 54 11-year-old children (*M* = 11.00 years; range: 10.50–11.67 years), and 57 young adults (*M* = 20.50; range = 18.67–23.83 years). Children attended schools in predominantly white, middle-class areas, and only participated if prior parental and child consent had been granted. The young adult sample consisted of undergraduates who participated in the experiment to fulfill a course requirement.

Design

The experimental design was 3 (age: 7 years, 11 years, young adult) × 2 (valence: positive versus negative) × 2 (arousal: high versus low) × 2 (type of memory: true versus false). The first factor was between-participants, and the others were within-participants.

Materials: The CEL

As mentioned, the CEL (Brainerd et al., 2008e) is a pool of 32 lists in which arousal and valence are varied factorially to generate 4 sets of 8 lists: negative valence/high arousal, positive valence/high arousal, negative valence/low arousal, and positive valence/low arousal. As usual with DRM materials, each CEL list consists of the first 15 forward associates [selected from the Nelson, McEvoy, and Schreiber (1999) norms of word association] of an unpresented critical distractor. The CEL lists were constructed in two steps: (a) critical distractor selection followed by (b) list construction.

Concerning the first step, the 32 critical distractors for the CEL lists are shown in Table 1. Note that three important word properties are controlled across the four sets of critical distractors: (a) valence, (b) arousal, and (c) backward associative strength (BAS). With respect to the first two properties, we have already discussed the need to separate valence from arousal when investigating how emotional content affects age trends in true and false memory. In Table 1, the pertinent data on arousal and valence appear in the first four columns. Because the question of central interest is how valence influences children's *false* memories, we used the ANEW norms (Bradley & Lang, 1999) to select 32 critical distractors that could be split into groups that differed in valence but not arousal and into groups that differed in arousal but not valence. We began with a much larger set of potential critical distractors from the ANEW norms, but other items were eventually eliminated because DRM lists could not be constructed for them, either because those items did not appear on the word-association norms that are used to construct DRM lists or because the norms did not provide enough associates to construct a 15-item word list. The final group of 32 critical distractors are the only items in the ANEW norms for which it is possible both to counterbalance valence and arousal and to generate corresponding DRM lists. With respect to valence-arousal counterbalancing, note two points about the critical distractors in Table 1. First, the mean valences of the 16 negative and 16 positive critical distractors are 3.4 and 7.2 (9-point scale), respectively, while the corresponding mean arousals are 5.0 and 4.9 (9-point scale), respectively, and second, the mean arousals of the 16 high-arousal and 16 low-arousal critical distractors are 5.9 and 4.1 (9-point scale), respectively, while the corresponding mean valences are 5.5 and 5.2, respectively.

The second step was to generate a DRM list for each of these 32 critical distractors. This was done in the usual way by selecting forward associates of each critical distractor from available norms of word association (Nelson et al., 1999). However, if the aim is to measure how the development of false memory varies as a function of uncontaminated manipulations of valence, it is essential to avoid confounding valence (or arousal) with other properties of words that are known to affect DRM false memory. Here, the construction of the CEL took advantage of the fact that word properties that affect DRM false memory have been extensively studied, with findings on most of the standard properties (e.g., concreteness, frequency, imagery, length) having been reported by Roediger, Watson, McDermott, and Gallo (2001) and by Brainerd, Yang, Reyna, Howe, and Mills (2008d). In an early study, Deese (1959) found that a single property, BAS, accounted for roughly three-quarters of the variance in DRM false memory, where BAS is the frequency with which participants give the critical distractor in response to DRM list words on tests of word association (e.g., Nelson et al., 1999). BAS was also found to correlate strongly with DRM false memory in the Roediger et al. and Brainerd et al. studies, and equally important, other word properties that correlate with DRM false memory were found to correlate strongly with BAS. The methodological denouement is that one can avoid confounding valence and arousal with other properties that affect DRM false memory by simply equating BAS across the four combinations of valence and arousal. As can be seen in the third column of Table 1, BAS has been equated in this manner in the CEL lists: Mean BAS is .16 for the negative-high, positive-high, and negative-low lists and .18 for the positive-low lists. Thus, if valence or arousal is found to affect false memory, it is not because other word properties that are known to affect DRM false memory have been confounded with valence or arousal.

A final feature the CEL concerns the valence and arousal values of the lists words, as opposed to the critical distractors. Owing to the manner in which the lists were constructed, it is possible that although valence and arousal were not confounded for the critical distractions, they would be confounded for the lists words. However, it can be seen in Table 1 that valence and arousal were not for the list words. The relevant data appear in the first and third columns. As with the critical distractors, two points should noted: First, the mean valences of the 16 negative and 16 positive lists are 4.6 and 6.2 (9-point scale), respectively, while the corresponding mean arousals are 5.0 and 4.8 (9-point scale), respectively, and second, the mean arousals of the 16 high-arousal and 16 low-arousal critical distractors are 5.2 and 4.7 (9-point scale), respectively, while the corresponding mean valences are 5.3 and 5.5, respectively. Thus, the CEL lists unconfound valence and arousal differences for critical distractors and for list words, although differences in mean valence and mean arousal are larger for critical distractors than for list words.

Finally, using the Toglia and Battig (1978) and Kučera and Francis (1967) norms, we investigated whether the CEL confounded valence and arousal differences with other properties of words that are known to affect the difficulty of remembering them on recognition tests. Here, we selected three such properties that have been extensively studied, *concreteness* (*C*; words with higher concreteness ratings are easier to recognize), *meaningfulness* (*m*; words with higher meaningfulness ratings are easier to recognize), and *frequency* (*f*; words that are used more often in written or spoken discourse are *harder* to recognize). We found that none of these common word-difficulty properties was confounded with valence and arousal differences in the CEL. With respect to valence, the mean *C*, *m*, and *f* values, respectively, for the 18 positive versus the 18 negative lists were 4.98 versus 4.90, 4.89 versus 4.77, and 99.22 versus 120.67. None of the three pairs of means different reliably. With respect to arousal, the mean *C*, *m*, and *f* values, respectively, for the 18 high versus the 18 low lists were 4.67 versus 5.10, 4.88 versus 4.78, and 92.56 versus 99.79. None of the three pairs of means differed reliably.

By administering lists from these four sets, then, the effects of positive versus negative valence on false (and true) memory can be measured without the confounding influence of arousal. The effects of higher versus lower arousal and Valence × Arousal interactions (i.e., whether valence effects are different for higher versus lower arousal) can also be measured. All of these effects can be measured without the confounding influence of other properties of words that are known to affect difficulty.

Procedure

The procedure for the 7- and 11-year-old subjects was presented on a laptop computer in a quiet room at the children's schools. Following preliminary instructions, each child was administered a total of 12 CEL lists, 3 from each of the 4 Valence × Arousal combinations, using a four-step procedure. The first step began with the following instructions: "You will be shown some lists of words one at a time. Pay attention because following these lists you will be asked if you remember some of the words. READY?" The first 10 words for each of 3 CEL lists were then presented by the computer, with each word being presented both visually and orally. Individual words were presented at 4-sec intervals, with a 15-sec delay between consecutive lists. After the third list was presented, children participated in a 30-sec distractor task (counting using numbers that appeared on the computer screen). This was followed by a recognition test for the three lists, which was also presented by the computer. The test consisted of 21 words: Nine target words (three from each list, taken from 5th, 7th, and 9th list presentation positions), the critical distractor for each of presented list, one related distractor for each presented list (an *unpresented* word from each presented list, taken from the 12th position of the 15-word list), and 6 unrelated distractors (2 words from each of 3 unpresented CEL lists). The unrelated distractors lists were matched to the presented lists in valence and arousal, so that the unrelated distractors matched the targets, critical, distractors, and related distractors in valence and arousal. This is an important consideration because valence and arousal could affect the bias rate for unrelated distractors, so that in computing statistics that correct for the influence of bias (see Results) it is necessary to use unrelated distractors that match true and false memory items in valence and arousal.

The second, third, and fourth steps of the procedure were the same as the first, except for the lists and the words that appeared on the recognition tests. During each step, three CEL lists were presented that had not been previously presented, and the words on the recognition test (9 targets, 3 critical distractors, 3 related distractors, 6 unrelated distractors) focused on those just-presented lists. After the fourth step was completed, each child had responded to recognition tests for three negative/high-arousal lists, three positive/high-arousal lists, three negative/low-arousal lists, and three positive/low-arousal lists. Other than this constraint, lists were randomly selected for inclusion in each block.

The procedure for the adult participants was the same, except that it involved eight steps, rather than four. Pilot work showed that the performance of some children deteriorated if more than four of the just-described cycles were administered, but that adults were able to respond to a larger number of cycles without any decrement in performance. Consequently, a total of 8 cycles (24 CEL lists, 6 from each Valence × Arousal combination) were administered to each adult. Otherwise, the procedure for each of the eight steps was the same as for the 7- and 11-year-old participants. That is, 3 CEL lists were presented, followed by the 30-sec buffer activity, followed by a 21-item recognition test (9 targets, 3 critical distractors, 3 related distractors, and 6 unrelated distractors). Thus, the procedure for each adult subject may be thought of as consisting of two halves. The first half (12 lists and 4 recognition tests) was identical to the procedure that was used with 7- and 11-year-olds. The second half was a repetition of the first half, except that all 12 lists were new. To determine whether there were any positive or negative effects from doubling the number of lists for adults, we compared performance on targets, critical distractors, related distractors, and unrelated distractors during the first versus the second half of the procedure. No reliable differences were observed, so this variable is not considered further.

Results

In Table 2, the mean hit rates for targets and the mean false-alarm rates for the three types of distractors (critical, related, and unrelated) are reported by age level, valence type, and arousal level. Statistical analyses are reported below, in three waves. Because this experiment was chiefly concerned with how emotional valence and arousal affect developmental reversals in false memory, the false-memory findings are reported first. Second, we report the corresponding findings for true memory. Third, because recent studies of the developmental reversal effect have found that age increases in false memory are sometimes so large that net accuracy declines with age, we report developmental trends in net accuracy as functions of valence and arousal.

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False Memory

In developmental studies of recognition memory, it is standard practice to use signal detection statistics, such as *d′* and *C*, to separate memory discrimination from response bias. That is because bias, which inflates both the hit rate and the false-alarm rate for distractors that are related to targets (i.e., the critical and related distractors in this experiment), usually declines between early childhood and young adulthood (e.g., Brainerd et al., 2002; Reyna & Kiernan, 1994). As can be seen in Table 2, the false-alarm rate for unrelated distractors was low (below .10) at all age levels, owing to the fact that there were only three lists per presentation block and the fact that the recognition test for each block was administered immediately following the 30 sec buffer activity. Nevertheless, the false-alarm rate for adults was roughly half the false-alarm rate for the two younger age levels. Therefore, we computed *d′* and *C* values for critical distractors and for related distractors as our measures of false memory and response bias. For each of the four Valence × Arousal list combinations, the computed *d′* and *C* values used false-alarm data for unrelated distractors that matched critical distractors in valence and arousal (see Method). Mean values of the two statistics are reported by age level, valence condition, and arousal condition in Table 3. We report analyses of memory discrimination first, followed by analyses of response bias.

Memory discrimination—The *d′* values for critical distractors are the primary measure of false memory in this paradigm. As preliminary information, it should be noted that levels of false memory for critical distractors were significantly above chance at all three age levels, for both types of valence and both levels of arousal. For each Age × Valence × Arousal combination, a test of the null hypothesis that the false memory level does not exceed chance can be obtained via a one-sample *t* test that compares the observed mean *d′* value to a predicted mean of 0. The results of those tests produced null hypothesis rejections for adults [mean $t(56) = 17.25$, $p < .0001$], 11-year-olds [mean $t(53) = 8.84$, $p < .0001$], and 7-year-olds [mean $t(52) = 4.95$, $p < .001$].

In order to measure developmental trends in false memory and to determine how false memory was affected by variations in valence and arousal, we computed a 3 (age) × 2 (valence type) × 2 (arousal level) analysis of variance (ANOVA) of *d′* values for critical distractors. With respect to the developmental reversal effect, there was a large age increase in false memory, $F(2, 161) = 76.82$, $MSE = 3.45$, $p < .0001$, partial $\eta^2 = .49$. The mean *d′* value more than tripled with age, increasing from 1.04 in 7-year-olds to 2.28 in 11-year-olds to 3.23 in young adults. A post hoc test (Tukey HSD, $p < .05$) showed that the 7-to −11 increase was reliable and that the 11-to-adult increase was also reliable.

Turning to the question of how valence and arousal each contribute to memory distortion, there was a main effect for valence, $F(1, 161) = 21.83$, $MSE = 2.57$, $p < .0001$, partial $\eta^2 = .12$, but not for arousal. The reason for the valence main effect is that negative valence elevated the tendency to erroneously accept critical distractors, relative to positive valence (mean *d′* values = 2.47 and 1.89, respectively). Importantly, however, valence also modified the developmental reversal effect because there was an Age × Valence interaction, $F(2, 161) = 4.80$, $MSE = 2.57$, $p < .009$, partial $\eta^2 = .06$. When this interaction was decomposed, it was found that the age increases in false memory were more pronounced for negative valence than for positive valence. This is shown in Figure 1, where age increases in mean *d′* for critical distractors are separately plotted for positive and negative valence. Two instructive results are apparent. First, false memory increased during this age range for *both* types of valence. Second, the adult tendency for memory to be more distorted for negative materials than for positive (or neutral) ones (Brainerd et al., 2008c) emerged between the ages of 7 and 11. At age 7, levels of false memory for negative versus positive valence do not differ reliably—indeed, the two *d′* values are virtually identical (1.05 versus 1.02). After that, the increase in false memory is steeper for negative than for positive critical distractors, until age 11, after which the two increase at the same rate: Between the ages of 7 and 11, the increase in mean d' for negative critical distractors is exactly twice the increase for positive critical distractors (1.66 *SD*s versus .83 *SD*s), whereas the corresponding increases between the ages of 11 and 20 are virtually identical (.95 *SD*s versus .94 *SD*s). Remember, here, that the d' statistic is measured in *SD* units of a Gaussian distribution.

Although there was no main effect for arousal, this variable interacted with age, F (2, 161) = 4.35, MSE = 10.72, $p < .01$, partial $\eta^2 = .05$. Post hoc analysis revealed that memory distortion was greater overall for high-arousal items than for low-arousal items. The reason for the interaction is that the effect of arousal in 11-yearolds ($M_{d'}$ = 2.57 and 2.00 for high and low arousal, respectively) was larger than it was in either 7-year-olds ($M_{d'}$ = .88 and 1.19 for high and low arousal, respectively) or adults ($M_{d'}$ = 3.36 and 3.01). Further, post hoc analysis revealed that this arousal effect was confined to negatively-valenced lists; that is, high-arousal negative lists produced higher levels of false memory in than low-arousal negative lists among 11-year-olds, but not at the other two age levels. Note that the magnitudes of these arousal differences (a little more than half a standard deviation for 11-year-olds and a third of a standard deviation for 7-yeare-olds and adults) are smaller than the corresponding valence differences (nearly a full standard deviation for both age levels). . It must be stressed that the difference in the magnitude of the effects of valence and arousal should not be interpreted as demonstrating that arousal has an inherently weaker influence on false memory than valence. Such conclusion is unwarranted because in the CEL, owing to limitations of extant valence and arousal norms for words, mean differences on the 9-point ANEW scale are larger for critical distractor valence than for critical distractor arousal (3.8 versus 1.8).

A second, weaker measure of false memory is provided by related distractors. In developmental research with DRM tasks, the typical pattern for related distractors (e.g., Brainerd et al., 2002, 2006) is that (a) they exhibit levels of false memory that are reliable but far lower than the corresponding levels for critical distractors, and (b) they exhibit reliable but smaller age increases than critical distractors. Both patterns were noted in the present experiment. Concerning a, the question of whether related distractors produced levels of false memory that were significantly above chance was addressed in the same way as for critical distractors--namely, by computing one-sample t tests of the null hypothesis that $M_{d'} = 0$ for each Age × Valence × Arousal combination. The results of those tests produced null hypothesis rejections for all four Valence × Arousal combinations in adults and for two combinations apiece in 7-year-olds (positive/high-arousal and negative/low-arousal) and 11-year-olds (positive/high-arousal and negative/high-arousal).

Concerning b, we computed a 3 (age) × 2 (valence type) × 2 (arousal level) ANOVA of related distractor d' values. There were two reliable results: a main effect for age, F (2, 161) = 4.66, MSE = 3.45, $p < .01$, partial $\eta^2 = .06$, and main effect for arousal, F (1, 161) = 14.78, MSE = 2.04, $p < .0001$, partial $\eta^2 = .08$. Concerning the age main effect, the mean d' value increased from .14 in 7-year-olds to .17 in 11-year-olds to .54 in young adults. A post hoc test (Tukey HSD) showed that the 7-to-adult and 11-to-adult increases were reliable but the 7-to-11 increase was not. Concerning the arousal main effect, the mean d' value was larger for high-arousal items than for low-arousal items. This relation held at all three age levels, as the Age × Arousal interaction was not reliable.

Bias—Next, we consider how response bias, as measured by the C statistic, was affected by age, valence, and arousal. In signal detection theory (e.g., Snodgrass & Corwin, 1988), C measures the placement of the decision criterion relative to the memory strength distributions of the two types of items that are being compared (in this instance, false memory items versus unrelated distractors). Positive values of C mean that the decision criterion is liberal (higher levels of non-memorial yea-saying), and negative values mean that the decision criterion is conservative (lower levels of non-memorial yea-saying). We computed a 3 (age) × 2 (valence type) × 2 (arousal level) ANOVA of the *C* values that had been calculated for critical distractors, and we found that the emotional content of DRM materials affected bias as well as memory (*d*′ statistic).

The ANOVA yielded an age main effect, F (2, 161) = 28.53, MSE = 3.26, $p < .0001$, a valence main effect, F (1, 161) = 11.75, MSE = 1.88, $p < .001$, partial $\eta^2 = .26$, an arousal main effect, F (1, 161) = 17.83, MSE = 2.03, $p < .0001$, partial $\eta^2 = .10$, and no interactions. Concerning the age main effect, the mean *C* value decreased from −3.20 in 7-year-olds to −3.91 in 11-year-olds to −4.50 in young adults. A post hoc test (Tukey HSD) showed that the 7-to-adult, 7-to −11, and 11-to-adult decreases were all reliable. Concerning the other two main effects, bias was greater for positive than for negative valence ($M_C = -3.36$ versus −4.05) and was greater for low than for high arousal ($M_C = -3.64$ versus −4.10).

A final important point is that these *C* values show that recognition performance was quite conservative at all three age levels. In the present experiment, low negative values of *C* were obtained in all Age × Valence × Arousal combinations (see Table 3). Most likely, this is due to the fact that participants studied a relatively small number of targets (30) before recognition tests were administered, and the fact that the tests were administered 30 sec after the targets were studied. Together, these factors should have ensured that verbatim memories of targets were strong, and strong verbatim memories have previously been linked to low levels of response bias (Brainerd et al., 2003).

Summary: emotion effects on false memory—The ANOVAs of the *d*′ and *C* data for critical and related distractors yielded four main findings. First, consistent with recent developmental research, false memory increased between age 7 and young adulthood. The increase was dramatic for critical distractors, with mean *d*′ values more than tripling with age, and was smaller but still reliable for related distractors. Second, this developmental reversal effect was modulated by the emotional content of false memory items. For critical distractors, which displayed far more age variability than related distractors (and therefore provide more sensitive tests of arousal and valence effects), age increases in false memory (a) were more pronounced for negatively-valenced items than for positively-valenced items and (b) were more pronounced for high-arousal items than for low-arousal items. Third, with respect to the directional effects of valence versus arousal, levels of false memory were higher for negatively-valenced items and for high-arousal items. Fourth, response bias levels were low at all age levels, but nevertheless, the familiar pattern of age declines in bias was observed. In addition, response bias was affected by both the valence and arousal of false memory items, with yea-saying bias being lower for negative valence and for low arousal. When the third and fourth findings are combined, a further conclusion emerges: The tendency for negative valence to elevate false alarms to critical distractors in the DRM paradigm (Brainerd et al., 2008; Howe, 2007; Howe et al., 2010) is not a response-bias artifact because valence has opposite effects on false memory (*d*′ statistic) and bias (*C* statistic).

True Memory

As with the false memory analyses, we used signal detection statistics to determine how true memory changed with age and how it was affected by valence and arousal. Specifically, we computed *d*′ and *C* values for targets as our measures of true memory and response bias. Mean values of *d*′ and *C* are reported by age level, valence type, and arousal level in Table 3. As with false memory, we report analyses of *d*′ in order to determine how true memory was affected by age, valence, and arousal. Levels of true memory were significantly above chance expectations at all three age levels, for both types of valence and both levels of arousal. For

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the 12 Age × Valance × Arousal combinations, one-sample *t*-tests revealed that all *d′* values differed significantly from an expected value of 0.

To assess developmental trends and to measure the effects of valence and arousal, we computed a 3 (age) × 2 (valence type) × 2 (arousal level) ANOVA of *d′* values for targets. Concerning development, there was a main effect for age, F (2, 161) = 23.44, MSE = 2.62, $p < .0001$, partial $\eta^2 = .23$. The mean *d′* value increased from 3.53 in 7-year-olds to 3.83 in 11-year-olds to 4.56 in young adults. A post hoc analysis (Tukey HSD) showed that the 7-to-adult and 11-to-adult increases were reliable, but the 7-to-11 increase was not. Concerning valence and arousal, there was a main effect for valence, F (1, 161) = 22.83, MSE = 1.77, $p < .0001$, partial $\eta^2 = .12$, and a main effect for arousal, F (1, 161) = 88.37, MSE = 1.59, $p < .0001$, partial $\eta^2 = .35$. The valence effect was due to the fact that contrary to the results for false memory, true memory levels were higher for positive than for negative valence ($M_{d'}$ = 4.22 and 3.72, respectively). The arousal effect was due to the fact that consistent with the results for false memory, true memory was higher for high than for low arousal ($M_{d'}$ = 4.43 and 3.51, respectively). Both effects were qualified by interactions. There was an Age × Valence interaction, F (2, 161) = 10.34, MSE = 1.77, $p < .0001$, partial $\eta^2 = .11$, and a Valence × Arousal interaction, F (1, 161) = 8.91, MSE = 1.76, $p < .003$, partial $\eta^2 = .05$. Concerning the former, the age increase in true memory was greater for positive than for negative valence: Between age 7 and young adulthood, the mean *d′* value increased by 1.5 *SD*s (from 3.63 to 5.13, $t(108) = 7.69$, $p < .0001$) for positive valence, but it increased by only one-third as much, .55 *SD*s (from 3.43 to 3.98, $t(108) = 2.73$, $p < .01$) for negative valence. Also, the tendency of positive valence to increase true memory was reliable in young adults (*d′* values = 5.13 and 3.98, $t(56) = 6.17$, $p < .0001$), but not in 7-year-olds olds (*d′* values = 3.63 and 3.43) or in 11-year-olds (*d′* values = 3.89 and 3.76). Concerning the Valence × Arousal interaction, the tendency of high-arousal items to increase true memory was larger for positive than for negative valence (*d′* values = 4.45 and 3.52, $t(163) = 9.41$, $p < .0001$).

In sum, both true and false memory were affected by age, valence, and arousal. The age effects were qualitatively similar: *d′* values increased with age for targets and for false-memory items. In addition, age increases in true and false memory were modulated by valence: Age increases in false memory were more marked for negative than for positive valence, whereas the age increases in true memory were more marked for positive than for negative valence. Turning to valence, its directional effects were different for true and false memory, with true memory being higher for positive valence and false memory being higher for negative valence. Last, with respect to arousal, its directional effect was the same for true and false memory (both were higher for high than for low arousal).

Net Accuracy

In their literature review, Brainerd et al. (2008a) found that some studies of the developmental reversal effect had produced another counterintuitive pattern: age *declines* in net accuracy (the ratio of true memory to total memory). This same pattern can be seen in Figure 2, where the mean *d′* values for targets and critical distractors have been plotted for each of the three age levels. On the one hand, the true memory mean *d′* is higher than the false memory mean *d′* at all three age levels; critical distractors were never "remembered" as well as presented items. On the other hand, the true-false gap narrows perceptibly with age; the superiority of true over false memory *is noticeably greater in 7-year-olds than in 11-year-olds or adults*. To test the latter trend for statistical reliability, we computed a 3 (age) × 2 (memory: true versus false) × 2 (valence type) × 2 (arousal level) ANOVA of *d′* values. In this ANOVA, the result of primary interest was the Age × Memory interaction, which Figure 2 suggests should be highly reliable. It was, F (2, 161) = 22.63, MSE = 1.83, $p < .0001$, partial $\eta^2 = .22$. Post hoc analysis revealed that the spread between true and false *d′* values was significantly greater in 7-olds ($\Delta d'$ = 2.49) than in either 11-year-olds ($d' = 1.55$) or young adults ($\Delta d' = 1.33$). In addition, there was an Age × Memory × Valence interaction, $F(2, 161) = 12.93$, $MSE = 1.73$, $p < .0001$, partial $\eta^2 = .14$. Here, post hoc analysis revealed that the age decline in net accuracy was more marked for negative than for positive valence.

Discussion

The outcome of overriding significance is that there is now a convincing empirical case that negative valence elevates false memory and suppresses true memory when the effects of valence are not confounded with those of arousal. Brainerd et al. (2008c) noted in this connection that FTT predicts that negative valence has opposite effects on true and false memory, under the following scenario. Negative valence is an especially salient gist that is more likely to be the focus of processing than positive valence, which leads to stronger gist memories and therefore higher false-alarm rates for negative than for positive distractors. However, such a focus would lower hit rates for negative targets, if, in addition to stimulating gist processing, it interfered with verbatim processing of targets because, on immediate memory tests, hits are heavily dependent on the retrieval of verbatim traces (Brainerd, Reyna, & Kneer, 1995; Reyna & Kiernan, 1994).

Beyond this, we were concerned with three specific questions about how emotional valence influences the ontogenesis of false memory. (a) When valence is disentangled from arousal, does negative valence reduce or eliminate counterintuitive age increases in false memory? (b) When valence is disentangled from arousal, do its effects wax with age, as predicted by FTT (Rivers et al., 2008)? (c) When valence is disentangled from arousal, are its effects consistent with the predictions of adult theories, such as the affect-as-information hypothesis (e.g., Storbeck & Clore, 1995)? Our results provided answers to all three questions.

Concerning the first, the baseline developmental patterns for the CEL were that false memory increased with age, with d' values for critical distractors more than tripling between age 7 and age 20, and that the net accuracy of memory *declined* during this age range (see Figures 1 and 2). The answer to the first question is that negative valence neither reduced nor eliminated these baseline patterns, which are similar to ones that have been reported for non-emotional DRM lists (Brainerd et al., 2008a). Concerning the second question, the effects of emotional valence increased with age, as predicted on theoretical grounds. Here, it will be remembered, the baseline effects of negative valence were to increase false memory and suppress true memory. Both effects increased with age, and indeed, neither was reliable at the youngest age level. Concerning the third question, a well-established finding from social psychological research is that young adults are especially sensitive to negatively-valenced information (Carstensen & Mikels, 2002). The affect-as-information hypothesis (see Storbeck & Clore, 2005; Corson & Verrier, 2007) explains this finding on the ground that negative valence draws processing attention to the surface details of events and away from their meaning content, leading to stronger verbatim traces and weaker gist traces for negative than for positive information. Thus, negative valence is expected to increase true memory (which is directly proportional to the strength of verbatim memory) and suppress false memory (which is directly proportional to the strength of gist memory and inversely proportional to the strength of verbatim memory). Our data disconfirmed both predictions, revealing the opposite of the predicted pattern in each case.

This brings us back to the studies of Howe and associates (2007; Howe et al., 2010), which were mentioned earlier. In that research, it was found that children's false recognition of critical distractors was elevated by negatively-valenced material and that developmental increases in such errors were just as robust as for material that was not negatively valenced. As we discussed, these findings are difficult to interpret because valence and arousal are confounded in the materials that Budson et al. (2006) developed. Three features of our results render these data more interpretable. First, we found that negative valence elevates false recognition of critical distractors, regardless of arousal level. Thus, our data provide direct support for Howe and associates' proposal that negative valence foments false memory in children. Second, we found that arousal intensifies the distortive effects of negative valence. The implication is that the elevations in false recognition that Howe and associates have reported are due to arousal and well as to valence, with their relative contributions to Howe and associates' data being indeterminate at present. Third, we found that the developmental reversal effect was more pronounced for negatively-valenced that for positively-valenced materials, whereas Howe and associates have observed comparable developmental reversals for negatively-valenced versus neutral materials. In this connection, it should be noted that (a) the mean valence of the "neutral" lists that Budson et al. developed is actually positive, as previously mentioned, and that (b) the valence difference between the negative and positive lists of the CEL is larger than the valence difference between the negative and "neutral" lists that were administered by Howe and associates. Thus, with respect to whether negative valence amplifies developmental reversals in false memory, the present experiment simply provided a more sensitive test of this possibility because it implemented a stronger valence manipulation than the materials that were used by Howe and associates.

Turning to the broader implications of our results for the study of memory development, the primary question to be answered is, Why do the effects of valence increase with age? As we have seen, such age increases were predicted in advance, using FTT. Specifically, Rivers et al. (2008) noted that valence is a type of semantic gist, a meaning that connects distinct items and events, and that various findings from the memory development literature converge on the conclusion that the ability to connect meaning across different exemplars increases during childhood and adolescence (Brainerd et al., 2008a). That line of reasoning is supported by neuro-physiological data, which show that valence activates later-maturing, semantic-processing regions of the brain, specifically regions of the prefrontal cortex. Here, there is convergent support from adult imaging studies of semantic-processing areas that are affected by valence manipulations, on the one hand, and developmental imaging studies of semantic-processing areas that are associated with age increases in DRM false memory, on the other hand. Studies of the former sort were reviewed by Kensinger (2004). In studies in which, like the present experiment, the effects of valence on memory performance were not confounded with the effects of arousal, Kensinger concluded that valence manipulations were most consistently associated with activation differences in such prefrontal cortical regions as the right and left dorsolateral prefrontal cortex and the left inferior prefrontal cortex (e.g., see Kensinger and Corkin, 2004). (Arousal manipulations were most consistently associated with differences in amygdala activation.) Developmentally, Paz-Alonso, Ghetti, Donohue, Goodman, and Bunge (2009) recently reported a brain imaging study of DRM false memory in 8-year-olds, 11-year-olds, and young adults. Age increases in false memory levels, which exceeded 50% during this age range, were associated with developmental changes in activation in the left ventrolateral prefrontal cortex. Thus, Rivers et al.'s prediction that the tendency of valence to inflate false memory should increase with age seems to have neuro-physiological basis because imaging data show that later-maturing prefrontal regions are associated both with the effects of valence manipulations on memory performance and with age variability in DRM false memory.

A secondary question about memory development that is posed by our data is, Why are the rates of age change for the two valences different for true versus false memory? On the one hand, for false memory, false-alarm rates for critical distractors increased more with age for negative valence than for positive valence. This is consistent with the foregoing remarks about preferential processing of negative gist and about developmental increases in the ability to connect gist across exemplars. On the other hand, for true memory, the interaction between age and valence was the opposite—hit rates increased less for negative than for positive valence. Here, the explanation may lie with the aforementioned tendency of negative valence to dilute the verbatim processing that is the chief component of hit rates, which would mean that age improvements in such processing would be more easily detected with positive than with negative targets.

To conclude, we return to a topic of enduring significance in developmental studies of false memory: the implications of research findings for children and the law. In criminal proceedings, the bulk of the evidence that bears on guilt or innocence takes the form of memory reports that victims, witnesses, and suspects supply through interviews, written statements, and sworn testimony (Brainerd & Reyna, 2005). Thus, memory distortion is always a key issue in the law because it compromises the reliability of the most important form of evidence (Ceci & Friedman, 2000; Goodman & Quas, 2008). Because a hallmark of crimes is that the events have emotional content, the question of whether memory distortion is affected by such content is of special interest. A related question is whether emotional content distorts the memories of children more than the memories of adolescents or adults.

With respect to the first question, adult theories, such as the affect-as-information hypothesis, imply that the valence qualities of crimes are fortuitous ones from the standpoint of memory distortion because negative valence is predicted to increase true memory and reduce false memory. Our data disconfirmed these predictions, showing instead that negative valence produced higher levels of false memory and lower levels of true memory than positive valence and that the tendency of negative valence to elevate false memory was exacerbated by the other emotional characteristic of crimes, arousal. Concerning the second legal question, our findings suggest a surprising conclusion about age changes in the distortive influence of emotional content. It has traditionally been thought that children are more vulnerable than adults to factors that warp memory, with suggestive interviewing being a well-researched case in point (Ceci & Bruck, 1995; Poole & Lamb, 1998; Goodman & Quas, 2008). According to our data, however, the emotional content of events may be an important exception to this rule. The tendency of negative valence to increase false memory and reduce true memory increased with development, and the effects of arousal also increased.

We stress that the forensic implications of our findings are constrained by the fact that our experimental design used emotional content that was mild in comparison to the events of crimes, which means that one must be cautious about generalizing the findings to memory for such events. We also stress, however, that there are obvious ethical obstacles to exposing children to events whose valence and arousal levels match those of serious crimes, such as realistic depictions of gruesome murders, horrific traffic accidents, or frightening injuries from assaults. Questions can also be raised about the necessity of exposing children to less intense criminal events before the distortive effects of emotional content have been thoroughly investigated with mild manipulations of valence and arousal. That was our strategy in the present research, and it was found that even mild manipulations of valence and arousal effect memory accuracy. This finding, along with the data that Howe and associates (2007; Howe et al., 2010) have reported with negative-arousing materials, demonstrate that it is possible for child memory researchers to make progress in understanding the distortive effects of emotional content on memory without having to expose children to events whose emotional intensity approximates that of crimes. A possible objection to this conclusion is that memory for emotional words is not the same as memory for real-life events and that the effects of valence and arousal may be qualitatively and directionally different for the latter versus the former. To some, this objection may seem like a self-evident truth, but actually, it is only a conjecture. Therefore, it is important to note that this conjecture was recently rejected in a study by Rubin and Talarico (2009). These investigators found that participants' emotional reactions were similar for real-life events, autobiographical memories, and words that varied in valence and arousal.

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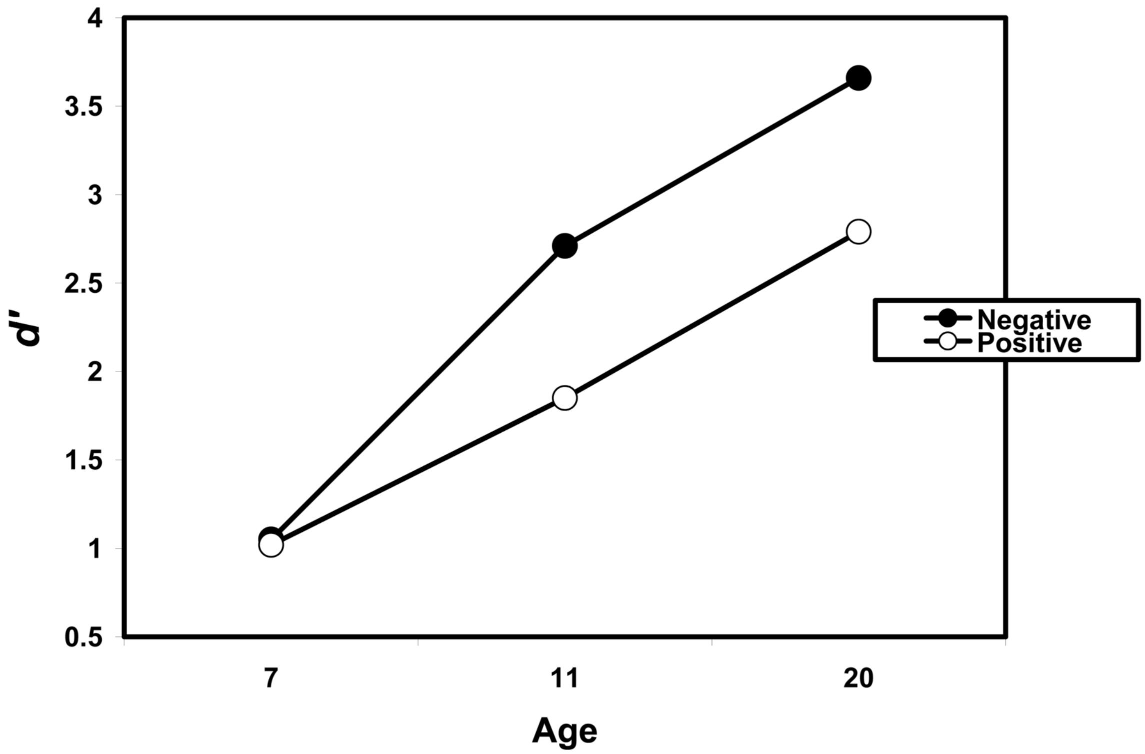

Figure 1.
The influence of valence on developmental reversals in false memory.

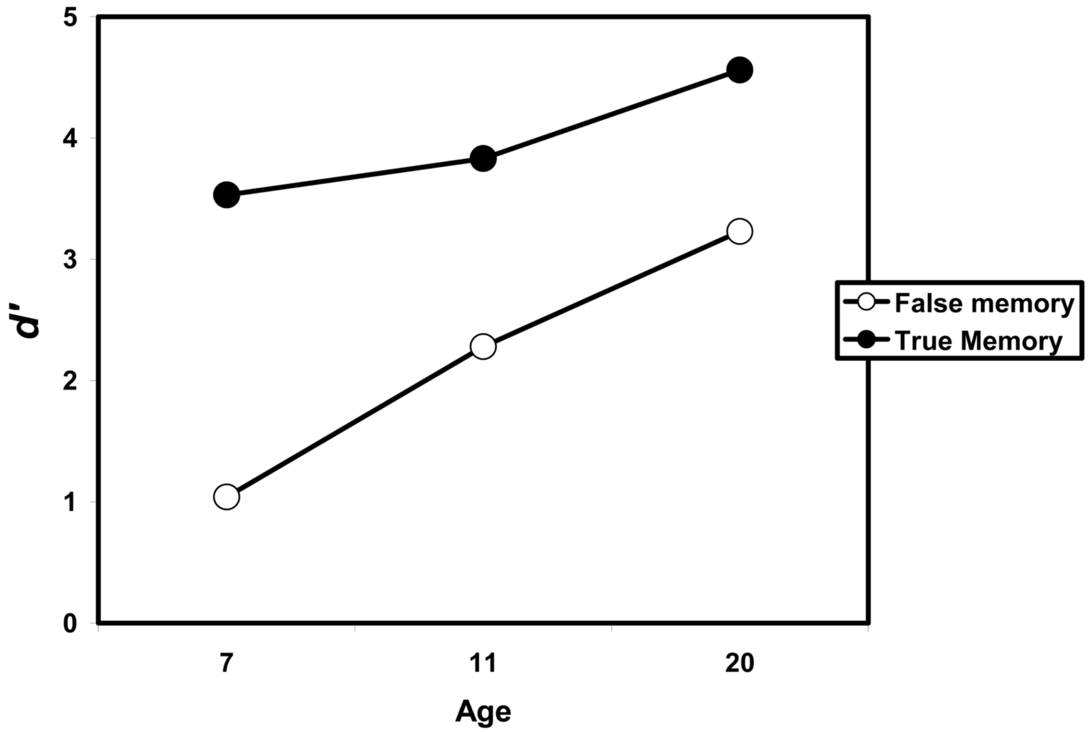

Figure 2.
The developmental decline in net accuracy.

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Table 1

The Cornell/Cortland Emotion Lists

Valence/arousal	Property				
	Mean Valence		Mean arousal		Mean BAS
	List	CD	List	CD	
Negative/high					
Cold	5.30	4.02	4.50	5.19	.23
Hurt	2.96	1.9	5.72	5.85	.21
Thief	3.61	2.13	5.66	6.89	.10
Spider	4.64	3.33	5.16	5.71	.16
Dead	4.18	1.94	4.94	5.73	.11
Anger	3.73	2.85	7.10	7.17	.16
Needle	4.48	3.82	4.88	5.36	.20
Grand means	4.27	3.09	5.27	5.90	.16
Positive/High					
God	6.25	8.15	5.58	5.95	.23
Baby	6.14	8.22	5.06	5.53	.18
Love	7.10	8.72	4.82	6.44	.17
Music	6.14	8.13	4.54	5.32	.18
City	5.40	6.03	4.98	5.24	.14
Beach	6.78	8.03	5.13	5.53	.13
Hug	6.94	8.00	4.73	5.53	.11
Pretty	6.29	7.75	4.99	6.03	.11
Grand means	6.38	7.88	4.98	5.70	.16
Negative/low:					
Sick	3.91	1.9	5.04	4.29	.26
Fat	5.54	2.28	4.55	4.81	.13
Shy	5.00	4.64	4.98	3.77	.14
Dirt	4.85	4.17	4.39	3.76	.21
Board	5.75	4.82	4.99	3.36	.13
Trash	4.15	2.67	4.43	4.16	.14
Glass	5.73	4.75	4.66	4.27	.13

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Valence/arousal	Property				
	Mean Valence		Mean arousal		Mean BAS
	List	CD	List	CD	
Fall	4.59	4.31	4.94	4.70	.11
Grand means	4.94	3.69	4.75	4.14	.16
Postive/low					
Soft	5.77	7.12	4.40	4.63	.18
Green	5.28	6.18	4.26	4.28	.09
Nice	6.36	6.55	5.19	4.38	.09
Sleep	6.12	7.20	3.70	2.80	.19
Bird	6.51	7.27	4.47	3.17	.39
Grass	6.31	6.12	4.57	4.14	.15
Fish	6.07	6.04	5.30	4.00	.17
River	6.25	6.85	4.42	4.51	.15
Grand means	6.08	6.67	4.54	4.00	.18

Note. List = the 15 words on each list, CD = the critical distractor for each list, BAS = mean backward associative strength from the 15 list words to the critical distractor for each list, as computed from Nelson, McEvoy, and Schreiber's (1999) norms of word association. For the 15 list words, some of the words on each list are not available in existing word norms for valence and arousal (Bradley & Lang, 1999; Toglia & Battig, 1978). The tabled means for valence and arousal of list words are therefore based on the words that are available in these norms.

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Table 2

Mean Target and Distractor Acceptance Probabilites for the Three Age Levels

Item	Valence-Arousal			
	Negative-High	**Positive-High**	**Negative-Low**	**Positive-Low**
7 years				
Target	.78	.74	.73	.57
Critical	.19	.18	.26	.23
Related	.07	.11	.09	.11
Unrelated	.04	.04	.07	.06
11 years				
Target	.86	.81	.77	.60
Critical	.54	.30	.39	.36
Related	.09	.10	.09	.06
Unrelated	.02	.02	.09	.05
Adult				
Target	.85	.95	.78	.94
Critical	.66	.54	.67	.54
Related	.13	.12	.11	.12
Unrelated	.02	.01	.04	.04

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Table 3

Mean d′ and C (in Parentheses) Values for the Three Age Levels

Item	Valence-Arousal			
	Negative-High	Positive-High	Negative-Low	Positive-Low
7 years				
Target	4.00(−4.80)	3.88(−4.83)	2.86(−4.02)	3.39(−4.14)
Critical	.96(−3.27)	.80(−3.29)	1.14(−3.17)	1.24(−3.07)
Related	.09(−2.64)	.37(−2.98)	.18(−2.68)	−.08(−2.41)
11 years				
Target	4.45(−5.21)	4.31(−5.15)	3.07(−4.25)	3.47(−4.13)
Critical	3.28(−4.62)	1.85(−3.92)	2.14(−3.78)	1.85(−3.32)
Related	.41(−2.92)	.54(−3.26)	−.07(−2.68)	−.20(−2.30)
Adult				
Target	4.57(−4.62)	5.40(−5.11)	3.38(−4.47)	4.87(−4.15)
Critical	3.63(−4.85)	3.08(−4.67)	3.69(−4.63)	2.51(−3.85)
Related	.71(−3.14)	.87(−-3.47)	.37(−2.97)	.21(−2.70)