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Emotional Modulation of Episodic Memory in School-Age Children and Adults: Emotional Items and Their Associated Contextual Details

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It is well established that emotional events are better remembered than neutral events. However, little is known about emotional enhancement of memory (EEM) in children. This is particularly the case when the main components of episodic memory are considered: core information (item memory) and its associated contextual details (associative memory). In 2 experiments, the present study tested whether the negative or positive emotional valence of words and pictures can influence item and associative memory. The contextual information to be associated with items was the gender of the voice pronouncing words and the type of frame in which pictures were displayed in Experiment 1, and the spatial location of stimuli in Experiment 2. Two groups of 8- to 11-year-old children (Experiment 1 $n = 32$ and Experiment 2 $n = 36$) performed the experiments and were compared to two groups of equivalent numbers of young adults. Participants completed an intentional-encoding task followed by immediate item recognition, associative recall and item recall tasks. Over the two experiments and in both groups, the results revealed (a) no EEM for words and pictures in recognition tasks, (b) EEM for words in item recall and associative recall tasks, and (c) mixed results for pictures, with an EEM being observed in item recall tasks but not systematically in associative recall tasks. By extending the results over two types of stimuli and their associated contextual information, our study provides new knowledge concerning the effect of emotions on episodic memory in children, which seems to be similar to that observed in young adults.

Keywords: school-age children, emotions, episodic memory, associative memory

Emotionally charged information is more likely to be remembered than neutral information (for reviews, see Hamann, 2001 and Dolcos et al., 2017). This effect, which is referred to as the emotional enhancement of memory (EEM), has been convincingly demonstrated in young and older adults regardless of the type of stimulus (pictures, words, stories, etc.), type of memory task, and interval between the initial encoding phase and the later memory retrieval test (Kensinger & Schacter, 2008). Emotional information is thought to be based on two underlying dimensions: arousal and valence (Barrett, Mesquita, Ochsner, & Gross, 2007; Russell, 1980, 2003). *Arousal* refers to a continuum that varies from calmness to excitement, whereas *valence* refers to a continuum that varies from negativity to positivity, with neutral as an intermediate value. Both dimensions are involved in the EEM (Kensinger & Corkin, 2004).

Although there is general agreement about the emotional regulation of memory in adults, the age-related difference in EEM is still being investigated. In fact, a *negativity* effect (better memory for negatively valenced stimuli) seems to be more specific to young adults and a *positivity* effect (better memory for positively valenced stimuli) more specific to older adults (Murphy & Isaacowitz, 2008). This may be explained by age-related differences in the availability of cognitive resources (e.g., Labouvie-Vief, Grühn, & Studer, 2010) or emotional regulation (e.g., Carstensen, Fung, & Charles, 2003). Surprisingly, less is known about the EEM in typically developing children. Nevertheless, the availability of cognitive resources and emotional processing also present specific patterns in children, which differ from those observed in young adults (Gee et al., 2013; Kujawa, Klein, & Hajcak, 2012; Luna et al., 2004; Perlman & Pelphrey, 2011; Thompson, 2011; Todd, Evans, Morris, Lewis, & Taylor, 2011). In particular, a recent review by Michalska and Davis (2019) suggested that, from a behavioral and functional perspective, emotional responses and regulation undergo significant development during childhood and adolescence, although this pattern of findings may vary depending on multiple factors such as the type of task, stimulus or analysis used. Importantly, Gee et al. (2013) showed a decline in amygdala

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reactivity to fearful faces coupled with increasing regulatory activity of the prefrontal cortex (PFC) during development. According to this study, this regulatory development seems to emerge as of 9 years of age and to grow stronger with age. In contrast, some findings have shown that children as young as 5 years old gave adult-like emotional responses in terms of subjective ratings and neuronal activity when pictures of visual scenes were used as stimuli (Hajcak & Dennis, 2009; McManis et al., 2001; McRae et al., 2012). Moreover, children showed the same attentional bias toward threatening stimuli as young adults (for a review, see Morales, Fu, & Pérez-Edgar, 2016). Considering these similarities or discrepancies relative to emotional reactivity and regulation between children and adults, we might expect the emotional regulation of memory processes in children to also present certain specificities. However, these specificities have largely been under-investigated.

Few studies have examined children's memory for emotional information, and these have reported inconsistent findings. Davidson, Luo, & Burden (2001) investigated 6 to 11-year-old children's recall of emotional and nonemotional behaviors presented in short stories. The results showed that the children recalled more negative and positive emotional behaviors than nonemotional behaviors when asked to perform immediate recall and recall after a 24-hr interval. Cordon, Melinder, Goodman, and Edelstein (2013) showed that 8 to 12-year-old children recognized more negative images than neutral ones after a 1-week interval. In addition, Quas and Lench (2007) observed that 5 to 6-year-old children's memory for fear-eliciting video clips was positively correlated with physiological arousal during encoding. However, as the Cordon et al. (2013) and Quas and Lench (2007) studies did not include positive stimuli, they provide only a partial insight into emotional memory in children. By contrast, the study by Van Bergen, Wall, and Salmon (2015) raises the possibility of a *negativity* effect in young children. The authors investigated 5 to 6-year-old children's recall of emotional experiences presented in six brief stories and showed that they recalled more emotional stories than neutral ones and also that negative stories were recalled better than positive ones. Taken together, these studies suggest that the emotional content of the stimuli enhances memory in children (for a review, see Hamann & Stevens, 2014). Nevertheless, the results of other studies, which did not show better memory for emotional than neutral stimuli, are inconsistent with this suggestion (Howe, Candel, Otgaar, Malone, & Wimmer, 2010; Leventon, Stevens, & Bauer, 2014; Peterson & Bell, 1996). Nonetheless, although Leventon et al. (2014) did not find an EEM in children's behavioral recognition responses, the neuronal activity associated with picture recognition was larger for negative pictures than for positive and neutral ones in children older than 7.5 years.

One important point is that all these studies have focused primarily on item memory tasks, that is, tasks that involve the ability to remember that an item was previously encountered. However, according to studies with adults, emotions also play a role in the ability to remember contextual details associated with an item (associative memory). The contextual details associated with an item can refer to the time or place at which the item was encountered, from whom it was learned, its modality of presentation and so forth. In several studies performed with young adults, an emotional enhancement of associative memory occurred when participants had to remember the color in which words were written (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003; D'Argembeau & Van der Linden, 2004) or the spatial location of words (D'Argembeau & Van der Linden, 2004) and pictures (Mather & Nesmith, 2008; Nashiro & Mather, 2011). Taken together, these findings may indicate that emotional events are often remembered in greater detail than neutral ones. However, other findings in the literature point toward an *emotion-induced memory trade-off* in associative memory (for a review, see Kensinger, 2009). This *memory trade-off* suggests that central arousing aspects of an emotional event are better remembered than the associated neutral peripheral information. This may be due to emotional arousal which tends to restrict the attentional focus to central aspects at the expense of irrelevant contextual details. This, in turn, impairs the binding (integration) of central and peripheral aspects into a stable memory representation. In addition, behavioral findings suggest that the effect of emotions on associative memory could be different depending on whether the to-be-remembered contextual details are intrinsically linked to the emotional item (within-item features), or whether they are extrinsic or contextual in nature (Yonelinas & Ritchey, 2015). Thus, emotions would support memory for specific intrinsic features but not for extrinsic contextual details such as nearby objects (Nashiro & Mather, 2011) or prompts (Mao, You, Li, & Guo, 2015) associated with emotional pictures or for colored frames surrounding emotional scenes (Rimmele, Davachi, Petrov, Dougal, & Phelps, 2011).

It is possible that developmental differences described in the effect of emotions on item memory may also be observed in associative memory. Support for this hypothesis comes from a number of studies that have investigated age-related differences in the emotional enhancement of associative memory in adults. The findings have shown that the *memory trade-off effect* is greater in older than in younger adults, with poorer memory for contextual details being observed, even in the case of details intrinsically linked to the emotional item (Nashiro & Mather, 2011). The authors suggested that, due to their limited cognitive resources, older adults do not use effective strategies to bind the emotional item with its contextual features, and that this in turn leads to the impairment of memory for the latter despite the presence of an emotional enhancement of item memory.

Although, as far as we know, no study has examined the effect of emotions on associative memory in children, some authors have investigated the developmental time course of associative memory in this population, since this is a critical component underpinning episodic memory (for a review, see Raj & Bell, 2010). Cycowicz, Friedman, Snodgrass, and Duff (2001), for example, compared the developmental change in associative memory, relative to item memory, in 7 to 9-year-old children and young adults. They showed that performance improved with age for both item and associative memory, and that the age difference for associative memory was much larger than for item memory. More recently, Picard, Abram, Orriols, and Piolino (2017) showed that factual memory is quite efficient from the age of 6, but that it increases continuously from the age of 8 through to young adulthood, that associative memory for details improves greatly from the age of 10, with very few differences being observed between 6 and 10 years, and that spatial and temporal associative memory develop progressively throughout childhood and reach maturity in young adolescence. From a neurodevelopmental point of view, the development of associative memory with age is thought to be due to functional and structural changes in the hippocampus and the medial temporal lobe (MTL) structures that occur during childhood (DeMaster & Ghetti, 2013; Guillery-Girard et al., 2013; Sastre, Wendelken, Lee, Bunge, & Ghetti, 2016) and are critical for binding items with their context (Diana, Yonelinas, & Ranganath, 2007), as well as to the protracted maturation of the PFC until young adulthood (Gogtay et al., 2004) and the increasing structural and functional connectivity of the PFC with MTL regions (DeMaster & Ghetti, 2013; Ofen, Chai, Schuil, Whitfield-Gabrieli, & Gabrieli, 2012). For example, Guillery-Girard et al. (2013) investigated the development of episodic memory in children in correlation with gray matter volume by exploring its three main associative components: feature (what), spatial (where), and temporal (when) information. The authors found that the performance of feature associative memory increases continuously up to the age of 10 years, that spatial associative memory performance increases until early adulthood and that temporal associative memory performance increases sharply between 9 and 10 years of age. These differential changes are related to the decrease in gray matter volume in cerebral networks, including dorsolateral and ventrolateral PFC, temporal regions, and the hippocampus. Similar results were found by Lee, Wendelken, Bunge, and Ghetti (2016). More recently, Lee et al. (2019) suggested that these differences in developmental time course are related to structural changes in the anterior and posterior hippocampus that occur through to adolescence. Taken together, these findings suggest that the different components of episodic memory jointly improve in children from 6 years old to late adolescence, but with different developmental time courses.

Therefore, with regard to the continuous development of item memory and the different types of associative memory in children, it seems essential to evaluate whether emotions might interact differentially with these components of episodic memory in this population. We therefore conducted two experiments examining the retrieval of items as well of associated contextual information through different paradigms. In Experiment 1, two different types of contextual information were used to evaluate associative memory, namely the shape of the frame in which pictures were displayed, and the gender of the voice (male or female) in which words were spoken. As the former type of information is somewhat extrinsic and the latter somewhat intrinsic to the item, we used the same type of contextual information (i.e., the spatial location of the stimuli), for both pictures and words in Experiment 2. As one possible explanation for the inconsistent findings relating to emotional enhancement of item memory in children is the variability in the employed methodology (e.g., using pictures vs. words as stimuli, and recall vs. recognition as memory retrieval tasks), it was essential in the present study to examine this effect in a more systematic way. Thus, because most studies have focused only on one type of stimulus, most frequently pictures, one of the goals of the current research was to examine the consistency of EEM in children across two different types of stimuli, namely pictures and words. Further, typically only one type of memory test has been used in previous studies, that is, a recall or recognition task. Thus, in the present study, it was essential to use both tasks, together with an associative recall task, to provide a more systematic assessment of the effect of emotions on the different components of episodic memory. Moreover, most studies have used only negative and neutral stimuli, thus rendering impossible the observation of any *negativity* or *positivity* effects in children. In the present study, both negative and positive stimuli were used to address an important shortcoming in our understanding of the emotional modulation of memory in children.

Two different groups of 8- to 11-year-old children, chosen because this age seems to be crucial for the development of both item and associative memory, performed the two experiments and were compared to two different groups of young adults. This approach made it possible to assess age-related differences. Through these two experiments, we hope to obtain new knowledge of emotional processing and memory functioning in school-age children.

Experiment 1

In this experiment, our goal was to examine the effect of emotions on item memory using recognition and free-recall tasks, as well as to examine their effect on associative memory using an associative recall task. This was done to investigate the main components of episodic memory, that is, item and associative memory. Specifically, we examined whether there is a dissociation between the ability to remember emotional (negative or positive) and neutral items and the ability to remember the item's associated contextual information. In this experiment, the contextual information used to evaluate associative memory was the gender of the voice (female, male) in which words were spoken (source) and the shape of the frame (picture, window) in which pictures were presented (context). For the item memory task, we hypothesized that negative and positive stimuli would elicit better memory performance than neutral ones in children, and that this effect could be broadened to different types of stimuli (pictures or words). Along with a general EEM, we considered it possible that a *negativity* effect might also occur given the attentional bias toward negative stimuli (Morales et al., 2016) and the stronger neuronal recognition responses observed for negative pictures than for positive ones (Leventon et al., 2014) among school-age children. However, it was not clear whether children would experience an emotional enhancement of associative memory. Given the late development of associative memory for nonemotional information in children (Cycowicz et al., 2001; Picard et al., 2017), emotions could either reduce this associative memory deficit or exacerbate it because of the lower availability of cognitive resources in children compared to young adults (Luna et al., 2004). The latter hypothesis would be similar to the case of older adults who have poorer associative memory for emotional items.

Method

Participants. Thirty-two typically developing children (9–11 years of age, 16 girls and 16 boys) and 32 young adults (18–29 years of age, 25 women and seven men) participated in this study (see Table 1). It should be noted that our group of young adults was not balanced on gender. However, we did not expect gender differences in the participants' performances in this study. The sample size was chosen in the light of an a priori power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) based on previous studies (ex. Cordon et al., 2013) that estimated that at least 20 participants per group were required to obtain a small effect size

Table 1
Mood and Neuropsychological Assessments for Children and Young Adults

Function and test	Children (n = 32)	Young adults (n = 32)
M age	10.45 (0.43)	23.75 (2.79)
Female/male	16 girls/16 boys	25 women/7 men
Mood assessment		
FMATC	5.14 (0.75)	—
BMIS	38.94 (4.63)	51.75 (3.63)
Intelligence		
WISC V similarities	0.72 (0.20)	—
WISC V matrix reasoning	0.77 (0.23)	—
Memory		
CMS spatial location 1	0.73 (0.24)	—
CMS spatial location 2 (delayed recall)	0.68 (0.20)	—
CMS story 1 (units)	0.65 (0.26)	—
CMS story 2 (units delayed recall)	0.72 (0.25)	—
CMS story 2 (recognition)	0.51 (0.25)	—
Rey Complex Figure (recall accuracy)	0.63 (0.28)	0.29 (0.28)
Executive functions		
Rey Complex Figure (copy accuracy)	0.65 (0.26)	0.74 (0.42)
TEA-Ch	0.68 (0.29)	—
TMT-A	—	0.63 (0.28)
TMT-B	—	0.47 (0.24)

Note. Raw mean scores are presented for Face Mood Assessment Test for Children (FMATC) and Brief Mood Introspection Scale (BMIS). Mean percentile ranks are presented for subtests of Wechsler Intelligence Scale for Children (WISC V), Children's Memory Scale (CMS), Rey Complex Figure, Test of Everyday Attention for Children (TEA-Ch) and Trail Making Test A and B (TMT-A and TMT-B). Standard errors are in parentheses.

(d = 0.3) with power of 0.80. The children were recruited from a local elementary school, and the young adults were undergraduate students recruited at the university. All the participants were healthy, native-French speakers and reported no history of psychiatric, neurodevelopmental, neurological, or learning disorders. They were not taking any somatic medications and did not have any uncorrected visual or hearing problems. Prior to testing, the children's parents and the young adults gave written informed consent, and the children gave verbal assent in accordance with the Helsinki declaration. The research was approved by the Ethical Review Board (Comité de Protection des Personnes Nord-Ouest IV, Lille, France, No. 2017 A03321 52).

Stimuli and material.

Pictures. Sixty color photographs (567 × 425 pixels) depicting various types of scenes with common animate and inanimate elements were used (equal number of pictures depicting and not depicting humans). In this way, 20 positive, 20 negative, and 20 neutral pictures were selected from the Developmental Affective Photo System (DAPS: Cordon et al., 2013), which provides ratings of the emotional valence, arousal and complexity of pictures obtained from adults and children. The pictures were similar for the children and adults and were selected to have equivalent valence and arousal ratings across the two age groups (all t test comparisons were nonsignificant, $p > .05$, see Table A1 in the Appendix for means and standard errors). For the children, the positive, negative and neutral pictures differed significantly in terms of valence (all t test comparisons were significant, $p < .0001$) and emotional pictures (negative and positive) were significantly more arousing than neutral pictures (both $p < .0001$). Negative and positive pictures did not differ in terms of arousal ($p = .65$). For the adults, the positive, negative and neutral pictures differed significantly in terms of valence (all t test comparisons were significant, $p < .0001$), and emotional pictures (negative and positive) were significantly more arousing than neutral pictures (both $p < .0001$). Negative and positive pictures did not differ in terms of arousal ($p = .17$). For both age groups, the positive, negative, and neutral pictures were also matched on visual complexity (all $p > .17$). The 60 pictures were split into two lists of 30 pictures (10 positive, 10 negative and 10 neutral) for the encoding and retrieval phases of our experiment in such a way that each list was used equally often for the two phases. All the pictures were presented visually, with half of the pictures framed with a gray picture frame and the other half with a gray window frame (the frame for the two halves was reversed across participants) in equal proportions over the positive, negative, and neutral pictures within each list. In neither of the valence categories did the pictures differ in terms of valence, arousal or complexity between the two lists and this was true for both children and adults (all t test comparisons were nonsignificant, $p > .22$).

Words. Sixty French concrete and abstract words were used (equal number of concrete and abstract words). Thus, 20 positive, 20 negative, and 20 neutral words were selected from two large corpora of French words (FAN and FANchild databases: Monnier & Syssau, 2014, 2017) in the light of their emotional valence and arousal as evaluated by adults and children. The words were similar for the children and adults and were selected to have equivalent valence and arousal ratings across the two age groups (all t test comparisons were nonsignificant, $p > .05$, see Appendix Table A1 for means and standard errors). For the children, the positive, negative, and neutral words differed in terms of valence (all t test comparisons were significant, $p < .0001$) and emotional words (negative and positive) were significantly more arousing than neutral words (both $p < .0001$). Negative and positive words did not differ in terms of arousal ($p = .11$). For the adults, the positive, negative, and neutral words differed in terms of valence (all t test comparisons were significant, $p < .001$) and emotional words (negative and positive) were significantly more arousing than neutral words (both $p < .0001$). Negative and positive words did not differ in terms of arousal ($p = .29$). For both age groups, the positive, negative, and neutral words were also matched on subjective psycholinguistic index *imageability*, word length, and frequency of use by school-age children and adults (all $p > .17$). All the words were concomitantly presented visually and aurally. They were recorded using Macintosh voice synthesis with a female voice ("Audrey") with a French accent for half of the words and a male voice ("Thomas") with a French accent for the other half (the gender of the voice for the two halves was reversed across participants). The voices were presented in equal proportions over the positive, negative, and neutral words. All the words were presented with a neutral tone of voice for two reasons: First, some words did not have an emotional meaning per se and it would therefore have been difficult to decide on the exact type of emotion that should be used to pronounce them; second, it has been shown that valence ratings for negative words, but not for positive words, can be affected by the tone in which they are spoken (emotional vs. neutral), meaning that negative words are judged as more negative when spoken in a negative tone than in a neutral tone (Bertels, Kolonsky, & Morais, 2009). This could potentially have interfered with the selection criteria for our stimuli. The 60 words were split into two lists of 30 words (10 positive, 10 negative, and 10 neutral) for the encoding and retrieval phases of our experiment in such a way that each list was used equally often for the two phases. In neither of the valence categories did the words differ in terms of valence, arousal, *imageability*, word length, and frequency of use between the two lists and this was true for both children and adults (all t test comparisons were nonsignificant, $p > .14$).

Mood and neuropsychological assessments. The Face Mood Assessment Test for Children (FMATC; Christodoulou & Burke, 2016) and the French version of the Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988) were administered to obtain self-reports of the children's and adults' emotional states. In the FMATC, the children had to select one of six faces illustrating emotional expressions on a scale of 1 (*sad*) to 6 (*happy*). The BMIS is a mood adjective scale consisting of 16 mood-adjectives that can indicate, among other moods, a pleasant or unpleasant mood. The BMIS was shortened to 12 mood-adjectives for the children by removing all the adjectives that are not commonly used and which could have impeded understanding. Thus, mood was evaluated on a scale of 16 (*very unpleasant mood*) to 64 (*very pleasant mood*) for the adults and 12 (*very unpleasant mood*) to 48 (*very pleasant mood*) for the children. To assess the children's memory ability, the spatial and story memory subscales of the Children's Memory Scale (CMS; Cohen, 1997) were administered. The children's executive functions were measured with the Rey Complex Figure Test (RCF; Rey, 1959) and the Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999), and those of the adults were measured using the RCF and the Trail Making Test A and B (TMT-A and TMT-B). The different tests evaluating executive functions were used as filler tasks in the procedure. Moreover, the Wechsler Intelligence Scale for Children (WISC V; Wechsler, 2014) was administered to the children to assess their verbal comprehension (similarities subtest) and fluid reasoning (matrix reasoning subtest).

Procedure. Before starting the experiment, the children and adults completed the FMATC and BMIS to self-report their emotional state.

The study consisted of two similar parts (both composed of encoding and retrieval phases), one including pictures and the other including words. These were performed successively in an order that was counterbalanced between participants.

During the picture encoding phase, 30 stimuli, including 10 positive, 10 negative, and 10 neutral pictures, were presented successively in a pseudorandom but fixed order in such a way that no more than two pictures of the same valence or with the same frame occurred in succession. Each picture was presented on a computer screen for 3,000 ms for adults and 5,000 ms for children and was preceded by a 1-s fixation cross to ensure that the participants fixated the center of the screen. The participants were asked to remember the pictures and the frame in which they were displayed. To focus the participants' attention, they were asked to respond to the question "Does the picture depict a human?" by pressing one of two keys, corresponding to "yes" or "no," respectively, and labeled with colored stickers. They did this for each of the pictures. The proportion of pictures that contained or did not contain a human was equivalent for each valence category and for each type of frame. After the encoding phase, the participants performed a 5-min filler task before completing the retrieval phase. First, they had to complete a recognition task together with an associative recall task. They saw the 30 old pictures from the encoding phase without the frame intermixed with 10 new pictures from each valence category to give a total of 60 pictures. The pictures were presented in a pseudorandom but fixed order in such a way that no more than three old or new pictures and no more than two pictures of the same valence occurred in succession. The participants indicated whether they thought each of the pictures was old or not using the same keypress response as previously. They then had to indicate, in the same way, if they thought the picture had been framed with a picture frame or a window frame (associative recall). For the pictures they thought were new, the participants were instructed to make a random response about the frame. For each task, the two options appeared below the picture in the same colors as the corresponding keypress responses. Each picture was presented on the computer screen until the response was made by the participant and was preceded by a 1-s fixation cross. The participants were asked to respond as accurately and quickly as possible. The two computer responses for the encoding phase and the retrieval phase (recognition and associative recall tasks) were counterbalanced across participants (see Figure 1). Finally, after another 5-min filler task, which followed the recognition and associative recall tasks, the participants had to complete a free item recall task and were instructed to orally recall as many pictures as they could remember from the encoding phase (out of the 30), regardless of the order in which they had appeared. This was to prevent potential interference effects in the associative recall task as reported by D'Argembeau and Van der Linden (2004) in a situation in which the free-recall task was completed first. This may have been because the participants reactivated contextual information during the item recall task and this, in turn, might have interfered with the later associative recall task. For this task, the participants were instructed to give as many details about the pictures as possible so that anyone could recognize them. If the experimenter felt that the description of the pictures was not

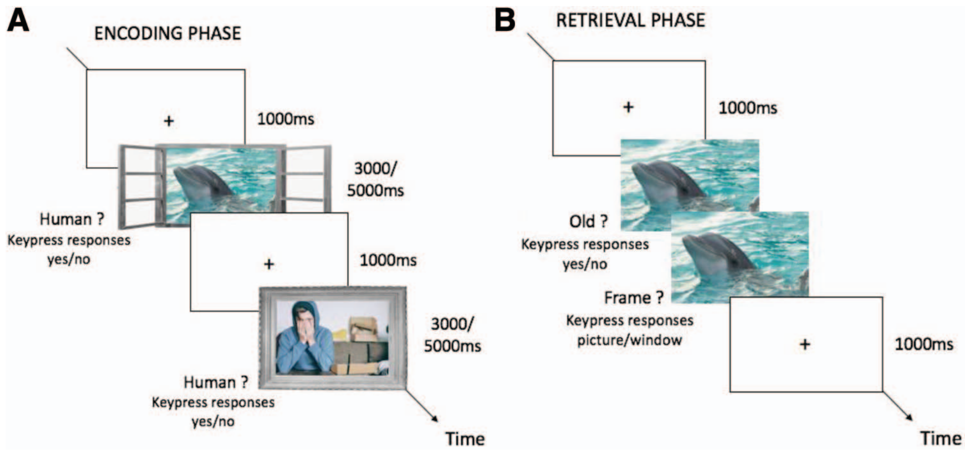

Figure 1. Procedures used in (A) encoding phase and (B) retrieval phase for pictures. The pictures are not from the Developmental Affective Photo System and are used for illustrative purposes only. They have been downloaded from the photography sharing website unsplash.com and are used in accordance with the Terms and Conditions of the website, which do not require further permission. See the online article for the color version of this figure.

precise enough, she asked the participant for clarification. The experimenter wrote down the participants' answers. If there was any doubt about the identity of the picture during scoring, double-scoring was performed.

The procedure for the word encoding and retrieval phases was identical to that for pictures, except that the words were displayed concomitantly visually and aurally in the encoding phase, with a 1-s fixation cross preceding each word onset. The adult participants were asked to respond to the question "Is the word concrete?," whereas the children had to answer the question "Can you physically touch the object named by the word?." The responses were given by pressing the same two keys as previously. In the retrieval phase, the words were only presented visually, and the participants indicated whether they thought each word was old or not and whether the word had been spoken with a female or a male voice. The same two keypresses were again used. The words were presented in black with a Courier New font in bold, 60-point size.

For both the picture and word parts, practice trials with four stimuli for the encoding phase were presented to make sure that the children understood how to complete the task. This was repeated as necessary until it was clear that the children understood. The experiment was programmed and run with the E-Prime software (2.0) on an HP PC.

At the end of the experiment, we administered several neuropsychological tests (described above) to characterize this population and to ensure that the cognitive functioning of all the children was within the normal range. This was indeed the case. The raw and standard means performances for all the tests are presented in Table 1.

Data analysis. The scores for correct free recall (item memory for pictures and words), recognition (corrected recognition scores: correctly recognized items (HITs)-false alarms (FAs) for pictures and words), and associative recall (associative memory: context for pictures and source for words) for the positive, negative and neutral stimuli were used for the statistical analysis.[1] Preliminary analyses were performed to check for sphericity (Mauchly's test) and homogeneity of variance and no violations were found for any of the data. First, we ran a mixed measures analysis of variance (ANOVA) including all the data, with valence (positive vs. negative vs. neutral), task (item recall vs. item recognition vs. associative recall), and stimulus (pictures vs. words) as within-subject factors and group (children vs. adults) as between-subjects factor. For associative recall (context or source), the mixed measures ANOVA was performed on correct responses for correctly recognized items only. Then, mixed measures ANOVAs with valence (positive vs. negative vs. neutral) as within-subject factor and group (children vs. adults) as between-subjects factor were performed on the different scores separately for the different tasks and for pictures and words. These were followed by planned comparisons.

All the results in the text and figures are expressed in percentages.

Results

See Appendix Table A2 for means and standard errors of all the results of Experiment 1.

Global analysis. Here we report only the significant main effects and interactions. The ANOVA showed significant main effects of valence $F(2, 124) = 17.99$, $p < .001$, partial $\eta^2 = .23$; stimulus $F(1, 62) = 5.01$, $p < .03$, partial $\eta^2 = .08$; and task $F(2, 124) = 1203.54$, $p < .001$, partial $\eta^2 = .95$. The Valence × Task $F(4, 248) = 5.76$, $p < .001$, partial $\eta^2 = .09$, Stimulus × Task $F(2, 124) = 26.52$, $p < .001$, partial $\eta^2 = .30$, and Task × Group $F(4, 248) = 20.29$, $p < .001$, partial $\eta^2 = .25$, interactions were significant. Most importantly, the Valence × Stimulus × Task interaction was also significant, $F(4, 248) = 3.90$, $p < .004$, partial $\eta^2 = .06$. First of all, for all the tasks (item recall, item recognition

[1] We also calculated the discriminability index d' and ran the statistical analysis on this index for pictures and words in both groups (i.e., children and adults). As the results were similar to those obtained for corrected recognition scores (HIT–FA), we do not report these analyses.

and associative recall), performances were similar for negative pictures and negative words, for positive pictures and positive words, and for neutral pictures and neutral words (all $p > .52$). To try to identify more precisely the effects of emotion as a function of the stimulus type and task, we performed separate mixed measures ANOVAs, with valence (positive vs. negative vs. neutral) as within-subject factor and group (children vs. adults) as between-subjects factor, on the different scores separately for pictures, words, and for each task. These were followed by planned comparisons (see below).

Pictures.

Item recall. For the pictures in the recall task, the ANOVA yielded a significant Valence × Group interaction, $F(2, 124) = 3.07$, $p < .05$, partial $\eta^2 = .05$. Planned comparisons showed that adults had better recall for negative ($M = 44.1$, $SD = 3.2$), $F(1, 31) = 15.98$, $p < .001$, and positive ($M = 41.6$, $SD = 3.2$), $F(1, 31) = 11.39$, $p < .01$, than for neutral stimuli ($M = 28.1$, $SD = 2.8$). The difference between negative and positive stimuli was not significant, $F(1, 31) = .28$, $p = .60$. Children had better recall for negative stimuli ($M = 37.5$, $SD = 3.1$) than for positive ($M = 26.9$, $SD = 3.2$), $F(1, 31) = 5.05$, $p < .05$, and neutral stimuli ($M = 28.1$, $SD = 3.3$), $F(1, 31) = 6.82$, $p < .01$. The difference between positive and neutral stimuli was not significant, $F(1, 31) = .09$, $p = .76$ (see Figure 2).

A significant main effect of group also emerged, $F(1, 62) = 6.35$, $p < .01$, partial $\eta^2 = .09$, with adults ($M = 37.9$, $SD = 2.0$) performing better than children ($M = 30.8$, $SD = 2.0$). A few intrusions of "new pictures" from the recognition task were also reported: four intrusions of negative pictures, four intrusions of positive pictures, and two intrusions of neutral pictures for the 32 participants overall.

Item recognition. For the pictures in the recognition task, there were no significant main effects or interactions (all $p > .05$) but there was a trend toward a main effect of valence, $F(2, 124) = 2.92$, $p = .06$, partial $\eta^2 = .05$. Planned comparisons showed that the participants tended to recognize negative stimuli ($M = 88.4$, $SD = 1.5$) better than neutral ones ($M = 84.1$, $SD = 1.9$), $F(1, 62) = 5.62$, $p < .05$. The difference between negative and positive stimuli ($M = 87.9$, $SD = 1.6$) was not significant, $F(1, 62) = .053$, $p = .82$, and there was a trend toward better recognition of positive stimuli than neutral ones, $F(1, 62) = 3.52$, $p = .07$.

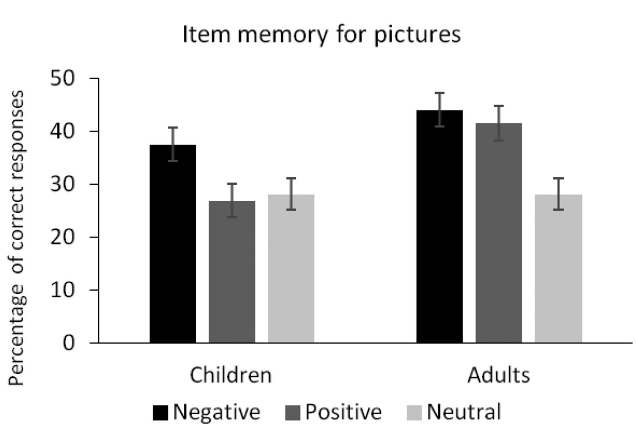

Figure 2. Mean percentage of correct responses for free recall of pictures as a function of group (children vs. adults) and emotional valence (negative vs. positive vs. neutral). Error bars represent standard errors.

Associative recall. For the pictures in the associative recall task, there were no significant main effects or interactions (all $p > .05$). The associative recall proportions for context (frames) were as follows: negative ($M = 49.2$, $SD = 1.9$), positive ($M = 50.0$, $SD = 2.2$), and neutral pictures ($M = 49.7$, $SD = 2.0$).

Words.

Item recall. For the words in the recall task, the ANOVA yielded a significant main effect of valence, $F(2, 124) = 11.02$, $p < .0001$, partial $\eta^2 = .15$. Planned comparisons showed that participants had better recall for negative ($M = 32.2$, $SD = 1.9$), $F(1, 62) = 22.38$, $p < .0001$, and positive stimuli ($M = 27.0$, $SD = 1.7$), $F(1, 62) = 8.83$, $p < .01$, than for neutral stimuli ($M = 20.9$, $SD = 1.6$). The difference between negative and positive stimuli was not significant but there was a trend toward better recall of negative stimuli, $F(1, 62) = 3.59$, $p = .06$ (see Figure 3A).

A significant main effect of group also emerged, $F(1, 62) = 11.04$, $p < .001$, partial $\eta^2 = .16$, with adults ($M = 30.4$, $SD = 1.6$) performing better than children ($M = 23.0$, $SD = 1.6$). The Valence × Group interaction was not significant, $F(2, 124) = .09$, $p = .92$, partial $\eta^2 = .001$. A few intrusions of "new words" from the recognition task were also reported: five intrusions of negative words, eight intrusions of positive words, and five intrusions of neutral words for the 32 participants overall.

Item recognition. For the words in the recognition task, the ANOVA yielded a significant main effect of Group only, $F(1, 62) = 10.05$, $p < .01$, partial $\eta^2 = .14$, with children ($M = 85.6$, $SD = 2.0$) performing better than adults ($M = 76.7$, $SD = 2.0$). The main effect of valence and the Valence × Group interaction were not significant, $F(2, 124) = .78$, $p = .46$, partial $\eta^2 = .01$, and $F(2, 124) = .43$, $p = .65$, partial $\eta^2 = .007$, respectively.

Associative recall. For the words in the associative recall task, the ANOVA yielded a significant main effect of valence, $F(2, 124) = 7.38$, $p < .001$, partial $\eta^2 = .11$. Planned comparisons showed that participants recalled the source better for negative ($M = 58.1$, $SD = 2.1$), $F(1, 62) = 11.38$, $p < .001$, and positive stimuli ($M = 58.3$, $SD = 2.4$), $F(1, 62) = 9.05$, $p < .004$, than for neutral stimuli ($M = 48.6$, $SD = 2.3$). The difference between associative recall for negative and positive stimuli was not significant, $F(1, 62) = .004$, $p = .95$ (see Figure 3B). The effect of group and the Valence × Group interaction were not significant, $F(1, 62) = .69$, $p = .41$, partial $\eta^2 = .01$ and $F(2, 124) = .37$, $p = .69$, partial $\eta^2 = .006$, respectively.

Discussion

In Experiment 1, an emotional enhancement of item memory was observed for both children and young adults. More precisely, EEM occurred for words and pictures in the item recall task, but not in the item recognition task (despite a trend toward better recognition of emotional pictures than of neutral ones). This was possibly due to the relatively high overall recognition scores (more than 80% of correct responses). These results are in line with other studies that have shown that the emotional content of information enhances item memory in children (e.g., Van Bergen et al., 2015, but for a review, see Hamann & Stevens, 2014) and adults (for a review, see Dolcos et al., 2017), but are also consistent with a

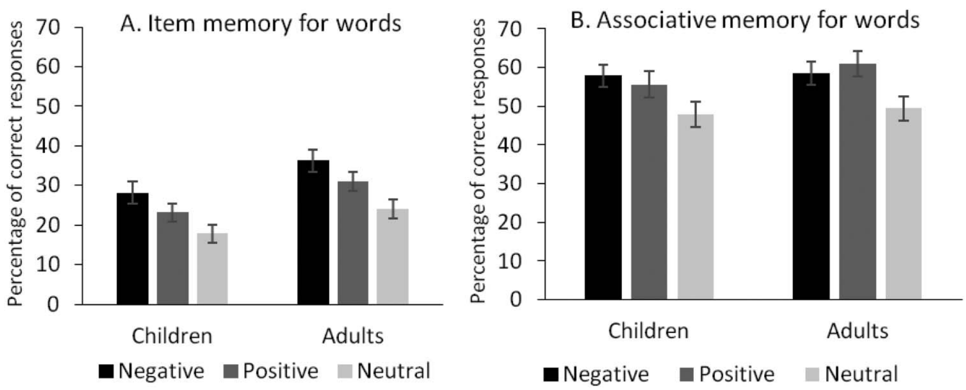

Figure 3. Mean percentage of correct responses for (A) words in free recall and (B) words in associative recall (source: voice gender) as a function of group (children vs. adults) and emotional valence (negative vs. positive vs. neutral). Error bars represent standard errors.

study that has not found EEM in recognition task in children (Leventon et al., 2014). Leventon et al. (2014) explained this in terms of the high levels of the recognition scores, almost representing ceiling effects, that may have limited their ability to detect EEM and this may also be the case in our study. In addition, our data showed, for the first time in children, an EEM in the associative recall task, although this enhancement was observed only for words. In fact, the children recalled positive and negative words and their associated source information (male or female voice) better than neutral ones. In the case of pictures, however, a dissociation emerged between the item memory and associative memory tasks, in that negative pictures were better recalled than positive and neutral ones, but there was no advantage for the recall of context information associated with negative or positive stimuli as compared to neutral ones. Moreover, it is of particular interest that the EEM in children did not differ significantly from that observed in adults across the different tasks, besides for the picture recall, in which the children presented a memory advantage only for negative pictures, whereas adults recalled negative and positive pictures similarly well relative to neutral ones. These results reveal that the children did experience an emotional enhancement of both item and associative memory when the stimuli were words, just as the young adults did. However, as we did not find an effect of emotions in associative memory for the pictures in either group, the emotional enhancement of associated contextual details overall may depend on the type of stimuli and/or the type of associated information.

With regard to the item memory tasks, our prediction that emotions, both negative and positive, would improve item memory in children whatever the type of stimulus was not entirely confirmed by our data. In fact, in the same way as for adults and in accordance with our hypothesis, we observed a general EEM for words in the case of both negative and positive stimuli, but unlike in adults and contrary to our hypothesis, only negative pictures were recalled better than positive and neutral ones. This was the only difference observed in EEM between children and adults. We have suggested that a negativity effect can occur in children along with a general emotional enhancement of memory. Despite this, positive pictures were not recalled better than neutral ones in this experiment. Our results therefore suggest that the influence of negative and positive emotions on item memory in children acts differently depending on the type of stimulus. This could be due to the specific features of visual stimuli. In fact, pictures from the DAPS database (which includes some pictures from the International Affective Picture System [IAPS]; Lang, Bradley, & Cuthbert, 1999) are thought to induce relatively strong emotional arousal due to certain evocative, explicitly imaged content such as people with guns, accidents, scenes of war, and so forth. Even if arousal were scrupulously controlled between negative and positive pictures within each group (children and adults) as well as between groups then, based on the existing evaluations, the children who participated in the present study might have somehow perceived the negative pictures as more arousing than the positive pictures and this might, in turn, have improved the memorization only of the negative pictures. It is important to note that differences in visual complexity between the different types of emotional stimuli cannot explain these results, given that we controlled the visual complexity of our stimuli. The existing literature on children reports only two studies that have used DAPS/IAPS pictures to evaluate emotional memory. The first one, Cordon et al. (2013), found that negative pictures were recognized better than neutral ones but, unfortunately, the authors did not include positive pictures in their tasks. The second, Leventon et al. (2014), used negative, positive, and neutral pictures but failed to show any emotional enhancement of memory in a behavioral recognition task. However, these authors have shown that children older than 7.5 years old exhibit greater neuronal activity when recognizing negative pictures than when recognizing positive and neutral ones, thus showing that negative emotions could influence memory earlier in development than positive ones. Similarly, other studies that have manipulated IAPS pictures have shown an attentional bias (Waters, Lipp, & Spence, 2004) and greater amygdala reactivity (McRae et al., 2012) in response to negative pictures in school-age children and this may well cause such pictures to be remembered better (LaBar & Cabeza, 2006) than positive and neutral ones.

With regard to associative memory, our main aim was to determine whether school-age children, like young adults, show an emotional enhancement of contextual information associated with items. The results indicated that associative memory for words was enhanced by both negative and positive emotions in young adults as well as children. Thus, this is the first study to show that school-age children could benefit from an overall emotional enhancement of memory for items and the associated contextual information, thereby providing evidence of a genuine emotional episodic memory. It appears that the children in our study possessed sufficient cognitive resources and mnemonic strategies to perform the associative recall task (Ghetti & Lee, 2011). Moreover, although the children's performances in the item recall task were overall significantly lower than those of the young adults, the children's and adults' performances in the associative recall task were similar, including for neutral words. Thus, emotions did not reduce the deficit in associative memory in children as we have suggested, because there was no such deficit. Many developmental studies agree that episodic memory, that is the ability to bind an item and its context into an integrated episodic representation, improves substantially during childhood (Ghetti & Lee, 2011; Guillery-Girard et al., 2013; Lee et al., 2016). Although heterogeneous age-related trajectories in episodic memory are reported depending on the type of relational binding, Guillery-Girard et al. (2013) highlighted, in particular, a critical period in the developmental time course of episodic memory at around 8 to 10 years of age. This could explain why, unlike the 7- to 8-year-old children in Cycowicz et al. (2001), who had an associative memory deficit relative to adults, the 9- to 11-year-old children in our study performed well on both the emotional and nonemotional items in the associative memory task, and even reached adult performances. Moreover, in our sample of children, the emotional system and its interaction with the memory system seem to have already been well developed, considering the emotional enhancement of item and associative memory observed for words. This is in line with developmental studies on emotional processing that have shown that children exhibit adult-like neuronal activity in response to negative and positive emotional stimuli, as measured by event-related potentials (ERPs; Bondy et al., 2018; Hajcak & Dennis, 2009). These emotional processing abilities may well bolster children's memory for emotional information, as has been reported in several child studies involving item memory (e.g., Van Bergen et al., 2015), and also improve their memory for associated contextual information. We further discuss the effect of emotions on item and associative memory in children in the general discussion.

Unlike in the case of words, we did not observe an EEM for associative memory for pictures in either children or adults. Thus, our data suggest that emotion may act differently on associative memory depending on the type of stimulus. Given that similar results were obtained for children and adults, this finding cannot be a consequence of developmental differences. However, it could possibly be due to the type of contextual information associated with the items. It has previously been demonstrated that emotion enhances memory for details, which correspond to intrinsic or within-item features but not for extrinsic contextual ones (for a review, see Yonelinas & Ritchey, 2015). Yet, the associative memory task for pictures used in our study required participants to remember the frames surrounding the pictures, which are considered to be extrinsic features, whereas the associative memory task used for words required them to remember the gender of the voice in which the words were spoken, and this is considered to be an intrinsic feature. In her review, Mather (2007) explained that the attention directed toward an emotionally arousing item does contribute to the processing of the item itself, but not to the processing of its extrinsic contextual information. Thus, emotional arousal in response to DAPS pictures could have restricted the participants' attention to the details of the emotional scene to the detriment of the contextual neutral frame. Such arousal might therefore have improved the memory for emotional pictures themselves but not for their context of presentation. If this were the case, it might be expected that, given that item memory improved for emotional pictures, associative memory for these pictures might be poorer than for neutral ones. However, this was not the case in our experiment. Another possibility is that, in comparison with written and spoken words, the DAPS pictures depicted relatively complex emotional and neutral scenes with many visual features. This could make the encoding of the content of the pictures, whatever their emotional nature, more effortful and attention-demanding, with the result that attention was drawn away from the surrounding context, thereby preventing it from being bound with the picture itself (Lee et al., 2016). Thus, it is possible that the participants might not have encoded the contextual features of the pictures because of the difficulty of switching their attention away from the content. In the case of words, by contrast, although the processing involved in identifying the gender of the voice in which words are spoken may require cognitive resources (Kausler & Puckett, 1981), the spoken words were heard automatically. Therefore, the participants did not have to switch their attention away from the words in order to encode voice information and had more attentional resources available to perform a more thorough processing in order to bind words with their sources. This was particularly true in the case of emotional words, which attract more attention, thereby leading to better associative memory.

Nevertheless, it is not clear whether the dissociation observed in both children and adults between item and associative memory for pictures but not for words depends on the type of stimulus or on the type of information to be associated with the item. Thus, in Experiment 2, we wanted to further examine the emotional modulation of associative memory by using the same contextual information for pictures and words, namely their spatial location. As the development of episodic memory may fluctuate depending on the type of information to be associated with an item (e.g., context, source, time, space) in childhood (Guillery-Girard et al., 2013; Lee et al., 2016; Picard et al., 2017), it seems essential to examine the emotional modulation of episodic memory in children under various conditions.

Experiment 2

In Experiment 1, an emotional enhancement of associative memory was observed for words in children and young adults, but not for pictures. This double discrepancy between words and pictures in the effect of emotions on associative memory was rather surprising. In the discussion of Experiment 1, we proposed that it might be due, at least in part, to the level of effortful processing required to bind items with their specific contextual information during encoding and to the fact that this effort is greater for pictures than words. Therefore, to evaluate associative memory in Experiment 2, we decided to use the same contextual information for pictures and words, that is, their spatial location (memory for where on a screen an item appeared). Moreover, as episodic memory exhibits different developmental trajectories in children depending on the type of information to be associated with an item, we wanted to ensure that the emotional enhancement of associative memory observed in children in our first experiment could be extended to another type of information. Based on the results of our first experiment, and given the assumption that the different results obtained for pictures and words in emotional associative memory in Experiment 1 were due to the different types of information that had to be associated with the pictures and words, we hypothesized that, in the present experiment, children and adults would benefit from a similar emotional enhancement of item and associative memory for both pictures and words.

Method

Participants. Thirty-six typically developing children (8–10 years of age, 23 girls and 13 boys) and 36 young adults (18–30 years of age, 18 women and 18 men) participated in this study (see Table 2). Recruitment and consent procedures, as well as inclusion and exclusion criteria, were the same as in Experiment 1 for both groups.

Stimuli and material. The stimuli were the same as those used in Experiment 1. For this experiment, all the stimuli were resized to 200 × 200 pixels so that they could be presented in a square grid during the encoding phase of the experiment. In the case of the picture stimuli, the 60 pictures were divided into six lists (two positive, two negative, and two neutral) of 10 pictures each in such a way that, for each category of valence, there were no interlist differences between the pictures in terms of valence, arousal and complexity for either the children or the adults, all $p >$ .22. Similarly, words were divided into six lists with no significant differences in terms of valence, arousal, imageability, word length or frequency of use between the lists for either the children or the adults, all $p > .14$.

The six lists were used to construct six experimental series of 10 stimuli each, all of which belonged to the same valence category (negative, positive or neutral). The six series were presented twice, giving a total of 12 series (four negative, four positive, and four neutral series of 10 stimuli). We decided to proceed in this way because we were unable to select enough stimuli to allow us to construct four series per valence using different stimuli and we considered that having only two series per valence might not have been enough to observe an effect of emotions on associative memory.

All the experiment was programmed and run with the OpenSesame software (3.0) (Mathôt, Schreij, & Theeuwes, 2012) on an HP PC.

Procedure. The study consisted of two similar parts (both composed of encoding and retrieval phases), one including pictures and the other including words. These took place successively with a counterbalanced order between participants. In each part of the experiment, the participants performed 12 series of encoding and immediate retrieval trials.

For the pictures, 12 series of 10 pictures were presented in succession in a grid of 16 white squares on a black background arranged in a similar way to Macri, Pavard, and Versace (2018). For each series, the 10 pictures were randomly assigned to 10 squares (out of the 16) within the grid in such a way that the pictures appeared equally frequently in each location for the negative, positive, and neutral series and for each participant. The series were presented in such a way that each of the valence categories followed one another in a sequence that prevented two series of the same valence appearing in succession. The order of valence presentation for the first six series was counterbalanced between participants in such a way that each category of valence appeared equally often at the beginning, in the middle, and at the end of the presentation of the series. More precisely, there were three orders of presentation depending on the valence of the series (Order 1: positive, negative, neutral; Order 2: neutral, positive, negative; Order 3: negative, neutral, positive). In addition, we counterbalanced the presentation of the two series of the same valence across the participants. Thus, for example, one participant

Table 2
Mood and Neuropsychological Assessments for Children and Young Adults

Function and test	Children (n = 36)	Young adults (n = 36)
M age	9.63 (0.55)	25.29 (3.28)
Female/male	23 girls/13 boys	18 women/18 men
Mood assessment		
FMATC	5.14 (0.79)	—
BMIS	38.86 (4.60)	50.61 (4.90)
Intelligence		
WISC V similarities	0.72 (0.20)	—
WISC V matrix reasoning	0.70 (0.22)	—
Memory		
Rey Complex Figure (recall accuracy)	0.62 (0.29)	0.41 (0.26)
Executive functions		
Rey Complex Figure (copy accuracy)	0.66 (0.26)	0.85 (0.34)
TEA-Ch	0.63 (0.28)	—
TMT-A	—	0.68 (0.20)
TMT-B	—	0.44 (0.30)

Note. Raw mean scores are presented for Face Mood Assessment Test for Children (FMATC) and Brief Mood Introspection Scale (BMIS). Wechsler Intelligence Scale for Children (WISC V), Children's Memory Scale (CMS), Rey Complex Figure, Test of Everyday Attention for Children (TEA-Ch) and Trail Making Test A and B (TMT-A and TMT-B). Standard errors are in parentheses.

saw the first six series in the following order: Positive Series 1, Negative Series 1, Neutral Series 1, Positive Series 2, Negative Series 2, and Neutral Series 2. Another participant saw the Series 1 and 2 in reverse order: Positive Series 2, Negative Series 2, Neutral Series 2, Positive Series 1, Negative Series 1, and Neutral Series 1. The same order of presentation was used for the six repeated series for any given participant but with a different order of stimulus presentation within each series and with different locations being used.

In the encoding phase, each picture was presented to the adults for 2,500 ms and to the children for 5,000 ms, with an interstimulus interval of 250 ms. The participants were asked to remember the pictures and their locations. The retrieval phase began after each series of 10 pictures, with the same pictures being presented again one after another in a random order and centered on a black background (with the initial size of 567 × 425). Each picture was displayed for 2,000 ms, after which the empty grid of white squares was presented. The participants then had to click on the square in which they thought the picture had been presented in the encoding phase (associative recall). Thus, for each of the 12 series, the participants first had to encode and then had to retrieve the locations of the pictures (see Figure 4). After performing the 12 series, the participants completed a 5-min filler task before orally recalling as many pictures (out of the 60) as they could remember,

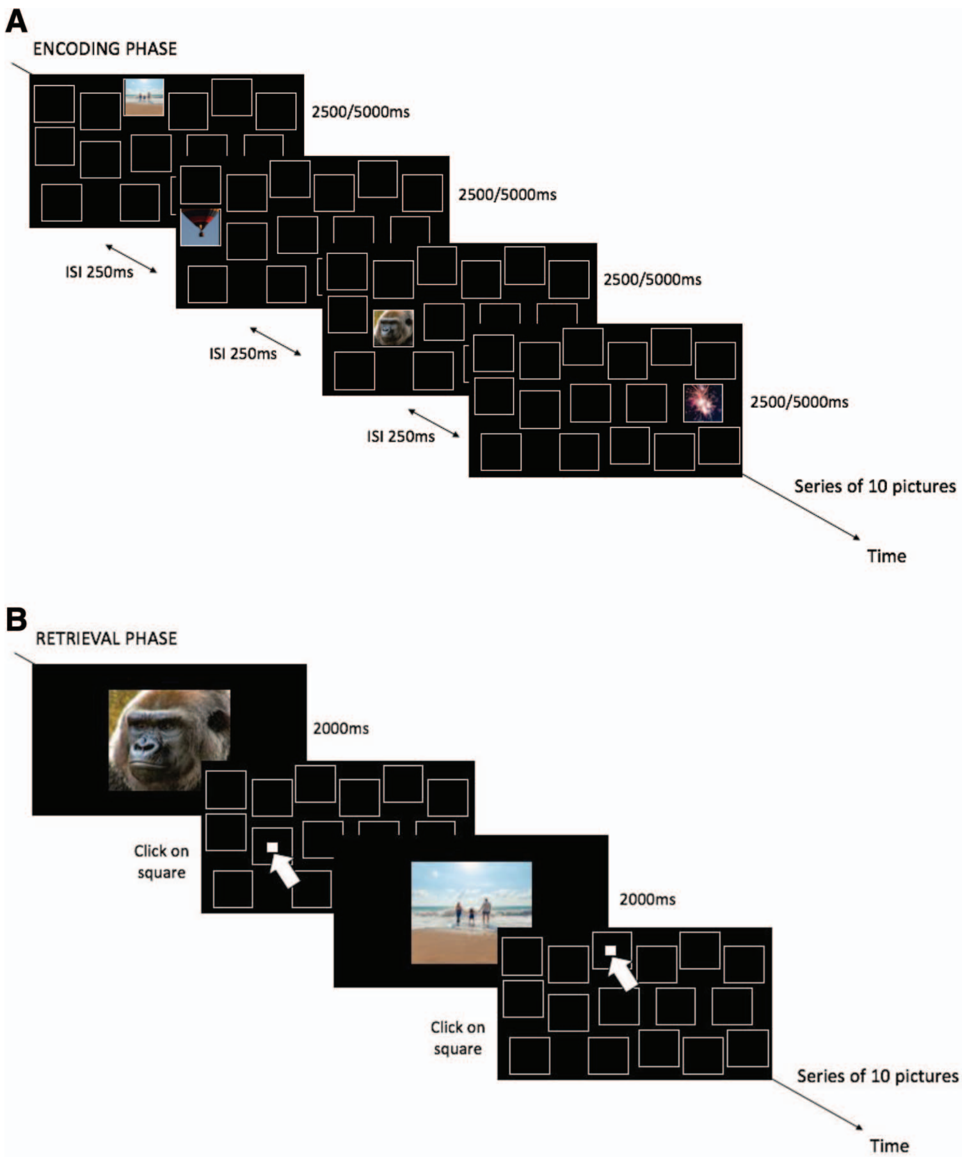

Figure 4. Procedures for (A) encoding phase and (B) retrieval phase are illustrated here for a series of 10 positive pictures. The pictures are not from the Developmental Affective Photo System and are used for illustrative purposes only. They have been downloaded from the photography sharing website unsplash.com and are used in accordance with the Terms and Conditions of the website, which do not require further permission. See the online article for the color version of this figure.

regardless of the order in which they had appeared. The participants were instructed to give as many details about the pictures as possible so that anyone could recognize them. If the experimenter felt that the description of the pictures was not precise enough, she asked the participant for clarifications. The experimenter wrote down the participants' answers. The same criteria as for Experiment 1 were applied for the scoring of the responses.

The procedure for the words was identical to that for pictures, with the words being presented in black inside a solid white square (Calibri font, 25-point size for the encoding phase and 75-point size for the retrieval phase).

At the end of the experiment, we administered several neuropsychological tests (described in the method part of Experiment 1) to characterize this population and to ensure that the cognitive functioning of all the children was within the normal range. This was indeed the case. The raw and standard means performances for all the tests are presented in Table 2.

Data analysis. The correct free recall (item memory for pictures and words) and associative recall (associative memory: location of pictures and words) scores for positive, negative, and neutral stimuli were used for the statistical analysis. Preliminary analyses were performed to check for sphericity (Mauchly's test) and homogeneity of variance. No violations were found for any of the data. We first performed a mixed measures ANOVA including all data, with valence (positive vs. negative vs. neutral), task (item recall vs. associative recall–six initial series vs. associative recall–six final series), stimulus (pictures vs. words) as within-subject factors and group (children vs. adults) as between-subjects factor. Next, mixed measures ANOVAs with valence (positive vs. negative vs. neutral) as within-subject factor and group (children vs. adults) as between-subjects factor, were performed on the different scores separately for the different tasks and for pictures and words. These were followed by planned comparisons. We included repetition of the series in the task factor to check that repetition of the six initial series did not impact the associative recall performances.

All the results in the text and figures are expressed in percentages.

Results

See Appendix Table A3 for means and standard errors of all the results of Experiment 2.

Global analysis. Here we report only the significant main effects and interactions. The ANOVA showed significant main effects of valence, $F(2, 140) = 27.26$, $p < .001$, partial $\eta^2 = .28$; stimulus $F(1, 70) = 120.91$, $p < .001$, partial $\eta^2 = .63$; task $F(2, 140) = 128.09$, $p < .001$, partial $\eta^2 = .65$; and group $F(1, 70) = 37.8$, $p < .001$, partial $\eta^2 = .35$. The Valence × Task $F(4, 280) = 13.73$, $p < .001$, partial $\eta^2 = .16$, Valence × Stimulus $F(2, 140) = 6.61$, $p < .002$, partial $\eta^2 = .09$, Stimulus × Task $F(2, 140) = 21.40$, $p < .001$, partial $\eta^2 = .23$, Stimulus × Group $F(1, 70) = 9.09$, $p < .004$, partial $\eta^2 = .12$, and Task × Group $F(4, 248) = 20.29$, $p < .001$, partial $\eta^2 = .25$, interactions were significant. The Stimulus × Task × Group interaction $F(2, 140) = 4.73$, $p < .01$, partial $\eta^2 = .06$ was also significant. In item recall, the children's performances, $t(152) = 1.6$, $p = .91$, were similar for both words ($M = 20.7$, $SE = 2.6$) and pictures ($M = 24.2$, $SE = 2.6$), whereas in associative recall, their performances were poorer for words than pictures, for both the six initial series, $t(152) = 4.0$, $p < .005$ (for words $M = 43.0$, $SE = 2.6$; for pictures $M = 51.8$, $SE = 2.6$), and for the six final series, $t(152) = 7.8$, $p < .001$ (for words $M = 32.3$, $SE = 2.6$; for pictures $M = 49.5$, $SE = 2.6$). In item recall, the adult's performances were poorer for words ($M = 35.9$, $SE = 2.6$) than for pictures ($M = 47.5$, $SE = 2.6$), $t(152) = 5.3$, $p < .001$, and the same was true in associative recall for both the six initial series, $t(152) = 9.5$, $p < .001$ (for words $M = 48.4$, $SE = 2.6$; for pictures $M = 69.1$, $SE = 2.6$), and the six final series, $t(152) = 8.7$, $p < .001$ (for words $M = 52.3$, $SE = 2.6$; for pictures $M = 71.5$, $SE = 2.6$). Most importantly, the Valence × Stimulus × Task interaction was also significant, $F(4, 280) = 4.39$, $p < .002$, partial $\eta^2 = .06$. To better understand this interaction, we performed the analysis for each task separately. In the item recall task, performances were better for negative pictures ($M = 43.7$, $SE = 2.2$) than for negative words ($M = 34.6$, $SE = 2.2$), $t(449) = 4.12$, $p < .006$, but were similar for positive pictures ($M = 36.8$, $SE = 2.2$) and positive words ($M = 29.2$, $SE = 2.2$), $t(449) = 3.30$, $p = .09$, as well as for neutral pictures ($M = 28.2$, $SE = 2.2$) and neutral words ($M = 21.7$, $SE = 2.2$), $t(449) = 2.89$, $p = .26$. In the associative recall task for the six initial series, performances were better for negative pictures ($M = 57.8$, $SE = 2.2$) than for negative words ($M = 50.1$, $SE = 2.2$), $t(449) = 3.52$, $p < .05$, for positive pictures ($M = 64.4$, $SE = 2.2$) than for positive words ($M = 46.8$, $SE = 2.2$), $t(449) = 7.89$, $p < .001$, and for neutral pictures ($M = 59.9$, $SE = 2.2$) than for neutral words ($M = 40.9$, $SE = 2.2$), $t(449) = 8.68$, $p < .001$. In the associative recall task for the six final series, performances were better for negative pictures ($M = 60.3$, $SE = 2.2$) than for negative words ($M = 47.4$, $SE = 2.2$), $t(449) = 5.98$, $p < .001$, for positive pictures ($M = 60.6$, $SE = 2.2$) than for positive words ($M = 39.9$, $SE = 2.2$), $t(449) = 9.41$, $p < .001$, and for neutral pictures ($M = 61.1$, $SE = 2.2$) than for neutral words ($M = 40.5$, $SE = 2.2$), $t(449) = 9.24$, $p < .001$. To try to identify the effects of emotion more precisely as a function of the stimulus type and task, we performed separate mixed measures ANOVAs, with valence (positive vs. negative vs. neutral) as within-subject factor and group (children vs. adults) as between-subjects factor, on the different scores for pictures, words and for each task separately. These analyses were followed by planned comparisons (see below).

Pictures.

Item recall. For the pictures in the recall task, the ANOVA yielded a significant main effect of valence, $F(2, 140) = 37.88$, $p < .0001$, partial $\eta^2 = .35$. Planned comparisons showed that the participants had better recall for negative ($M = 43.3$, $SD = 1.8$) than for positive ($M = 36.3$, $SD = 1.9$), $F(1, 70) = 17.99$, $p < .0001$, or neutral pictures ($M = 27.9$, $SD = 1.7$), $F(1, 70) = 65.39$, $p < .0001$. Positive pictures were also recalled better than neutral ones, $F(1, 70) = 23.01$, $p < .0001$ (see Figure 5A).

A significant main effect of group also emerged, $F(1, 70) = 60.06$, $p < .0001$, partial $\eta^2 = .46$, with adults ($M = 47.5$, $SD = 2.1$) performing better than children ($M = 24.2$, $SD = 2.1$). The Valence × Group interaction was not significant, $F(2, 140) = .95$, $p = .39$, partial $\eta^2 = .01$.

Associative recall. For the pictures in the associative recall task, the ANOVA yielded a significant Valence × Repetition interaction, $F(2, 140) = 3.24$, $p = .04$, partial $\eta^2 = .04$. For the six initial series, planned comparisons showed that participants had better recall for the locations of positive ($M = 64.0$, $SD = 2.3$) than of negative ($M = 57.6$, $SD = 1.9$), $F(1, 70) = 12.03$, $p < .001$, or neutral pictures ($M = 59.7$, $SD = 2.2$), $F(1, 70) = 5.30$, $p < .05$. The difference between negative and neutral pictures was

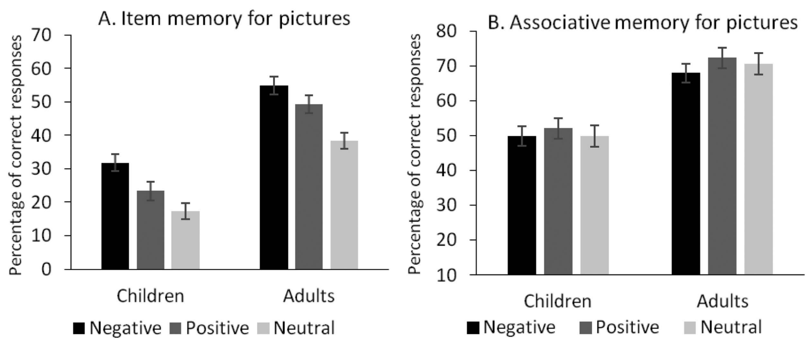

Figure 5. Mean percentage of correct responses for (A) free recall of pictures and (B) associative recall of pictures (spatial location) as a function of group (children vs. adults) and emotional valence (negative vs. positive vs. neutral). Error bars represent standard errors.

not significant, $F(1, 70) = 1.30$, $p = .26$. For the six final series, however, there was no effect of emotional valence, with all planned comparisons between negative, positive and neutral pictures having $p > .78$ (see Figure 5B).

A significant main effect of group also emerged, $F(1, 70) = 26.22$, $p < .0001$, partial $\eta^2 = .27$, with adults ($M = 70.3$, $SD = 2.7$) performing better than children ($M = 50.6$, $SD = 2.7$). The Valence × Group interaction was not significant, $F(2, 140) = .55$, $p = .58$, partial $\eta^2 = .008$.

Words.

Item recall. For the words in the recall task, the ANOVA yielded a significant main effect of valence, $F(2, 140) = 19.52$, $p < .0001$, partial $\eta^2 = .22$. Planned comparisons showed that participants had better recall for negative ($M = 34.2$, $SD = 1.8$) than for positive ($M = 29.0$, $SD = 1.7$), $F(1, 70) = 6.39$, $p < .01$, or neutral words ($M = 21.5$, $SD = 1.8$), $F(1, 70) = 44.68$, $p < .0001$. Positive words were also recalled better than neutral ones, $F(1, 70) = 12.01$, $p < .001$ (see Figure 6A).

A significant main effect of group also emerged, $F(1, 70) = 36.63$, $p < .0001$, partial $\eta^2 = .34$, with adults ($M = 35.8$, $SD = 1.8$) performing better than children ($M = 20.7$, $SD = 1.8$). The Valence × Group interaction was not significant, $F(2, 140) = .67$, $p = .51$, partial $\eta^2 = .01$.

Associative recall. For the words in the associative recall task, the ANOVA yielded a significant main effect of valence, $F(2, 140) = 16.59$, $p < .0001$, partial $\eta^2 = .19$. Planned comparisons showed that participants had better recall of the locations of negative ($M = 48.4$, $SD = 2.0$) than of positive ($M = 43.1$, $SD = 2.0$), $F(1, 70) = 14.37$, $p < .0002$, or neutral words, ($M = 40.5$, $SD = 2.0$), $F(1, 70) = 34.91$, $p < .0001$. The difference between positive and neutral words was not significant but there was a trend toward better recall of the locations of positive stimuli than of neutral ones, $F(1, 70) = 3.21$, $p = .07$.

There was also a trend toward a Valence × Repetition interaction, $F(2, 140) = 2.36$, $p = .09$, partial $\eta^2 = .03$. For the six initial series, planned comparisons showed that participants had better recall for the locations of negative ($M = 49.9$, $SD = 2.3$), $F(1, 70) = 26.29$, $p < .0001$, and positive words ($M = 46.6$, $SD = 2.3$), $F(1, 70) = 7.66$, $p < .007$, than for those of neutral words ($M = 40.6$, $SD = 2.1$). The difference between negative and positive words was not significant, $F(1, 70) = 2.41$, $p = .13$. For the six final series, however, participants had better recall for the locations of negative ($M = 47.0$, $SD = 2.2$) than of positive ($M = 39.6$, $SD = 2.4$), $F(1, 70) = 11.17$, $p < .001$, or neutral words, ($M = 40.4$, $SD = 2.4$), $F(1, 70) = 9.60$, $p < .003$. The difference between positive and neutral words was not significant, $F(1, 70) = .12$, $p = .73$.

There was also a trend toward a Valence × Group interaction, $F(2, 140) = 2.45$, $p = .09$, partial $\eta^2 = .03$. Planned comparisons showed that children had better recall of the locations of negative

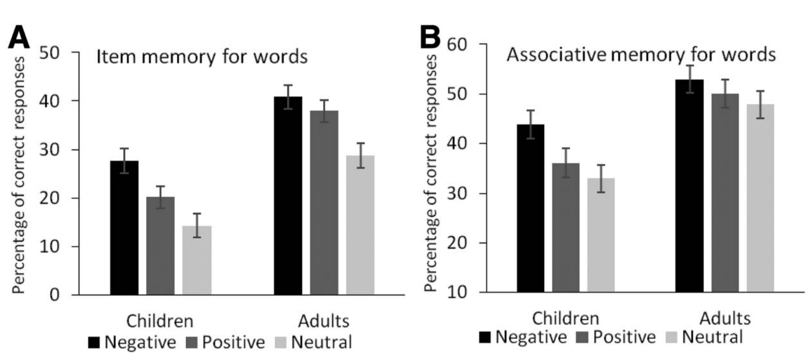

Figure 6. Mean percentage of correct responses for (A) free recall of words and (B) associative recall of words (spatial location) as a function of group (children vs. adults) and emotional valence (negative vs. positive vs. neutral). Error bars represent standard errors.

(M = 43.9, SD = 2.8) than of positive (M = 36.1, SD = 2.9), $F(1, 70) = 15.20$, $p < .0002$, or neutral words (M = 32.9, SD = 2.8), $F(1, 70) = 32.53$, $p < .0001$, and that adults were better able to recall the locations of negative (M = 52.9, SD = 2.8) than of neutral words (M = 47.9, SD = 2.8), $F(1, 70) = 7.03$, $p < .009$, (see Figure 6B).

A significant main effect of group also emerged, $F(1, 70) = 12.10$, $p < .0001$, partial $\eta^2 = .15$, with adults (M = 50.3, SD = 2.6) performing better than children (M = 37.7, SD = 2.6).

Discussion

In Experiment 2, a similar emotional enhancement of memory was observed for words and pictures in both children and young adults in the item recall task, whereas the enhancement differed in the associative recall task depending on the type of stimulus. It is important to note that in none of these tasks did the influence of emotion on memory in children differ significantly from that observed in adults. In fact, in the case of item memory for words and pictures, both groups recalled negative and positive stimuli better than neutral ones, with negative stimuli being memorized better than positive ones. This points to the existence of a negativity effect along with a general emotional enhancement of memory. In the case of associative memory, a general emotional enhancement of memory occurred for words, with the locations of negative and positive words being recalled better than those of neutral ones. In the case of pictures, there was a positivity effect, with the locations of positive pictures being recalled better than those of negative and neutral ones. Moreover, the emotional enhancement of associative memory was impacted by stimulus repetition, especially in the case of positive stimuli. These results are inconsistent with our prediction that if the type of contextual information to be associated with an item is identical then a similar emotional enhancement of associative memory should be observed for both words and pictures. However, at the developmental level, both children and adults did exhibit the same effect of emotions on item and associative memory, as we had predicted.

With regard to the item memory tasks, our results confirm our prediction that children would, like young adults, exhibit a general emotional enhancement of memory whatever the type of stimulus, with, in particular, a memory advantage being observed for negative stimuli over positive ones. These results are in line with Van Bergen et al. (2015) who showed that 5- to 6-year-old children recalled negative and positive stories better than neutral ones, and also recalled negative stories better than positive ones. This pattern is also broadly observed in young adults (Murphy & Isaacowitz, 2008). A review by Vaish, Grossmann, and Woodward (2008) argues that several factors may account for the negativity effect. One of the most important of these is the crucial adaptive evolutionary function of helping infants to avoid potentially harmful stimuli. However, according to Vaish et al. (2008), the strength of negative emotions results from the positive context established early in development, when positive emotions and interactions are largely experienced and perceived. Another suggestion, made by LoBue and DeLoache (2008) in line with Vaish et al.'s. proposition, is that negative stimuli mobilize more attentional resources than other stimuli, both in children and adults. Indeed, LoBue and DeLoache (2008) demonstrated that 3- to 5-year-old children are as able as adults to detect threatening stimuli more quickly than other neutral stimuli in an array of distractors. This facilitated attention for negative stimuli could lead to these stimuli being processed more thoroughly during encoding and this, in turn, would enhance their memorability (for reviews, see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001 and Kensinger, 2009).

If we consider associative memory, as we tested it using location recall tasks, a general emotional enhancement occurred for words, and a positivity effect occurred for pictures. Therefore, for words, we replicated our results from Experiment 1 while using a different type of contextual information. This argues in favor of the existence of an emotional enhancement of associative memory in children and adults regardless of the contextual information to be associated with an item. This is consistent with certain other studies in the literature on adults that have shown an emotional enhancement of the memory for the spatial locations of words or the color in which they were presented or framed (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001 and Kensinger & Corkin, 2003). Pictures differ from words in that emotions have been found to modulate associative memory only for positive pictures. Our results are inconsistent with other studies that have assessed the modulation of associative memory for locations in young adults by negative and positive emotions when using IAPS pictures. In these studies, this modulation was either absent (Mather et al., 2006) or present (Mather & Nesmith, 2008; Nashiro & Mather, 2011), but with no difference between negative and positive pictures. The authors specified that the different findings could be the result of the specific use of a rehearsal technique to remember series of pictures. Thus, rehearsing several arousing pictures immediately after seeing them in a sequence makes it very difficult to integrate the stimuli with their locations because of the attentional focus required during rehearsal, thus leading to poorer associative memory for emotionally arousing pictures. It is therefore possible that in our experiment, it was more difficult to bind the negative pictures with their locations than the positive ones due to the specific ability of the former to increase attentional selectivity, even when they elicited the same level of physiological arousal as positive pictures (Van Steenbergen, Band, & Hommel, 2011).

In addition, the emotional enhancement of associative memory was impacted by stimulus repetition for pictures and a corresponding tendency was observed for words, and especially for positive ones. Indeed, a general emotional enhancement of associative memory occurred for words in the six initial series, whereas a negativity effect was obtained when the series were repeated. Similarly, for pictures, the positivity effect obtained for the first series gave way to equivalent performances for emotional and neutral pictures when the stimuli were repeated. Thus, in our experiment, stimulus repetition seemed to affect solely memory for positive stimuli. This is in line with the ERP study of Carretié, Hinojosa, and Mercado (2003), who found stronger attentional habituation in response to positive than to negative stimuli which, nevertheless, were matched on arousal level. It is also consistent with the findings reported by Wright et al. (2001) who observed a higher level of habituation for happy than for fearful faces. Thus, in these studies, negative stimuli were better able to attract and maintain the participants' attention across repetitions. Moreover, by repeating the same stimuli in different locations from the initial ones, we also increased the level of interference between the first and second stimulus presentations and this could have impaired the participants' associative memory performances, especially for positive stimuli.

Most importantly, emotions again enhanced associative memory in school-age children in our experiment: a general emotional enhancement of memory occurred for words and a positivity effect occurred for pictures. However, in this experiment, the children's performances were poorer than those of the young adults in all the tasks and both for emotional and neutral stimuli. This could be explained by the slow development of associative memory, and therefore also episodic memory, across childhood (for a review, see Raj & Bell, 2010). This applies in particular to the spatial component of episodic memory, which may not be fully developed until early adulthood (Guillery-Girard et al., 2013). We further discuss these developmental differences in episodic memory performances in the general discussion.

General Discussion

In the present study, we conducted two experiments to investigate the effect of emotions on item and associative memory in school-age children and young adults. To do this, we used two different memory tasks and two different types of stimulus together with contextual information to be associated with the item. Overall, an effect of emotions was observed only in the recall tasks (free item recall and associative recall). In the case of words, the children exhibited a general emotional enhancement of both item and associative memory, regardless of the contextual information to be associated with the item. However, the results we obtained for pictures were quite mixed, with an emotional enhancement of item memory limited to negative pictures being observed in the first experiment and such an enhancement being observed for both negative and positive pictures in the second experiment. There was also no emotional modulation of associative memory in the former experiment and a positivity effect in the latter. It is important to note that although, in our experiments, the children's overall memory performances were poorer than those of the young adults, both groups exhibited a similar effect of emotions on memory across all the tasks, except in the case of item memory in the first experiment. In this experiment, the adults recalled both negative and positive pictures better, whereas the children presented better memory only for negative pictures. These findings therefore indicate that children do experience an emotional enhancement of both components of episodic memory (item and contextual information) similar to that observed in young adults, although this effect may vary depending on the type of stimulus used, that is, pictures or words. Before considering the implications of the type of stimulus for emotional associative memory, we present a number of mechanisms that underlie the developmental time course of episodic memory and emotional systems, as well as the way they interact as age increases. We then discuss how these mechanisms can account for our present findings.

Many developmental studies have shown that episodic memory improves greatly during childhood (Ghetti & Lee, 2011; Lee et al., 2016) and that it is related to the improvement of the capacity to bind the central and peripheral aspects of an event into a unique and coherent episode. On the behavioral level, Guillery-Girard et al. (2013); Lee et al. (2016) and Picard et al. (2017) have emphasized different age-related trajectories relating to the developmental time course of item and associative memory from 6 years of age through to adulthood. Overall in our study, compared to young adults, the 9- to 11-year-old (Experiment 1) and 8- to 10-year-old (Experiment 2) children had poorer recall performances for item memory, and the 8- to 10-year-old children in Experiment 2 had poorer recall performances for the associative memory of spatial locations. Thus, in line with the aforementioned studies, it appears that episodic memory processes in our sample of school-age children are still developing. However, the fact that the 9- to 11-year-old children achieved performances similar to those of the young adults for associative memory in Experiment 1 (context for pictures and source for words), as well as for picture recognition, and performed even better on word recognition, may suggest that some encoding and retrieval processes reach maturation faster than others. In fact, in this group of children, free recall abilities were less efficient than associative recall and recognition skills, suggesting that they experienced more difficulty for some types of retrieval. Indeed, when retrieval cues were given (presentation of the item during recognition and associative recall tasks), the children were able to retrieve the item and its associated contextual information, thus suggesting the existence of successful recognition and binding processes. Moreover, the different findings obtained for associative memory performances in children relative to young adults in Experiment 1 and Experiment 2 possibly suggest the existence of developmental differences in episodic memory processes. These might have been less developed in the children in Experiment 2, who were a little younger than those in Experiment 1. More particularly, these findings might be due to the different developmental time course of the capacity to process specific contextual information. Thus, memory for spatial location could become established later than memory for context or source. This would further support the findings of Guillery-Girard et al. (2013) and Picard et al. (2017). However, as we did not directly compare children's performances in Experiment 1 and Experiment 2, these findings need further investigation.

Concerning emotional processing, the amygdala, a brain structure that mediates emotional responses, is activated in a similar way in response to negative pictures in children and young adults (McRae et al., 2012) and is increasingly regulated by the PFC with age (Gee et al., 2013; Perlman & Pelphrey, 2011). This structure is also closely related to MTL regions, including the hippocampus, which support the emotional modulation of memory (LaBar & Cabeza, 2006). Across two experiments in the present study, we observed an emotional enhancement of episodic memory in children which was similar to that observed in young adults. Therefore, although the emotional and memory systems are still undergoing development, it seems that they interacted in the school-age children involved in the present study. These results are in line with several studies that have found that item memory was enhanced by emotions in children (Cordon et al., 2013; Davidson et al., 2001; Van Bergen et al., 2015; but for a review, see Hamann & Stevens, 2014). Moreover, our study is the first one to show that children might also exhibit an emotional enhancement of associative memory, especially for words, and provides us with a deeper understanding of the interaction between emotional and memory systems in children. Indeed, given that episodic memory, which requires the binding of items and their context, is mainly supported by the hippocampus in combination with other MTL and PFC regions (Ghetti & Lee, 2011), we may assume that the amygdala is already connected with these different regions in children, thus leading to an emotional enhancement of episodic memory overall. It could be pointed out, however, that these findings relate to short retention intervals and may be different in the case of longer retention intervals, given that the activation of the amygdala has been shown to modulate the long-term consolidation of memory traces in the hippocampus (LaBar & Cabeza, 2006; Yonelinas & Ritchey, 2015). Further behavioral and neuroimaging studies investigating the emotional modulation of memory in children across short and long retention intervals are needed to clarify these matters. Moreover, if we consider recent works that have shown that activation of the amygdala could be predominately linked to the motivational salience of the stimuli (for a review, see Cunningham & Brosch, 2012), the effect of emotions on memory could be linked to the subject's current motivational state and this possibility should be taken into account in future investigations.

Another question addressed in the present study concerns the role of the specific type of stimulus and contextual information in associative memory performances. Indeed, in our first experiment, an emotional enhancement of item memory was observed for both words and pictures, whereas an associative memory enhancement was observed only for words. The level of effortful processing required to bind items with their contextual information was not the same for the two types of stimuli used in this experiment and we therefore think it likely that this is the reason why this discrepancy occurred. This explanation seems even more probable if we consider that the memory trade-off is more likely to occur for extrinsic associated details (pictures and frames in our experiment) than for intrinsic ones (words and voice gender; Kensinger, 2009; Yonelinas & Ritchey, 2015). Our Experiment 2, in which the type of contextual information was intrinsic and identical (spatial location) for words and pictures, but different from that used in Experiment 1, allows us to widen the scope of our findings. In both experiments, words elicited better item and associative memory in children and young adults, regardless of the type of contextual information (source or spatial location). However, for pictures, although an EEM was observed for item memory in both experiments, it did not extend to associative memory in Experiment 1 (for an extrinsic context) and only a positivity effect was observed in Experiment 2 (for spatial location, which is intrinsic) for all the participants. As the type of contextual information was both identical and intrinsic for both the words and the pictures in Experiment 2, and given that we still observed differences in associative memory between these two types of stimuli, the memory trade-off effect and type of contextual information to be associated with the items cannot entirely account for our findings. This discrepancy might, therefore, reflect differences in the properties belonging specifically to words and pictures rather than differences in the contextual information. Indeed, as discussed in Experiment 1, DAPS/IAPS pictures, which depict real-life visual scenes, induce stronger emotional reactions in terms of physiological arousal, valence, and attentional bias than individual words, because these have poorer ecological value (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013). In addition, DAPS pictures, whether emotional or neutral, are physically more complex than words and have many visual features that further capture participants' attention. Therefore, these findings suggest that the processing and binding of associated contextual information for pictures depicting visual scenes could be more idiosyncratic and may not depend on the type of contextual information. Thus, it will be necessary to examine whether this excess of attentional resources devoted to the content of pictures leads to better or weaker associative memory and whether this outcome is or is not dependent on valence.

In conclusion, the present study demonstrates, for the first time, that school-age children present an emotional enhancement of both components of episodic memory, namely both core and contextual information, although the enhancement may be modulated by the type of stimulus. Indeed, the children in our study had better item memory for emotional than for neutral words, and this EEM extended to the specific contextual information of these words, regardless of its type. They therefore remembered the overall episode better in the case of emotional than neutral words. Moreover, no significant developmental difference in EEM was observed between school-age children and young adults for item and associative memory for words. This suggests that the interaction between emotional and memory systems is already well developed in 8- to 11-year-old children, even though the memory performances of the children were worse overall. As a dissociation between item and associative memory was observed for pictures in all the participants, regardless of the type of contextual information, it seems that the type of stimulus was the main factor in the various effects involved in associative memory performances across these two experiments. With regard to these contrasting findings between words and pictures in the case of associative memory, it seems essential to further investigate this issue using different paradigms and different age groups of children to better understand the effect of emotions on both components of episodic memory during development. From a broader perspective, we think that this work may be of interest to researchers studying real-world experiences of emotion and who focus on the impact of these experiences on children's well-being and development.

Context of the Research

The present research is part of a more general avenue of research that we are conducting concerning the relation between emotion and memory. Although there is general agreement about the emotional modulation of memory in adults, several points are currently being investigated. In particular, these include (a) age-related differences in the emotional enhancement of memory (EEM) and (b) its modulation by neurological or psychiatric diseases (e.g., Alzheimer's disease, depression, schizophrenia). In fact, the negativity effect (better memory for negative stimuli) seems to be more prominent in young adults and the positivity effect (better memory for positive stimuli) more prominent in older adults. Our previous studies have focused on this relation in normal and pathological aging, because of Alzheimer's disease, and have confirmed the presence of a positivity effect in normal aging and, under some circumstances, in Alzheimer's disease. The positivity effect may be explained by age-related differences in the availability of cognitive resources or emotional regulation. It is therefore possible that the effect of emotions on memory is different in children and young adults. Surprisingly, fewer studies have focused on this question and consequently less is known about EEM in typically developing children and children with neurodevelopmental disorders. We therefore decided to use a behavioral and electrophysiological approach to study the effect of emotions on memory in typically developing children and children with Williams-Beuren syndrome, who have specific emotional and memory processes. We are currently collecting data using the same protocol as that used in the present study with children with Williams-Beuren syndrome and we are conducting another study using EEG measures in combination with recognition and recall tasks to better understand the age-related neural bases of emotional memory enhancement.

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Appendix

Table A1
Mean Ratings of the Stimuli for Emotional Valence and Arousal Given by Children and Adults in the Developmental Affective Photo System (DAPS; Pictures) and Affective Norms for French Words (FAN; Words) Databases

	Children		Adults			
DAPS and FAN databases	Valence[a]	Arousal[a]	Valence[a]	Arousal[a]	Complexity[b]	Imageability[c]
Pictures						
Negative	3.18 (.32)	5.94 (.89)	3.16 (.26)	5.90 (.52)	2.45 (.47)	
Positive	7.21 (.36)	5.82 (.82)	7.07 (.36)	5.67 (.56)	2.13 (.44)	
Neutral	5.80 (.42)	3.72 (.42)	5.73 (.38)	3.43 (.70)	2.20 (.67)	
Words						
Negative	3.26 (.73)	4.79 (.69)	3.09 (.63)	5.19 (1.01)		5.10 (1.57)
Positive	7.09 (.69)	5.24 (1.04)	7.29 (.61)	4.88 (1.00)		5.14 (1.74)
Neutral	5.07 (.35)	3.96 (.41)	5.21 (.51)	3.78 (.55)		5.44 (1.24)

Note. This table also includes mean ratings of visual complexity for pictures and imageability for words. Standard deviations are in parentheses.
[a] Valence and arousal are rated on a scale of 1 (*very negative/not arousing at all*) to 9 (*very positive/highly arousing*). [b] Visual complexity is rated on a scale of 1 (*very simple*) to 4 (*very complex*). [c] Imageability is rated on a scale of 1 (*very low imagery value*) to 7 (*very high imagery value*).

(*Appendix continues*)

Table A2
Mean Proportions of Correct Responses for Free Recall, Associative Recall, and Recognition for Negative, Positive, and Neutral Stimuli (Pictures and Words) in Experiment 1 (Standard Errors Are in Parentheses)

Experiment 1	Children	Young adults
Pictures		
Free recall		
Negative	.38 (.03)	.44 (.03)
Positive	.27 (.03)	.42 (.03)
Neutral	.28 (.03)	.28 (.03)
Associative recall (context: frames)		
Negative	.49 (.03)	.49 (.03)
Positive	.49 (.03)	.51 (.03)
Neutral	.47 (.03)	.53 (.03)
Recognition		
Negative	.89 (.02)	.88 (.02)
Positive	.91 (.02)	.85 (.02)
Neutral	.86 (.03)	.82 (.03)
Words		
Free recall		
Negative	.28 (.03)	.36 (.03)
Positive	.23 (.02)	.31 (.02)
Neutral	.18 (.02)	.24 (.02)
Associative recall (source: voice gender)		
Negative	.58 (.03)	.58 (.03)
Positive	.56 (.03)	.61 (.03)
Neutral	.48 (.03)	.49 (.03)
Recognition		
Negative	.86 (.03)	.78 (.03)
Positive	.83 (.03)	.77 (.03)
Neutral	.88 (.03)	.76 (.03)

Table A3
Mean Proportions of Correct Responses for Free Recall and Associative Recall for Negative, Positive, and Neutral Stimuli (Pictures and Words) in Experiment 2 (Standard Errors Are in Parentheses)

Experiment 2	Children	Young adults
Pictures		
Free recall		
Negative	.32 (.03)	.55 (.03)
Positive	.23 (.03)	.49 (.03)
Neutral	.17 (.03)	.38 (.03)
Associative recall (spatial location)		
Negative	.50 (.03)	.68 (.03)
Positive	.52 (.03)	.72 (.03)
Neutral	.50 (.03)	.70 (.03)
Words		
Free recall		
Negative	.28 (.02)	.41 (.02)
Positive	.20 (.02)	.38 (.02)
Neutral	.14 (.02)	.29 (.02)
Associative recall (spatial location)		
Negative	.44 (.03)	.53 (.03)
Positive	.36 (.03)	.50 (.03)
Neutral	.33 (.03)	.48 (.03)

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