MEMORY
2026, VOL. 34, NO. 7, 845–857
https://doi.org/10.1080/09658211.2026.2681870

Routledge
Taylor & Francis Group



# The "what" and "where" of the threat superiority effect in children's memory

Elodie Lhoste, Patrick Bonin, Patrick Bard, Bénédicte Poulin-Charronnat and Annie Vinter

Université Bourgogne Europe, CNRS, LEAD UMR5022, 21000 Dijon, France

**ABSTRACT**

Although a substantial body of research has demonstrated a processing advantage for threatening entities compared to nonthreatening ones in adults, very few studies have investigated the effect of threat on memory processes in children. The present study aimed to address this gap by testing memory for dangerous entities and their locations in 88 children aged 5–10 years. To do so, the children played Memory games on a digital tablet. Location memory was assessed by recording the number of errors made when matching card pairs. Item memory was assessed using a free recall task administered after the Memory game session. The results revealed a significant threat superiority effect for both item and location memory. Specifically, dangerous animals were remembered better than nondangerous ones as early as age 5. Location memory advantages for threatening items emerged by the age of 8. Further analysis showed significant relationships between memory performance and the emotional dimensions of the stimuli (arousal and emotional intensity). Finally, modern threats were recalled better than evolutionary threats, although no differences were observed in location memory. Overall, these findings provide further evidence to support the idea that threatening information has an adaptive value in memory processes during childhood.

**ARTICLE HISTORY**
Received 12 February 2026
Accepted 21 May 2026

**KEYWORDS**
Threat superiority effect; location memory; evolutionary psychology; children; danger

Imagine walking through tall grass when you suddenly spot the curved shape of a snake. In an instant, your heart rate increases, your attention focuses on the threat, and your body prepares to react. You may remember this event and the precise location where you found the snake particularly well. Would that be the case if you had crossed paths with a butterfly? Probably not. This privileged status of dangerous entities over nonthreatening ones in human information processing is known as the threat superiority effect (Brosch & Sharma, 2005; LoBue & DeLoache, 2010, 2008; Öhman, Flykt, et al., 2001).

Not all stimuli are equal when it comes to survival. According to evolutionary psychology, our cognition has been shaped by the selective evolutionary pressures that our hunter-gatherer ancestors encountered (e.g., Bonin & Méot, 2019; Nairne & Pandeirada, 2010). These pressures are thought to have favoured cognitive mechanisms that prioritise the processing of fitness-relevant information (i.e., information crucial for survival and reproduction; e.g., Nairne, 2022). A central challenge for our ancestors in the deep past was protecting themselves from danger (Öhman & Mineka, 2001). Some researchers argue that natural selection has favoured attentional and memory biases that permit threatening stimuli to be detected, processed and retained more efficiently than neutral ones, thus conferring a critical adaptive advantage (e.g., LoBue, 2012). Research in evolutionary psychology distinguishes between multiple classes of dangers (e.g., Pelešková et al., 2024), including those involving predators (e.g., lions), natural threats (e.g., volcanoes), modern dangers (e.g., guns), and pathogens (e.g., viruses, bacteria). The present study focuses on the threat superiority effect in relation to the first three aforementioned classes of danger.

## *Effects of threat in conditioning and attentional paradigms*

A growing body of research supports the hypothesis that threats have exerted strong selective pressure on our cognitive systems. The first studies in this field used the classical conditioning paradigm (see Öhman & Mineka, 2001, for a review). For instance, Öhman and Soares (1998) presented participants with masked pictures of threatening (i.e., snakes and spiders) and nonthreatening (i.e., flowers and mushrooms) entities as conditioned stimuli, paired with mild electric shocks serving as the unconditioned stimulus. Results showed that masked threatening stimuli elicited robust conditioned skin conductance responses, whereas nonthreatening stimuli did not.

**CONTACT** Elodie Lhoste elodie.lhoste@u-bourgogne.fr CNRS UMR5022 – LEAD, Université Bourgogne Europe, Pôle AAFE, 11 Esplanade Erasme, 21000 Dijon, France

Supplemental data for this article can be accessed online at https://doi.org/10.1080/09658211.2026.2681870.

Building on these initial findings, a substantial body of work has shown that threat biases attentional and perceptual processes. In visual search tasks, dangerous animals that posed recurrent threats in the ancestral past (e.g., snakes and spiders) are detected faster than neutral ones (e.g., caterpillars, see Blanchette, 2006; Fox et al., 2007; Öhman, Flykt, et al., 2001). This effect has been replicated using variants of the visual search paradigm (Zsido et al., 2019), as well as with eye-tracking methodologies (Yorzinski et al., 2014). Moreover, threatening animals have been shown to hold attention longer (Burra et al., 2019; Holmes et al., 2014), and are more likely to escape inattentional blindness than neutral items (Gao & Jia, 2017). Similar threat superiority effects have been reported when using fearful expressions (Yang et al., 2007) or angry faces as stimuli (Hansen & Hansen, 1988; Öhman, Lundqvist, et al., 2001; however, see Becker et al., 2011).

To further support the hypothesis that humans are equipped with an evolved predisposition to rapidly detect threatening entities, several researchers have examined whether such biases can be found in very young children, who have limited opportunity to acquire threat-relevant experience. In line with adult studies, infants orient preferentially toward photographs of snakes or threatening faces rather than flowers as early as 8 months (LoBue & DeLoache, 2010), look longer at schematic spiders or snakes than at reconfigured controls at 5 months (spiders: Rakison & Derringer, 2008; snakes: Rakison, 2018), and by 5 years detect a snake among flowers more rapidly than the reverse (LoBue & DeLoache, 2008).

Extending these findings to older children and adolescents, Wolters et al. (2012) showed with a dot-probe paradigm that participants aged 8–18 years responded faster to threatening than to nonthreatening stimuli, while Waters and Lipp (2008) demonstrated with a visual detection task that children aged 9–13 years detected snakes and spiders more quickly than a variety of nondangerous animals. In addition, physiological data support the hypothesis of a differentiated processing of threatening versus nonthreatening stimuli: by 6 months of age, infants exhibit a slower heart rate (Thrasher & LoBue, 2016) and greater pupillary dilation (Hoehl et al., 2017) when viewing photographs of snakes and spiders compared to other animals. While the precise mechanisms underlying this effect remain debated (see Pakai-Stecina et al., 2024), several authors (e.g., LoBue, 2014) have argued that the threat superiority effect in attentional tasks is likely to be supported by a combination of bottom-up perceptual biases and top-down influences. At the perceptual level, these biases have been linked to low-level visual features such as an orientation bias toward curvilinear shapes resembling snakes (e.g., LoBue, 2014) or an attentional advantage for downward-pointing V shapes (Larson et al., 2007). Emotional dimensions such as negative valence and heightened arousal have also been proposed to contribute to the prioritisation of threatening stimuli (e.g., LeDoux, 2012). Thus, general cognitive (here, perceptual and emotional) mechanisms may contribute to the threat superiority effect (see Howe & Derbish, 2014; Howe & Otgaar, 2013, for a similar standpoint regarding the memory advantage of fitness-relevant information).

Importantly, attentional biases are not limited to ancestral threats (i.e., entities that posed recurrent threats during the deep past). Modern threats such as guns or knives have also been found to capture attention (e.g., Blanchette, 2006; Fox et al., 2007; Subra et al., 2017), which supports the view that while our cognitive architecture is evolutionarily prepared for ancestral threats, experience enables the emergence of comparable biases toward modern threats (LoBue, 2012). However, there are different views regarding whether one category holds an advantage over the other. Whereas a "strong" version of the evolutionary account proposes a processing advantage for evolutionary threats, a "soft" version emphasises the role of contextual relevance and predicts an advantage for modern threats (Subra et al., 2017). Several studies using attentional paradigms have attempted to disentangle these accounts by examining whether evolutionary threats benefit from preferential processing over modern threats. Results obtained in adults yielded mixed findings, as some demonstrated a superiority of either evolutionary (Zhang & Guo, 2019) or modern threats (Subra et al., 2017), or even no difference between both categories (Fox et al., 2007). Few studies have investigated these effects in children and infants, and the available findings are also mixed, likely due to variations in age groups and methodological approaches. For instance, Erlich et al. (2013) reported that 9-month-old infants displayed greater heart-rate deceleration and larger startle eye-blinks when listening to evolutionarily threatening sounds compared to modern fear-relevant and pleasant sounds. In contrast, Zsido et al. (2018) found no difference in detection times between photographs of evolutionary threats (e.g., spiders) and modern threats (e.g., a syringe) that were equally familiar to 5-year-old children.

### *Effect of threat in memory tasks*

The effects of threat are not limited to attentional processes. Indeed, while there is less research in this domain, memory processes also seem to be tuned to prioritise such stimuli. For instance, adults remember threatening items better than nonthreatening ones in recognition or free recall tasks, using either words (Leding, 2019, 2020) or pictures as stimuli (Chapman et al., 2013; Lhoste et al., 2025; Makovski et al., 2020). As far as children are concerned, existing studies have shown that preschoolers are better at recognising the faces of individuals described as having committed harmful rather than helpful actions (Kinzler & Shutts, 2008). Similarly, Prokop and Fančovičová (2017) found that children aged 10–13 years remembered information about animals better when it was presented

alongside illustrations depicting the animals in aggressive rather than in neutral postures. Barrett and Broesch (2012) showed that children from very different cultures aged 4–6 exhibit similar prepared social learning regarding dangerous animals.

These results align with the adaptive memory view (Nairne et al., 2017; Nairne & Pandeirada, 2016), according to which memory functioning still bears the imprint of ancestral selective pressures, particularly with regard to information that was relevant for survival, such as threatening entities. However, research in this area in children is still scarce. Only a few studies have directly examined the impact of threat on item memory in children, highlighting the need for further investigation. Furthermore, from an adaptive perspective, recalling that one has seen a lion provides little survival value if one cannot remember where it was seen. Survival in ancestral environments required detecting and identifying threatening entities, as well as encoding and retrieving the spatial context in which they were encountered (Bröder et al., 2011). Thus, it is particularly interesting and important to determine whether threats enhance not only item memory, but also the binding of items to their locations. Two studies have already investigated this issue in adults, yielding either a threat superiority effect (see Lhoste et al., 2025, who used a Memory game task as a paradigm) or inconsistent results, with evidence of a threat superiority effect in one experiment and no such effect in another (Gallup, 2022). No similar study has been conducted in children.

### The present study

This study aimed to address these research gaps by further investigating the effects of threatening stimuli on memory for items in children aged 5–10 years, extending this investigation to location memory for the first time. To this end, the children performed three Memory games on a digital tablet. The Memory game task is a suitable paradigm for investigating our research questions because it has been used to explore the effects of fitness-relevant entities on location memory (Lhoste et al., 2025; van Buren & Scholl, 2017; Wilson et al., 2011). For example, Wilson et al. (2011) asked participants to complete two Memory games, each with a $5 \times 4$ grid, to compare spatial memory for evolutionarily relevant and modern threats. In our experiment, we designed two games to compare dangerous entities and nondangerous entities. In one game, participants were shown dangerous animals (e.g., snakes) and harmless animals (e.g., penguins). The other game featured natural threats (e.g., an erupting volcano) and nonthreatening natural elements (e.g., a river). Based on the results of Lhoste et al. (2025) with adults and studies demonstrating attentional and memory biases for threat in children, we expected to find a threat superiority effect in children's item and location memory. Additionally, a third game aimed to compare modern threatening entities (e.g., a gun) and evolutionary threatening entities (e.g., a tornado). As mentioned above, it remains unclear whether modern and evolutionary threats are processed equivalently or not. The present study aimed to further investigate this issue. Finally, if significant results were obtained, correlational analyses would be conducted between the emotional dimensions of the stimuli (i.e., arousal, valence, and emotional intensity) and the dependent variables to examine their relationship.

## Method

### Participants

We conducted an a priori power analysis using G*Power 3 (Faul et al., 2007) to estimate the sample size. Since our leading hypothesis was that children would remember dangerous items better than nondangerous ones, regardless of age (e.g., a positive within-factor effect), we based our power analysis on data from Lhoste et al. (2025). They reported a medium effect size of threat on location memory in adults using the same paradigm as ours.[1] Using the effect size convention "as in G*Power 3.0" and the default assumed correlation among repeated measures, the analysis indicated that a total of 36 participants (12 per age group) would be sufficient to detect a medium main effect of threat ($f = 0.25$) in a mixed-design ANOVA with $\alpha = .05$ and power = .80 (or 57 participants with power = .95). For ethical reasons, we included all children who volunteered to participate in the experiment through their classroom, resulting in a final sample size that exceeded the minimum requirement.

Eighty-eight children, aged 5–10 years old ($M_{age} = 8$ years 2 months, $SD = 2$ years and 1 month; 51 boys and 37 girls), were recruited from preschools and elementary schools in middle-class, urban neighbourhoods. Three age groups were selected: 5-year-olds (preschoolers; $N = 28$), 8-year-olds (younger elementary schoolers; $N = 29$), and 10-year-olds (older elementary schoolers; $N = 31$). All of the children were native French speakers, and according to their teachers, none exhibited any atypical development. Written informed consent was obtained from the parents, and only willing children were included in the study. The study was approved by a local ethics committee (N° UBFC-2023-12-12-059).

### Materials

In total, 36 drawings were used across the three Memory games, with 12 pictures in each game. Two of the Memory games opposed pictures of dangerous entities to nondangerous entities (e.g., 6 threatening animals to 6 nonthreatening animals and 6 natural threats to 6 nondangerous natural elements) and one Memory game compared modern and evolutionary threats (i.e., 6 evolutionary threats to 6 modern threats). Each of the three Memory games presented participants with pairs of the 12 pictures arranged in a $6 \times 4$ configuration. The stimuli were the

same as those used in Experiment 2 of Lhoste et al. (2025). The list of picture names used in the study is provided in the Supplementary Methods (section "Emotional Variables Ratings").

For each pair of categories compared in the analyses (i.e., dangerous vs. nondangerous stimuli; modern vs. evolutionary threats), stimuli were matched as closely as possible on six variables related to the drawings and their labels (see Table 1). A few significant differences emerged between threatening and nonthreatening items, as well as between modern and evolutionary threats. However, none of these variables correlated with our two dependent measures (i.e., free recall and location memory scores). One exception was the lexical frequencies of the items in textbooks, which were positively correlated with free recall scores of the 5-year-old children, $r(10) = .438$, $p = .032$. Dangerousness ratings were collected from the child participants (see the Procedure section) to ensure that the threatening entities were perceived as more dangerous than the nonthreatening ones and that the evolutionary and modern threats were perceived as equally dangerous. As expected, Table 1 showed that threatening entities were indeed rated as more dangerous than nonthreatening ones ($p < .001$), and no difference emerged between natural and modern threats ($p = .589$).

### Procedure

Each child completed the games individually in the presence of one experimenter, in a quiet room at their school. After performing the game, the children were warmly thanked for their participation.

### Game phase

First, the participants were told that they would be asked to play three Memory games on a digital tablet (Lenovo M10 tablets). The order of the games was randomised for each participant. Then, the experimenter explained the aim of the game, which was to match pairs of identical pictures (see Supplementary Methods for a complete description of how the game worked). Location memory was assessed by calculating the mean number of location errors per participant and per item. Errors were recorded only when the participant had previously revealed the target card and thus had already seen its position (see Supplementary Methods for a description of error cases).

### Surprise free recall task

After completing the three Memory games, the children were asked to recall as many pictures as possible to assess their memory of the items. Their responses were recorded in an Excel spreadsheet. When a child's label was unclear to the experimenter, meaning it was difficult to determine which picture the participant was referring to, the child was asked to describe the picture. Although a time limit of four minutes was set for the recall test, no child reached this limit in practice. When children indicated that they could not remember any additional words, they were encouraged to try to produce more responses. If they were unable to do so, the recall task was stopped. Some flexibility was allowed when scoring responses in the free recall task. Children were not required to produce the exact target label. The important thing was that the label they provided made it possible to identify the intended item unambiguously when needed.

### Naming and dangerosity rating tasks

After completing the surprise free recall task, the children performed a naming task and then a dangerosity rating task. During this phase, children were shown the entire set of pictures from the games in a randomised order. For each picture, they were first asked: "Do you know what this is? Can you name it?" Then, they were asked: "Is it dangerous, somewhat dangerous, or not dangerous?"

The naming task was administered to measure children's ability to retrieve a lexical label for the pictures. The children's answers were coded on a three-point scale. A score of 0 was given whenever the child provided no label (e.g., "I don't know"). A score of 1 was attributed whenever the child provided a descriptive answer instead of a specific label (e.g., "it is for cutting trees" when shown a saw; "it's in the desert and it's prickly" when shown a cactus, "it lives on ice" when shown a penguin). A score of 2 was given when the child produced an acceptable lexical label (i.e., the expected lexical label, a synonym, or a plausible label; for instance, "lake" instead of "river"; "wind" instead of "tornado"). Regarding the dangerosity rating task, ratings were coded on a 3-point scale: 0 = "not dangerous", 0.5 = "somewhat dangerous", and 1 = "dangerous".

## Results

We analyzed the impact of threat on free recall performance first, followed by memory location performance. The same analysis schema was applied to each variable. To compare dangerous and nondangerous entities (two games), we grouped the scores obtained for dangerous animals and natural threats together and did the same for the scores obtained for nondangerous animals and nondangerous natural elements. Further analyses were conducted to specifically compare dangerous and nondangerous animals, natural threats and nondangerous natural elements. A separate analysis was performed to compare free recall scores between evolutionary and modern threats (third game). Finally, we investigated the role of naming performance in the impact of threat on the free recall scores, as well as the influence of emotional variables related to the pictures (arousal, valence, and emotional intensity) on free recall and memory location scores.

The main analyses were conducted using repeated-measures ANOVAs with Category (dangerous vs. nondangerous, or modern vs. evolutionary) as a within-subjects

**Table 1.** Means and standard deviations of the words used in each comparison.

| | Dangerous entities | Nondangerous entities | *p*-value | Evolutionary threats | Modern threats | *p*-value |
|---|---|---|---|---|---|---|
| Dangerousness | 0.83 (0.11) | 0.16 (0.12) | <.001 | 0.80 (0.12) | 0.80 (0.23) | .589 |
| Name Agreement[a] | 6.34 (0.49) | 6.48 (0.40) | .256 | 5.55 (0.70) | 6.52 (0.31) | .011 |
| Number of letters | 6.67 (1.50) | 6 (1.13) | .231 | 7.83 (1.47) | 5.83 (2.40) | .252 |
| Number of syllables | 2.08 (0.67) | 1.67 (0.49) | .100 | 2.50 (0.84) | 1.83 (0.75) | .172 |
| Book frequency[b] | 4.60 (6.36) | 31.5 (35) | .039 | 11.02 (7.87) | 10.45 (6.59) | .894 |
| Visual complexity[c] | 306 (78) | 241 (73) | .047 | 343 (95) | 179 (19) | .002 |

Note: Standard deviations are presented in parentheses.
[a]Data taken from Lhoste et al. (2025). It is important to stress that comparable child-based norms were not available.
[b]Values taken from Lexique (www.lexique.org; New et al., 2004). It should be noted that these frequencies primarily reflect adult lexical familiarity. Child-based frequency measures could not be used, as a large proportion of the items were not available in Manulex (Lété et al., 2004), a database based on school textbooks.
[c]Assessed by the number of bytes in JPEG format, expressed in $10^3$ bytes (see Bonin et al., 2020).

factor and Age group (5-year-old, 8-year-old, and 10-year-old children) as a between-subjects factor. All analyses were conducted using JASP (0.19.1). The data are available on the Open Science Framework and can be accessed at https://osf.io/9eqha/overview?view_only=2c2001e23639441ab12de5820b4c21d1.

## Free recall scores analyses

### Are threatening entities better recalled than nonthreatening ones?

First, we checked that children had seen an equal number of pictures from the threatening and nonthreatening categories during the game phase. Repeated-measures ANOVAs revealed that children were more frequently exposed to pictures depicting nonthreatening entities ($M = 59.59$, $SD = 10.35$) than threatening entities ($M = 57.23$, $SD = 9.79$), $F(1, 85) = 6.12$, $p = .015$, $\eta_p^2 = .067$, regardless of age, $F(2, 85) = 0.49$, $p = .62$, $\eta_p^2 = .011$. Despite this frequency advantage for nondangerous entities, children recalled more pictures of threatening entities ($M = 0.24$, $SD = 0.18$) than nonthreatening entities ($M = 0.19$, $SD = 0.13$), $F(1, 85) = 10.11$, $p = .002$, $\eta_p^2 = .106$ (see Figure 1). This effect was not modulated by age, $F(2, 85) = 0.70$, $p = .500$, $\eta_p^2 = .016$. As suggested by Figure 1, however, unilateral *t*-tests (or Wilcoxon test in case of non-normality) conducted within each age group revealed no significant difference between dangerous and nondangerous entities among 5-year-old children, $t(27) = 1.04$, $p = .154$, $d_z = .197$, contrary to 8-year-old, $W = 113$, $p = .010$, $r = .662$, and 10-year-old children, $t(30) = 1.04$, $p = .030$, $d_z = .352$.

Note that this global contrast between dangerous and nondangerous items combines qualitatively different categories (living beings and environmental phenomena). While this provides an overall picture, it may obscure category-specific patterns of memory performance. More detailed analyses were therefore necessary to specifically compare dangerous and nondangerous animals as well as natural threats and nondangerous natural elements. The results are reported below.

***Are dangerous animals better remembered than nondangerous ones?.*** We first verified that the subcategories were equivalent with respect to the variables controlled for the global comparison. The dangerous and nondangerous animal categories did not differ in name agreement,

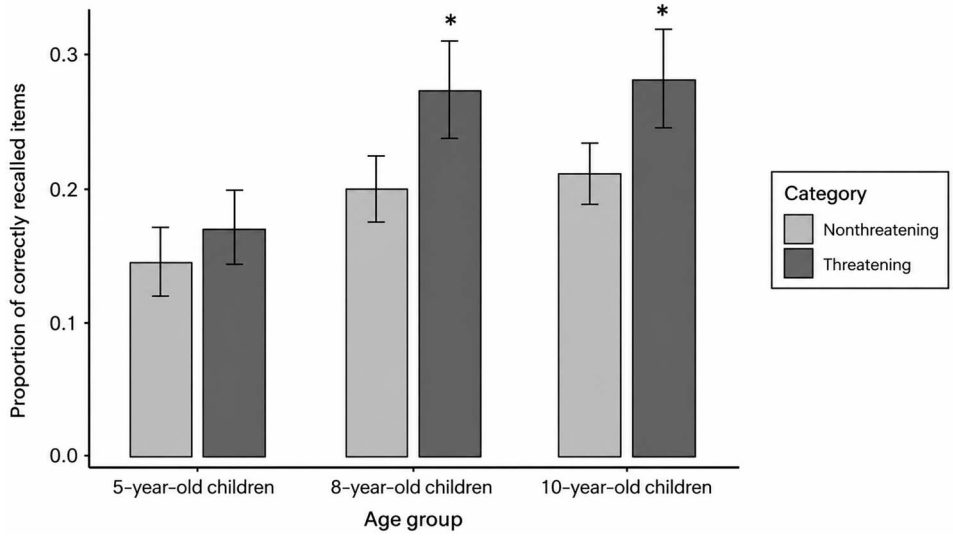


**Figure 1.** Proportion of correctly recalled items as a function of category and age for the comparison between threatening and nonthreatening entities.
Note: Error bars represent standard errors of the mean. *$p < .05$.

number of letters or syllables, visual complexity, or book frequencies, $p_s > .223$ (see Table S1 of the Supplementary Methods for more details). As expected, participants rated dangerous animals as more dangerous than nondangerous ones, $F(1, 85) = 653.59$, $p < .001$, $\eta_p^2 = .885$, regardless of age, $F(2, 85) = 0.24$, $p = .788$, $\eta_p^2 = .006$.

An analysis of frequencies of exposure revealed a significant main effect of Threat, $F(1, 85) = 5.72$, $p = .024$, $\eta_p^2 = .058$, regardless of age, $F(2, 85) = 0.93$, $p = .40$, $\eta_p^2 = .021$. Children were more frequently exposed to pictures of nondangerous animals ($M = 29.25$, $SD = 5.91$) than dangerous animals ($M = 27.82$, $SD = 5.55$). However, a repeated-measures ANOVA indicated that the proportion of correctly recalled items was higher for dangerous animals ($M = 0.34$, $SD = 0.30$) compared to nondangerous animals ($M = 0.22$, $SD = 0.19$), $F(1, 85) = 14.18$, $p < .001$, $\eta_p^2 = .146$. The Threat × Age interaction was not significant, $F(2, 85) = 0.251$, $p = .779$, $\eta_p^2 = .006$, suggesting that the effect of Threat did not vary across school levels. There was a significant main effect of age, $F(2, 85) = 3.97$, $p = .022$, $\eta_p^2 = .085$, indicating that the number of images recalled increased with age.

***Are natural threats better remembered than nondangerous natural elements?.*** Natural threats and nondangerous natural elements did not differ in name agreement, number of letters or syllables, and visual complexity, $p_s > .054$. However, the names of nondangerous natural elements appeared more frequently in books than the names of natural threats, $p = .006$ (see Table S1 of the Supplementary Methods for more details). This variable was positively correlated with 5-year-old children's free recall scores, $p = .010$, who remembered better the more frequent items across both dangerous and nondangerous items. As expected, natural threats were rated as more dangerous than nondangerous natural elements, $F(1, 85) = 2101.99$, $p < .001$, $\eta_p^2 = .961$, regardless of age, $F(2, 85) = 0.95$, $p = .392$, $\eta_p^2 = .022$.

During the games, children were exposed to an equal number of pictures from each category, $F(1, 85) = 1.41$, $p = .238$, $\eta^2_p = 0.02$, regardless of age, $F(2, 85) = 1.75$, $p = .180$, $\eta^2_p = 0.04$. When analyzing free recall scores, no difference was found between natural threats ($M = 0.15$, $SD = 0.17$) and nondangerous natural elements ($M = 0.15$, $SD = 0.19$), $F(1, 85) = 0.55$, $p = .815$, $\eta^2_p < 0.001$, regardless of age, $F(2, 85) = 0.64$, $p = .531$, $\eta_p^2 = .015$. Natural threats were recalled as often as nondangerous natural elements, which was also supported by a Bayesian analysis. Model comparison indicated that the null model was the best-fitting model. All alternative models, including those that considered stimulus category, age, or their interaction, received substantially less support than the best model ($BF_{10} \leq 0.27$). This provides moderate to strong evidence that there were no differences between natural threats and nondangerous natural elements.

***Are there differences in free recall scores between modern and evolutionary threats?***

There was no reliable difference in the frequency of occurrence of the two entity types during the course of the Memory game, $F(1, 85) = 0.33$, $p = .567$, $\eta_p^2 = .004$, regardless of age, $F(2, 85) = 0.79$, $p = .456$, $\eta_p^2 = .018$. A repeated-measures ANOVA revealed that children recalled more pictures of modern threats ($M = 0.17$, $SD = 0.19$) than evolutionary threats ($M = 0.12$, $SD = 0.17$), $F(1, 85) = 7.59$, $p = .007$, $\eta_p^2 = .08$. This effect was not modulated by age, $F(2, 85) = 0.90$, $p = .409$, $\eta_p^2 = .021$.

## *Additional analyses*

***Did naming performance affect the free recall results?.*** Since lexical access may affect recall performance (Postma & van der Ham, 2017), we examined whether children's naming performance differs across item categories. Regarding the comparison between dangerous and nondangerous animals, a repeated-measures ANOVA revealed no significant main effect of Threat on naming performance, $F(1, 85) = 1.80$, $p = .184$, $\eta^2_p = 0.021$, regardless of age, $F(2, 85) = 2.54$, $p = .085$, $\eta^2_p = 0.06$.

Regarding the comparison between natural threats and nondangerous natural elements, natural threats ($M = 1.80$, $SD = 0.21$) were significantly less well named than nondangerous natural elements ($M = 1.98$, $SD = 0.07$), $F(1, 85) = 93.58$, $p < .001$, $\eta^2_p = 0.523$. This effect was modulated by age, $F(2, 85) = 14.63$, $p < .001$, $\eta^2_p = 0.27$, indicating that category-related differences in naming performance decreased with age. However, when naming performance was included as a covariate in the free recall analysis (computed as the difference between naming scores for natural threats and nondangerous natural elements), the main effect of Threat remained not significant in recalling natural threats or nondangerous natural elements, $F(1, 84) = 0.01$, $p = .924$, $\eta^2_p < .001$, suggesting that naming performance did not explain the pattern of results observed in the free recall task.

Finally, a repeated-measures ANOVA revealed no significant difference in naming performance between modern threats ($M = 1.83$, $SD = 0.21$) and evolutionary threats ($M = 1.87$, $SD = 0.15$), $F(1, 85) = 2.91$, $p = .09$, $\eta_p^2 = .033$, and there was no interaction with age, $F(2, 85) = 1.56$, $p = .213$, $\eta_p^2 = .04$.

***Is there a relationship between the emotional dimensions of the pictures and free recall scores?.*** We examined the relationship between the free recall scores and the emotional dimensions of the stimuli: arousal (how exciting, stimulating or energising is the picture), valence (to what extent each picture evokes positive or negative feelings), and emotional intensity (how intense is the emotional reaction to each picture). We ran unilateral Spearman's rank correlation analyses at the item level between children's free recall scores and the emotional ratings of the pictures drawn from the adult study by

Lhoste et al. (2025) (see the "Emotional variables ratings" section of the Supplementary Methods).

Regarding the comparison between dangerous and nondangerous animals, the analyses indicated significant positive correlations between arousal and free recall scores across all age groups, $p_s < .034$, as well as between emotional intensity scores and free recall scores, $p_s < .043$. Thus, pictures that were more arousing and emotionally intense were more likely to be remembered. In all age groups, emotional intensity and arousal scores were highly correlated with dangerousness ratings, $p_s < .001$ (Spearman's $\rho > 0.82$). Additionally, we found nearly significant, $p = .06$, and significant, $p = .025$, negative correlations between free recall scores and valence ratings in 8- and 10-year-old children respectively, but not in 5-year-old children, $p = .237$.

No differences were found in valence, arousal, or emotional intensity ratings between modern and evolutionary threats, $p_s > .08$. Moreover, none of these emotional variables were correlated with free recall scores associated with modern or evolutionary threats, regardless of age, $p_s > .345$.

As previously stated, from an adaptive point of view, memorising the locations of dangerous entities is just as important as memorising the entities themselves. We therefore assessed whether children would show better memory for the location of dangerous items, as observed in adults using the same paradigm (Lhoste et al., 2025).

## Location memory scores analyses

### Are the locations of threatening entities better remembered than those of nonthreatening entities?

An analysis of the number of location errors revealed a significant main effect of Threat, $F(1, 85) = 6.40$, $p = .013$, $\eta_p^2 = .070$. Children made more errors when matching pairs of nonthreatening entities ($M = 6.94$, $SD = 3.96$) than when matching pairs of threatening entities ($M = 5.97$, $SD = 3.65$). This is why they were more often exposed to nondangerous than dangerous items. This effect was not modulated by age, $F(2, 85) = 0.86$, $p = .427$, $\eta_p^2 = .020$. However, unilateral *t*-tests conducted within each age group revealed no significant difference between dangerous and nondangerous entities among 5- and 8-year-old children, $p_s > .195$. The effect was significant among 10-year-old children, $p = .002$ (see Figure 2). Additionally, a significant effect of age revealed that the number of errors decreased with age, $F(2, 85) = 5.30$, $p = .0007$, $\eta_p^2 = .111$.

In addition to the global comparison between dangerous and nondangerous entities, separate analyses were conducted to examine the memory location of dangerous vs. nondangerous animals and natural threats vs. nondangerous natural elements.

***Are the locations of dangerous animals better remembered than those of nondangerous ones?.*** The locations of dangerous animals ($M = 5.16$, $SD = 4.12$) were remembered better than those of nondangerous animals ($M = 6.31$, $SD = 3.79$), $F(1, 85) = 5.61$, $p = .020$, $\eta_p^2 = .062$. The Threat effect was not modulated by age, $F(2, 85) = 0.50$, $p = .611$, $\eta_p^2 = .012$. However, unilateral *t*-tests revealed no significant difference between dangerous and nondangerous animals for location memory among 5-year-old children, $t(27) = 0.42$, $p = .34$, $d_z = .08$. This is in contrast to what occurred among 8-year-old, $t(28) = 2.05$, $p = .025$, $d_z = .38$, and 10-year-old children, $t(30) = 2.41$, $p = .01$, $d_z = .43$.

### Are the locations of natural threats better remembered than the locations of nondangerous natural elements?.

No difference was found in location errors between natural threats and nondangerous natural elements, $F(1, 85) = 1.60$, $p = .209$, $\eta^2_p = 0.018$, regardless of age, $F(2, 85) =$

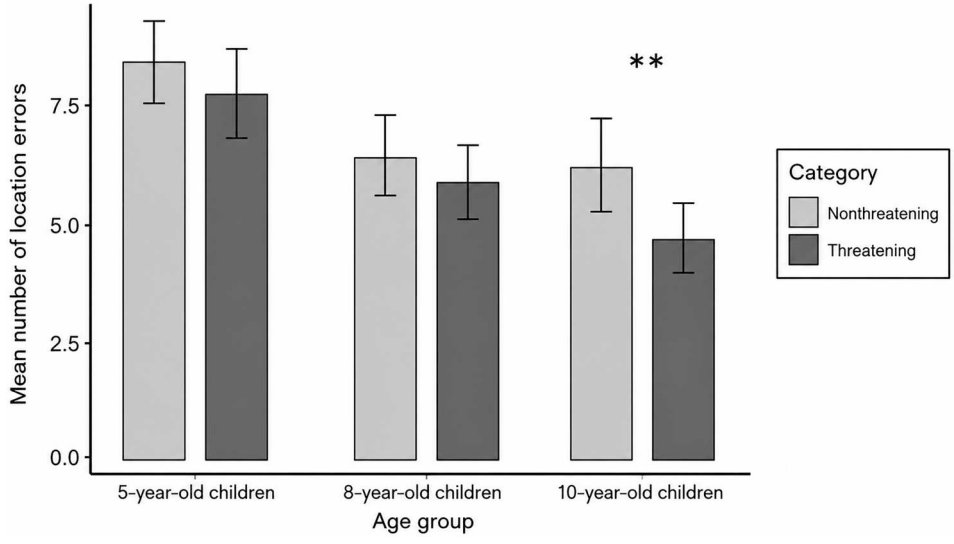


**Figure 2.** Mean number of location errors as a function of category and age for the comparison between threatening and nonthreatening entities.
Note: Error bars represent standard errors of the mean. $^{**}p < .01$.

1.44, $p = .242$, $\eta_p^2 = .033$. Additionally, there was a significant main effect of age, $F(2, 85) = 3.61$, $p = .031$, $\eta_p^2 = .078$, with fewer errors committed with increasing age.

### *Are there differences in location memory scores between modern and evolutionary threats?*

An analysis of the number of location errors revealed no significant effect of Category, $p = .971$, regardless of age, $p = .631$. Thus, participants remembered the locations of modern and evolutionary threats equally well. Additionally, the number of location errors decreased with age, $F(2, 85) = 6.96$, $p = .005$, $\eta_p^2 = .118$.

### *Additional analysis: is there a relationship between the emotional dimensions of the pictures and location memory scores?*

Regarding the comparison between dangerous and nondangerous animals, no correlation was found between valence and location memory scores in 5-year-old children, $r_s(10) = .152$, $p = .319$, contrary to 8- and 10-year-old children, $r_s(10) = .529$, $p = .039$. Spearman's rank correlation analyses also revealed a negative correlation between location memory errors and arousal scores in 8- and 10-year-old children, $r_s(10) = -.636$, $p = .015$. Likewise, emotional intensity was negatively related to location memory errors in 8- and 10-year-old children, $r_s(10) = -.581$, $p = .024$. Thus, the more arousing and emotionally intense the pictures were, the fewer location errors the children aged 8–10 committed. By contrast, no correlations were found in 5-year-old children between location memory scores and either arousal, $p = .389$, or emotional intensity, $p = .280$.

## Discussion

The threat superiority effect in attentional tasks has been widely investigated in both children and adults (e.g., Blanchette, 2006; Fox et al., 2007; Zsido et al., 2019). However, far fewer studies have addressed the impact of threat on memory in children (e.g., Kinzler & Shutts, 2008). The aim of the present study was therefore to extend this line of research by investigating whether threat affects item and location memory in children. We used the same paradigm as in Lhoste et al.'s (2025) Experiment 2. Children played Memory games on a digital tablet to assess location memory and then performed a free recall task to assess item memory. Two games enabled us to compare dangerous vs. nondangerous entities. A third game was designed specifically to compare evolutionary threats to modern threats. Based on prior evidence of attentional and memory biases for threat in children, we predicted that children would exhibit a threat superiority effect in both item and location memory. Regarding the comparison between evolutionary and modern threats, we were agnostic and therefore did not put forward a directional hypothesis due to the mixed findings in the literature (Subra et al., 2017; Zhang & Guo, 2019; Zsido et al., 2018).

### *Comparison between dangerous and nondangerous entities*

#### *Effect of threat on item memory*

Overall, free recall performance improved with age, in line with developmental work showing substantial improvements in free recall between early and middle childhood (e.g., Cole et al., 1971; Geis & Hall, 1978; Puff et al., 1984). In addition, our results revealed a significant effect of threat on item memory: Children aged 5–10 years recalled dangerous items presented during the Memory games better than nondangerous ones. This pattern is consistent with previous studies that have reported a threat superiority effect in both adults (Chapman et al., 2013; Leding, 2019) and children (Kinzler & Shutts, 2008; Prokop & Fančovičová, 2017). To our knowledge, this study is the first to demonstrate such an effect in children as young as 5 years old. This finding may support the adaptive memory view, insofar as it suggests that survival-relevant entities are prioritised in memory (e.g., Nairne et al., 2017; Nairne & Pandeirada, 2016).

However, this pattern of results was restricted to the comparison between dangerous and nondangerous animals. As shown in the detailed analyses, no threat superiority effect emerged when comparing natural threats to nondangerous natural elements. This null result is not easy to account for. Since naming ability can influence memory performance (e.g., Forsberg et al., 2020), we examined whether this factor could explain the lack of a threat effect. However, including naming performance as a covariate did not reveal a significant main effect of threat, suggesting that naming ability did not explain this null result. Another possible explanation is that natural threats are conceptually less familiar to young children than nondangerous natural elements. Conceptual familiarity is here understood as distinct from lexical access, referring to children's knowledge and semantic representation of a concept rather than their ability to retrieve its label. Consistent with this idea, adult-based frequency norms reveal that natural threats are less frequent than nondangerous natural elements in books. However, correlations between frequency norms and free recall performance were observed only in 5-year-old children. Furthermore, despite potential differences in conceptual familiarity, participants' dangerousness ratings clearly indicated the threatening nature of natural threats. This suggests that children clearly distinguished these two categories in terms of perceived dangerousness. From a theoretical perspective, one possibility is that dangerous animals and natural threats differ in their evolutionary relevance. As Shapouri et al. (2023) suggested, "it remains uncertain whether the neural processing of predatory animals and natural disasters necessarily exhibits similarity" (p. 15). Indeed, it can

be argued that dangerous animals have posed more frequent and imminent threats throughout human evolution, favouring the selection of mnemonic biases, as suggested by the idea of prepared social learning regarding dangerous animals in children (Barrett & Broesch, 2012; Broesch et al., 2014). In contrast, natural threats may have posed more sporadic dangers and may not have conveyed the same immediacy or relevance to action as dangerous animals. In addition, natural threats may be more heterogeneous in their form (Štolhoferová et al., 2026) and may not afford a clear or consistent set of adaptive responses, unlike dangerous animals, which may more readily elicit stereotyped action tendencies such as freezing, fleeing, or fighting. Therefore, it is unclear whether animal and natural threats are processed in the same way, meaning they cannot be directly compared.

Overall, further research using a larger number of items will be needed to determine whether the present findings reflect robust category-level effects or, in part, item-level variability.

### *Effect of threat on location memory*

This study demonstrated a threat superiority effect in location memory for the first time, in children aged 8–10. However, as with free recall, this effect was restricted to the animal category.

Location memory is a crucial cognitive component from an adaptive perspective (Nairne et al., 2012; Postma et al., 2008). As stated by Misirlisoy et al. (2019), "for an item to successfully aid the organism's survival, it is essential that the context in which it was encountered is also remembered". Our results support this adaptive memory framework and align with studies showing that source memory for spatial locations in adults is tuned to efficiently process fitness-relevant information (Lhoste et al., 2025; New et al., 2007; Nikakhtar et al., 2025). From an ultimate point of view, it is reasonable to assume that avoiding danger would be prioritised early in development. Threat may strongly influence associative memory processes involved in binding "what" and "where" information. Threatening stimuli robustly recruit emotional systems, such as the amygdala. Through direct projections to the hippocampal formation, the amygdala may facilitate the encoding of spatial location (Phelps, 2004; Song, 2023). Consistent with this claim, we found negative associations between emotional variables (arousal and emotional intensity) and location memory scores in our experiment (see below). However, it is important to mention that no threat superiority effect was found in 5-year-old children for memory location. Younger children's location memory may not be mature enough (e.g., Cestari et al., 2007) to benefit from threat-related enhancement.[2] This aligns with the position of Otgaar et al. (2014) who argue that the development of general memory processes primarily accounts for adaptive memory effects.

### *Comparison between modern and evolutionary threats*

Another objective of the present study was to examine whether the evolutionary relevance of threatening entities influences memory processes in children. Although there is a general consensus on preferential threat (vs. non-threat) processing, there are different views on the relative advantage of evolutionary versus modern threats (e.g., Subra et al., 2017). Studies using attentional paradigms have yielded mixed findings (Erlich et al., 2013; Fox et al., 2007; Subra et al., 2017). To our knowledge, only two studies have compared modern and evolutionary threats in memory tasks in adults. Lhoste et al. (2025) reported no difference in item or location memory between modern and evolutionary threats, whereas Wilson et al. (2011) found superior location memory for evolutionary threats (e.g., dangerous animals) compared to modern threats (e.g., weapons) in a Memory game paradigm.

Our free recall results showing the superiority of modern threats in children align with a soft version of the evolutionary perspective and some previous studies (e.g., Zsido et al., 2019). However, this pattern contrasts with attentional paradigm findings that report an advantage for ancestral threats (e.g., Zhang & Guo, 2019). An important methodological consideration concerns the nature of the stimuli used to represent evolutionary threats in previous studies. To our knowledge, all existing studies have used animate stimuli to represent evolutionary threats and inanimate stimuli to represent modern threats. This approach may conflate threat status with animacy status (Grossi, 2014; Leding, 2019; Sulikowski, 2022). The present study addressed this limitation. However, as discussed above, dangerous animals may not be directly comparable to natural threats despite both being classified as evolutionary threats. Therefore, caution should be exercised when drawing direct comparisons with earlier work.

Despite using identical stimuli and a similar paradigm, children in our experiment recalled more modern threats than evolutionary threats, whereas this was not the case in adults in the Lhoste et al. (2025) study. The source of this discrepancy remains unclear, but an interesting possibility involves developmental differences in stimulus relevance. With increasing experience, natural threats may become more conceptually familiar and acquire a level of relevance comparable to that of modern threats in adults, resulting in no clear prioritisation of one category over the other. In contrast, modern threats such as weapons may be perceived as particularly relevant by children, leading to preferential processing. This interpretation aligns with relevance-based accounts of threat processing, which posit that prioritisation depends on the perceived relevance of a stimulus rather than its evolutionary origin alone (Fox et al., 2007). Nevertheless, this explanation remains speculative and requires direct investigation in future developmental research.

Finally, no difference was observed in location memory scores between modern and evolutionary threats, regardless of age. This aligns with the results of adults in Lhoste et al. (2025), but not in Wilson et al. (2011). However, the latter study did not clearly define how location memory errors were identified. This may make it difficult to compare the two studies. The lack of a location memory advantage also contrasts with the memory benefit for modern threats observed in the free recall task. The discrepancy between location memory and free recall performance may reflect differences in the adaptive relevance of the information retained. From an adaptive perspective, it may be less critical to prioritise the precise spatial location of weapons or natural threats than to retain information about their presence.

### *Role of the emotional dimensions of the pictures*

Threatening stimuli are commonly assumed to benefit from a memory processing advantage because they elicit strong emotional responses. These responses modulate memory through interactions between emotion and memory-related brain regions (e.g., Kensinger, 2007). Several theoretical models emphasise the role of arousal conveyed by threatening stimuli in their memory advantage (LeDoux, 2012, 2022). According to these models (Cahill & McGaugh, 1998; McGaugh, 2000), emotionally intense experiences activate stress-related physiological systems, resulting in hormonal and neuromodulatory changes that engage the basolateral amygdala. The amygdala then modulates the consolidation of memory traces through its extensive structural and functional connections with long-term memory systems (e.g., Kensinger & Corkin, 2004; McGaugh, 2004; Šimić et al., 2021).

Consistent with these accounts, children's danger ratings were highly correlated with adults' ratings of arousal and emotional intensity. Additionally, significant correlations were found between free recall performance and arousal and emotional intensity ratings for animals. Pictures of animals that evoke stronger emotional responses were more likely to be better remembered, regardless of age. Similar patterns of associations were also observed for location memory errors in children aged 8–10. Fewer location memory errors were made for pictures of animals that elicit stronger emotional activation. This was not the case for children aged 5, but these younger children did not exhibit a memory location advantage for dangerous animals. However, it is worth mentioning that these correlational findings do not allow us to determine whether arousal or emotional intensity mediates the relationship between stimulus dangerousness and memory performance. Mediation analyses would have provided additional insight, but they could not be conducted due to substantial collinearity between dangerousness, arousal, and emotional intensity ratings. Thus, the present results support a close association between perceived threat, emotional activation, and memory performance, but do not permit conclusions about the causal mechanisms underlying this relationship.

Before concluding, another potential limitation of the present study is worth mentioning: Arousal and emotional intensity were assessed through subjective ratings rather than objective physiological measures. Therefore, they may reflect explicit evaluations of emotional experience rather than direct indices of physiological arousal. Additionally, these ratings were obtained from adults, whereas memory performance was assessed in children. This may limit the extent to which the ratings capture the actual emotional responses elicited in the child participants. However, this limitation is not unique to the present study, as stimulus ratings are often obtained from adult samples in developmental research (e.g., Kujawa et al., 2012; Solomon et al., 2012).

## Conclusion

Taken together, our results offer interesting insights into the impact of threat-related stimuli on children's memory processes. Overall, our findings are consistent with previous research suggesting an early-developing bias towards dangerous entities, with a threat-related advantage already evident in item memory by the age of 5 and emerging later in location memory, by the age of 8. Furthermore, compared to neutral stimuli, threat-related stimuli appear to engage emotional processing mechanisms that support the binding of item and spatial information in memory. Finally, our findings reveal an interesting distinction between the processing of dangerous animals and natural threats, underscoring the need for future studies to address this issue more directly.

## Notes

1. It should be noted that the study of Lhoste et al. (2025) was conducted in adults. Developmental studies on threat-related memory remain scarce and, when available, differ substantially from the present study in terms of materials and procedure. Nevertheless, the few available child studies provide a useful point of reference. In particular, the effect size reported by Kinzler and Shutts (2008) ($d = .45$) would require a sample size of approximately 36 participants in total (12 per age group), which aligns with the estimate derived from the adult study used here. Estimates derived from Barrett and Broesch (2012) suggest a smaller sample size (approximately 6 per age group).
2. An alternative interpretation is that the memory game used in the present study may have been too cognitively demanding for 5-year-old children to reveal an advantage for specific stimulus categories. Although this task provides an ecologically valid and engaging way to assess location memory, it also involves strategic and decision-making components, including exploration–exploitation trade-offs. Future studies should therefore examine whether similar findings could be obtained with simpler location memory tasks.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Data availability statement

The data are available on the Open Science Framework and can be accessed at https://osf.io/9eqha/overview?view_only=2c2001e23639441ab12de5820b4c21d1.

## ORCID

*Elodie Lhoste* http://orcid.org/0009-0007-4748-2966
*Patrick Bonin* http://orcid.org/0000-0003-1576-863X
*Patrick Bard* http://orcid.org/0000-0001-5464-4766
*Bénédicte Poulin-Charronnat* http://orcid.org/0000-0003-3244-6747
*Annie Vinter* http://orcid.org/0000-0003-4108-6106

## References

Barrett, H. C., & Broesch, J. (2012). Prepared social learning about dangerous animals in children. *Evolution and Human Behavior*, *33*(5), 499–508. https://doi.org/10.1016/j.evolhumbehav.2012.01.003

Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General*, *140*(4), 637–659. https://doi.org/10.1037/a0024060

Blanchette, I. (2006). Snakes, spiders, guns, and syringes: How specific are evolutionary constraints on the detection of threatening stimuli? *Quarterly Journal of Experimental Psychology*, *59*(8), 1484–1504. https://doi.org/10.1080/02724980543000204

Bonin, P., & Méot, A. (2019). Pourquoi avons-nous encore peur des serpents? Apport de la psychologie évolutionniste à la compréhension de certains biais comportementaux. *L'Année psychologique*, *119*(3), 363–396. https://doi.org/10.3917/anpsy1.193.0363

Bonin, P., Poulin-Charronnat, B., Lukowski Duplessy, H., Bard, P., Vinter, A., Ferrand, L., & Méot, A. (2020). Imabase: A new set of 313 colourised line drawings standardised in French for name agreement, image agreement, conceptual familiarity, age-of-acquisition, and imageability. *Quarterly Journal of Experimental Psychology*, *73*(11), 1862–1878. https://doi.org/10.1177/1747021820932822

Bröder, A., Krüger, N., & Schütte, S. (2011). The survival processing memory effect should generalise to source memory, but it doesn't. *Psychology*, *02*, 896–901. https://doi.org/10.4236/psych.2011.29135

Broesch, J., Barrett, H. C., & Henrich, J. (2014). Adaptive content biases in learning about animals across the life course. *Human Nature*, *25*(2), 181–199. https://doi.org/10.1007/s12110-014-9196-1

Brosch, T., & Sharma, D. (2005). The role of fear-relevant stimuli in visual search: A comparison of phylogenetic and ontogenetic stimuli. *Emotion*, *5*(3), 360–364. https://doi.org/10.1037/1528-3542.5.3.360

Burra, N., Pittet, C., Barras, C., & Kerzel, D. (2019). Attentional suppression is delayed for threatening distractors. *Visual Cognition*, *27*(3-4), 185–198. https://doi.org/10.1080/13506285.2019.1593272

Cahill, L., & McGaugh, J. L. (1998). Mechanisms of emotional arousal and lasting declarative memory. *Trends in Neurosciences*, *21*(7), 294–299. https://doi.org/10.1016/s0166-2236(97)01214-9

Cestari, V., Lucidi, A., Pieroni, L., & Rossi-Arnaud, C. (2007). Memory for object location: A span study in children. *Canadian Journal of Experimental Psychology*, *61*(1), 13–20. https://doi.org/10.1037/cjep2007002

Chapman, H. A., Johannes, K., Poppenk, J. L., Moscovitch, M., & Anderson, A. K. (2013). Evidence for the differential salience of disgust and fear in episodic memory. *Journal of Experimental Psychology: General*, *142*(4), 1100–1112. https://doi.org/10.1037/a0030503

Cole, M., Frankel, F., & Sharp, D. (1971). Development of free recall learning in children. *Developmental Psychology*, *4*(2), 109–123. https://doi.org/10.1037/h0030435

Erlich, N., Lipp, O. V., & Slaughter, V. (2013). Of hissing snakes and angry voices: Human infants are differentially responsive to evolutionary fear-relevant sounds. *Developmental Science*, *16*(6), 894–904. https://doi.org/10.1111/desc.12091

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Forsberg, A., Fellman, D., Laine, M., Johnson, W., & Logie, R. H. (2020). Strategy mediation in working memory training in younger and older adults. *Quarterly Journal of Experimental Psychology*, *73*(8), 1206–1226. https://doi.org/10.1177/1747021820915107

Fox, E., Griggs, L., & Mouchlianitis, E. (2007). The detection of fear-relevant stimuli: Are guns noticed as quickly as snakes? *Emotion*, *7*(4), 691–696. https://doi.org/10.1037/1528-3542.7.4.691

Gallup, A. (2022). Do humans possess a superior location memory for snakes? *Letters on Evolutionary Behavioral Science*, *13*(1), 33–39. https://doi.org/10.5178/lebs.2022.96

Gao, H., & Jia, Z. (2017). Detection of threats under inattentional blindness and perceptual load. *Current Psychology*, *36*(4), 733–739. https://doi.org/10.1007/s12144-016-9460-0

Geis, M. F., & Hall, D. M. (1978). Encoding and congruity in children's incidental memory. *Child Development*, *49*(3), 857–861. https://doi.org/10.2307/1128256

Grossi, G. (2014). A module is a module is a module: Evolution of modularity in evolutionary psychology. *Dialectical Anthropology*, *38*(3), 333–351. https://doi.org/10.1007/s10624-014-9355-0

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, *54*(6), 917–924. https://doi.org/10.1037/0022-3514.54.6.917

Hoehl, S., Hellmer, K., Johansson, M., & Gredebäck, G. (2017). Itsy bitsy spider … : Infants react with increased arousal to spiders and snakes. *Frontiers in Psychology*, *8*, 1710. https://doi.org/10.3389/fpsyg.2017.01710

Holmes, A., Mogg, K., de Fockert, J., Nielsen, M. K., & Bradley, B. P. (2014). Electrophysiological evidence for greater attention to threat when cognitive control resources are depleted. *Cognitive, Affective, & Behavioral Neuroscience*, *14*(2), 827–835. https://doi.org/10.3758/s13415-013-0212-4

Howe, M. L., & Derbish, M. H. (2014). Adaptive memory: Survival processing, ancestral relevance, and the role of elaboration. In B. L. Schwartz, M. L. Howe, M. P. Toglia, & H. Otgaar (Eds.), *What is adaptive about adaptive memory?* (pp. 77–109). Oxford University Press.

Howe, M. L., & Otgaar, H. (2013). Proximate mechanisms and the development of adaptive memory. *Current Directions in Psychological Science*, *22*(1), 16–22. https://doi.org/10.1177/0963721412469397

Kensinger, E. A. (2007). Negative emotion enhances memory accuracy: Behavioral and neuroimaging evidence. *Current Directions in Psychological Science*, *16*(4), 213–218. https://doi.org/10.1111/j.1467-8721.2007.00506.x

Kensinger, E. A., & Corkin, S. (2004). Two routes to emotional memory: Distinct neural processes for valence and arousal. *Proceedings of the National Academy of Sciences*, *101*(9), 3310–3315. https://doi.org/10.1073/pnas.0306408101

Kinzler, K. D., & Shutts, K. (2008). Memory for "mean" over "nice": The influence of threat on children's face memory. *Cognition*, *107*(2), 775–783. https://doi.org/10.1016/j.cognition.2007.09.005

Kujawa, A., Klein, D. N., & Hajcak, G. (2012). Electrocortical reactivity to emotional images and faces in middle childhood to early adolescence. *Developmental Cognitive Neuroscience*, *2*(4), 458–467. https://doi.org/10.1016/j.dcn.2012.03.005

Larson, C. L., Aronoff, J., & Stearns, J. J. (2007). The shape of threat: Simple geometric forms evoke rapid and sustained capture of attention. *Emotion*, *7*(3), 526–534. https://doi.org/10.1037/1528-3542.7.3.526

Leding, J. K. (2019). Adaptive memory: Animacy, threat, and attention in free recall. *Memory & Cognition*, *47*(3), 383–394. https://doi.org/10.3758/s13421-018-0873-x

Leding, J. K. (2020). Animacy and threat in recognition memory. *Memory & Cognition*, *48*(5), 788–799. https://doi.org/10.3758/s13421-020-01017-5

LeDoux, J. (2012). Rethinking the emotional brain. *Neuron*, *73*(4), 653–676. https://doi.org/10.1016/j.neuron.2012.02.004

LeDoux, J. E. (2022). As soon as there was life, there was danger: The deep history of survival behaviours and the shallower history of consciousness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *377*(1844), 20210292. https://doi.org/10.1098/rstb.2021.0292

Lété, B., Sprenger-Charolles, L., & Colé, P. (2004). Manulex: A grade-level lexical database from French elementary-school readers. *Behavior Research Methods, Instruments, & Computers*, *36*(1), 156–166. https://doi.org/10.3758/BF03195560

Lhoste, E., Bonin, P., Bard, P., Poulin-Charronnat, B., & Vinter, A. (2025). Animacy and threat influence location memory in adults. *Memory & Cognition*, *53*(7), 2172–2186. https://doi.org/10.3758/s13421-025-01704-1

LoBue, V. (2012). Perceptual biases for threat. In G. W. Mills & S. J. Stone (Eds.), *Psychology of bias* (pp. 37–52). Nova Science Publishers, Inc.

LoBue, V. (2014). Deconstructing the snake: The relative roles of perception, cognition, and emotion on threat detection. *Emotion*, *14*(4), 701–711. https://doi.org/10.1037/a0035898

LoBue, V., & DeLoache, J. (2010). Superior detection of threat-relevant stimuli in infancy. *Developmental Science*, *13*(1), 221–228. https://doi.org/10.1111/j.1467-7687.2009.00872.x

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science*, *19*(3), 284–289. https://doi.org/10.1111/j.1467-9280.2008.02081.x

Makovski, T., Michael, S., & Chajut, E. (2020). How does a threatening stimulus affect the memory of the display? *Quarterly Journal of Experimental Psychology*, *73*(5), 676–687. https://doi.org/10.1177/1747021820905735

McGaugh, J. L. (2000). Memory—A century of consolidation. *Science*, *287*(5451), 248–251. https://doi.org/10.1126/science.287.5451.248

McGaugh, J. L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annual Review of Neuroscience*, *27*(1), 1–28. https://doi.org/10.1146/annurev.neuro.27.070203.144157

Misirlisoy, M., Tanyas, H., & Atalay, N. B. (2019). Does survival context enhance memory for source? A within-subjects comparison. *Memory*, *27*(6), 780–791. https://doi.org/10.1080/09658211.2019.1566928

Nairne, J., & Pandeirada, J. (2010). Adaptive memory: Nature's criterion and the functionalist agenda. *The American Journal of Psychology*, *123*(4), 381–390. https://doi.org/10.5406/amerjpsyc.123.4.0381

Nairne, J. S. (2022). Adaptive education: Learning and remembering with a stone-age brain. *Educational Psychology Review*, *34*(4), 2275–2296. https://doi.org/10.1007/s10648-022-09696-z

Nairne, J. S., & Pandeirada, J. N. S. (2016). Adaptive memory: The evolutionary significance of survival processing. *Perspectives on Psychological Science*, *11*(4), 496–511. https://doi.org/10.1177/1745691616635613

Nairne, J. S., Pandeirada, J. N. S., & Fernandes, N. L. (2017). Adaptive memory. In J. H. Byrn (Ed.), *Learning and memory: A comprehensive reference* (pp. 279–293). Elsevier. https://doi.org/10.1016/B978-0-12-809324-5.21060-2

Nairne, J. S., VanArsdall, J. E., Pandeirada, J. N. S., & Blunt, J. R. (2012). Adaptive memory: Enhanced location memory after survival processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(2), 495–501. https://doi.org/10.1037/a0025728

New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers*, *36*(3), 516–524. https://doi.org/10.3758/BF03195598

New, J., Krasnow, M. M., Truxaw, D., & Gaulin, S. J. C. (2007). Spatial adaptations for plant foraging: Women excel and calories count. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1626), 2679–2684. https://doi.org/10.1098/rspb.2007.0826

Nikakhtar, A., Prokop, P., & Zabihzadeh, A. (2025). Remembering the orchard: Evolutionary biases in spatial memory for forageable plants. *Evolutionary Psychological Science*, *11*(2), 195–206. https://doi.org/10.1007/s40806-025-00434-6

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*(3), 466–478. https://doi.org/10.1037/0096-3445.130.3.466

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology*, *80*(3), 381–396. https://doi.org/10.1037/0022-3514.80.3.381

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*, *108*(3), 483–522. https://doi.org/10.1037/0033-295X.108.3.483

Öhman, A., & Soares, J. J. (1998). Emotional conditioning to masked stimuli: Expectancies for aversive outcomes following nonrecognized fear-relevant stimuli. *Journal of Experimental Psychology: General*, *127*(1), 69–82. https://doi.org/10.1037/0096-3445.127.1.69

Otgaar, H., Howe, M. L., Smeets, T., & Garner, S. R. (2014). Developmental trends in adaptive memory. *Memory*, *22*(1), 103–117. https://doi.org/10.1080/09658211.2013.781653

Pakai-Stecina, D. T., Hout, M. C., Bali, C., & Zsido, A. N. (2024). Can the processing of task-irrelevant threatening stimuli be inhibited? – The role of shape and valence in the saliency of threatening objects. *Acta Psychologica*, *243*, 104150. https://doi.org/10.1016/j.actpsy.2024.104150

Peléšková, Š, Polák, J., Janovcová, M., Chomik, A., Sedláčková, K., Frynta, D., & Landová, E. (2024). Human emotional evaluation of ancestral and modern threats: Fear, disgust, and anger. *Frontiers in Psychology*, *14*, 1321053. https://doi.org/10.3389/fpsyg.2023.1321053

Phelps, E. A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. *Current Opinion in Neurobiology*, *14*(2), 198–202. https://doi.org/10.1016/j.conb.2004.03.015

Postma, A., Kessels, R., & Vanasselen, M. (2008). How the brain remembers and forgets where things are: The neurocognition of object–location memory. *Neuroscience & Biobehavioral Reviews*, *32*(8), 1339–1345. https://doi.org/10.1016/j.neubiorev.2008.05.001

Postma, A., & van der Ham, I. J. M. (2017). Keeping track of where things are in space: The neuropsychology of object location memory. In A. Postma & I. J. M. van der Ham (Eds.), *Neuropsychology of space: Spatial functions of the human brain* (pp. 231–265). Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-801638-1.00007-0

Prokop, P., & Fančovičová, J. (2017). Animals in dangerous postures enhance learning, but decrease willingness to protect animals. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(9), 6069–6077. https://doi.org/10.12973/eurasia.2017.01000a

Puff, C. R., Tyrrell, D. J., Heibeck, T. H., & Van Slyke, D. A. (1984). Encoding activities and free recall of categorized and

noncategorized pictures by young children. *Bulletin of the Psychonomic Society*, *22*(5), 389–392. https://doi.org/10.3758/BF03333853

Rakison, D. H. (2018). Do 5-month-old infants possess an evolved detection mechanism for snakes, sharks, and rodents? *Journal of Cognition and Development*, *19*(4), 456–476. https://doi.org/10.1080/15248372.2018.1488717

Rakison, D. H., & Derringer, J. (2008). Do infants possess an evolved spider-detection mechanism? *Cognition*, *107*(1), 381–393. https://doi.org/10.1016/j.cognition.2007.07.022

Shapouri, S., Martin, L. L., & Arhami, O. (2023). Affective responses to natural and technological disasters; an evolutionary perspective. *Adaptive Human Behavior and Physiology*, *9*(3), 308–322. https://doi.org/10.1007/s40750-023-00224-z

Šimić, G., Tkalčić, M., Vukić, V., Mulc, D., Španić, E., Šagud, M., Olucha-Bordonau, F. E., Vukšić, M., & Hof, P. R. (2021). Understanding emotions: Origins and roles of the amygdala. *Biomolecules*, *11*(6), 823. https://doi.org/10.3390/biom11060823

Solomon, B., DeCicco, J. M., & Dennis, T. A. (2012). Emotional picture processing in children: An ERP study. *Developmental Cognitive Neuroscience*, *2*(1), 110–119. https://doi.org/10.1016/j.dcn.2011.04.002

Song, J. (2023). Amygdala activity and amygdala-hippocampus connectivity: Metabolic diseases, dementia, and neuropsychiatric issues. *Biomedicine & Pharmacotherapy*, *162*, 114647. https://doi.org/10.1016/j.biopha.2023.114647

Štolhoferová, I., Hladíková, T., Janovcová, M., Peterková, Š, Frynta, D., & Landová, E. (2026). Subjective and psychophysiological response to pictures of ancestral and modern threats: Not all evolutionary threats are alike. *PLoS One*, *21*(3), e0343680. https://doi.org/10.1371/journal.pone.0343680

Subra, B., Muller, D., Fourgassie, L., Chauvin, A., & Alexopoulos, T. (2017). Of guns and snakes: Testing a modern threat superiority effect. *Cognition and Emotion*, *32*(1), 81–91. https://doi.org/10.1080/02699931.2017.1284044

Sulikowski, D. (2022). Are natural threats superior threats? *Evolution and Human Behavior*, *43*(1), 34–43. https://doi.org/10.1016/j.evolhumbehav.2021.08.003

Thrasher, C., & LoBue, V. (2016). Do infants find snakes aversive? Infants' physiological responses to "fear-relevant" stimuli. *Journal of Experimental Child Psychology*, *142*, 382–390. https://doi.org/10.1016/j.jecp.2015.09.013

van Buren, B., & Scholl, B. J. (2017). Minds in motion in memory: Enhanced spatial memory driven by the perceived animacy of simple shapes. *Cognition*, *163*, 87–92. https://doi.org/10.1016/j.cognition.2017.02.006

Waters, A. M., & Lipp, O. V. (2008). The influence of animal fear on attentional capture by fear-relevant animal stimuli in children. *Behaviour Research and Therapy*, *46*(1), 114–121. https://doi.org/10.1016/j.brat.2007.11.002

Wilson, S., Darling, S., & Sykes, J. (2011). Adaptive memory: Fitness relevant stimuli show a memory advantage in a game of pelmanism. *Psychonomic Bulletin & Review*, *18*(4), 781–786. https://doi.org/10.3758/s13423-011-0102-0

Wolters, L. H., de Haan, E., Vervoort, L., Hogendoorn, S. M., Boer, F., & Prins, P. J. M. (2012). The time-course of threat processing in children: A temporal dissociation between selective attention and behavioral interference. *Anxiety, Stress & Coping*, *25*(3), 259–273. https://doi.org/10.1080/10615806.2011.581278

Yang, E., Zald, D. H., & Blake, R. (2007). Fearful expressions gain preferential access to awareness during continuous flash suppression. *Emotion*, *7*(4), 882–886. https://doi.org/10.1037/1528-3542.7.4.882

Yorzinski, J. L., Penkunas, M. J., Platt, M. L., & Coss, R. G. (2014). Dangerous animals capture and maintain attention in humans. *Evolutionary Psychology*, *12*(3), 534–548. https://doi.org/10.1177/147470491401200304

Zhang, S., & Guo, Q. (2019). Superiority effect in detecting phylogenetic threats under unattentional condition: A visual mismatch negativity study. *Journal of Psychology Research*, *9*(9), 353–370. https://doi.org/10.17265/2159-5542/2019.09.002

Zsido, A. N., Csatho, A., Matuz, A., Stecina, D., Arato, A., Inhof, O., & Darnai, G. (2019). Does threat have an advantage after all? – Proposing a novel experimental design to investigate the advantages of threat-relevant cues in visual processing. *Frontiers in Psychology*, *10*, 2217. https://doi.org/10.3389/fpsyg.2019.02217

Zsido, A. N., Deak, A., Losonci, A., Stecina, D., Arato, A., & Bernath, L. (2018). Investigating evolutionary constraints on the detection of threatening stimuli in preschool children. *Acta Psychologica*, *185*, 166–171. https://doi.org/10.1016/j.actpsy.2018.02.009