



“In your head, zombie”: zombies, predation and memory

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ABSTRACT

Imagining fictional creatures like zombies in survival situations boosts long-term memory for words encoded in these situations more than rating words for pleasantness (zombie effect). Study 1 required word-ratings in a zombie-survival scenario; participants were told they had to protect against either possible zombie attack or contamination. The zombie-survival situations yielded identical recall levels but higher recall rates than pleasantness. Study 2 matched a zombie-survival scenario on perceived fear with scenarios involving ghosts or predators. Perceived disgust in the zombie scenario was higher than in these other survival conditions. Words were remembered better when processed in survival scenarios than when rated for pleasantness, but there was no reliable difference in recall between the scenarios. In neither study did the number of death-related words produced in a word-fragment completion task fit the mortality salience account of the zombie memory effect. Overall findings suggest that this effect relates to the fear system.

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Predation, and more precisely the relationship between predators and prey, has been a major selection pressure for many living creatures (Barrett, 2016). Human ancestors have also been subject to predation in the distant past (Hart & Sussman, 2008; Treves & Palmqvist, 2007), and one hypothesis is that the brains of modern humans bear the imprints of this selection pressure (Isbell, 2006). Indeed, a large body of evidence suggests that our perceptual and attentional processes have been shaped by predation (Isbell, 2009). For instance, children and adults detect dangerous animals, such as snakes or lions, more quickly than non-dangerous animals (e.g. LoBue & DeLoache, 2008; Öhman, Flykt, & Esteves, 2001; Penkunas & Coss, 2013; Prokop, 2018; Yorzinski, Penkunas, Platt, & Coss, 2014). Even babies have a perceptual and attentional bias to snakes and spiders (Hoehl & Pauen, 2017; Hoehl, Hellmer, Johansson, & Gredebäck, 2017). Recent findings at the neural level (Dhum, Herwig, Opialla, Siegrist, & Brühl, 2017) have also shown stronger activation of the amygdala in response to photographs corresponding to evolutionary threats (e.g. snakes, spiders, bears) compared to both modern threats (e.g. guns,

knives) and neutral items. From a general standpoint, adults detect animates more quickly, and more accurately, than inanimates (e.g. Abrams & Christ, 2003; New, Cosmides, & Tooby, 2007; Öhman, Flykt, et al., 2001; Öhman, Lundqvist, & Esteves, 2001; Pratt, Radulescu, Guo, & Abrams, 2010; Yang et al., 2012) because they correspond to living entities that are capable of self-propulsion and can suddenly change direction without warning. These preferences were also found in two-day old newborns (Simion, Regolin, & Bulf, 2008), suggesting that they are innate, rather than learned. In the distant past, animates were often predators or prey that required great levels of monitoring: the animacy monitoring hypothesis (New et al., 2007). As yet, however, there has been less work on the relationship between predation and long term memory than between predation and perceptual-attentional processes.

We know from Nairne and colleagues' research that information processed in relation to survival and/or to reproduction is remembered better than information not processed for its fitness value, i.e. the adaptive memory view (Nairne, 2010; Nairne & Pandeirada, 2008, 2010). One well-investigated

type of evidence in favour of this view is that words processed for their relevance in a survival scenario are memorised better than words processed in non-survival scenarios (e.g. moving to a foreign land), or than words encoded deeply (e.g. rating words for their pleasantness) (Nairne, Thompson, & Pandeirada, 2007). This memory effect – referred to as *the survival processing advantage* – has been replicated a number of times (see Bonin & Bugajska, 2014 and Kazanas & Altarriba, 2015, for reviews) and is therefore robust in an explicit memory test, whereas evidence for this effect is lacking in implicit memory tasks (McBride, Thomas, & Zimmerman, 2013; Tse & Altarriba, 2010; Wilck & Altarriba, *in press*).

In the original survival scenario (Nairne et al., 2007), three types of survival problems are mentioned: (1) finding food, (2) finding potable water and (3) protecting from predators. It could therefore be asked whether all three problems contribute to the generation of the survival processing advantage, or whether one problem out of the three, is more important. There is evidence suggesting that predation, as well as finding food, are important dimensions underlying the survival processing advantage. Nairne and Pandeirada (2010) first determined that mentioning only predation in an ancestral survival scenario is able to boost memory compared to a non-survival scenario, i.e. moving to a foreign land. In another study, Nairne and Pandeirada (2010) demonstrated that rating words for their relevance, when searching for nourishment in a survival scenario (searching for and gathering edible plants in grasslands), enhanced free recall compared to rating words for their pleasantness. Interestingly, Kroneisen and Erdfelder's (2011) findings revealed that when the survival scenario was limited to "finding potable water", the survival advantage did not emerge compared to a control condition corresponding to a moving scenario. The mere observation that encoding words in relation to protecting from predators yields a memory advantage compared to encoding words in a non-survival context (Nairne & Pandeirada, 2010) strongly suggests that predation is an important dimension underpinning the survival processing advantage. Also of interest is the finding that the level of threat manipulated within the survival scenario – predators that are easy to detect and avoid vs. are difficult to detect and avoid – has been found to increase the survival processing advantage (Olds, Lanska, & Westerman, 2014). It has also been

determined that when pictures of animals were shown in dangerous postures, the information placed below these images of aggressive-looking animals was remembered better than the information placed below neutral-looking animals (Prokop & Fančovičová, 2017). Finally, when humans are perceived as potentially dangerous (e.g. angry males), their faces are also remembered better (Jackson, Wu, Linden, & Raymond, 2009; Tay & Yang, 2017).

Our study expands upon the adaptive memory literature, and more precisely, it is conceptualised as a follow-up to Soderstrom and McCabe's (2011) study. In this fascinating study, the authors have shown that thinking that fictional creatures such as zombies – that are clearly predators (Nairne, 2014) and can even be envisioned as super-predators (Kazanas & Altarriba, 2017) – are threatening your life has the effect of boosting long term memory of words that had been encoded in relation to this survival situation compared to a deep encoding condition such as judging words for their pleasantness. We shall refer to this effect hereafter as the *zombie effect*. Interestingly, they also found that words encoded in a survival scenario involving zombies were also remembered better than the same words encoded in an ancestral (or a modern) survival scenario involving realistic predators (or attackers). The survival processing advantage discovered by Nairne and his colleagues has been qualified as "(...) one of the best – if not *the* best – encoding procedures yet identified in human memory research (...)" (Nairne, Pandeirada, & Thompson, 2008, p. 180), and as far as we know, this claim has proven to be true with one exception, namely Soderstrom and McCabe (2011) who found that zombie processing was even more effective in boosting memory than the original survival processing scenario. Thus, the reason why zombie processing is so effective in enhancing memory is an issue which we believe has not as yet received the attention it deserves (Nairne & Pandeirada, 2016).

Zombies have become increasingly popular in recent years (Clasen, 2017). Zombies are clearly *fictional* creatures. As a result, they did not exist in the deep past such as the Pleistocene, and therefore, they have never been a threat to our remote ancestors. Zombies have three distinctive features, however, that make them special: (1) They are *living-dead* creatures, (2) They are *disgusting* agents, and (3) They are *fearsome* creatures. Soderstrom and McCabe (2011) put forward two potential

accounts of zombie effects in direct relation with these three features. They did not, however, submit these accounts to an empirical test. To quote these authors: “*Perhaps survival scenarios that included zombies led to the activation of ‘death and disgust systems’, making this threat more salient*” (p. 568). Thus, zombie effects could be due to (1) their potential to activate death-related thoughts, (2) the activation of the disgust system, or as suggested by Soderstrom and Cleary (2014), (3) the activation of the fear-related system. As we shall now explain, these three hypotheses are likely to account for the zombie effect in memory. From an evolutionary point of view, emotions such as fear or disgust have evolved to help us cope with a range of survival issues such as signalling dangers in the environment (see Al-Shawaf, Conroy-Beam, Asao, & Buss, 2016; Oaten, Stevenson, & Case, 2009, for reviews).

According to the mortality salient account, the zombie effect in memory would be due to the fact that zombies activate death-related thoughts. Supportive evidence for the idea that mortality salience is beneficial to memory was initially provided by Hart and Burns (2012). They showed that inducing mortality salience yielded better memory performance on recall tests compared to several control conditions (mundane or aversive, like watching TV, experiencing paralysis or dental pain). This effect has been called the “Dying To Remember (DTR) effect” (Burns, Hart, & Kramer, 2014; Burns, Hart, Kramer, & Burns, 2014). The DTR effect was later replicated by Bugajska, Mermillod, and Bonin (2015). Bugajska et al. (2015) found that when individuals were first reminded of their future death, and were then instructed to process unrelated words, these were recalled better than when participants had to think about an aversive event such as dental pain. The superiority of recall under the mortality salience condition would be due to the fact that thoughts of death engage more relational or elaborative processing (Hart & Burns, 2012). Importantly, Burns, Hart, and Kramer (2014) introduced the hypothesis that survival processing induces a mortality salient state which mediates the survival processing advantage. In effect, according to Burns, Hart, and Kramer (2014), if the survival and the DTR effects are underpinned by similar proximate mechanisms, both effects on memory performance should be redundant. To test this hypothesis, both mortality salience and survival processing were manipulated within a study. In the first

step, adults had to write about either death or dental pain, and then were instructed to rate the words according to their pleasantness value or their relevance to an ancestral survival scenario. Better recall of words was found in the mortality salience condition than in the dental pain condition after the words were rated for their pleasantness. The benefit in memory of processing words after a mortality induction was not found, however, after the words were rated for their relevance in a survival situation. According to Burns, Hart, and Kramer (2014), these findings suggest that the processing induced by mortality salience overlaps with the processing required by the survival task, and thus, that the survival processing advantage is underpinned by death-related thoughts. This account has been challenged, however (Bell, Röer, & Buchner, 2013; Bugajska et al., 2015; Klein, 2014).

A second account is that zombies activate the fear-related system (Kazanas & Altarriba, 2017; Soderstrom & Cleary, 2014). Fear is an emotion that is able to activate the neural systems that boost memory (Chapman, Johannes, Poppenk, Moscovitch, & Anderson, 2013; McKinnon et al., 2015; Palombo et al., 2016). It has been shown that information related to dangerous-looking animals (Prokop & Fančovičová, 2017), photos depicting guns or sharks (Chapman et al., 2013), which therefore trigger fear, are remembered better than non-dangerous-looking animals, or photos of neutral objects. Threatening conspecifics are identified better than non-threatening conspecifics (e.g. angry outgroup members: Ackerman et al., 2006; attractive rivals: Maner, Miller, Rouby, & Gailliot, 2009), and it has been found that when self-protective goal states are activated, faces perceived stereotypically as threatening (e.g. faces of men from out-groups) are remembered well (Becker et al., 2010). Thus, the zombie effect in memory could be due to the fact that these imaginary creatures are threatening, and more specifically, *fearsome* (Kazanas & Altarriba, 2017).

In relation to the classical survival scenario, and not specifically to the zombie survival scenario, Olds et al. (2014) claimed that: “(...) *the threat of imminent bodily harm or sickness may be the factor that best explains the survival processing advantage*” (p. 33–34). Indeed, another source of threat is pathogens, which can be conceived of as “micro-predators” and have the potential to contaminate us. Pathogens can be transmitted through things that elicit disgust such as blood, feces, vomit, etc., and when people are shown photographs of disgusting

things, these are remembered better than photographs of things that do not look disgusting (Chapman, 2018; Chapman et al., 2013; Prokop, Fančovičová, & Fedor, 2014). More precisely, Chapman et al. (2013) found that disgusting pictures were remembered better than both fear-inducing and neutral pictures when important dimensions were controlled for (arousal, valence). Objects touched by sick people, who are well recognised as such by others due to the presence of cues indicating contamination (Axelsson et al., 2018), were remembered better than those touched by healthy people (Bonin, Thiebaut, Witt, & Méot, 2019; Fernandes, Pandeirada, Soares, & Nairne, 2017). Disgusting behaviour is also remembered better (Bell & Buchner, 2010). It therefore remains a possibility that the zombie effect in memory is due to the activation of the emotion of disgust. This is a core component of the behavioural immune system (Schaller & Park, 2011), which consists of mechanisms that have evolved to protect us from contamination. At a proximate level, one possibility is that imagining zombies triggers certain disgust-related neural substrates that are known to boost memory, such as the insula (Calder, Keane, Manes, Antoun, & Young, 2000), the connection between the insula and the hippocampus (Augustine, 1996), or some interaction of the insula with the amygdala (Chapman, 2018). Since disgusting things are memorised even better than fear-inducing things (Chapman et al., 2013), the zombie effect could be attributable to the disgust they induce more than to the fact that zombies are also fearsome living-dead agents.¹

We designed two studies to test the above hypotheses. In the first study, the participants had to rate words in three different encoding conditions: two survival conditions and one control condition which was the same as that used by Soderstrom and McCabe (2011), namely pleasantness. Pleasantness is a deep encoding condition that is often used to evaluate the processing survival advantage (e.g. Kazanas & Altarriba, 2017; Nairne & Pandeirada, 2010; Olds et al., 2014). In one survival condition, participants had to rate the relevance of words in a survival condition involving zombies, as in the original scenario of Soderstrom and McCabe's (2011) study. The instructions were modified slightly, however, in order to specify to the participants that

they had to protect themselves from zombies specifically because *they could attack them*. In another survival scenario, exactly the same instructions were used except that participants were told to protect themselves from zombies because they could *be contaminated by them*. Finally, in the control condition, participants had to rate words for their pleasantness. Our general prediction was that, compared to the control condition, both zombie-scenarios should lead to an enhanced memory for words. More importantly, if zombies mostly induce disgust, and the zombie effect is due to the activation of disgust evolved mechanisms, then the contamination-oriented scenario should yield a better memory performance than the fear-oriented scenario. In a second study, we opted for a different procedure to test the disgust hypothesis of the zombie effect; the rationale will be presented later when introducing Study 2. Finally, we tested in both studies the hypothesis that the zombie effect in memory could be due to death-thought activation. In order to measure the extent to which death thoughts had been activated in the zombie scenarios, compared to the control pleasantness rating condition, we used an implicit word-fragment completion task (as used in Bugaiska et al., 2015). This task has been used successfully to test several hypotheses related to a very influential theory in social psychology: the Terror Management Theory (TMT, e.g. Greenberg, Pyszczynski, & Solomon, 1986; Hayes, Schimel, Arndt, & Faucher, 2010; Pyszczynski, Solomon, & Greenberg, 2015). A number of studies have shown that after a mortality salience induction, not immediately but after a delay, unconscious death-related thoughts are activated. Thus, if thinking about zombies acts as a mortality prime boosting memory, one should observe that more thoughts related to death are activated in the zombie scenarios than in the control pleasantness condition, as indexed by the implicit word-fragment completion task.

Study 1. Zombies: attacking or contaminating agents

In the following study, words were encoded into two survival conditions: one in which the focus was made on predation, and one in which the focus was made

¹Fear stimulates sympathetic pathways, heightening information processing which consequently captures human attention (Krusemark & Li, 2011). In contrast, disgust activates parasympathetic pathways (de Jong, van Overveld, & Peters, 2011) reducing the heart rate, blood pressure and respiration (Gilchrist, Vrinceanu, Bédard, Bacon, & Ditto, 2016), which suggests that disgust and fear may have opposing effects on sensory perception and attention (Buck et al., 2018).

on contamination. The control condition was pleasantness. We anticipated a survival processing advantage, that is to say, more words should be recalled in the two survival-zombie conditions than in the pleasantness condition. More importantly, we predicted that if mentioning zombies induces the emotion of disgust more than fear, because disgusting things are remembered better than both fearsome and neutral things (Chapman, 2018; Chapman et al., 2013), the zombie scenario focusing on contamination should yield a better memory performance than the zombie scenario focusing on fear. (Alternatively, if zombies induce fear far more than disgust, perhaps the reverse pattern of results on recall rates should be found.) Finally, if the zombie effect in memory is underpinned by mortality salience, both scenarios should activate death thoughts to the same extent, and the recall rates should not reliably differ between the two scenarios. However, importantly, for the latter hypothesis to be valid, more words related to death should be completed in the implicit word-fragment completion task after the two zombie scenarios than after the pleasantness judgement task.

Method

Participants

One hundred and five students (90 females; mean age 19.68 years) at the University of Bourgogne were involved and were divided into three groups ($n = 35$ in each group) that differed on the encoding condition. All were native speakers of French, received course credits for their participation and none were taking medication known to affect the central nervous system. The number of participants per condition was chosen on the basis of Scofield, Buchanan, and Kostic's (2018) meta-analysis of the survival-processing advantage in memory. The set of studies included in their analysis for between-subjects designs had a mean of 37.5 participants per group. If we take as an η_p^2 estimation the centre of the interval given by Scofield et al. (.06; .09), that is to say .075, our study has a power of .73.²

Stimuli

The word list was exactly the same as the list used by Nairne et al. (2007, Experiments 2–4), translated into French.

Procedure

The participants were tested individually and were seated comfortably in a quiet room. They were assigned to one of the three encoding conditions (zombie-attack vs. zombie-contamination vs. pleasantness). For the grasslands–zombie scenarios, the instructions used were similar to the ones used by Soderstrom and McCabe (2011). The changes from the original instructions were the following. In the zombie-contamination condition, the instructions stated that they had to pay increased attention to zombies because they were disgusting and they could contaminate them. In the zombie-predator condition, the words *disgusting* and *contaminate* were replaced by the words *fearsome* and *attack* respectively. More precisely:

Survival-zombie conditions: "In this task, we would like you to imagine that you are stranded in the grasslands of a foreign land, without any survival equipment. In the coming months, you will have to find stable supplies of food and water and protect yourself from **zombies**. You will have to pay great attention to the zombies because they are **disgusting [fearsome]** and they could **contaminate [attack] you**. We will present you with a list of words and we want you to rate the relevance of each word in the survival situation."

In the pleasantness condition, the participants had to rate the words for their pleasantness.

The words were presented, centred on the screen, until the participant's response and different random orders were used across participants. The ratings were made by pressing a key (indicated 1 to 5, with 1 = not at all relevant and 5 = extremely relevant) on the keyboard. After the encoding task, the participants had to perform two interference tasks that lasted about three minutes: the "X-O" letter-comparison task (Salthouse, Toth, Hancock, & Woodard, 1997) and the "plus-minus" task from Jersild (1927) and Spector and Biederman (1976). The surprise recall test took place immediately after the two interference tasks. The participants had five minutes to write down the previously presented words in any order they liked. After the recall task, the participants were given a word-completion task to assess the accessibility of death-related thoughts. The task consisted of five words that were related to death, five words that were negative and twelve that were neutral words.

²Power was computed using the cumulative non central F distribution function available in IBM SPSS® version 24. It corresponds to the probability to obtain a value in the region of the null hypothesis rejection, given the group size and the estimated effect size.

Table 1. Mean (*M*) and standard deviations (*SD*) of encoding times (in ms), ratings (1–5), correct recall rates and number (proportion in brackets) of extra-list intrusions as a function of the different encoding conditions in Study 1.

	Zombie-contamination		Zombie-predator		Pleasantness	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Encoding times	2054	345	2168	560	2036	567
Ratings	2.68	0.47	2.85	0.45	3.12	0.31
Correct recall	.48	.114	.50	.123	.40	.117
Intrusions	1.00 (.07)	1.59 (.10)	1.54 (.10)	2.20 (.12)	.83 (.08)	.98 (.09)

Note: Proportions of intrusions are computed as the number of extra-list items divided by the total number of items reported by the participant.

Results and discussion

The mean encoding times and the mean ratings (together with their standard deviations), the mean correct recall rates and their standard deviations, and number of extra-list intrusions are reported in Table 1.

Encoding times (msec) and relevance ratings

As far as the time taken to rate the words is concerned, the ANOVA did not indicate a reliable effect of Type of encoding, $F < 1$, $\eta_p^2 = .014$. There was a significant effect of the Type of encoding factor on the relevance ratings, $F(2, 102) = 10.31$, $p < .001$, $\eta_p^2 = .168$. The difference between pleasantness and zombie-contamination was significant, $t(102) = 4.5$, $p < .001$, $\delta = 1.08^3$ as was the difference between pleasantness and zombie-predator, $t(102) = 2.79$, $p = .006$, $\delta = .67$. The difference, however, between the two zombie conditions was not reliable, $t(102) = -1.71$, $p = .09$, $\delta = -.41^4$.

Recall rates

A reliable effect of Type of Encoding was found, $F(2, 102) = 7.44$, $p < .001$, $\eta_p^2 = .127$. More words were recalled in both survival conditions – zombie-contamination and zombie-predation – than in the pleasantness condition (see Table 1), and the differences were significant for the first comparison, $t(102) = 2.97$, $p = .004$, $\delta = .71$, as well as for the second comparison, $t(102) = 3.62$, $p < .001$, $\delta = .87$, while the difference in recall rates between the two zombie conditions was not significant, $t(102) = -0.65$, $p = .516$, $\delta = -.16$.

Concerning the numbers of extra-list intrusion (Table 1), they did not differ reliably across the

different encoding conditions, $F(2, 102) = 1.75$, $p = .179$, $\eta_p^2 = .033$.

Word completion

As can be seen from Table 2, more death-words were completed compared to negative-words, $F(1,102) = 13.73$, $p < .001$, $\eta_p^2 = .119$. Neither the main effect of Type of Encoding, nor the interaction between Type of words and Type of Encoding, was significant, both $F_s < 1$, $\eta_p^2 = .007$ and $\eta_p^2 = .017$.

In summary, a general survival processing advantage was found on the recall rates. Contrary to our expectation that the zombie-contamination scenario would yield a higher recall rate than the zombie-predator scenario, we found that these two encoding conditions did not differ significantly. Given that disgusting things are remembered better than fearsome things (Chapman, 2018; Chapman et al., 2013), this finding suggests that the emotion of disgust was not more involved in the zombie-contamination scenario than in the zombie-predator scenario, and that, perhaps, the zombie effect in memory is not underpinned by the threat of contamination. Alternatively, we cannot exclude the possibility that our experimental manipulation was not successful in disentangling fear from disgust when thinking about the threat of zombies. Indeed, perceived fear of some predatory animals like snakes correlate with perceived disgust (Matchett & Davey, 1991; Prokop & Fančovičová, 2013) which further complicate disentanglement of the influences of these two emotions in humans. Finally, the implicit word completion task yielded no support for the mortality salience account of the zombie effect.⁵ In Study 2, we opted for a different procedure to test further the hypothesis

³For between-subjects designs, δ was computed as the ratio of the difference between the observed means over the square root of the mean square error.

⁴For all follow-up analyses, uncorrected pairwise comparisons were compared with the results found using a Tukey correction. Only the disagreement between the two procedures is mentioned in the text.

⁵It may be asked whether the procedure was appropriate to capture death-thought accessibility because in the TMT literature thoughts of death are activated after a mortality induction but only after a delay (e.g. Hayes et al., 2010; Schimel, Hayes, Williams, & Jahrig, 2007). Indeed, the delay is a critical issue when accessing death-thought activation (see Steinman & Updegraff, 2015, for a thorough discussion) and it could be argued that the

Table 2. Mean numbers (and standard deviations in parenthesis) of death and negative words that were completed after the different encoding conditions.

	Zombie-contamination	Zombie-predator	Pleasantness
Death-words	1.40 (.65)	1.23 (.84)	1.11 (.68)
Negative-words	0.83 (.78)	0.86 (.85)	0.89 (.90)

that the zombie effect in memory is driven by the threat of contamination (with disgust as an associated emotion) or, alternatively, by the threat of predation (with fear as an associated emotion).

Study 2. Zombies, ghosts and predators

Our general working hypothesis is that if zombies induce a specific emotion (e.g. fear) which subserves the zombie effect in memory, then encoding words in a scenario that is matched to the zombie encoding scenario in term of the emotion in question (e.g. fear), should yield a retention performance similar to that found when encoding words in the survival-zombie scenario. In a pre-experiment, we aimed at finding other imaginary creatures than zombies that were matched on either the level of disgust or of fear they elicited.

Pre-experiment

We initially selected the following fictional creatures: mummy, ghost, werewolf, vampire, because they are well-known by undergraduates who are generally the participants in memory experiments. We also included “predator” because it was used in the original survival scenario (Nairne et al., 2007) and serves as a standard for evaluating the survival processing advantage. The participants had to rate the above-mentioned creatures for their potential to elicit the emotions of disgust and fear.

Method

Participants

Seventy-eight adults (mean age: 19.69, range: 17–25) were recruited via different Facebook groups of students in psychology.

Stimuli and procedure

The questionnaire was created using Limesurvey and was performed online by the participants. There were two questions that assessed, via Likert scales (0–8), the levels of perceived fear and disgust respectively for zombie, werewolf, vampire, mummy, ghost, predator (e.g. To what extent do you feel fear/disgust about *name of the creature*? 0 = not at all, 8 = a lot). The two questions were randomly presented to the participants with the Likert scale below each question. The participants responded at their own pace. The survey took about five minutes to complete.

Results and discussion

Concerning fear, pairwise comparisons between zombie (Z) and other creatures were not significant with two of them: ghost ($M_Z = 4.94$, $SD = 2.21$ vs. $M = 4.87$, $SD = 2.39$), $t(77) = .206$, $p = .837$, $d = .04$,⁶ and predator ($M = 4.55$, $SD = 2.17$), $t(77) = 1.38$, $p = .171$, $d = .18$. Moreover, with $t(77) = 2.17$, $p = .033$, $d = .32$, the difference with werewolves was also not significant when using the Šidák correction. As far as perceived disgust is concerned, zombie had significantly higher perceived disgust scores than both ghost ($M_Z = 5.94$, $SD = 1.94$ vs. $M = 1.01$, $SD = 1.58$), $t(77) = 17.17$, $p < .001$, $d = 2.78$, predator ($M = 2.68$, $SD = 2.40$), $t(77) = 10.62$, $p < .001$, $d = 1.49$, and werewolves ($M = 1.68$, $SD = 1.81$), $t(77) = 16.23$, $p < .001$, $d = 2.27$. The difference between perceived fear and perceived disgust was higher for ghost than for predator, $t(77) = 5.43$, $p < .001$, $d = .77$, and werewolves, $t(77) = 3.75$, $p < .001$, $d = .57$, but failed to reach the significance between predator and werewolves, $t(77) = -1.84$, $p = .069$, $d = -.28$. It is worth mentioning that zombie turned out to be the unique creature yielding more perceived disgust than fear, $t(77) = 4.28$, $p < .001$, $d = .48$. (See Figure 1A in the Supplementary Material for a depiction of the means (and their 95% confidence intervals) of the ratings obtained for perceived fear and perceived disgust for the different creatures.)

Based on the ratings of fear and disgust, two fictional creatures – ghost and werewolves – could

delay we introduced between the end of word encoding and the beginning of the word completion task was not long enough. We used a delay after word presentation of about 480 s, however, i.e. a distractor task of about 3 min or 180 s plus a free recall task of about 5 min or 300 s, which is not shorter compared to many TMT studies in which evidence for death thought accessibility has been reported after a mortality induction (Steinman & Updegraff, 2015). In Bugaiska et al.'s (2015) work on the role of death thoughts in long term memory, evidence for death-thought accessibility was found after an explicitly mortality induction (i.e. writing about your own death) with a slightly shorter delay (a free recall task lasting about 5 min or 300 s) than the one used here.

⁶In order to describe changes in the original metric, d was computed as if independent t tests were computed (see, e.g. Kline, 2013, pp. 134–136).

be matched with the zombie creature on perceived fear while at the same time being lower on perceived disgust. As (1) the difference between zombie and werewolves on fear was not significant when a correction was applied to pairwise comparisons, whereas the difference between zombie and ghost was not significant even with no correction applied, and (2) the difference between fear and disgust was more pronounced for ghost than for werewolves, we decided to select the ghost creature as a fictional creature for the following memory experiment. Predator was also included since it refers to real creatures and is matched with both zombie and ghost in terms of perceived fear. Moreover, a predator has also always been part of the classical survival scenario (e.g. Nairne et al., 2007).

Thus, on the basis of this pre-experiment, we were able to select one imaginary creature – ghost – that was matched with zombie and predator in terms of perceived fear. Zombie elicited a higher level of perceived disgust than either ghost and predator.

Memory experiment

Method

In this experiment, the participants were randomly assigned to one of the following three survival scenarios: zombie, ghost or predator. As in Study 1, we used pleasantness as a control condition. The inclusion of the predator condition permitted us to assess whether the zombie scenario would lead to better recall than the predator scenario, as found by Soderstrom and McCabe (2011). However, and more interestingly, we tested whether the zombie survival condition would bring about better memory performance than both the ghost *and* the predator conditions, since the latter two conditions were matched with the zombie condition on the level of perceived fear, whereas the zombie condition elicited more perceived disgust than either the ghost or predator conditions. The latter pattern of results would fit with the hypothesis that the zombie effect is due to the activation of the disgust-related system. Once again, we tested the hypothesis that the zombie effect on memory could be due to death-thought activation in the same way as in the previous study. Finally, the participants (apart from those in the pleasantness condition) were required to provide retrospective ratings of valence and arousal for each scenario as in Soderstrom and McCabe's (2011) study.

Participants

One hundred and eighty-four students (157 females; mean age: 20.12 years) at the University of Bourgogne were involved in the study and were divided into 4 groups ($n=46$ participants per group corresponding to the four encoding conditions). As in the previous study, they were native speakers of French and received course credits. None were taking medication known to affect the central nervous system. As for Study 1, power was estimated on the basis of the same information provided by Scofield et al. (2018). With a .075 estimated η_p^2 value, power was estimated as being equal to .91 at the .05 significance level.

Stimuli

The word list was the same as that used in the previous study.

Procedure

The procedure was the same as that in Study 1. The instructions for the survival-zombie scenario was the same as in the ancestral zombie scenario used in Soderstrom and McCabe (2011). The word *zombie* was replaced by *ghost* and *predator*, respectively to create the corresponding scenarios. The pleasantness condition was the same as in Study 1. After a distraction phase of three minutes, the recall test phase lasted five minutes. After the recall phase, the participants were involved in the word-fragment completion task as used in Study 1. In the last step of the study, they were again presented with the scenarios in which their ratings were based during the encoding phase. Below the scenario were 9-point scales in order to rate the scenario on the dimensions of valence (1 = happy and 9 = sad) and arousal (1 = excited and 9 = calm). All the questionnaires were anonymous, completed alone in a quiet room.

Results and discussion

Encoding times (msec) and relevance ratings

Encoding times (see Table 3) did not reliably differ between the four encoding conditions, $F(3, 180) = 2.18, p = .092, \eta_p^2 = .035$. The rating scores (Table 3) were also significantly different between the four encoding conditions, $F(3, 180) = 15.58, p < .001, \eta_p^2 = .206$. The mean ratings were higher in the pleasantness condition than in all other conditions, zombie: $t(180) = 5.48, p < .001, \delta = 1.14$; ghost: $t(180) = 5.72, p < .001, \delta = 1.19$; predator: $t(180) =$

Table 3. Mean (*M*) and standard deviations (*SD*) of encoding times (in ms), ratings (1–5), correct recall rates and number (proportion in brackets) of extra-list intrusions as a function of the different encoding conditions in Study 2.

	Zombie		Ghost		Predator		Pleasantness	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Encoding times	2139	707	2130	469	2107	538	1872	602
Ratings	2.75	.45	2.73	.47	2.75	.41	3.23	0.34
Correct recall	.54	.126	.52	.123	.50	.112	.43	.106
Intrusions	.70 (.04)	1.28 (.07)	.70 (.05)	.81 (.06)	.74 (.05)	1.24 (.08)	.52 (.04)	.86 (.07)

Note: Proportions of intrusions are computed as the number of extra-list items divided by the total number of items reported by the participant.

5.54, $p < .001$, $\delta = 1.15$. Differences between the other conditions were not reliable (all $|t| < 1$).

Recall rates

The main effect of Type of encoding was significant, $F(3, 180) = 7.39$, $p < .001$, $\eta_p^2 = .110$. The mean in the recall rate in the pleasantness condition was significantly lower than the corresponding mean in the zombie, $t(180) = -4.45$, $p < .001$, $\delta = -.92$, predator, $t(180) = -3.02$, $p = .003$, $\delta = -.63$, and ghost, $t(180) = -3.50$, $p < .001$, $\delta = -.73$, conditions. The recall rate was not significantly higher for zombies than for predators, $t(180) = 1.43$, $p = .154$, $\delta = .30$. Also, the recall rate differences between ghost and zombie, $t(180) = -.95$, $\delta = -.20$, and between ghost and predator, $t(180) = .48$, $\delta = .10$, were not significant (See note 3). Finally, the number of extralist intrusions (Table 3) was not significantly different between the different encoding conditions, $F < 1$, $\eta_p^2 = .006$.

To sum up, general survival processing effects were found on the memory performance. However, and importantly, all the pairwise comparisons involving the predator condition turned out to be non-significant.

Word completion

The mean (and standard deviations) corresponding to the number of death and negative words that were completed are provided in Table 4. As found in the previous study, the participants completed more death-words than negative-words, $F(1, 180) = 7.29$, $p = .008$, $\eta_p^2 = .039$. The main effect of Type of Encoding was significant, $F(3, 180) = 4.40$, $p = .005$, $\eta_p^2 = .068$. The interaction effect was significant, $F(3, 180) = 3.50$, $p = .017$, $\eta_p^2 = .055$. The simple effects of Type of encoding were significant for both death-related words, $F(3, 180) = 3.14$, $p = .027$, $\eta_p^2 = .050$, and negative words, $F(3, 180) = 4.62$, $p = .004$, $\eta_p^2 = .071$.

Table 4. Mean numbers (and standard deviations in parenthesis) of death and negative words that were completed after the different encoding conditions in Study 2.

	Zombie	Ghost	Predator	Pleasantness
Death-words	1.17 (.77)	1.43 (.91)	0.96 (.63)	1.09 (.76)
Negative-words	.98 (.77)	1.07 (.90)	1.15 (.97)	.54 (.75)

$\eta_p^2 = .071$. For death-related words, post-hoc comparisons revealed that the number of completed words was significantly higher in the ghost condition than in the pleasantness, $t(180) = 2.16$, $p = .032$, $\delta = .45$, and predator conditions, $t(180) = 2.97$, $p = .003$, $\delta = .62$. (With a Tukey correction only the difference with predator was significant.) The finding that more death-related word fragments were completed in the ghost condition than in the pleasantness condition is worth noting because it shows that our measure of death-thought activation was sufficiently sensitive. For negative-words, the number of completed words was significantly lower in the pleasantness condition than in all other scenarios (zombie: $t(180) = -2.44$, $p = .016$, $\delta = -.51$; ghost: $t(180) = -2.93$, $p = .004$, $\delta = -.62$; predator: $t(180) = -3.42$, $p < .001$, $\delta = -.71$). (With a Tukey correction the difference between pleasantness and zombie was marginally significant, $p = .073$).

Valence and arousal ratings

Both valence and arousal ratings were analysed using a one-way repeated measure design with the three scenarios involving creatures as the independent variable. Valence ratings differed significantly between the different scenarios involving creatures, $F(2, 366) = 12.30$, $p < .001$, $\eta_p^2 = .063$. The differences between zombie ($M = 6.46$, $SD = 1.81$) and ghost ($M = 6.16$, $SD = 1.55$) and predator ($M = 5.77$, $SD = 1.78$) were both significant, $t(183) = 2.20$, $p = .029$, $\delta = .17^7$ and $t(183) = 4.75$, $p < .001$, $\delta = .40$,

⁷In order to describe changes in the original metric in within-subjects designs, δ was computed as the ratio of the difference between the observed means over the square root of the mean square error obtained as if a between participants design was used (see, e.g. Kline, 2013, p. 199).

whereas the mean valence associated with the scenario involving the ghost creature was more positive than that for the predator condition, $t(183) = 2.83$, $p = .005$, $\delta = .22$. Note that with the Šidák correction, the significant difference between zombie and ghost vanished.

As far as arousal ratings are concerned, the differences were also significant, $F(2, 366) = 3.76$, $p = .024$, $\eta_p^2 = .02$. The ghost scenario ($M = 3.45$, $SD = 1.84$) was less arousing than both the zombie ($M = 3.14$, $SD = 1.86$; $t(183) = 2.18$; $p = .031$, $\delta = .17$) and predator ($M = 3.05$, $SD = 1.78$; $t(183) = 2.43$, $p = .016$, $\delta = .21$) conditions. As found for valence, the significant difference between zombie and ghost vanished when the Šidák correction was applied. In contrast to Soderstrom and McCabe (2011) who found that participants rated the zombie scenarios (in the city or in the grasslands version) as more arousing than the predator scenarios, we did not find such a difference on arousal ratings. Importantly, the patterns of findings on both valence and arousal do not mirror that on correct recall rates. It is worth mentioning that the inclusion of valence or arousal ratings as covariables in the recall rates analyses did not change the results. Further assessment of arousal and valence with physiological sources (e.g. peripheral signals and EEG signals, see Chanel, Kronegg, Grandjean, & Pun, 2006) are required.

General discussion

According to evolutionary psychologists, our cognition is still peculiarly attuned toward processing issues that our ancestors faced during the distant past, such as finding food and potable water and protecting from predators (e.g. Buss, 2011). Fitting with this assumption is the now well-established finding that processing words for their relevance in finding food, water, and protecting from predators when stranded in the grasslands of a foreign land yields better memory than when rating words for their relevance in a non-survival context: the survival processing advantage. Soderstrom and McCabe (2011) have found, however, that thinking that zombies, instead of predators, were stranded in the grasslands or inside a city, also had the effect of boosting memory for words encoded in these fictional scenarios compared to encoding words for their pleasantness. Given that zombies are imaginary creatures, and thus did not exist in the distant past, one might argue that this finding is a serious “threat” to an evolutionary account of the

survival processing advantage. The question is consequently: does the fictional nature of zombies really weaken an evolutionary account of the survival processing advantage?

The adaptative memory view, according to which our memory systems were tuned to process threatening information better than non-threatening information, does not assume that threats need to be threats that existed in the distant past. Insofar as fictional creatures such as zombies are able to activate self-protection systems (Nairne, 2014; Tenga & Zimmerman, 2013), they can be as effective as real creatures that humans were faced with in the distant past. An ultimate explanation of the zombie effect in memory is that these fictional creatures indeed possess characteristics of real predators, and given that predators have been a strong selection pressure on primates (Barrett, 2016; Hart & Sussman, 2008; Isbell, 2009; Treves & Palmqvist, 2007), our modern brains react to creatures that look dangerous, even though they did not exist in the distant past. As argued by Olds et al. (2014): “*It is likely the case that ancestral-like contexts readily invoke feelings of threatened survival, yet other modern, fictional, or far-fetched contexts may do the same as well*” (p. 33).

We were able to replicate the classical survival processing advantage since we found better memory performance when words were encoded in relation to a survival situation involving predators than when they were rated for their pleasantness. Also of importance was the finding that there was a processing advantage with the imaginary creatures corresponding to zombies and ghosts. The key issue we tried to address in the current research was what exactly underpins the zombie effect. Before discussing further, some readers may ask themselves whether it makes sense to continue to talk of a “zombie effect” as an established phenomenon when, given the current findings it seems to be absent. Indeed, we have talked about the “zombie effect” throughout the paper because, until now, zombie processing had proven to be even more effective in boosting memory than the original survival processing scenario which was remarkable enough to be qualified as such since, as stated earlier, the survival processing effect discovered by Nairne and his colleagues has been claimed to be one of the best encoding procedures yet discovered in the memory field (Nairne et al., 2008).

As discussed below, we believe that our studies make an important contribution by demonstrating

that the zombie effect is due neither to the activation of death-related thoughts, nor to the activation of the disgust-related system, but in all probability, to the activation of the fear-related system. From a general standpoint, our findings suggest that only scenarios that include a direct threat to survival (and thus elicit fear) lead to a mnemonic advantage (for a similar claim see Tay, Jonason, Li, & Cheng, 2019).

Before going further in discussing the proximate explanations of the zombie effect, it might be argued that the zombie effect in memory (as well as the ghost-effect found here, see also Kostic, McFarlan, & Cleary, 2012) is simply due to general fears about things that are unknown (Kazanas & Altarriba, 2017), and that our remote ancestors learned to fear unknown things. We are not of the opinion, however, that such an account is supported by our data. In effect, we found that the ghost and zombie scenarios led to a similar level of performance in recall than the predator scenario. Kazanas and Altarriba (2017) came to the conclusion that a survival scenario including a supernatural predator – a demon – yielded a higher level of word recall compared to rating words for their pleasantness. However, contrary to the idea that our hunter-gather ancestors feared unknown creatures, and that the survival advantage could be due to undefined fears, they found that the demon scenario did not yield higher recall as the classical predator scenario. We consequently share Kazanas and Altarriba's (2017) view that fear of predation in our hominid ancestors was to a large extent shaped by threats that they regularly encountered, i.e. real predators like bears, lions or saber tigers, and not to general fears of unknown things.

Soderstrom and McCabe's (2011) study was framed in the debate about whether or not the survival processing advantage required real issues pertaining to the distant past in order to be obtained, and their study was not therefore aimed at providing some explanations of zombie effects in terms of proximate mechanisms. In their General Discussion, the authors merely speculated about potential accounts of zombie effects in memory. Indeed, the goal of the present research was precisely to assess the merits of several accounts of the zombie effect. These are now discussed in turn.

First of all, the findings from the present studies do not provide support for the idea that the zombie effect is due to the activation of death-related thoughts. In effect, in the implicit word-fragment

completion tasks, we did not find that there were definitively more words related to death completed after rating words for their relevance to the zombie scenario compared to the pleasantness condition. Interestingly, however, ghosts are also related to death, and we indeed observed that more death-related words were completed in the word-fragment completion task after the words had been encoded in the ghost scenario compared to both the pleasantness, and to some extent predator, encoding conditions. However, the pattern of recall rates found in Study 2 does not fit well with the hypothesis that mortality salience is a key factor underpinning the global survival advantage (and in particular the zombie- and ancestral-survival advantage) found here. Indeed, our findings accord with previous findings in the literature that failed to find evidence supporting the idea that the survival processing advantage was related to mortality salience (e.g. Bugajska et al., 2015).

Second, Soderstrom and McCabe (2011) put forward the interesting idea that the zombie effect in memory could be due to the involvement of the disgust-related system, and more generally the behavioural immune system because the emotion of disgust is a core component of this defense system (Schaller & Park, 2011). Indeed, zombies are by definition disgusting entities since they are corpses that are living. They comprise putrid matters which are disgusting and potential contaminating agents. Our ratings confirm that zombies are perceived as disgusting entities, far more than other fictional or real creatures, such as ghosts or predators, respectively. Given that disgusting things have been found to be better memorised than both fear and neutral things (Chapman, 2018; Chapman et al., 2013), we predicted that the survival-zombie scenario should yield better recall than both the survival-ghost and the survival-predator scenarios if the disgust-related system was activated to some extent.

In Study 1, we did not find that framing the scenario in terms of contamination yielded a memory advantage compared to framing it in terms of predation, but both recall rates of words were higher after rating words in the two zombie scenarios than after rating them for their pleasantness. This is in agreement with recent views suggesting that both disgust and fear have ultimately a protective function, albeit both could act differently on human perception (Buck, Weinstein, & Young, 2018). In Study 2, we did not replicate the superior recall of words after

encoding words in a zombie scenario compared to the predator scenario, as found by Soderstrom and McCabe (2011). It is worth stressing that this specific difference in recall rates was not anticipated by these authors. Indeed, we did not find that the zombie scenario led to a higher recall rate than both the ghost and the predator scenarios. Because the three survival scenarios were matched to perceived fear, this pattern of recall rates fits better with the idea that the zombie effect is due to the activation of mechanisms related to fear, and not to mechanisms related to disgust. Overall, our findings, along with Kazanas and Altarriba's (2017) findings, suggest that the fear-related system is involved in the zombie effect in memory. Indeed, fear-inducing stimuli, but not disgust-inducing stimuli, heighten information processing, arousal and attention (Krusemark & Li, 2011), which might result in better recall rates. A further test of the latter hypothesis would be to demonstrate that psychophysiological factors related to threat and to the emotion of fear are involved in the zombie effect. Indeed, Fiacconi, Dekraker, and Köhler (2015) used measures of heart rate, in addition to affective ratings, to index the presence of fear bradycardia which is a marker of the defensive freezing response. They found that when encoding words within a classical survival scenario, i.e. protecting from predators, there was a larger deceleration in heart rate for the survival scenario compared to the moving scenario, suggesting that autonomic fear responses are engaged in the former scenario. Future studies on the zombie effect could therefore benefit from using psychophysiological measures.

Perhaps the fear-related system does not run in isolation and instead triggers a set of additional mechanisms that have the potential to boost memory. One popular proximate mechanism put forward to account for the survival processing advantage is elaboration (see Erdfelder & Kroneisen, 2014; Howe & Otgaar, 2013 and Nairne, 2014 for reviews) and indeed the zombie effect is a specific case of the survival processing advantage. Thus, one hypothesis could be that the zombie effect is just another case of a scenario promoting greater levels of elaboration. According to this account, the survival processing advantage would be due to the fact that the survival-zombie scenario provides a rich encoding context (Kroneisen & Erdfelder, 2011; Röer, Bell, & Buchner, 2013). When words are rated for their relevance in a survival situation, this

triggers more elaborative processing than other types of control scenarios (e.g. moving scenario) or other deep encoding conditions (e.g. pleasantness). It cannot be excluded that the zombie scenario triggers more elaborative processing and our findings do not speak to this issue since our studies were not aimed at testing the elaboration account of the zombie effect. There are findings in the literature, however, suggesting that the survival processing advantage in general, and therefore the zombie processing advantage in particular, is not reducible to situations involving a large amount of elaboration. To take one example, contrary to the claim made by Kroneisen and Erdfelder (2011) that reducing the number of survival problems in a scenario yield less elaboration (and less distinctive encoding), and thus to a reduction of the recall rates compared to the original survival scenario including all three survival problems, Nairne and Pandeirada (2010) have also found a survival processing advantage when only one survival problem was included in the survival scenario, namely "protection from predators".

We want to acknowledge a potential limitation of our findings resulting from the use of pleasantness as a control condition. It is important to stress, however, that the use of a pleasantness rating as a control condition when evaluating survival effects in memory is an issue which is not specific to our studies. Indeed, this condition has been – and still is – widely used as a benchmark control condition in the literature on the survival processing advantage (Nairne, Coverdale, & Pandeirada, *in press*). Pleasantness is thought to be a quintessential form of "deep processing" (Nairne, Pandeirada, VanArsdall, & Blunt, 2015) and one of the most powerful types of deep encoding leading to long-term retention (Packman & Battig, 1978). It is worthy of note that other deep encoding procedures have been employed as control conditions in order to test for a survival processing advantage in memory, such as self-reference, imagery, or generation tasks (see Nairne & Pandeirada's, 2008, Figure 2, p. 242). The use of a pleasantness rating instead of a scenario-based control condition (e.g. moving to a foreign city) as a control condition raises the possibility that any mnemonic benefits due to survival processing is due to "general scenario processing". If this were indeed the case, it would undermine our conclusion that the zombie and ghost scenarios test the role of fear in the survival processing effect. However, several studies

have found that, when compared to the pleasantness control condition, certain survival/reproduction scenarios did not yield memory benefits (e.g. a mating scenario [Klein, 2013; Sandry, Trafimow, Marks, Rice, & Poyatos, 2013]; a jealousy scenario [Sandry et al., 2013]). This should certainly not be the case if the survival processing effect were due to general scenario processing. Interestingly, certain studies have found that the memory performance in the pleasantness condition did not differ significantly from performance in schematic control conditions such as moving house (e.g. Nairne et al., 2007). Other criticisms that might be levelled at the use of the pleasantness rating task as a control for assessing survival effects are as follows: The survival and pleasantness conditions are not matched for the length of the instructions (namely a short paragraph in the survival conditions but seemingly only a sentence in the control condition); the survival conditions are perceived as more fun, novel, positive (or alternatively negative) or engaging than the pleasantness condition. However, survival processing advantages have been found when compared to various control conditions involving novelty and excitement (Kang, McDermott, & Cohen, 2008), negativity (Bell et al., 2013), or positivity (Yang, Lau, Truong, & Paterson, 2014). More importantly, survival effects have been found when words were rated *in exactly the same activities* (e.g. search for food), but in a context that varied on the fitness dimension, i.e. to survive (fitness-relevant) vs. To win a scavenger hunting contest (fitness-irrelevant) (Nairne, Pandeirada, Gregory, & Van Arsdall, 2009), and, more recently, in a survival generation task (e.g. the word DOOR is presented and the participants have to think of a survival situation in which this object is involved) (Nairne et al., *in press*). Of course, we welcome future research that looks further into the issue of how best to evaluate the survival processing advantage in memory.

In conclusion, the present findings suggest that the zombie effect in memory is due neither to mortality salience, nor to the activation of the disgust-related system, but is, as claimed by Soderstrom and Cleary (2014), rooted in all probability in the fear of predation that has long been a strong selection pressure on our remote ancestors. To test further the idea that the survival processing advantage in memory is related to fear, one should observe that different levels of fear in different survival scenarios are associated with different effects on

memory. Indeed, this represents an avenue for future research.

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