Adaptive Memory: Thinking About Function

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Abstract

Rating the relevance of words for the imagined situation of being stranded in the grasslands without survival material leads to exceptionally good memory for these words. This survival processing effect has received much attention because it promises to elucidate the evolutionary foundations of memory. However, the proximate mechanisms of the survival processing effect have to be identified before informed speculations about its adaptive function are possible. Here, we test and contrast 2 promising accounts of the survival processing effect. According to the 1st account, the effect is the consequence of the prioritized processing of threat-related information. According to the 2nd account, thinking about the relevance of items for survival stimulates thinking about object function, which is a particularly elaborate form of encoding. Experiment 1 showed that the emotional properties of the survival scenario, as manipulated by the negative or positive framing of the scenario, did not influence recall. A focus on threat at encoding led to worse recall than a focus on function. The latter finding was replicated in Experiment 2, which further showed that focusing on threat did not lead to a memory advantage over a pleasantness control condition. The beneficial effect of inducing a functional focus at encoding even surpasses that of the standard survival processing instruction. Together, the results support the theory that thinking about function is an important component of the survival processing effect.

Keywords: Adaptive memory, emotional memory enhancement, encoding instructions, valence framing

Adaptive Memory: Thinking About Function

In the survival processing paradigm (Nairne & Pandeirada, 2008; Nairne, Pandeirada, & Thompson, 2008; Nairne, Thompson, & Pandeirada, 2007), participants are required to imagine themselves being stranded in the grasslands, deprived of food and water, and in danger of predators. Thereafter a list of items is presented, which participants are asked to rate according to their relevance in this situation. Eventually, the rating task is followed by a surprise memory test. Usually, a robust survival-processing effect is obtained, that is, enhanced memory after encoding under survival instructions compared to a range of control instructions including intentional encoding (Nairne & Pandeirada, 2008; Nairne et al., 2007, 2008). This finding has received much attention because it promises to shed light upon the evolutionary origins of memory. The proximate mechanisms behind the survival processing effect are yet to be identified, although different types of explanations have been brought forward so far, including stress (Smeets, Otgaar, Raymaekers, Peters, & Merckelbach, 2012), arousal (Kang, McDermott, & Cohen, 2008), threat (Olds, Lanska, & Westerman, 2014; Soderstrom & McCabe, 2011), mortality salience (Burns, Hart, Kramer, & Burns, 2014), self-referential encoding (Klein, 2012), richness of encoding (Kroneisen & Erdfelder, 2011; Röer, Bell, & Buchner, 2013), and planning (Klein, Robertson, & Delton, 2010, 2011). Such proximate explanations have been discussed as being opposed to evolutionary explanations of the survival processing effect (e.g., Bröder, Krüger, & Schütte, 2011), but identifying the proximate mechanisms may actually be a prerequisite for reasonable speculations about the evolutionary origins of this effect. Here, we contrast two promising proximate explanations of the survival processing effect. According to the first explanation, the effect is the consequence of the prioritized processing of threat-related information. According to the second explanation, thinking about the relevance of items for survival stimulates thinking about object function, which is a particularly elaborate form of encoding.

A central assumption of evolutionary psychology is that the human cognitive architecture can be viewed as a package of specialized modules that regulate human behavior in adaptive ways. According to Tooby and Cosmides (2005) the main aim of evolutionary psychology is to "dissect [the] computational architecture into functionally isolable information processing units— programs—and to determine how these units operate" (p. 25). They described this research strategy as *reverse engineering*: "Evolutionary psychologists (...) approach the study of the mind like an engineer. You start by carefully specifying an adaptive information processing problem; then you do a task analysis of that problem. A task analysis consists of identifying what properties a program would have to have to solve that problem well. This approach allows you to generate hypotheses about the structure of the programs that comprise the mind, which can then be tested" (p. 16).

Nairne and colleagues share the interest in the evolutionary origins of cognition, but their approach is in many ways opposed to the research strategy outlined above (cf. Nairne et al., 2007). (a) It does not start with a specific adaptive problem, which allows to derive testable hypotheses about the kinds of mechanisms that may have evolved to solve it. Although staying alive is naturally one of the ultimate goals of human beings, the concept is much too broad

to allow for the identification of specific memory mechanisms that may have evolved to solve the problem of survival. (b) Lumping together different evolutionary domains, such as foraging and predator avoidance, is incompatible with the assumption of massive modularity. (c) While "a common requirement of evolutionary shaped behavioral systems is their relative selectivity with regard to the input to which they respond" (Öhman & Mineka, 2001, p. 485), the survival processing effect is reliably demonstrated with randomly sampled verbal and pictorial stimulus material. (d) Even though memory plays a key role in specific adaptive problems such as foraging (e.g., remembering the distinction between edible and poisonous mushrooms) or predator avoidance (e.g., remembering the hiding place of a tiger), it is far from evident how reproducing a list of unrelated words may help to increase one's fitness in these contexts. (e) The adaptive problems that may have led to the survival processing effect, and the mechanisms responsible for it, are yet to be identified.

In the following, we discuss two potential mechanisms of the survival processing effect that have been proposed in the literature. We demonstrate that the evolutionary foundations of the effect are not self-evident as they are likely to depend on these proximate mechanisms. One influential idea, originally proposed by Nairne et al. (2007), is that the survival processing advantage is due to emotion or arousal. Stimuli that pose imminent threats for health or survival (guns, snakes, aggressive faces, decaying bodies, or spoiled food), or are relevant for reproduction (erotic stimuli) are usually perceived as being highly emotional, and the effects of emotion on attention and memory have been amply demonstrated (e.g., Kensinger, 2007). The hypothesis suggests itself that the survival processing advantage is nothing more than a variant of these well-known influences of emotion on cognition that lead to a prioritization of survival-relevant stimuli. However, this hypothesis should be viewed with caution because the effects of emotion on memory are not straightforward. Although emotional events are often vividly remembered (e.g., Kensinger, 2007), emotion does not have uniformly positive effects on memory. For instance, memory for emotionally neutral events encoded in emotionally distressing situations is often decreased, or simply not affected by emotion (Levine & Edelstein, 2009). Furthermore, the emotional memory enhancement is often reduced when conditions are blocked (Schmidt & Saari, 2007; Talmi & McGarry, 2012), while the survival processing effect is reliably obtained in between- subjects designs (Nairne & Pandeirada, 2008), which may also reduce the plausibility of an emotional mediation account.

With respect to the survival processing literature, there is little evidence that the survival processing advantage is mediated by stress (Smeets et al., 2012) or emotional arousal (Kang et al., 2008; Soderstrom & McCabe, 2011). However, several studies support the assumption that the survival processing effect is determined by the perceived threat associated with imagining oneself being stranded in the grasslands, without food and water, and in danger of being attacked by predators (Olds et al., 2014; Soderstrom & McCabe, 2011). For instance, Soderstrom and McCabe (2011) were able to show that increasing the threat level of the scenarios by exchanging the word “predators” with “zombies” led to a reinforcement of the effect. Given that predation has always been an important force in the evolution of mammals, the threat hypothesis points to a possible role of a threat module of ancient evolutionary origin, which may be located in phylogenetically old subcortical midbrain and limbic regions (e.g., Öhman & Mineka, 2001).

An alternative hypothesis that was originally proposed by Nairne et al. (2007), too, is that the survival processing effect is due to active elaboration (Kroneisen & Erdfelder, 2011; Röer et al., 2013). We use the term “active” to describe these elaborative processing mechanisms because they are much more likely to be under cognitive control than the operations of ancient evolutionary threat modules described above (e.g., Öhman & Mineka, 2001). Thinking about using randomly sampled objects for survival in the grasslands can be considered a broad, difficult problem-solving task that requires participants to perform many operations on the word material at a "deep," semantic level (Kroneisen & Erdfelder, 2011; Kroneisen, Erdfelder, & Buchner, 2013; Röer et al., 2013). Klein et al. (2010, 2011) have argued that the survival processing effect is mediated by a planning component. When confronted with a novel situation, planning necessarily includes problem solving. A central component of planning and problem solving is thinking about the function of objects, that is, thinking about how to use a certain object to reach a specified goal. Memory is naturally an intrinsic part of problem solving and planning, which involve both the retrieval of former episodes and multimodal simulation to determine an object's function (Morris & Ward, 2005). According to Deák (2006, p. 1), "the central cognitive achievement in human tool-use is the capacity to remember and flexibly imagine (i.e., simulate), different possible events in which an agent uses objects to cause effects." The assumption that thinking about function represents a particularly elaborate way of processing an object's meaning is also inherent in the HIPE model of function (Barsalou, Sloman, & Chaigneau, 2005), which implies that object functions are dynamically constructed and actively simulated using multimodal knowledge about (a) how (H) an object is supposed to be used and has been previously used, (b) an agent's intentions (I) and goals when using the object, (c) the physical environment (P) that determines an object's use, and (d) the event sequence (E) that involves the object's behavior and its effects (Oakes & Madole, 2008).

It has long been acknowledged that function is one of the most basic semantic properties of objects (Miller & Johnson-Laird, 1976). Children may acquire concepts of objects on the basis of function by manipulating them (Nelson & Ware, 2002), or by observing the use of objects (Booth, Schuler, & Zajicek, 2010), and the importance of function still increases in later years (Deák, Ray, & Pick, 2002). The central role of functional information is also evident from the finding that the functional properties of concrete nouns are rapidly and effortlessly activated, suggesting that function is a primary factor in categorization (Moss, McCormick, & Tyler, 1997; Myung, Blumstein, & Sedivy, 2006). Studies with dementia patients confirm this conception by showing that semantic deficits are associated with disrupted object use (Bozeat, Ralph, Patterson, & Hodges, 2002; Silveri & Ciccarelli, 2009). Not surprisingly, thinking about the functional properties of things is one of the standard levels-of-processing manipulations to induce "deep" elaborative semantic encoding

(Schacter & Cooper, 1993). Note that an object may serve many functions such that thinking about function may leave many traces in memory through which the object can later be retrieved. In essence, thinking about function may be one of the driving forces of the survival-processing effect. Again, this hypothesis has implications for the possible evolutionary foundations of the survival processing effect. Flexibility in tool use, problem solving and planning are some of the most striking features of human intelligence, and depend on structures of the cerebral cortex that have undergone dramatic changes during our most recent evolutionary past (Ambrose, 2001; Reader & Laland, 2002).

As set out above, it is difficult to reasonably consider the evolutionary origins of the survival processing effect without identifying its proximate mechanisms first. Here, we test the relative importance of threat versus functional thinking. A common approach toward identifying the proximate mechanisms of the survival processing effect is to compare the original grassland scenario with a control scenario that is assumed to differ in one dimension (e.g., the degree to which it stimulates thoughts about dying) while other dimensions are held constant (e.g., the degree to which elaborate processing is stimulated). For instance, the grassland scenario has been compared to scenarios as different as being an elderly person with Alzheimer's disease (Otgaar et al., 2011), robbing a bank (Butler, Kang, & Roediger, 2009), or being lost in a ghost town (Kostic, McFarlan, & Cleary, 2012). However, these findings are open to interpretation because the scenarios differ simultaneously in many aspects that may or may not affect memory. Another approach (Kroneisen & Erdfelder, 2011; Soderstrom & McCabe, 2011; Weinstein, Bugg, & Roediger, 2008) is to compare identical versions of the grassland scenario that differ only in certain words (e.g., by replacing the word "grassland" with "city," or by replacing the word "predators" with "zombies"). This is the approach that we used in the present study. First, we framed the survival scenario in a negative or a positive way. Research on prospect theory has shown that framing outcomes in terms of negative or positive valence can have pronounced effects on cognitive processing (e.g., Levin, Schneider, & Gaeth, 1998). We implemented the framing of the scenarios by asking participants to concentrate on the negative survival risks (e.g., starvation, homelessness, disease, physical injury) or on the positive goals of survival (e.g., food, shelter, health, physical integrity). Orthogonal to the framing of the scenario, we manipulated whether the encoding task required participants to focus on the potential function of the items for survival (functional focus) or on the potential threats to survival associated with the items (threat focus).

The threat hypothesis predicts that the survival processing effect should be modulated by the positive or negative framing of the scenario. If the survival processing effect were mainly due to enhanced attention to phylogenetically old threats to survival, we would expect that a focus on risks to survival following a negative framing increases the memory advantage relative to focusing on positive survival goals. By orthogonally manipulating the emotional framing of the scenario and the focus on threat or function at encoding, our design allowed us to further differentiate between two types of the threat hypothesis. If experiencing threat, or contemplating death, prior to encoding is essential for obtaining a recall advantage, then a negative framing of the scenario that forces participants to focus on the imminent risk of failing to survive before studying the material should enhance recall relative to an a priori positive framing of the scenario. Another possibility is that memory for the items is less affected by the properties of the scenario presented prior to encoding than by the type of processing necessitated by the rating task performed at encoding, in which case memory should be enhanced when participants are required to rate the threat posed by the items relative to rating their function.

Regarding the effects of the encoding-focus manipulation, the functional-thinking hypothesis makes the opposite prediction. If the survival processing effect were mediated by making plans (Klein et al., 2010, 2011) or by thinking about using items as tools to achieve one's goals (Kroneisen & Erdfelder, 2011; Kroneisen et al., 2013; Röer et al., 2013), then thinking about an object's function should be associated with enhanced recall relative to thinking about risks. To further evaluate the functional-thinking hypothesis, we manipulated the concreteness of the to-be-remembered words. A priori it seemed reasonable to speculate that a possible advantage of a functional focus over a threat focus at encoding might be restricted to concrete words. Including abstract words thus allowed us to explore the boundary conditions of a possible functional-thinking effect.

Experiment 1

Method

Participants

The data of four persons had to be excluded because they had participated twice. The remaining sample consisted of 109 participants (81 female; mean age = 24.19, SD of age = 4.57) recruited on campus. Participants were assigned to the four groups of the experiment (see below) in the sequence in which they arrived at the laboratory, with the first participant being assigned to the first group, the second participant being assigned to the second group, and so on. The four groups consisted of 28, 28, 27, and 26 participants. Participants were tested in smaller groups of 1 - 5 participants, each in a separate cubicle, wearing headphones with high-insulation hearing protection covers.

Materials and procedure

Type of scenario was manipulated between participants. Four instructions were used in a 2 × 2 design with framing of the scenario (negative, positive), and encoding focus (threat, function) as independent variables. The rating instructions are given in Table 1.

Participants saw lists consisting of 15 concrete and 15 abstract words that were randomly drawn from a pool of 43 concrete words (e.g., *giraffe, custard, lettuce, leopard, missile, tanker, flower, basket, parcel, pendant, subway, harbor, wagon, pocket, elbow*) and 43 abstract words (e.g., *expanse, carnage, caution, treason, decade, rumor, leader, lesson, combat, pension, stanza, mission, magic, volume, talent*). All words were German translations of words used in a study examining the effects of word concreteness on short-term memory (Romani, McAlpine & Martin, 2008).

The scenarios and rating instructions were presented both visually and auditorily before the rating started. Depending on the encoding focus each word was rated on a scale ranging from 1 ("not helpful at all") to 5 ("extremely helpful"), or from 1 ("not dangerous at all") to 5 ("extremely dangerous"), respectively. The words were presented in a random order, each for 5 s with a blank 1 s inter-stimulus interval. If participants failed to respond, a visual feedback instructed them to respond faster. Response time was not assessed. After the rating phase, participants completed eight trials of a distractor task (serial recall of digit lists) taken from a recent short-term memory study (Röer, Bell, Dentale & Buchner, 2011). Performance in the distractor task was unaffected by the framing of the scenario, $F(1,105) = 0.77$, $p = .38$, $\eta_p^2 < .01$, and by the encoding focus, $F(1,105) = 0.01$, $p = .94$, $\eta_p^2 < .01$, and there was no interaction, $F(1,105) = 0.07$, $p = .79$, $\eta_p^2 < .01$. Subsequently, participants received a blank sheet of paper and a pen for the surprise free recall test, which lasted for 10 min.

Design

A 2 × 2 × 2 design was used, with framing of the scenario (*negative*, *positive*), and encoding focus (*threat focus*, *functional focus*) as between-subjects variables, and word concreteness (*abstract*, *concrete*) as within-subject variable. Given a total sample size of 109, $\alpha = .05$ and a correlation between the levels of the repeated-measures variable of $\rho = .50$, effects of size $f = 0.30$ could be detected with a statistical power of $1 - \beta = .95$ for the between-subjects variables (Faul, Erdfelder, Lang & Buchner, 2007).

Results

Correct Recall

We start by analyzing the recall data (mean proportion of words correctly recalled, see Table 2). Participants' answers were transcribed, and a computer program was used to compare these answers with the to-be presented words. Only exact matches were scored as correct, but spelling errors were ignored. A 2 × 2 × 2 MANOVA showed no effect of the framing of the scenario, $F(1,105) = 1.50$, $p = .22$, $\eta_p^2 = .01$. In contrast, the effect of encoding focus on recall was significant, $F(1,105) = 18.73$, $p < .01$, $\eta_p^2 = .15$. A functional focus at encoding led to better recall than a threat focus (Table 2). There was no interaction between framing of the scenario and encoding focus, $F(1,105) = 0.04$, $p = .84$, $\eta_p^2 < .01$.

Consistent with many previous studies, concrete words were better remembered than abstract words, $F(1,105) = 173.87$, $p < .01$, $\eta_p^2 = .62$, but there was no interaction of word concreteness with framing of the scenario, $F(1,105) = 1.62$, $p = .21$, $\eta_p^2 = .02$, or with encoding focus, $F(1,105) = 1.51$, $p = .22$, $\eta_p^2 = .01$, and no three-way interaction between word concreteness, framing of scenario, and encoding focus, $F(1,105) = 1.00$, $p = .32$, $\eta_p^2 = .01$.

Intrusions

A 2 × 2 ANOVA on the number of intrusion errors showed neither an effect of framing of the scenario, $F(1,105) = 0.07$, $p = .79$, $\eta_p^2 < .01$, nor of encoding focus, $F(1,105) = 0.11$, $p = .74$, $\eta_p^2 < .01$. There was also no interaction between both variables, $F(1,105) = 0.11$, $p = .74$, $\eta_p^2 < .01$. This shows that the beneficial effects of a functional orientation at encoding cannot be attributed to a more liberal output criterion at retrieval. Given previous reports of survival processing effects on false memory (Otgaar & Smeets, 2010), the results may seem surprising at first sight. However, the survival processing effects on false recall seem to be robust only when DRM lists (Roediger & McDermott, 1995) or categorized lists are used in which false memories are highly primed, and might occur as a result of retrieving the "gist" of the former encoding episode. When lists of unrelated words are used, intrusion errors are often found not to be affected by survival processing instructions (e.g., Bell, Röer & Buchner, 2013).

Ratings

A 2 × 2 × 2 MANOVA on the ratings (Table 3) showed that framing of the scenario had no effect, $F(1,105) = 0.09$, $p = .77$, $\eta_p^2 < .01$, but there was an interaction between framing of the scenario and word concreteness, $F(1,105) = 13.13$, $p < .01$, $\eta_p^2 = .11$. For concrete words, negative framing led to descriptively higher ratings than positive framing, $F(1,105) = 2.31$, $p = .13$, $\eta_p^2 = .02$, but for abstract words, positive framing led to higher ratings than negative framing, $F(1,105) = 4.57$, $p = .03$, $\eta_p^2 = .04$. This unexpected effect might be linked to previous observations that positive mood leads to a different processing style than negative mood, causing information to be processed at a more abstract, and less concrete level (Bolte, Goschke & Kuhl, 2003; Gasper & Clore, 2002). Encoding focus had an effect on the ratings, $F(1,105) = 49.47$, $p < .01$, $\eta_p^2 = .32$, but this effect was qualified by an encoding focus × word concreteness interaction, $F(1,105) = 131.99$, $p <$

.01, η_p^2 = .56. For concrete words, function ratings were higher than threat ratings, $F(1,105)$ = 132.42, $p < .01$, η_p^2 = .56. For abstract words, the perceived functionality of the items was equivalent to the perceived threat associated with these items, $F(1,105) = 0.12$, $p = .74$, $\eta_p^2 < .01$. There was neither an interaction between framing of the scenario and encoding focus, $F(1,105) = 0.14$, p = .71, $\eta_p^2 < .01$, nor a three-way interaction between framing of the scenario, encoding focus, and word concreteness, $F(1,105) = 0.31$, $p = .58$, $\eta_p^2 < .01$. With respect to the present research question, it seems most important to note that the recall data shows a different pattern, which demonstrates that theoretical accounts that attribute the survival processing effect to “task relevance”, as operationalized by the magnitude of the ratings, are not valid because the survival processing effect is independent of these ratings (e.g., Bell et al., 2013; Kroneisen, Erdfelder & Buchner, 2013; Nairne & Pandeirada, 2011).

Discussion

Framing the survival processing scenario in a positive or negative way had no effect on later recall. A potential objection is that the framing manipulation may have not affected participants’ emotional state at all, as a consequence of which no effects on later recall were to be expected. However, an independent norming study (N = 28) shows that the emotional evaluation of the scenarios clearly differs between these two conditions, thereby refuting this interpretation (Table 4). A further objection may be that despite our best efforts to equate the framing conditions, some differences may have remained. Despite this limitation, the results suggest that the a priori characteristics of the scenarios may be less important than the processes operating at encoding of the items.

Focusing on threats at encoding led to worse recall than a functional orientation at encoding. This finding provides evidence that the mnemonic effects of the survival processing scenario cannot be primarily attributed to the attention-grabbing power of a situation signaling imminent danger and death, as implied by several accounts of the survival processing effect. Instead, the results are consistent with the functional-thinking hypothesis, which emphasizes the roles of problem solving and planning in which the processing of an item is embedded, representing a particularly elaborate way of processing that item’s meaning.

Experiment 2

Experiment 1 confirms that functional thinking is more important in determining the survival processing advantage than threat. However, we do not know yet whether the functional-focus condition and the threat condition would produce memory benefits compared to the standard survival condition, in which participants are required to evaluate the *relevance* of words for survival in the grasslands. Therefore, we addressed this question in Experiment 2 empirically. Relevance instructions are indeterminate in that they may stimulate thinking either towards function or towards threat. For instance, when rating the relevance of the word "vulture" for survival, you might either think of the vulture attacking you ("threat"), or you might think about ways of using its flesh, bones, beak, and feathers ("function"). In consequence, the functional-thinking hypothesis predicts that memory performance after standard relevance instructions should be better than memory after threat-focus instructions, and worse than after functional-focus instructions. The threat hypothesis predicts the opposite pattern. Furthermore, the survival condition was compared to a standard control condition (pleasantness rating) in Experiment 2. If the survival processing advantage is mainly due to thinking about function, the functional-focus condition, but not the threat-focus condition, should produce a significant memory advantage in comparison to this control condition. If the survival processing advantage is mainly driven by thinking about threat, the opposite pattern should emerge.

Method

Participants

Three data sets were excluded because these persons had participated twice, and the rating data of 14 participants were lost due to equipment failure. In the present analysis, these data are not included. However, the recall sheets of these participants were available, and excluding these data sets did not change the memory results at all. Statistical analyses were performed with the data of 204 participants (140 female; mean age = 23.94; SD of age = 4.83). Participants were assigned to the four groups of the experiment (see below) as in Experiment 1. The four groups consisted of 50, 52, 53, and 49 participants.

Materials and procedure

The materials and procedure were identical to those of Experiment 1 with the following exceptions. The functional-focus condition and the threat-focus condition were compared to a standard control condition (pleasantness) and a standard relevance condition (see Table 5). In the pleasantness condition, participants were required to rate each word on a scale ranging from 1 (“not pleasant at all”) to 5 (“extremely pleasant”). In the relevance condition, the rating scale ranged from 1 (“not relevant at all”) to 5 (“extremely relevant”). A positive framing was used for all survival scenarios. Performance in the unrelated distractor task after encoding was not affected by encoding focus, $F(3,200) = 1.36$, $p = .36$, $\eta_p^2 = .02$.

Design

A 4 × 2 design was used, with encoding focus (*pleasantness*, *threat*, *relevance, function*) as between-subjects variable, and word concreteness (*abstract*, *concrete*) as within-subject variable. Given a total sample size of 204, $\alpha = .05$ and a correlation between the levels of the repeated-measures variable of $\rho = .50$, effects of size $f = 0.25$ could be detected with a statistical power of $1 - \beta = .94$ for the between-subjects variable (Faul et al., 2007).

Results

Recall

Again, we start by reporting the recall data (Table 2). Concrete words were better remembered than abstract words, $F(1,200) = 218.00$, $p < .01$, $\eta_p^2 = .52$. Encoding focus affected recall, $F(3,200) = 4.96$, $p < .01$, $\eta_p^2 = .07$, but the main effect of encoding focus was qualified by a significant interaction between encoding focus and word concreteness, $F(3,200) = 5.78$, $p < .01$, $\eta_p^2 = .08$. For concrete words, both the standard relevance condition, $t(101) = 2.65$, $p < .01$, $d_z = .26$, and the functional-focus condition, $t(97) = 4.75$, $p < .01$, $d_z = .48$, differed from the pleasantness control condition, but the latter difference was much larger than the former, as predicted by the functional-thinking hypothesis. The threat-focus condition, in contrast, did not differ from the pleasantness control condition, $t(100) = 1.08$, $p = .29$, $d_z = .11$. Recall in the functional-focus condition was even better than recall in the standard relevance condition, $t(100) = 2.34$, $p = .02$, $d_z = .23$, and the size of this difference was in the order of magnitude of the difference between the standard relevance condition and the pleasantness control condition. Recall of abstract words, in contrast, did not differ significantly between any of those conditions.

Intrusions

As in Experiment 1, the number of intrusions was not affected by encoding focus, $F(3,200) = 0.4$, $p = .53$, $\eta_p^2 = .01$, which suggests that encoding focus did not affect the output criterion at retrieval.

Rating

There were main effects of encoding focus, $F(3,200) = 43.54$, $p < .01$, $\eta_p^2 = .40$, and word concreteness, $F(1,200) = 47.63$, $p < .01$, $\eta_p^2 = .19$, on the ratings (Table 3), that were qualified by a significant interaction, $F(3,200) = 31.55$, $p < .01$, $\eta_p^2 = .32$. The relevance ratings again show a different pattern than the recall data, showing that the recall findings cannot be “explained” by task relevance as measured by the magnitude of the relevance ratings.

Discussion

The results of Experiment 2 show that focusing on the threats associated with being stranded in the grasslands does not have beneficial effects on memory. Compared to the pleasantness control condition, the threat focus did not enhance recall at all. This is problematic for theories of the survival processing effects implying that the processing of threat and death is sufficient to produce mnemonic benefits. Given that all three survival scenarios dealt with survival in an ancestral environment as the central theme but were not equally effective in promoting recall, merely activating the concept of survival obviously does not suffice to produce mnemonic benefits either. Consistent with this conclusion, Klein et al. (2011) showed that a survival-irrelevant scenario with a strong planning component led to better memory than a survival scenario without a planning component. Hence, activating fitness-related topics such as survival and reproduction is not sufficient for finding a memory advantage because the mnemonic benefits are not a direct consequence of the activation of fitness-related themes, but rather a consequence of active, goal-oriented engagement with the stimulus material.

For concrete words, thinking about the function of items at encoding even led to better memory than thinking about the relevance of the items. This was predicted based on the assumption that thinking about the relevance might either stimulate thinking about threat or thinking about function, only the latter of which is associated with enhanced recall. Thus, the present results strengthen the functional-thinking hypothesis, according to which considering an item's functions to reach certain goals constitutes a particularly elaborate form of encoding its meaning, which has beneficial effects on the retrieval of the items later on. This corresponds to the purpose of memory in many everyday tasks. For instance, if you want to go on a hunting trip, you will first need to identify a list of items you may need based on internal simulations of the future situation, and memorize the items so that no important item is left behind.

A significant survival processing effect compared to the pleasantness control condition was only obtained for the concrete words, but not for the abstract words. As mentioned in the Introduction, this pattern can be predicted based on the functional- thinking hypothesis. When reviewing the literature on the survival processing effect, it is striking to note that almost all published studies have used concrete nouns (e.g., Nairne et al., 2007; Soderstrom & McCabe, 2011; Weinstein et al., 2008) or pictures of objects (Otgaar, Smeets, & van Bergen, 2010) as stimulus material. Furthermore, the effect often vanishes with other types of to-be-remembered material (Bröder et al., 2011; Savine, Scullin, & Roediger, 2011). We know of only two studies that have manipulated word concreteness directly. First, we (Bell et al., 2013) have found that thinking about the relevance of words for "survival" led to better recall than thinking about the relevance of words for "death." This effect, however, was only present for concrete words (and absent for abstract words). Second, Tse and Altarriba (2010) reported a post hoc analysis suggesting that the effects of survival processing on intermixed lists of nouns and adjectives was not mediated by word concreteness, but mention an unpublished study showing the opposite pattern. The lack of a significant concreteness effect in the present Experiment 1 may seem surprising at first sight, but note that some of the abstract words could stimulate problem solving and planning to some extend (e.g., leader, combat, magic, treason, master, torture, native, sample, angle, damage, budget). Furthermore, the results are almost identical in both experiments at a descriptive level, and the descriptive difference between the functional-focus and threat-focus conditions is more pronounced for concrete words in both experiments. Thus, the absence of a significant interaction with word concreteness in Experiment 1 may have simply been due to insufficient power. Although the available results do not allow us to draw definite conclusions on the role of word concreteness in survival processing—it is for future studies to explore this issue further—the overall impression is that the effect may indeed be somewhat more pronounced for concrete than for abstract words.

General Discussion

Many results suggest that the survival processing effect reflects evolutionary forces that have shaped our memory (e.g., Weinstein et al., 2008). Therefore, the survival processing paradigm promises to be a useful tool in understanding the evolutionary foundations of memory (Nairne & Pandeirada, 2008; Nairne et al., 2007, 2008). However, it is unlikely that strong evolutionary inferences can be drawn without first identifying the proximate mechanisms behind the survival processing effect. An evolutionary analysis requires identifying the adaptive problems behind the survival processing effect (Tooby & Cosmides, 2005). Given that the adaptive significance of remembering a list of words in the grasslands is not immediately obvious, the survival processing effect is likely to be a byproduct of an adaptive mechanism yet to be identified. Here, we discuss two proximate mechanisms with likely distinct neural underpinnings and evolutionary origins. First, the survival processing effect may be due to prioritized processing and learning of items associated with threat (Olds et al., 2014; Soderstrom & McCabe, 2011). Second, the survival processing effect may be an aftereffect of a functional encoding focus (Klein et al., 2010, 2011; Kroneisen & Erdfelder, 2011; Kroneisen et al., 2013; Röer et al., 2013).

Our results are inconsistent with the hypothesis that the survival processing effect is due to the prioritized processing of threatening (e.g., fear-of-death inducing) information. Particularly problematic for the threat hypothesis is the finding that a threat focus at encoding (following grassland survival instructions) did not lead to enhanced recall compared to the pleasantness control condition in Experiment 2. At first sight, this finding seems inconsistent with studies that have been interpreted as demonstrating an important role of threat in the survival processing paradigm (Olds et al., 2014; Soderstrom & McCabe, 2011). However, alternative interpretations of those results are conceivable. For instance, Olds et al. (2014) manipulated threat level by requiring participants to imagine that food and water are easy or difficult to obtain, and that predators are easy or difficult to avoid. Although this manipulation clearly correlated with the perceived level of threat, it could also be reinterpreted as reflecting the difficulty of the problem-solving task posed by the survival scenario. Likewise, the zombie scenario used by Soderstrom and McCabe (2011) may be more novel than the grasslands scenario, which could have consequences for the internal simulation of object use (see the discussion below).

Given the evolutionary arguments for the existence of a threat advantage, the advantage of a functional over a threat focus might seem surprising. For example, Baumeister, Bratslavsky, Finkenauer, and Vohs (2001) “believe that throughout our evolutionary history, organisms that were better attuned to bad things would have been more likely to survive threats, and consequently, would have increased probability of passing along their genes” (p. 325). However, evolutionary arguments have to be backed up by a thorough analysis of the specific function of a potential memory advantage and the adaptive problem it is supposed to solve (Tooby & Cosmides, 2005). For instance, the learning of phobic reactions in response to snakes, and their persistence, may be of evolutionary significance because it supports avoiding lethal threats (Öhman & Mineka, 2001), acquired food avoidance after an episode of nausea may serve as a protection against food poisoning (Garcia & Koelling, 1966), and remembering that someone is a cheater will help you to protect yourself from social exploitation (Buchner, Bell, Mehl, & Musch, 2009). The adaptive benefit of improved memory for a list of unrelated words in a threatening situation, however, is not equally evident. In fact, the effects of threat on memory are not uniformly positive, and it has been amply demonstrated that memory for emotionally neutral material encoded in an emotionally straining situation may even be impaired (Levine & Edelstein, 2009), possibly to protect the emotionally significant (e.g., avoidance-relevant) information from interference. Furthermore, although less prominently discussed, there are also many reports showing that memory for the nonemotional aspects of a situation may simply remain unaffected by emotion (Levine & Edelstein, 2009). Thus, it is probably wrong to assume that evolutionary arguments can be used to hypothesize that the mere presence of evolutionary threat should lead to a memory advantage for all aspects of an encoding situation.

The present results support the hypothesis that thinking about an item's function is a crucial component of the survival processing effect. We do not argue that the survival processing effect is caused by a highly specialized module for tool use. Instead, the effect may be a byproduct of the adaptive mechanisms that constitute the unique human capabilities of making plans, and to flexibly simulate actions with the goal of manipulating the external environment. Importantly, this explanation of the survival processing effect is consistent with the notion of general memory mechanisms long identified in the literature. To identify the usefulness of objects in a novel environment, it is necessary (a) to retrieve former episodes of object use, (b) to internally manipulate multimodal representations of the objects, and (c) to flexibly shift attention to different object attributes (Barsalou et al., 2005; Oakes & Madole, 2008). Given that memory is known to benefit from memory retrieval (Roediger & Karpicke, 2006), generation (Bertsch, Pesta, Wiscott, & McDaniel, 2007), elaboration (Anderson & Reder, 1979), and semantic processing at encoding (Lockhart & Craik, 1990), it seems unsurprising that thinking about function leads to enhanced memory. Considering the tight integration of memory and problem solving, it seems possible to speculate that these memory benefits have adaptive consequences. For instance, Garner and Howe (2014) have demonstrated that (false) memory for information processed under survival instructions has beneficial effects on later problem-solving tasks via spreading-activation. Conversely, the engagement in active, creative problem solving may be responsible for the mnemonic benefits of survival processing in the first place.

The functional-thinking hypothesis faces the challenge of explaining why the grasslands survival scenario leads to enhanced memory performance in comparison to other scenarios such as the moving scenario that involve thinking about the function of objects. Hence, it could be argued that the concept of survival remains a critical aspect of the memory advantage. However, the threat condition included the survival scenario and did not differ from the pleasantness control condition, suggesting that the survival scenario, in itself, was not sufficient to improve memory (see Klein et al., 2011, for similar evidence and conclusions). Although our results do not allow for a definite answer, it seems possible to speculate that the relevance of ordinary objects within everyday scenarios such as moving to another city may be part of the knowledge about the objects and can be easily retrieved from long-term memory. The same may be true for the valence—and, by implication, for the threat—associated with these objects. However, when confronted with novel tasks such as using ordinary objects to protect oneself against predators or zombies, participants have to perform internal simulations involving the manipulation of multimodal object representations with the aim of reaching the desired goal to determine the object's relevance. For instance, when thinking about the potential usefulness of a pencil to protect oneself against predators or zombies, you may think about the common function (writing tool), as well as about novel functions (stabbing tool, firewood, digging tool). These novel functions can only be derived by retrieving different object characteristics such as the object's form (sharp), material (wood), and stability (may break) from long-term memory, and by internally simulating the use of the object in the novel situation. It is reasonable to assume that thinking about the object's use in more everyday scenarios such as moving to another city is more restricted to the usual function of the object (writing). To back this claim up, we analyzed the ideas produced in response to the survival or moving scenario. Ninety-one participants were required to rate the creativity of the ideas that were spontaneously generated by other par- ticipants in a previous experiment (Röer et al., 2013), in which it has been already demonstrated that people spontaneously generate more different ideas in the survival in comparison to the moving condition. As Figure 1 shows, the ideas produced under survival instructions received higher creativity ratings than the ideas generated in the moving condition, $F(1,90) = 38.95$, $p < .01$, $\eta_p^2 = .30$. Recall of the words in a surprise memory test paralleled the creativity ratings $F(1,90) = 16.60$, $p < .01$, $\eta_p^2 = .16$. These results confirm that the grasslands survival problem may stimulate more creative problem solving—and, by implication, more elaborate encoding—than everyday tasks such as moving.

A further challenge for the functional-thinking hypothesis may be that Nairne et al. (2008) have shown that survival processing leads to better memory performance than rich encoding conditions such as self-reference, generation, and imagery. However, the control conditions were designed to isolate these mechanisms, whereas the survival condition arguably reflects a combination of all of them, as discussed above. Furthermore, control conditions such as imagery or generation only involve the manipulation of a

single attribute (e.g., switching two letters of the word), whereas determining the function of objects in the survival processing task likely involves the retrieval and active manipulation of multiple object attributes (e.g., a pencil's form, material, stability, coloring). Thus, thinking about function likely leads to many traces in memory though which the object can later be retrieved. Previous studies have shown that instructions that constrain or interfere with the internal simulation of multiple object uses lead to the abolishment of the survival processing effect (Kroneisen & Erdfelder, 2011; Kroneisen et al., 2013).

Given that theoretical models of function (Barsalou et al., 2005; Oakes & Madole, 2008) imply that functional thinking does not only depend on an object's functional properties and environmental factors that constrain an object's use but also on the individual's goals and intentions, the functional-thinking hypothesis is able to account for findings, suggesting a role of motivational factors in the survival processing effect. For instance, scenarios implying the imminent threat of death do not lead to a memory advantage when the scenarios are designed to induce hopelessness, and might therefore discourage active planning and internal simulations of object use (Bell et al., 2013; Bugaiska, Mermillod, & Bonin, in press; Klein, 2014).

Conclusion

Although the survival processing task has been presented as reflecting evolutionary influences on memory, the evolutionary foundations of the survival processing effect are unknown until its proximate mechanisms are identified. We tested whether the survival processing effect is due to thinking about threat or due to thinking about function. Experiment 1 showed that the emotional properties of the scenarios did not influence recall. Focusing on threat at encoding led to worse memory than focusing on function. The latter finding was replicated in Experiment 2, which also demonstrated that (a) focusing on threat did not lead to a survival processing effect at all, (b) inducing a functional focus at encoding was even more beneficial to recall than the standard survival processing instructions, and (c) the beneficial effects of survival processing were more pronounced for concrete in comparison to abstract words. In sum, these results support a functional-thinking explanation of the survival processing effect.

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Table 1

Framing of the Scenario	Rating Dimension	Instructions used in the present experiment as a function of framing of the scenario and encoding focus. The words that differed between conditions are printed in italics.
All Conditions		Please imagine that you are stranded in the grasslands of a foreign land, where you have to survive.
Negative	Threat	Please take one moment to think about the *negative risks* that you really want to try to *avoid* in order to survive in the grasslands: *starvation, homelessness, dangerous animals, disease, physical injury*. (Pause). You are going to see a list of items. Some of these items are *dangerous* because they *hinder* the *avoidance of these negative risks*, others are not. Please rate how *dangerous* these things are because they *hinder* the *avoidance of the negative risks*.
	Function	Please take one moment to think about the *negative risks* that you really want to try to *avoid* in order to survive in the grasslands: *starvation, homelessness, dangerous animals, disease, physical injury*. (Pause). You are going to see a list of items. Some of these items are *useful* because they *facilitate* the *avoidance of these negative risks*, others are not. Please rate how *useful* these things are because they *facilitate* the *avoidance of the negative risks*.
Positive	Threat	Please take one moment to think about the *positive goals* that you really want to try to *achieve* in order to survive in the grasslands: *food, shelter, protection from dangerous animals, health, physical integrity*. (Pause). You are going to see a list of items. Some of these items are *dangerous* because they *hinder* the *achievement of the positive goals*, others are not. Please rate how *dangerous* these things are because they *hinder* the *achievement of the positive goals*.
	Function	Please take one moment to think about the *positive goals* that you really want to try to *achieve* in order to survive in the grasslands: *food, shelter, protection from dangerous animals, health, physical integrity*. (Pause). You are going to see a list of items. Some of these items are *useful* because they *facilitate* the *achievement of the positive goals*, others are not. Please rate how *useful* these things are because they *facilitate* the *achievement of the positive goals*.

Table 2

Mean proportion of correctly recalled words as a function of framing of the scenario, encoding focus, and word concreteness.

Experiment 1								
Framing	Negative				Positive			
Encoding Focus	Threat		Function		Threat		Function	
	M	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*
Concrete Words	.51	(0.03)	.63	(0.03)	.45	(0.03)	.59	(0.03)
Abstract Words	.29	(0.02)	.39	(0.02)	.30	(0.03)	.36	(0.02)

Experiment 2								
Encoding Focus	Pleasantness		Threat		Relevance		Function	
	M	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*
Concrete Words	.44	(0.02)	.47	(0.02)	.52	(0.02)	.59	(0.02)
Abstract Words	.33	(0.02)	.31	(0.02)	.31	(0.02)	.35	(0.02)

Table 3

Mean ratings as a function of framing of the scenario, encoding focus, and word concreteness.

Experiment 1								
Framing	Negative				Positive			
Encoding Focus	Threat		Function		Threat		Function	
	M	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*
Concrete Words	2.1	(0.1)	3.3	(0.1)	2.0	(0.1)	3.1	(0.1)
Abstract Words	2.2	(0.1)	2.2	(0.1)	2.4	(0.1)	2.4	(0.1)

Experiment 2								
Encoding Focus	Pleasantness		Threat		Relevance		Function	
	M	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*
Concrete Words	3.3	(0.1)	2.0	(0.1)	3.0	(0.1)	3.2	(0.1)
Abstract Words	2.9	(0.1)	2.4	(0.1)	2.5	(0.1)	2.4	(0.1)

Note: Pleasantness was rated on a scale ranging from 1 (“not pleasant at all”) to 5 (“extremely pleasant”), threat was rated on a scale ranging from 1 (“not dangerous at all”) to 5 (“extremely dangerous”), function was rated on a scale ranging from 1 (“not helpful at all”) to 5 (“extremely helpful”), relevance was rated on a scale ranging from 1 (“not relevant at all”) to 5 (“extremely relevant”).

Table 4

Valence and arousal ratings for the two framing conditions used in Experiment 1.

	Framing of the Scenario			
	Negative		Positive	
	M	*(SE)*	*M*	*(SE)*
Valence	-2.29	(0.21)	-0.11	(0.31)
Arousal	5.07	(0.40)	4.18	(0.40)

Note: Valence was rated on a scale ranging from -4 (extremely negative) to +4 (extremely positive). Arousal was rated on a scale ranging from 1 (extremely low) to 9 (extremely high). As in Experiment 1, participants (N = 28) were asked to think about the negative risks they wanted to avoid in order to survive in the grasslands, or to think about the positive goals they wanted to achieve. The Self-Assessment Manikin (Bradley & Lang, 1994) was used to visualize the meanings of the ratings scales. The negative framing condition was associated with a more negative valence, $t(27) = 8.14$, $p < .01$, $d_z = 1.57$, and with higher arousal, $t(27) = 3.32$, $p < .01$, $d_z = 0.64$, than the positive framing condition.

Table 5

Instructions used in Experiment 2. The instructions in the risk condition and in the utility condition were identical to those used in Experiment 1 in the positive framing condition. The words that differed between conditions are printed in italics.

Pleasantness	You are going to see a list of items. Some of these items are *pleasant, others are not*. Please rate how *pleasant* these things are.
Relevance	Please imagine that you are stranded in the grasslands of a foreign land, where you have to try to survive. Please take one moment to think about the positive goals that you really want to try to achieve in order to survive in the grasslands: food, shelter, protection from dangerous animals, health, physical integrity. (Pause). You are going to see a list of items. Some of these items are *relevant for* the achievement of the positive goals, others are not. Please rate how *relevant* these things are *for* the achievement of the positive goals.

Figure 1

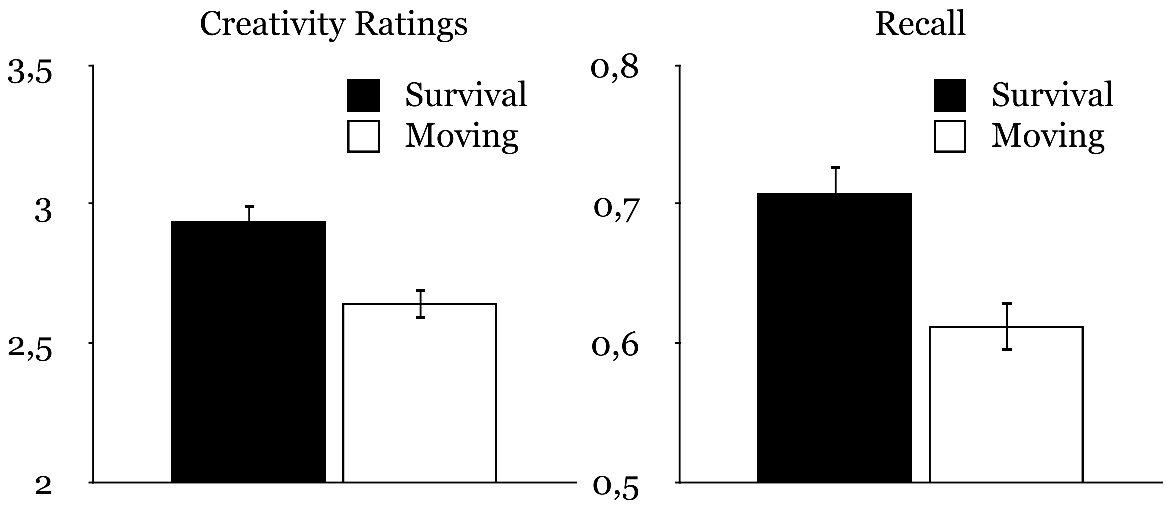

Figure 1: Mean creativity ratings and mean recall as a function of scenario (survival in the grasslands vs. moving to another city). Left panel: Mean creativity ratings. Ninety-one participants rated the creativity of 120 randomly selected ideas about how to use 15 different items in either a survival or moving scenario (4 ideas for each of the 15 different items in each of the two scenarios) on a scale ranging from 1 ("not creative at all" to 5 "very creative"). The ideas had been spontaneously produced by participants in a previously reported study (Röer et al., 2013). Right panel: Mean proportion of items correctly recalled in a subsequent surprise free recall test. The error bars represent the standard errors of the means.