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The proximate memory mechanism underlying the survival-processing effect: Richness of encoding or interactive imagery?

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Nairne and collaborators showed that assessing the relevance of words in the context of an imagined survival scenario boosts memory for these words. Although this survival-processing advantage has attracted a considerable amount of research, little is known about the proximate memory mechanism mediating this effect. Recently, Kroneisen and Erdfelder (2011) argued that it is not survival processing itself that facilitates recall but rather the richness and distinctiveness of encoding that is triggered by the survival-processing task. Alternatively, however, it is also conceivable that survival processing fosters interactive imagery, a process known to improve associative learning. To test these explanations we compared relevance-rating and interactive imagery tasks for survival and control scenarios. Results show that the survival advantage replicates in the relevance-rating condition but vanishes in the interactive imagery condition. This refutes the interactive imagery explanation and corroborates the richness-of-encoding hypothesis of the survival-processing effect.

Keywords: Episodic memory; Evolution; Survival-processing effect; Interactive imagery.

Many memory researchers have argued that our capacity to remember evolved because of its fitness-enhancing properties (see, e.g., Klein et al., 2009; Klein, Cosmides, Tooby, & Chance, 2002; Klein, Robertson, & Dalton, 2010; Nairne, 2010; Nairne & Pandeirada, 2008a; Nairne, Thompson, & Pandeirada, 2007). However, despite this consensus there is some debate on the specific adaptive function of human episodic memory. According to Nairne and collaborators (e.g., Nairne et al., 2007), episodic memory contributed to fitness maximisation by helping our ancestors to solve important adaptive problems related to survival. Consequently the operating characteristics of episodic memory should ‘‘bear the imprints of the specific selection pressures that shaped their development’’ (Nairne & Pandeirada, 2010a, p. 977).

In line with this evolutionary framework Nairne et al. (2007) and Nairne, Pandeirada, and Thompson (2008) showed that verbal information processed in the context of a hypothetical ancestral survival scenario (i.e., being stranded in the grasslands of a foreign land) is recalled much better than information encoded using alternative mnemonic procedures known to be highly effective. For example, when words are rated with respect to their relevance for an imagined grassland survival scenario characterised by predators, lack of food, and lack of potable water, then

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memory performance in a subsequent surprise free recall test is much better than when the same words are rated with respect to their pleasantness (e.g., Nairne et al., 2007, 2008), imagery (Nairne et al., 2008), self-relevance (Kostic, McFarlan, & Cleary, 2012; Nairne et al., 2008; but see Klein, 2012), or their relevance for a control scenario such as a moving scenario (e.g., Nairne et al., 2007).

The mnemonic benefit of survival-relevance processing has been called the survival-processing effect. It has been replicated many times and for different context conditions, for example, using other control scenarios designed to match the survival scenario in novelty and arousal (Kang, McDermott, & Cohen, 2008; Nairne et al., 2008), using pictorial stimuli instead of words (e.g., Otgaar, Smeets, & van Bergen, 2010), or focusing on memory for locations rather than memory for words and pictures (Nairne, VanArsdall, Pandeirada, & Blunt, 2012). Moreover, it could be demonstrated that there is also a survival-processing effect for both children (Aslan & Bäuml, 2012; Otgaar & Smeets, 2010) and older adults (Nouchi, 2012).

An issue of some debate currently is the proximate memory mechanism that mediates the effect of survival-relevance processing on retention (see, e.g., Burns, Burns, & Hwang, 2011; Butler, Kang, & Roediger, 2009; Howe & Derbish, 2010; Klein, 2012; Klein, Robertson, & Dalton, 2011; Kostic et al., 2012; Kroneisen & Erdfelder, 2011; Nairne et al., 2007, 2008; Otgaar & Smeets, 2010; Smeets, Otgaar, Raymaekers, Peters, & Merckelbach, 2012; Soderstrom & McCabe, 2011; for a review see Erdfelder & Kroneisen, in press). According to Nairne and collaborators (e.g., Nairne, Vasconcelos, & Pandeirada, 2012), the survival-processing effect is evidence of human learning and memory being tuned selectively during evolution to process and retain information that is relevant to survival (selective-tuning hypothesis). To fully understand this phylogenetically acquired, hard-wired capacity of our memory systems it is crucial to find encoding conditions that are congruent with the assumed natural design of memory (Nairne & Pandeirada, 2010b). Accordingly, assessing the relevance of various objects for a typical ancestral survival situation (e.g., using a relevance-rating task) is such a design-congruent encoding condition and therefore produces the mnemonic benefit (see, however, Kostic et al., 2012, and Soderstrom & McCabe, 2011, for evidence that the survival-processing effect does not necessarily require ancestral survival scenarios).

Kroneisen and Erdfelder (2011), in contrast, argued that the survival-processing effect can be traced back to the richness of encoding triggered by the survival-relevance-rating task (see also Nairne & Pandeirada, 2008b, p. 378). They assume that relevance ratings in a complex survival scenario provide a particularly inspiring and rich encoding context, comparable to complex sentence frames in depth-of-processing tasks (e.g., Craik & Tulving, 1975, Exp. 7). Therefore this task enables elaborate and distinctive encoding more than do control tasks and scenarios. With the relevance-rating task participants are implicitly encouraged to think about many distinct arguments supporting the claim that a certain object is relevant in a context characterised by a variety of survival problems. This, in turn, generates a large number of potential memory cues for the retrieval situation, each of which provides access to the target information in memory.

The impact of self-generated encoding cues on subsequent retrieval has been established many times (Hunt & Smith, 1996; Hunt & Worthen, 2006; Mäntylä, 1986). Mäntylä (1986), for instance, asked participants to enumerate properties of each item in a list of items. In a surprise cued recall test the participants received their own previous responses and were instructed to use these self-generated ideas as retrieval cues to remember the original items. Mäntylä (1986) observed more than 90% correct recall under these conditions. The process of conceiving many distinct survival relevance arguments for specific objects resembles the task of enumerating as many properties of objects as possible. The major difference is that, in the survival-relevance-rating task, the focus is on various functional aspects of objects (e.g., ''I can use a stone as a missile'') rather than on perceptual attributes (''A stone is heavy'') or semantic features (''A stone is a small rock'').

To test the richness-of-encoding hypothesis, Kroneisen and Erdfelder (2011) compared the standard grassland survival scenario (e.g., Nairne et al., 2007) against a reduced scenario. The latter was identical to the former except that only a single survival problem was explicitly mentioned in the description: lack of potable water. The other two problems addressed in the original scenario—lack of food and predators—were not referred to in the reduced scenario. Given that both the standard and the reduced scenario are ancestral grassland survival scenarios, this manipulation should not affect the strength of the survival-processing effect if the selective-tuning hypothesis holds. However, if the richness-of-encoding hypothesis is correct, then the effect should diminish in the reduced scenario because it provides less opportunity for distinctive encoding than the standard scenario. Consistent with this prediction the survival-processing advantage failed to be significant in the reduced scenario condition, regardless of whether a within-participant or a between-participants design was used (Kroneisen & Erdfelder, 2011, Exp. 1 & 2, respectively). In a third experiment the authors manipulated the number of relevance arguments participants were asked to generate with respect to the standard survival scenario (one argument vs. four arguments per word in the list). As expected, they found a strong survival-processing advantage in the four arguments condition but no such effect in the one argument condition. These results are in line with the richness-of-encoding hypothesis and difficult to reconcile with alternative proximate explanations of the survival-processing effect (see Erdfelder & Kroneisen, in press). Nevertheless, Kroneisen and Erdfelder's (2011) results do not provide conclusive evidence for the richness-of-encoding account. In addition to elaboration and distinctive encoding, the survival-relevance-rating task could also trigger mental imaginations of acts in which the objects indicated in the word list are used for purposes of survival. Such spontaneous imagery processes resemble "interactive imagery" (e.g., Bower, 1970; Bower & Winzenz, 1970; Wilton, 1990, 2006), a powerful mnemonic mechanism known to be highly beneficial particularly in associative learning tasks. According to Bower (1970), interactive imagery causes stronger associations between elements such as pairs of words in paired-associate learning. Applied to the survival-relevance-rating task, the imagination of using an object in the survival context could strengthen the object's association to the survival scenario, thus enabling later recall of these words when the scenario is activated.

Interactive imagery appears to be a reasonable candidate to explain the survival-processing effect. To account for the available empirical evidence, two assumptions are sufficient: First, processing a list of words with respect to their relevance for a complex grassland survival scenario invites spontaneous interactive imagery more than do control conditions; second, this effect increases with the number of relevance arguments generated per word, thus improving later recall by strengthening the association between each word and the survival scenario multiple times. These assumptions appear plausible because the grasslands survival scenario is particularly appealing to the imagination, as exemplified by numerous books and movies devoted to this topic. To assess the relevance of objects in such a scenario, participants might try to imagine uses of objects they have never seen or heard about before. This seems less likely for typical familiar control scenarios such as the moving scenario, for which relevance assessments often can be made based on previous experience. Note that the interactive imagery explanation is also consistent with the fact that previous research failed to find evidence for a role of different types of simple imagery (Nairne et al., 2008, Nairne & Pandeirada, 2010b). In all previous studies simple imagery of words without a survival context (Nairne et al., 2008) or simple imagery of the survival scenario in general (i.e., detached from survival-processing of words) was assessed (Nairne & Pandeirada, 2010b), both of which clearly differ from imagery of using objects in a complex survival context which is crucial according to the interactive imagery account.

We thus aimed to scrutinise the possible role of interactive imagery in the survival-processing effect. Following Nairne et al. (2007), we compared the grassland survival scenario with the moving control scenario to assess the size of the survival-processing effect. After reading the respective scenario, half of the participants rated the relevance of each word with regard to this scenario (relevance-rating condition; see Nairne et al., 2007, Exp. 1). To foster interactive imagery the other half of the participants were explicitly asked to imagine using each object in the respective context and to rate the ease of interactive imagery for each word (interactive imagery condition).

We predicted the survival-processing advantage would replicate in the standard relevance-rating condition. For the interactive imagery condition, however, the prediction differs for the hypotheses discussed above. According to the interactive imagery hypothesis, memory performance should benefit from explicit instructions to make use of interactive imagery. In principle this should hold for both the survival and the moving control scenario. However, given the assumption that the survival condition invites more spontaneous interactive imagery than the moving condition, explicit imagery instructions should have a stronger effect on free recall performance in the moving condition. According to the richness-of-encoding hypothesis, in contrast, prompting participants to engage in interactive imagery should impair memory performance especially for the survival-processing scenario. This is so because deliberate imagery of using an object in a specific way distracts from generating multiple relevance arguments and thus reduces distinctive encoding, which is of crucial importance according to the richness-of-encoding account. In essence, the effect of interactive imagery instructions should be functionally similar to the one argument condition in Experiment 3 of Kroneisen and Erdfelder (2011). By implication, the survival-processing advantage should diminish or even vanish in the interactive imagery condition.

METHOD

Participants

A total of 68 University of Mannheim students and 7 University of Heidelberg students participated. Three participants were excluded due to runtime errors of the computer program and two more participants due to their very low performance level (fewer than two words recalled). Thus data analyses are based on the remaining 70 students (17 male) who either received a monetary compensation or a course credit for participating. Participants' age ranged from 18 to 42 years ($M = 22$; $SD = 4$).

Apparatus and materials

Following Kroneisen and Erdfelder (2011, Exp. 1), the words to be rated for their relevance or their ease of imagination were taken from Experiment 1 of Nairne et al. (2007) and translated into German. Thus target words were 30 typical words from 30 unique categories. To absorb primacy and recency effects typically found in free recall we added 12 buffer words drawn from the German version of the Battig and Montague norms (Mannhaupt, 1983), 6 at the beginning and 6 at the end of the list. All words, except the buffer words, were presented in random order. Personal computers running Eprime 2.0 (Psychology Software Tools, Pittsburgh, PA) controlled the experiment. The survival and moving descriptions were identical to those used by Nairne et al. (2007). All materials were presented in German.

Design

A 2 (Rating task: relevance rating vs interactive imagery) $\times 2$ (type of scenario: survival vs moving) between-participants design was used. Participants were randomly assigned to one of four groups (group 1: survival scenario plus relevance rating, $n = 17$, group 2: moving scenario plus relevance rating, $n = 17$, group 3: survival scenario plus interactive imagery, $n = 17$, group 4: moving scenario plus interactive imagery, $n = 19$). Free recall performance, ratings, response times in the rating task, and extra-list intrusions in the free recall test served as dependent variables.

Procedure

Participants read either the grassland survival scenario or the moving scenario, and were then asked either to rate the relevance of each item with respect to their scenario or to imagine using the item in their scenario and then rate ease of imagery. The instructions for the rating conditions were as follows:

Relevance-rating instructions. We are going to show you a list of words, and we would like you to rate the relevance of each of these objects in the situation described previously.

Interactive imagery instructions. We are going to show you a list of words, and we would like you to imagine using each of these objects in the situation described previously. Please indicate how easy or difficult you find this task.

Words were presented individually for 5 seconds each. Participants rated each word on a 5-point scale, with 1 indicating ''absolutely not relevant'' and ''very difficult to imagine'' in the relevance-rating and the interactive imagery condition respectively, and 5 indicating ''extremely relevant'' for the scenario and ''very easy to imagine'', respectively. Participants had to respond within 5 seconds or else a warning message appeared. The experiment started with two practice trials illustrating the rating task. The actual rating task consisted of 42 trials (30 target words and 12 buffer words). Following a subsequent

10-minute distractor activity (simple problem-solving tasks unrelated to the word list and the scenarios), free recall instructions appeared unexpectedly for the participants. Eight minutes were allowed for the final recall phase. The experiment took approximately 30–35 minutes.

RESULTS

The significance level was set to $\alpha = .05$ for all statistical tests. To facilitate comparisons two-tailed p values are reported for all tests, even in case of directed predictions. Relevance and ease-of-interactive imagery ratings were provided for 98% of the presented words. The number of words participants failed to rate within 5 seconds did not differ among the four experimental groups. As expected there were strong Pearson correlations between average relevance and ease-of-interactive imagery ratings both for the survival scenario, $r = .76, p < .001$, and the moving scenario, $r = .84$, $p < .001$. The higher the prototypical relevance rating of an object, the easier it is to imagine using this object in the respective scenario.

Figure 1 displays the mean proportions of correct free recall and their standard errors for all groups. Significant main effects of both scenario, $F(1,\ 66) = 4.03$, $p = .049$; $\eta^2 = 0.06$, and rating task were found, $F(1,\ 66) = 7.41$, $p = .008$; $\eta^2 = 0.10$, indicating better recall memory overall for the survival scenario and the relevance-rating task, respectively. Likewise, the interaction between scenario and rating task was significant, $F(1,\ 66) = 4.19$, $p = .045$; $\eta^2 = 0.06$. For the groups with relevance-rating instructions, planned comparisons based on the overall error term revealed the typical survival-processing advantage ($M_{Survival+Relevance} = 16.82$, $SD = 3.41$; $M_{Moving+Relevance} = 12.82$; $SD = 4.38$); $t(66) = 2.83$, $p < .006$, $\eta^2 = 0.11$. In contrast, for the groups with interactive imagery instructions, the survival-processing effect disappeared ($M_{Survival+Imagery} = 12.12$, $SD = 3.85$, $M_{Moving+Imagery} = 12.16$, $SD = 4.66$); $t(66) = 0.03$, $p = .98$, $\eta^2 < 0.001$. Note that this null effect cannot be attributed to low statistical power. For a medium effect size of $f^2 = .15$ (Cohen, 1988), $\alpha = .05$, and $df = 66$, the power of our planned contrast t-tests is approximately .94 (Faul, Erdfelder, Buchner, & Lang, 2009).

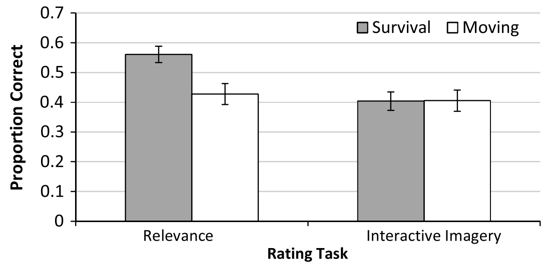

Figure 1. Mean proportion of correct recall for each scenario, separately for each group. The error bars represent standard errors of the means.

Table 1 shows the average median response times of the ratings for each participant as a function of the four conditions. There was no significant main effect of scenario, $F(1,\ 66) = 3.39$, $p = .07$; $\eta^2 = 0.05$, or of rating condition, $F(1,\ 66) = 1.75$, $p = .19$; $\eta^2 = 0.03$, but a significant interaction between scenario and rating condition, $(1,\ 66) = 4.50$, $p = .038$; $\eta^2 = 0.06$. No differences were observed between the two rating conditions for the survival scenario, $t(66) = 0.20$, $p = .84$; $\eta^2 < 0.001$. However, a significant difference between both rating conditions occurred for the moving

TABLE 1
Rating latencies, ratings, and intrusion errors by condition

Condition		*Rating latencies (ms)*		*Ratings*		*Intrusion errors*	
		M	*SEM*	*M*	*SEM*	*M*	*SEM*
Relevance rating							
	Survival	2321.27	94.72	2.90	0.15	1.64	0.43
	Moving	1805.65	82.28	2.72	0.16	1.71	0.42
Ease of interactive imagery rating							
	Survival	2217.26	144.62	3.06	0.14	2.57	0.53
	Moving	2253.97	167.03	3.43	0.13	2.38	0.56

Means (M) and standard errors (SEM) of participants' median rating latencies, participants' ratings (relevance rating: 1 = ''absolutely not relevant'', 5 = ''extremely relevant''; interactive imagery rating: 1 = ''very difficult to imagine'', 5 = ''very easy to imagine''), and participants' intrusion error frequencies.

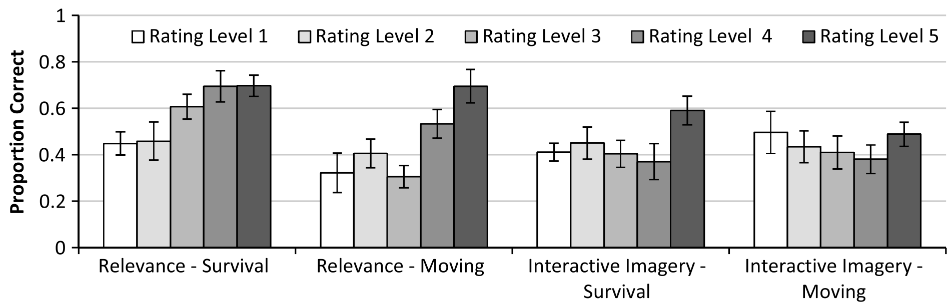

Figure 2. Mean proportions of correct recall for each scenario, separately for each rating category. The error bars represent standard errors of the means.

scenario, $t(66) = 2.77$, $p = .007$; $\eta^2 < 0.10$. When evaluating items with respect to the moving scenario, participants provided relevance ratings faster than ease-of-interactive imagery ratings.

In addition we compared the mean ratings across conditions. As Table 1 shows, average ratings were higher for the interactive imagery conditions than for the relevance-rating conditions. An ANOVA revealed a significant main effect of rating condition, $F(1, 66) = 12.51$, $p = .001$; $\eta^2 = 0.16$, but not of scenario, $F(1, 66) = 0.11$, $p = .738$; $\eta^2 = 0.002$. This was qualified by a significant interaction between rating condition and scenario, $F(1,66) = 4.75$, $p = .033$; $\eta^2 = 0.07$, indicating that participants found it easier to imagine using objects in the moving scenario than in the survival scenario. Importantly, relevance ratings did not differ significantly between the survival and the moving scenario, $t(66) = 1.29$, $p = .20$, $\eta^2 = 0.02$, showing that the survival-processing effect observed in the relevance-rating conditions cannot be attributed to differences in scenario congruity of the items.

The rating data were also analysed within conditions to determine whether items with higher ratings were remembered better later on. Figure 2 shows the proportion of words recalled correctly in the free recall test as a function of initial rating, rating task, and type of scenario. For most conditions there is a significant correlation between ratings and the proportion of words recalled subsequently. Controlling for overall recall performance of the participants, the partial correlation between rating and recall rates was significant for the survival-plus-relevance-rating group ($r = .20$; $p < .05$) and the moving-plus-relevance-rating group ($r = .25$; $p < .05$), but not for the survival-plus-interactive imagery group ($r = .09$; $p = .06$) and the moving-plus-interactive imagery group ($r = .04$; $p = .40$).

Finally we examined intrusions of extra-list items in free recall. As can be seen in Table 1, no differences in intrusion frequencies were observed between the survival and the moving scenario. In contrast, there appears to be a slight tendency for more intrusion errors in the interactive imagery conditions compared with the relevance-rating conditions. However, neither the main effects nor the interaction effect reached statistical significance: all $F(1, 66) \leq 2.56$, $p \geq .12$; $\eta^2 \leq 0.08$.

DISCUSSION

Our experiment evaluated the richness-of-encoding hypothesis and the interactive imagery explanation of the survival-processing advantage. The results are in line with the former hypothesis and clearly inconsistent with the latter. We compared the standard relevance-rating task and an interactive imagery task for both the grassland survival scenario and a moving control scenario. These scenarios have often been used to assess the size of the survival-processing effect (e.g., Nairne et al., 2007; Smeets et al., 2012). We found that an interactive imagery instruction (replacing the relevance-rating instruction) does not improve memory performance in these contexts. Rather, despite the strong correlation between prototypical relevance ratings and ease-of-interactive imagery ratings, the interactive imagery task causes the survival-processing advantage to disappear. In fact there was no difference in recall rates between the survival scenario with an interactive imagery instruction and both moving conditions (relevance-rating and interactive imagery). This null effect cannot be attributed to low statistical power; that is, if there were a notable survival-processing advantage under interactive imagery conditions, our test would have detected it with a very high probability.

Obviously interactive imagery is not the process underlying the mnemonic advantage in the survival scenario. In contrast, it is possible to explain the present results in the framework of the richness-of-encoding hypothesis. Richness of encoding enables distinctive encoding in the survival scenario, provided that participants are not distracted from generating a multitude of relevance arguments for each object described by a list of words. The relevance-rating task, in particular, stimulates thoughts about several different possible uses of objects. Plausibly, the number of different uses is one possible cue to relevance; that is, knowing how many different uses of an object exist helps coming up with a reasonable relevance rating.[1] Things change when the relevance-rating task is replaced by an interactive imagery task. This task may be accomplished by forming just one single image (e.g., using a stone as a missile). Thus the interactive imagery condition functionally resembles the one-argument-generation condition in Experiment 3 of Kroneisen and Erdfelder (2011). Consequently distinctiveness of encoding decreases in the survival condition and fewer retrieval cues are available in the retrieval situation, resulting in a decrease in recall performance.

We also tested several alternative explanations of our results. One possible source of bias is variability in intrusion rates between conditions, indicating differences in response criteria. However, extra-list intrusions of items in free recall were rare, and differences between conditions were insignificant. Similarly, differences in average ratings between conditions did not show a pattern consistent with the free recall results. If anything there was a tendency towards higher ratings in the interactive imagery conditions although recall rates were lower in these conditions. This is opposite to what one would expect if differences in free recall performance between conditions were due to differences in average ratings. Moreover, the response time data revealed no significant differences between both rating tasks for the survival scenario. Survival-relevance ratings, therefore, are not associated with more time for item processing than interactive imagery ratings. For the moving scenario, in contrast, there appears to be a difference in processing times. However, participants spent more time for imagery ratings than for relevance ratings although memory performance was in fact slightly worse in the interactive imagery condition. Differences in processing times per item, therefore, also cannot explain the memory performance data obtained in our experiment.

Replicating other studies (Aslan & Bäuml, 2012; Butler et al., 2009; Kroneisen & Erdfelder, 2011; see, however, Nairne & Pandeirada, 2011), reliable congruity effects were observed within both relevance-rating conditions: The higher the relevance rating, the better the memory performance. Assuming that higher relevance ratings correspond to more relevance arguments generated by a participant and thus more elaboration, this congruity effect is perfectly in line with the richness-of-encoding hypothesis.

Correspondingly, correlations between ratings and memory performance were much less pronounced or entirely absent in the interactive imagery conditions. Thus ease or difficulty of interactive imagery appears to be unrelated (or only weakly related) to memory performance. Like the memory performance data, this result is difficult to reconcile with the interactive imagery explanation of the survival-processing effect.

Parts of the present results can also be accommodated by other proximate explanations of the survival-processing effect; for example, the congruity account (Butler et al., 2009). This suggests that different mechanisms may be involved in the survival-processing effect. It is less clear, however, how the whole pattern of observations can be explained in terms of a single mechanism such as congruity (Butler et al., 2009), relational and item-specific processing (Burns et al., 2011), priming of associative networks (Howe & Derbish, 2010), or gist processing (Otgaar & Smeets, 2010), particularly if combined with the results of Kroneisen and Erdfelder (2011). Thus the major strength of the richness-of-encoding hypothesis is that it can account for a number of different results within a single theoretical framework. Recent results such as a decrease of the survival-processing effect in older adults (Nouchi, 2012) and null effects of survival-processing in indirect memory tests (Tse & Altarriba, 2010) and source memory tests (Bröder, Krüger, & Schütte, 2011) are easily accommodated (Erdfelder & Kroneisen, in press). Even the surprising result that changing just two

[1] As correctly pointed out by an anonymous reviewer, the present data do not strictly rule out that these thoughts—or some of these thoughts—are associated with imagery of acts. That is, elaborate encoding and interactive imagery are not mutually exclusive. Importantly, however, interactive imagery itself cannot be the cause of the survival-processing benefit. Otherwise, interactive imagery instructions should foster memory performance, which they obviously do not.

words in the scenario description moderates the strength of the survival-processing effect significantly (e.g., Soderstrom & McCabe, 2011; Weinstein, Bugg, & Roediger, 2008) can be explained by assuming that these two words affect the creativity and uniqueness (hence the distinctiveness) of the relevance arguments invented by the participants (see Erdfelder & Kroneisen, in press).

In sum, the present experiment clearly shows that the task participants are required to perform vis-à-vis a specific survival or control scenario is crucial for obtaining the survival-processing advantage. Survival processing per se—even if applied to the ancestral grassland survival scenario introduced by Nairne et al. (2007)—is not sufficient. Some tasks produce the effect (e.g., the relevance-rating task), others do not (e.g., the interactive imagery task). Both the present results and the results previously reported by Kroneisen and Erdfelder (2011) suggest that mental generation of distinct arguments emphasising the relevance of objects for survival is a necessary ingredient for obtaining the survival-processing effect. This pattern of results is most parsimoniously explained by the richness-of-encoding hypothesis.

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