Adaptive Memory: What does the Think-Aloud Protocol tell us about the Survival-Processing Advantage

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Abstract

Nairne et al. (2007) discovered a strong mnemonic advantage for the information processed in the survival context. Later studies showed that this survival-processing advantage might be due to the higher elaboration induced by the survival scenario, known as the richness-of-encoding hypothesis (Kroneisen & Erdfelder, 2011). Our study directly tested this hypothesis through the adapted version of the think-aloud protocol (Ericsson & Simon, 1984) using typing instead of speaking. Our results showed that we did not find a statistically significant survival-processing advantage. Nevertheless, we did find that participants showed more elaboration in terms of producing more functions for the given objects in the survival scenario compared to the control moving scenario. Being able to analyze the exact thoughts of the participants, we also found that the survival scenario triggers thinking about goals that require functional focus for their achievement, while this did not occur for the moving scenario. Additionally, participants in the rating task referred to all three goals mentioned in the scenario when being in the survival condition, while they referred to only one goal in the moving condition. Translating these findings into the search-inference framework (Baron, 2008), we reasoned that a survival scenario offers more chances to link the objects to the goals of the scenario, resulting in higher elaboration. Therefore, the mnemonic advantage of the survival-processing context might not be due to the scenario per se, but rather the more general mechanism of elaboration that this scenario induces.

Keywords: survival-processing advantage, recall, memory, relevance, think-aloud protocol

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It is assumed that selection pressures of the human ancestral past shaped our memory systems to better remember information relevant to survival (Sherry & Schacter, 1987; Nairne & Pandeirada, 2016). Nairne et al. (2007) tested this idea that memory systems evolved for fitness enhancement through the survival-processing paradigm where participants were asked to imagine being stranded in the grassland of a foreign land, having no food, or water, and being in danger of predators. After this, a rating task followed, where participants rated a list of words in relation to the survival scenario. In the control conditions, participants rated words for their pleasantness or their relevance to a scenario that involved moving to a foreign place. The pleasantness condition is often used as a standard deep-processing control, as it is related to the memory advantage observed in processing the items for their meaning (Craik & Tulving, 1975). On the other hand, the moving scenario equates to the survival scenario in terms of promoting schematic processing, but without survival threats (Nairne et al., 2007). The rating task was followed by a surprise-free-recall test where memory for the objects that were rated with relevance to the survival in the grassland was better compared to items in the control conditions. In later studies, this survival-processing advantage was found to be a robust phenomenon also detected in small children (Aslan & Bäuml, 2012), elderly people (Nouchi, 2012), and different experimental set-ups such as differences in stimulus (Otgaar et al., 2010), or task demands (Nairne et al., 2019). Accordingly, it has been argued that a survival situation produces superior retention than most known encoding techniques, with Nairne et al. (2008a, p. 180) concluding that “survival processing is one of the best – if not the best – encoding procedures yet identified.”

The idea of memory being naturally “tuned” to the processing of fitness-relevant information would mean that we have a distinct cognitive adaptation specialized only for

survival-relevant information (Nairne et al., 2007). This notion of having a 'survival module' was often criticized as too general (e.g., Klein et al., 2010; Klein, 2012). Rather, specific memory modules working in concert were more likely to develop in order to solve particular adaptive problems. After all, our ancestors faced all sorts of environmental problems, not just the Pleistocene environments in which the brain was sculpted. Indeed, there has also been evidence of survival-processing advantages in non-ancestral scenarios (e.g., Kostic et al., 2012; Soderstrom & McCabe, 2011), which suggests that the survival-processing advantage is not specific to the use of a grassland scenario as a proxy to our Pleistocene environment. Therefore, it has also been argued that the survival advantage might reflect specific proximate mechanisms that did not primarily develop for survival reasons in our ancestral history (Nairne et al., 2007; Erdfelder & Kroneisen, 2014). Several contributors have been considered in pursuit to identify these mechanisms, where results remain controversial. Mechanisms such as stress (Smeets et al., 2012), arousal and novelty (Kang et al., 2008), planning (Klein et al., 2010, 2011), threat (Olds et al., 2014), congruity (Butler et al., 2009), and self-relevance (Klein, 2012; Bonin et al., 2020) have been proposed but often showed little explanatory power or inconsistent results. Yet, one of the process explanations, namely richness of encoding, has gathered the greatest amount of empirical support with steadily showing to play a role in the survival-processing effect (e.g., Kroneisen & Erdfelder, 2011; Röer et al., 2013, Forester et al., 2020).

The Richness-of-Encoding Hypothesis

As already discussed by Nairne et al. (2007), survival processing might accrue from particularly effective elaboration or distinctive processing. This richness-of-encoding perspective evolved from the depth of processing framework by Craik and Tulving (1975) who argued that the depth of processing is crucially determined by the level of richness and distinctiveness. They operationally defined the roles of richness and distinctiveness through

the experiment where participants were asked to process words at different depths by three different tasks, all requiring a ‘yes’ or ‘no’ response. Results showed that deeper encoding took longer to accomplish a task and resulted in a better performance in the unexpected recognition and recall test. Additionally, questions requiring a deep level of encoding that led to a positive ‘yes’ response were associated with a better retention level. In their interpretation, the ‘yes’ response allowed for a better-integrated unit between the given word and the sentence in the task than the ‘no’ response, which was translated into the conclusion that positive responses yield a richer encoding with a more elaborate unit formed. In the survival-processing paradigm, rating the words in relation to the scenario could also be determined by the high-level processing. Thus, the richness-of-encoding hypothesis (Nairne & Pandeirada, 2008b; Kroneisen & Erdfelder, 2011) states that rating the usefulness of objects in the survival context leads participants to generate more unique and distinctive ideas about the object’s use. These ideas can later work as a retrieval cue on the free-recall test and prompt the retrieval of items. The richness-of-encoding hypothesis has shown to be a promising explanation of the survival-processing advantage. For example, there have been several studies that found boundary conditions for the survival-processing advantage that seem compatible with the richness-of-encoding account (e.g., Erdfelder & Kroneisen, 2014). Furthermore, neuroimaging studies also offer support for this account (Forester et al., 2019, 2020). In the following sections, we will review the evidence in favor of the richness-of-encoding hypothesis.

Boundary conditions

The richness-of-encoding hypothesis seems to be aligned with the boundary conditions for the survival-processing advantage (Erdfelder & Kroneisen, 2014), such that the survival-processing advantage was found to be reduced when the possibility of elaboration was restrained. For example, decreasing the number of survival problems through which the

objects could be evaluated decreased the survival-processing advantage (Kroneisen & Erdfelder, 2011; Experiment 3). Similarly, putting people under a high cognitive load reduced the survival mnemonic advantage, since people could not elaborate on the information (Kroneisen et al., 2014). Furthermore, survival advantage disappeared for abstract words, while concrete words produced more mnemonic advantage (Bell et al., 2015), meaning that people have a harder time elaborating on the abstract word or thinking about its function. Taken together, boundary conditions of the survival-processing advantage seem to appear when the possibility of spontaneous idea generation is constrained.

Thinking about the Function

Results such as better survival-processing advantage for the concrete words (Bell et al., 2015) can be explained through the functional-thinking hypothesis (Bell et al., 2015) where we can only think about the function of the concrete words. Thus, the relevance rating of the word might encourage thinking about the function, which represents an elaborate form of processing. Consistent with this account, one study found that asking participants to think about the function of an object surpassed the standard survival-processing advantage obtained when participants were asked to rate the object's relevance (Bell et al., 2015). The functional focus could also explain the results from Klein et al. (2011) who showed that the planning component mediates the survival-processing advantage. Put differently, a non-survival scenario with a strong planning component produced better memory than a survival scenario without the planning component. Indeed, when we plan, we often think about the function of the objects to solve the problem (Nairne & Pandeirada, 2016).

Functional Fixedness. Objects differ in regard to the number of novel ways in which they can be used, which is referred to as 'functional fixedness' (Duncker, 1945). It has been shown that objects that are low in functional fixedness produce better survival-processing advantages than objects high in functional fixedness (Kroneisen et al., 2021), which can be

explained through the richness-of-encoding hypothesis – objects low in functional fixedness offer more possible uses and consequently produce more elaboration. Functional fixedness appeared to be more important for the survival condition since thinking about novel functions provides higher chances of survival while the moving scenario stimulates thinking about objects' prototypical functions which ultimately do not provide more distinct and elaborative retrieval cues (Kroneisen et al., 2021). Röer et al. (2013) directly measured the amount of cognitive elaboration, where participants who were asked about the usefulness of the items generated more ideas in the survival condition than participants in non-survival control conditions. The probability of successful retention on the following free-recall test was increased with the number of generated ideas, serving as potential retrieval cues. Ideas generated in the survival scenario have also been shown to be more creative than ideas generated in a moving scenario (Bell et al., 2015). This idea was also tested through the measurement of the neurocognitive processes (Forester et al., 2020), finding that potential functional usefulness determines the word's salience only in the survival condition. Control scenarios like moving are probably sensitive to other kinds of salience, such as initial congruence or valence of the word. Indeed, Forester et al. (2020) showed that a moving scenario leads to lower-level encoding processes, while survival processing leads to more elaborative forms of encoding reflected in increased frontal slow-wave activity in electroencephalogram (EEG) measurements, providing direct evidence for the richness-of-encoding hypothesis.

In sum, the richness-of-encoding hypothesis proposes that survival processing does not offer some kind of special processing adaptation but can be rather explained with the traditional proximate mechanisms – through the amount of elaboration that survival processing stimulates. Most of the studies offering support for this hypothesis have

manipulated elaboration by affording more or less opportunity for thinking about the possible functions of the given objects (e.g., Bell et al., 2015).

Search-inference Framework

We argue that we can explain the richness-of-encoding hypothesis through the search-inference framework (Baron, 2008) that posits thinking to have two constituents: search and inference. According to this framework, thinking begins with doubt about what to do or what to think, which we try to resolve by searching for goals, possibilities to achieve those goals, and arguments (i.e., "evidence") for the extent to which these possibilities might help to achieve our goals (a process of inference).

Translating the search-inference framework (Baron, 2008) to the survival-processing paradigm, it can be argued that the goals and possibilities are determined by the task, such that a given word or object (a possibility) needs to be evaluated in terms of whether it can help in achieving the goals of finding food and water and avoiding predators (Nairne et al., 2007). Participants in the survival-processing paradigm search for "evidence" or arguments for why an object might or might not be useful to the goals in the scenario. Consistent with the richness-of-encoding hypothesis, previous studies showed that these arguments comprise ideas about the possible use of an object (e.g., Röer et al., 2013; Wilson, 2016). This means that inferences consist of evaluating the extent to which a possible use of the object would help in achieving one of the goals of the scenario. In other words, participants match their survival goals (securing food, water, and avoiding predators) and moving goals (locating a new home, purchasing a new home, and transporting the belongings) by making inferences about possible uses of the objects given. Previous findings (Kroneisen et al., 2021; Forester et al., 2020) proposed that the survival scenario stimulates thinking about alternative uses of the objects while the moving scenario focuses on primary uses, which needs less elaboration. Moreover, the time spent to make an inference could be also understood as an index of depth

of encoding, where making inferences in the survival scenario usually takes longer than in the moving scenario (Kroneisen & Erdfelder, 2011; Nairne et al., 2007). Taken together, evidence shows that people seem to make more searching and inferences in the survival scenario than in the moving scenario, which is in line with the richness-of-encoding hypothesis.

Current Study

In the current study, we want to explore the reasons why the survival scenario brings such a powerful mnemonic advantage. None of the existent studies has directly explored what kind of thinking participants engage in when doing the task or reading the description of scenarios. Most prior studies tried to explain the survival-processing advantage based on the indirect inferences about encoding through the performance on the surprise-recall test. In other words, they did not provide direct insight into the thinking process that happens when participants judge the relevance of objects for a survival or control scenario. Only a handful of studies used direct measurements of neurocognitive processes (e.g., event-related potentials (ERPs)) that showed results favoring the richness-of-encoding hypothesis (Forester et al., 2019, 2020). To further investigate the role of the richness of encoding and other proximate mechanisms in survival processing, the current study uses another direct measurement of encoding processes, namely the adaptation of a verbal think-aloud protocol (Ericsson & Simon, 1984) that directly explores what participants think while doing the task in original survival-processing paradigm (Nairne et al., 2007). We adapted the original protocol by using the typing method instead of the spoken one: therefore, naming it the ‘type-aloud’ protocol. As described in more detail below, this method has shown to be a valid approximation of people’s thoughts obtained using a think-aloud protocol (Magliano & McNamara, 2006).

Hypotheses and Their Rationale

Our study was in first place intended as an exploratory pilot study to see what kind of data the think-aloud protocol produces. Specifically, we wanted to see what people think

whilst imagining the scenarios or rating the objects and see how this relates to the subsequent recall. We aimed to explore this through analysis of people's thoughts and recall performance for survival and a moving condition. In line with the richness-of-encoding hypothesis, we predicted the following:

Hypothesis 1. Replicating the survival-processing advantage found in the original survival-processing paradigm, the survival scenario will be related to a better recall in the surprise memory task than the moving scenario.

Hypothesis 2. Participants will take longer to rate the relevance of the objects in the survival scenario than in the moving scenario.

Hypothesis 3. Participants will think of more possible functions when rating the relevance of objects in the survival scenario than in the moving scenario.

Hypothesis 4. The number of functions related to an object will predict an increased recall for this object.

Object Relevance

Moreover, we decided to distinguish items according to their relevance to the scenario since relevant items were often found to provide a better survival-processing advantage (e.g., Nairne et al., 2007; Kroneisen et al., 2021), which could be interpreted as relevance to the context leading to richer and more elaborate encoding (Schulman, 1974). On the other hand, a study by Butler et al. (2009) showed that highly relevant or highly irrelevant objects diminish the effect of survival processing. Translating this to the search-inference framework (Baron, 2008), highly relevant objects' use might be immediately matched to the survival goals, so participants do not elaborate on the object, producing fewer retrieval cues for later recall. Likewise, highly irrelevant objects might be immediately matched to the goal and referred to as non-relevant. This is connected to the idea of functional fixedness where you can elaborate on the object only if the object allows for various possible uses (Kroneisen et al., 2021). The

notion of lower elaboration on highly relevant and highly irrelevant objects was also investigated by Yildirim (2020) who pre-determined objects according to their relevance and divided them into three groups: relevant (most often rated as high in relevance), irrelevant (most often rated as low in relevance), and ambiguous (objects with a high variety in relevance ratings). Consistent with the richness-of-encoding hypothesis, participants in a study by Hansen-Manguikian (2021) appeared to elaborate less on judging highly relevant and highly irrelevant objects since their response time to rate the relevance of the object was lower than for the ambiguous objects. Perhaps, ambiguous objects' functional fixedness is low which allows participants to think about an object for a longer time, creating richer retrieval cues. Ambiguous objects might require longer consideration before matching the use of an object to the given survival goals. These objects might also require more creative inferences about object uses, which is consistent with previous findings (Röer et al., 2012; Bell et al., 2015; Forester et al., 2020). To explore these findings in more detail, we will also divide the objects into relevant, irrelevant, and ambiguous, with the following hypothesis:

Hypothesis 5. Participants will come up with more functions of the object when rating the relevance of ambiguous objects compared to relevant and irrelevant objects.

The Imagination of the Scenario

Aside from asking participants to report their thoughts during the relevance-rating task, we also asked them to report their thoughts about the imagined scenario. Since this has not been investigated in any of the previous studies, analyzing the thoughts about the scenario allows for exploratory analysis of whether participants might also imagine a survival scenario more richly (i.e., generating more ideas about details or events) than a moving scenario, which could play a role in the amount of search and inference participants subsequently engage in while judging the relevance of the object.

'Type-aloud' Protocol

We will test our hypotheses using the adaptation of the think-aloud protocol (Ericsson & Simon, 1984), where we will use typing instead of speaking, in a so-called 'type-aloud' protocol. Using typing proved to be equal to the spoken version in terms of elaboration which is vital for our study (Magliano & McNamara, 2006). By means of standard think-aloud protocol, participants will be instructed to type instead of verbalizing their thoughts while completing the cognitive task, namely (1) when reading the description of the scenario, and (2) when rating the relevance of the object presented. These data will be later used for the identification of cognitive processes used while completing the task. Like other process-tracing methods, the type-aloud method does not consider the subject's conclusions, but rather the steps and moves that were necessary to reach that conclusion. Putting it in the search-inference framework, this method directly reveals whether the thinker searches for possibilities, evidence, or goals (Baron, 2008).

Methods

Participants

The sample included 12 participants recruited through the Prolific Webpage. Ethical approval was granted by the Ethics Committee of the Faculty of Behavioral and Social Sciences at the University of Groningen. The final participant pool included 5 males and 7 females. Eligibility criteria for the study included age between 18 and 35, being an English native speaker, and having student status. Participants were paid £8 per hour to complete the experiment.

Materials

The experiment was created using Open Sesame (Mathôt et al., 2012) and was conducted online, such that participants completed the task on a laptop or desktop computer.

The stimuli consisted of 24 words that were selected from a dataset obtained in a study by Yildirim (2020). From this dataset, we selected words that yielded low, high, or ambiguous

relevance ratings for the moving and survival scenarios. The low-relevance objects' ratings were skewed towards 1 on a 5-point scale, meaning that they were the least relevant to the presented scenario. The high relevance objects' ratings were skewed towards 5, and the ambiguous objects had a flat distribution of ratings, indicating inconsistent relevance ratings across the participants in the study by Yildirim (2020). For our study, we picked four items from each of these three relevance categories for both scenarios – using 12 words for the survival scenario, and 12 words for the moving scenario. We sought to ensure that the objects used in the three relevance categories, over the two scenarios, were distributed equally across different categories of objects (e.g., foods and tools). A list of the words used in the study can be seen below (see Table 1).

Table 1

Word list of objects with the corresponding relevance category

Survival Condition		Moving Condition	
Object	Relevance category	Object	Relevance category
Kite	Low	Pumpkin	Low
Window	Low	Harp	Low
Ruler	Low	Bird	Low
Roller skate	Low	Whistle	Low
Hammer	High	Refrigerator	High
Well	High	Suitcase	High
Corn	High	Drawer	High
Tree	High	Screwdriver	High
Cake	Ambiguous	Mitten	Ambiguous
Car	Ambiguous	Pitcher	Ambiguous
Fork	Ambiguous	Sledge	Ambiguous
Hat	Ambiguous	Wagon	Ambiguous

Note. Items and relevance categories are retrieved from the Yildirim (2020).

Design

A within-subject design was used; each participant rated 12 words within the survival scenario and 12 words within the moving scenario. Rating conditions were counterbalanced,

so half of the participants rated words for the survival scenario before the moving scenario and vice versa.

Procedure

Before the start of the experiment, participants provided informed consent to participate. Then the experiment was initiated, and participants were instructed to read the description of one of the following scenarios adapted from the study by Nairne et al. (2007):

Survival: *"We would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival materials. Over the next few months, you'll need to find steady supplies of food and water and protect yourself from predators. Please take your time to imagine that you are in this situation. After you have done this, you can continue by pressing 'Spacebar'."*

Moving: *"We would like you to imagine that you are planning to move to a new home in a foreign land. Over the next few months, you'll need to locate and purchase a new home, and transport your belongings. Please take your time to imagine that you are in this situation. After you have done this, you can continue by pressing 'Spacebar'."*

After reading this description, participants were asked to report any thoughts while imagining the scenario. They were specifically reminded to type in any associations or thoughts they came up with and not just the conclusions of their thinking process. Having reported their thoughts, the answer was submitted by pressing the 'Enter.'

After imagining the scenario, participants did the rating task for the first scenario. For each presented word they had to think about how relevant it would be for them in a given scenario. In the instructions, we asked them to report their thoughts as they tried to judge the relevance of the word. Again, they were reminded to type in anything that came to their mind during that process: "We are interested in how people arrive at their judgment, not just their conclusion. It is fine if you change your mind during this process. Just type in what you are

thinking!" Instructions also included a reminder that some of the words may be relevant, and others may not, so it was up to them to decide. After these instructions for the rating task, they pressed 'Spacebar' and were presented with the object word in a combination with a blank page where they could type in their thoughts. Specifically, they received the following instructions: "Describe your thoughts as you think about whether this word would be of relevance to you in the scenario." Subsequently, participants were asked to rate the object in terms of relevance to the scenario on a scale from 1 (completely irrelevant) to five (extremely relevant). They indicated their rating from 1 to 5 by pressing the corresponding key. This task was performed for two words, serving as practice trials. Participants were notified about the end of the practice trial and reminded about the scenario they should imagine themselves. To continue with a rating task of an actual experiment, they had to press 'Spacebar.' After completing the rating task of all 12 objects of the first scenario, participants performed the same procedure for the second scenario. The rating task was followed by a surprise-free-recall test. Here participants were asked to type in as many words as they could remember from the rating tasks. Finally, the participants were debriefed about the experiment and its purposes.

Type-aloud Scoring Procedure

To construct a coding scheme for the analysis of our data we ran a pilot study collecting data from three participants. All three participants fit the eligibility criteria, namely, they were English native speakers and students with ages ranging from 18-35. Initially, we constructed a coding scheme adapted from the theory of Baron (2008). This included distinct categories of Goals, Relevant Functions, and Other Functions (see Table 2). After familiarization with the responses that participants gave, it was evident that some essential information present in responses was not captured by the existing coding scheme. Therefore, we adapted our coding scheme by including additional categories: Self-references and arguments for the irrelevance of an object to the scenario ('Arguments Irrelevance'). Self-

reference was added as it became apparent that many answers included references to the self. Furthermore, the Arguments Irrelevance category was added in order to capture participants' critiques, evidence, or argumentation against an object.

Intraclass correlation coefficient (ICC) was used as a reliability index for interrater reliability as prescribed by Koo & Li (2016). It was decided to use a two-way mixed-effects model with 3 raters of which the mean of the three raters was selected. ICC values are indicative of reliability with scores below 0.5 being poor, 0.5-0.75 being moderate, 0.75-0.9 being good, and above 0.9 being excellent (Koo & Lee, 2016). ICC estimates were calculated using SPSS based on mean ratings (k = 3) and consistency agreement in a 2-way mixed-effects model. In our pilot study, ICC for Other Functions ($\alpha = 0.893$) and Relevant Functions ($\alpha = 0.849$) were good (Koo & Lee, 2016). All raters also had a good agreement for the Self-reference category ($\alpha = 0.838$) and Argument Irrelevance ($\alpha = 0.853$). Goals had low inter-rater reliability ($\alpha = 0.217$), so we changed the scoring to include a more liberal definition of what constitutes a goal. A new definition of a goal constituted any kind of goal that was implicitly or explicitly stated (see Table 2).

Table 2

Scoring rules for 'Type-aloud' protocol

Criterion	Definition	Example
Goals	Count all goals implicitly or explicitly present in the answer.	"source of water", "A suitcase is essential for traveling", "creating shelter"
Relevant Function	Count functions that are relevant to the three goals of the scenario.	"you could hunt with it" "create fire and cook meals"
Other Function	Count functions that are not relevant to the three goals of the scenario.	"shelter from the rain", "protect against the sunshine", "signal passing planes", "relevant for shelter".
Self-reference	Statements indicating personal affective response, personal trait, or anecdote related to the object.	"When my siblings and I were younger", "takes me back to being at my grandmother's house", "I always found whistles annoying"
Argument Irrelevance	Arguments for why the object is not relevant, not relating to goals or functions of the scenario.	"Pitcher wouldn't be relevant as I wouldn't want to drink that much beer", "I do not play the harp, so it would be pretty useless to have."

Note. All examples are drawn from the responses in our pilot data.

Results

Coding Scheme

In our final experiment, we used the coding scheme developed based on the answers given in the pilot study with three participants (see Table 2). As with the pilot study, we used a two-way mixed-effects model with three raters to calculate the ICC. According to the definition of ICC from Ko and Lee (2016), there was an excellent ICC found for the Relevant Functions ($\alpha = 0.91$) and Other Functions ($\alpha = 0.91$) categories. A good ICC was found for the Arguments Irrelevance category ($\alpha = 0.87$). Lastly, a moderate ICC was found for Goals ($\alpha=0.69$) and Self-reference ($\alpha = 0.63$).

Noteworthy, due to incorrect logging of the answers for participants 1 and 12, we excluded the answers on the rating task for the following words: participant 1 had excluded the data for the object ‘well’ in the survival condition and ‘whistle’ in the moving condition. For participant 12, objects ‘hammer’ and ‘hat’ in the survival condition and object ‘mitten’ in the moving condition were excluded.

Recall

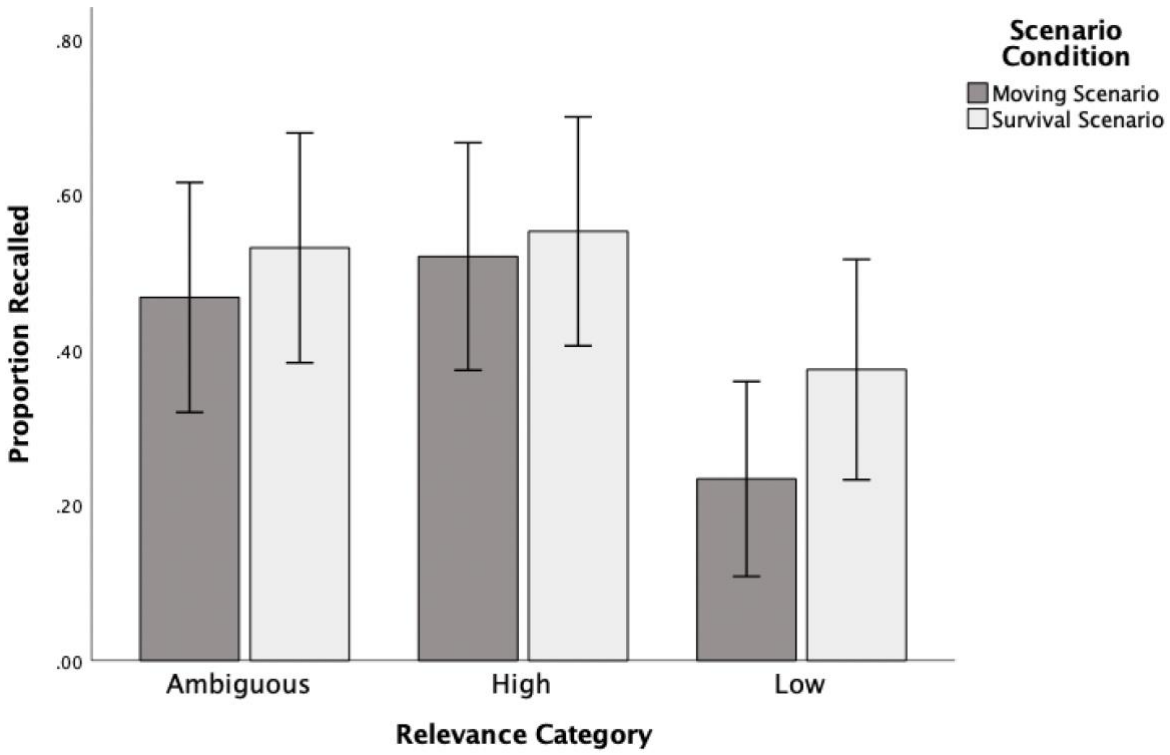
Our first hypothesis was that we would replicate a survival-processing advantage with a higher recall of objects in the survival scenario compared to the moving scenario. The average recall of objects in the survival scenario was 48.59%, and 40.85% in the moving scenario. An analysis using Generalized Estimating Equations (GEE) and a probit model for recall accuracy showed that this difference between the survival and moving condition was not significant, X^2 (1, N = 12) = 1.03, p = 0.31.

We then investigated whether the survival-processing advantage occurred in any of the object-relevance categories, namely the high relevance, low relevance, and ambiguous category. A GEE analysis showed that the relevance category had a significant effect on recall, X^2 (2, N = 12) = 11.73, p = 0.003. However, no interaction effect of the scenario

condition and relevance category was found, X^2 (2, N = 12) = 1.36, p = 0.51, indicating that the lack of survival-processing advantage was consistent across all three relevance categories. A follow-up test looking at the difference between the three relevance categories showed that ambiguous, X^2 (1, N = 12) = 10.59, p = 0.001, and high-relevance, X^2 (1, N = 12) = 5.53, p = 0.019, objects were significantly better recalled than the low-relevance objects (see Figure 1). In summary, the results showed that the scenario condition did not predict better recall, while the relevance category predicted the subsequent recall. In addition, the scenario condition and relevance category showed no interaction.

Figure 1

Mean proportion of the recalled objects for each relevance category sorted by 2 scenario conditions



Note. Error bars represent 95% confidence intervals

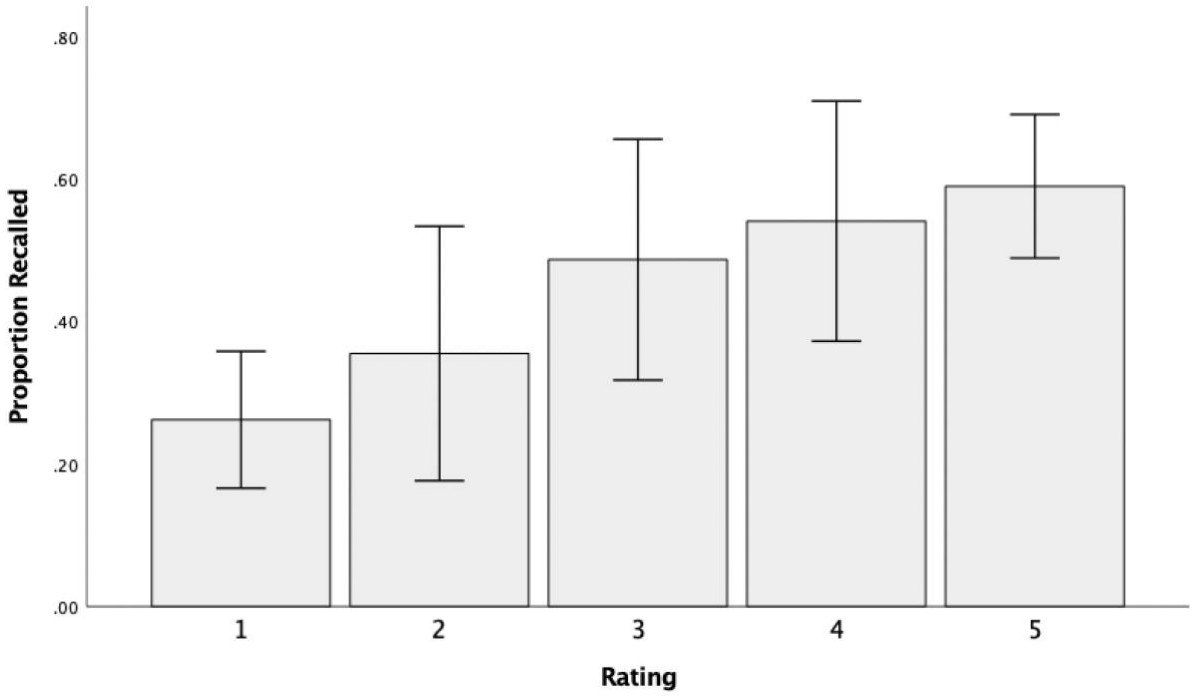
Rating

We also investigated whether the relevance ratings differed between scenarios. Using the GEE model, we found no significant difference in the average relevance rating between

the survival and moving scenario, X^2 (1, N = 12) = 1.69, p = 0.19. On contrary, we did find a significant relationship between the relevance rating and recall, X^2 (4, N = 12) = 10.68, p = 0.03, with better recall for words receiving a higher rating (see Figure 2). Notably, the difference in recall between objects receiving ratings from 1 to 5 was significant only between the rating of 1 and 5, X^2 (1, N = 12) = 5.84, p = 0.016, indicating a possible congruity effect with better recall for objects that were rated as highly relevant for the scenario than for objects rated as completely irrelevant.

Figure 2

Mean proportion of the recalled objects, separately for each rating category



Note. Error bars represent 95% confidence intervals. Rating included a 5-point scale (1 = completely irrelevant, 5 = extremely relevant)

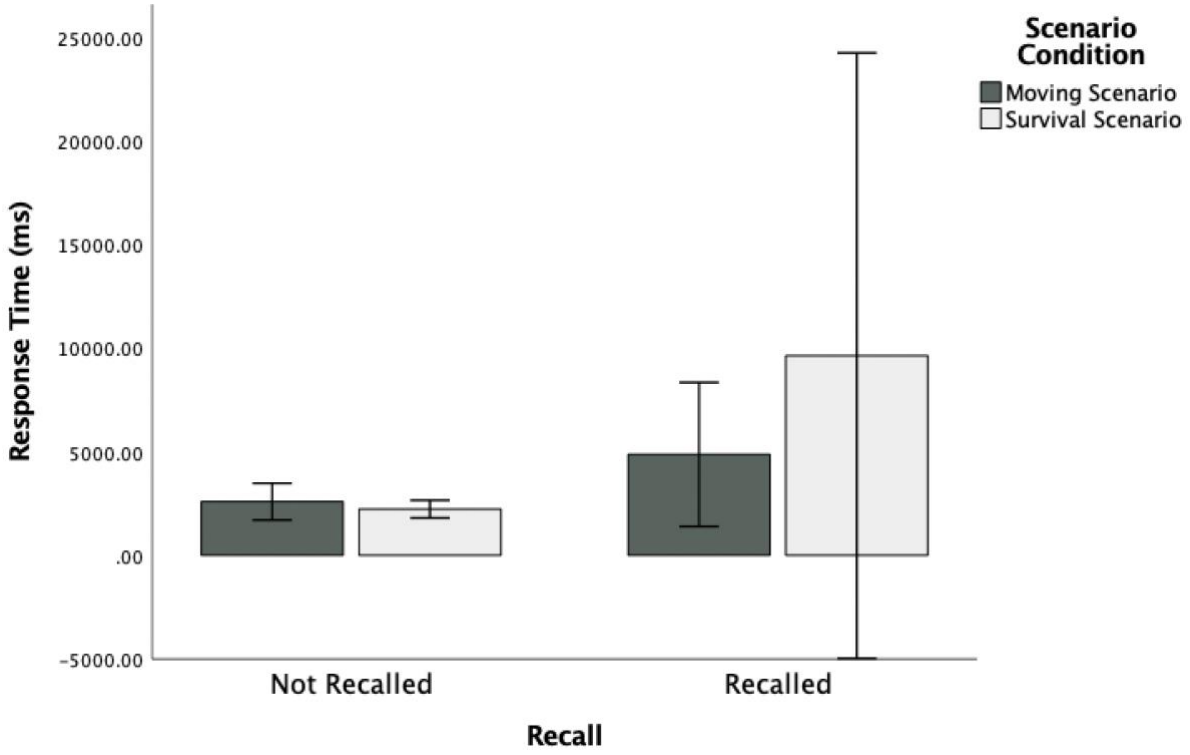
Response Time

Our second hypothesis predicted participants would take longer to rate the relevance of objects in the survival scenario compared to the moving scenario. For this analysis, we did not exclude any outliers in response times (RTs). The mean RTs were higher for the survival

scenario (*M* = 5827.18ms, *SD* = 42411.61ms) than for the moving scenario (*M* = 3521.22ms, *SD* = 9036.33ms). However, the GEE analysis showed that RTs during the rating task did not differ across the two conditions, X^2 (1, N = 12) = 0.56, *p* = 0.45. That is, our second hypothesis stating that participants would take longer to rate the objects in the survival scenario than in the moving scenario was not supported by the data. Using RT as an index of effortful processing we further analyzed whether participants took significantly longer to rate the recalled objects compared to the non-recalled ones. GEE model showed no main effect of RT on the correct recall, X^2 (1, N = 12) = 0.65, *p* = 0.42. Additionally, there was no interaction effect between RT and scenario condition on recall, X^2 (1, N = 12) = 0.003, *p* = 0.96; see Figure 3. In short, using RT as an index of the elaboration failed to explain the recall data.

Figure 3

Response time in milliseconds (ms) for the recalled and not recalled objects across the two scenario conditions



Note. Error bars represent 95% confidence intervals

Thinking about Functions

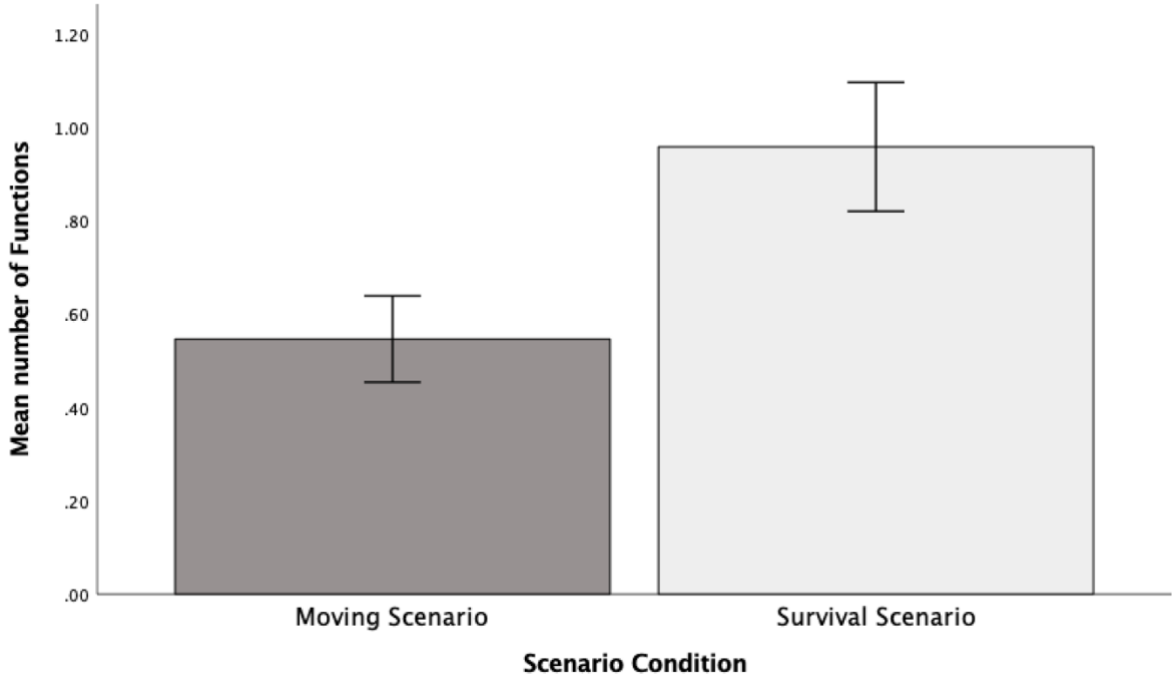
The main focus of our study was to investigate what participants think while doing the relevance rating, where we predicted that thinking about function will play an important role.

Functions and the Scenario Condition. We hypothesized that participants would think of more possible functions when rating the relevance of objects in the survival scenario compared to the moving scenario. Looking at the GEE model, participants thought of significantly more functions while judging the relevance of words for the survival scenario, X^2 (1, N = 12) = 20.01, $p < .001$, with a mean of 0.96 functions being mentioned in the thought reports for the survival scenario compared to 0.55 functions in the moving scenario (see

Figure 4). Since significantly more functions were mentioned in the survival scenario, the data supported Hypothesis 3.

Figure 4

Mean number of functions stated while rating the object for the two scenario conditions



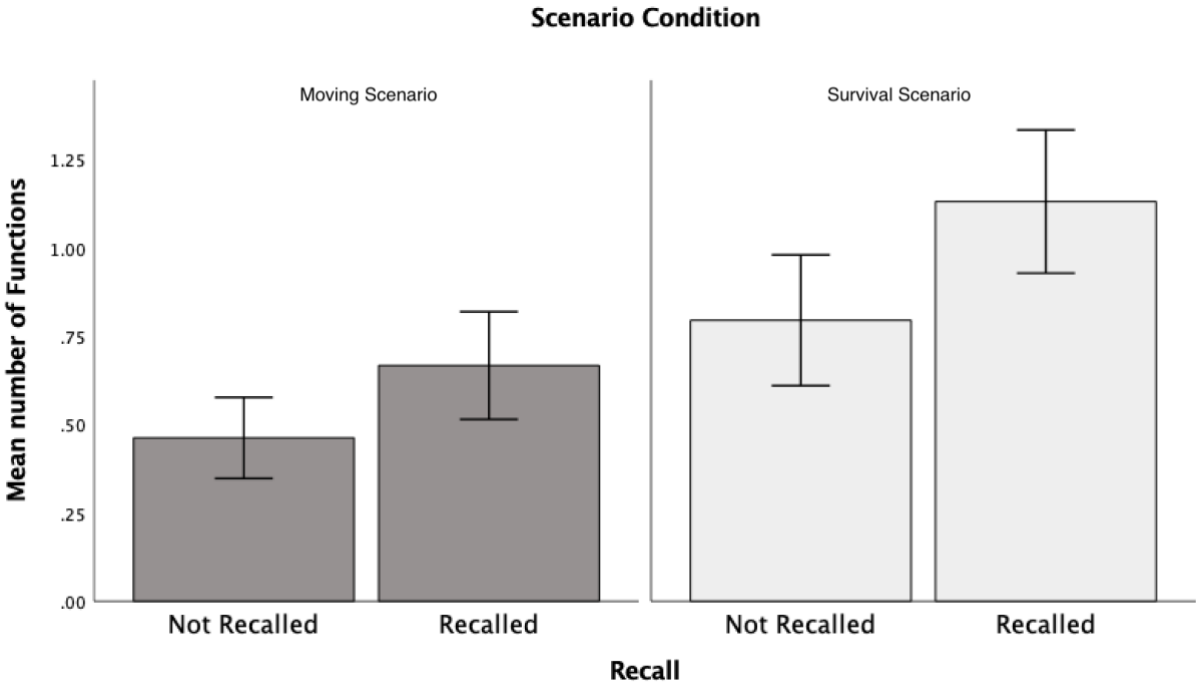
Note. Error bars represent 95% confidence intervals

Functions and Recall. Further GEE testing of Hypothesis 4, which was that we expected that the number of functions mentioned would predict an increased recall, showed that functions indeed had a main effect on the recall, X^2 (1, N = 12) = 5.71, p = 0.017. In other words, there was a higher recall performance for words for which participants thought of more functions, supporting our Hypothesis 4. When we considered separately the effect of functions that were related to the three goals specified in the scenario (see 'Relevant Functions' in Table 2) and other kinds of functions (see 'Other Functions' in Table 2), the GEE analyses showed that only 'Other Functions' had a significant effect on recall, X^2 (1, N = 12) = 7.43, p = 0.006. Noteworthy, despite the number of functions mentioned being significantly higher in the survival scenario and the average number of functions predicting

better recall, there was no interaction effect of scenario condition and the mean number of functions on recall, X^2 (1, N = 12) = 0.39, p = 0.53 (see Figure 5). In addition, we also noticed that participants never mentioned more than two functions for an object when they rated it in relation to a moving scenario, while the highest number of functions in relation to the survival scenario was four. Interestingly, when the mean number of functions came to 2.67, the object was always recalled, apart from one object with 4 functions not being recalled (see Figure 6). Put shortly, the number of functions significantly predicted a better recall and were significantly higher in the survival scenario. However, this did not translate into a significant interaction between the scenario condition and the mean number of functions in predicting the recall.

Figure 5

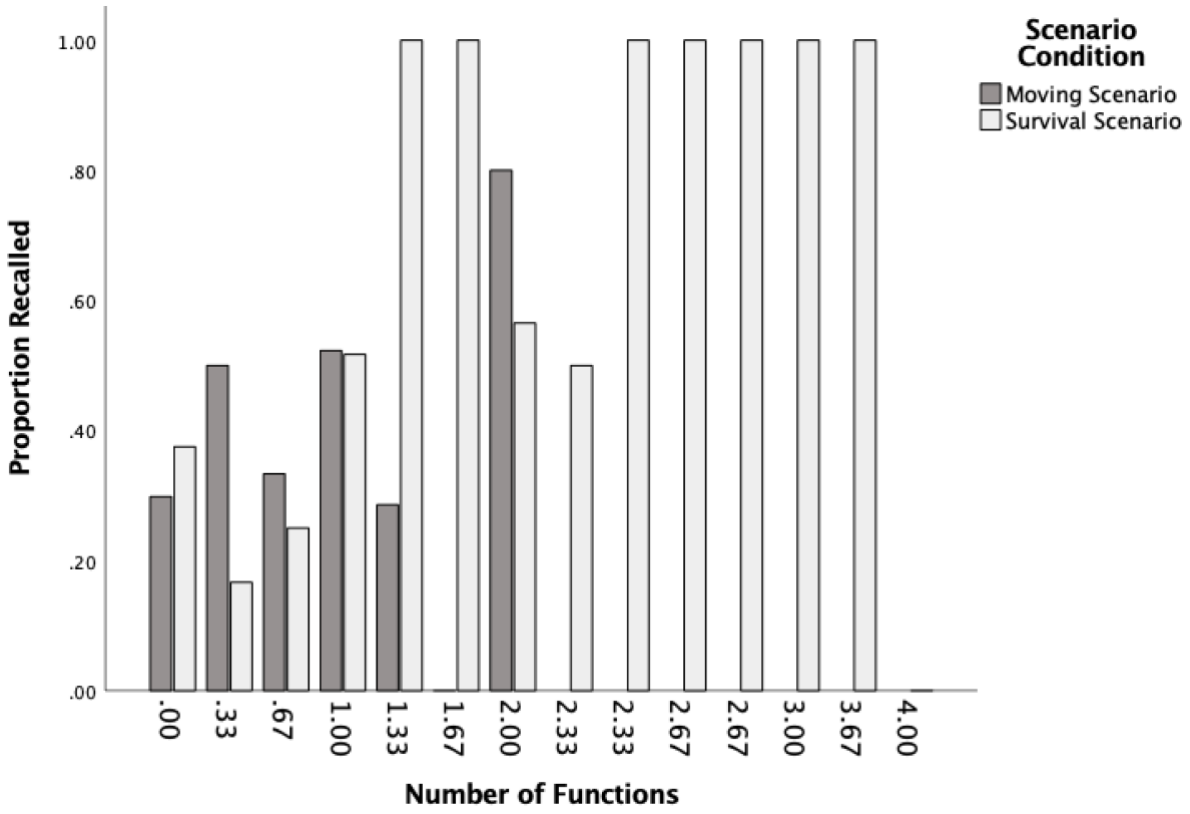
Mean number of functions as a function of recall presented for each scenario condition



Note. Error bars represent 95% confidence intervals

Figure 6

Mean proportion of the recalled objects as a function of a number of functions stated across two scenario conditions

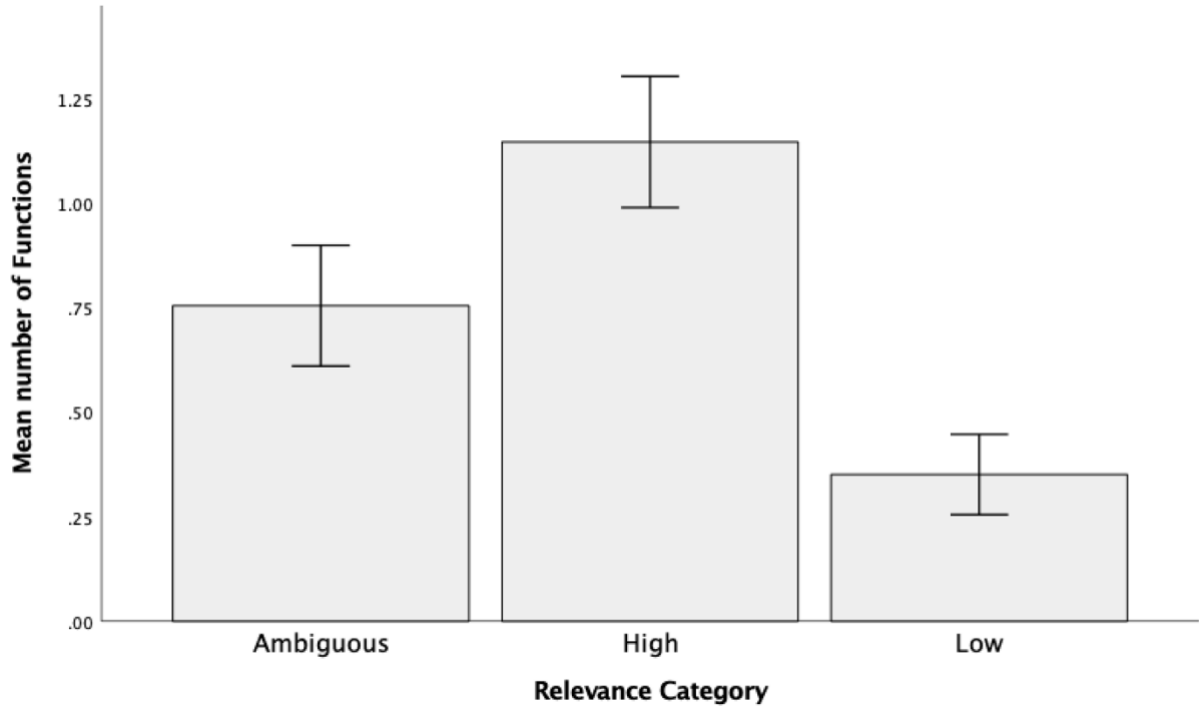


Functions and Relevance Category. Hypothesis 5 stated that more functions will be mentioned for words in the ambiguous relevance category compared to words in the high and low relevance categories. Contrary to what we predicted, the highest number of functions were mentioned in the high-relevance category (M = 1.15, SD = 0.77), followed by the ambiguous category (M = 0.76, SD = 0.71), and low-relevance category (M = 0.35, SD = 0.47; see Figure 7). Statistical analysis using the GEE model showed that the relevance category was significantly related to the number of functions mentioned, X^2 (2, N = 12) = 86.33, p < .001, with high-relevance objects, X^2 (1, N = 12) = 85.86, p < .001, and ambiguous objects, X^2 (1, N = 12) = 43.44, p < .001, being related to significantly more functions compared to low-relevance objects. We also found that relevance category and functions mention produced a significant interaction effect in predicting the correct recall, X^2 (2, N = 12) = 7.35, p = 0.025.

Briefly, the data did not support Hypothesis 5 since most functions were mentioned in the high relevance category instead of the ambiguous one. Nevertheless, the relevance category was found to be a significant predictor of the number of functions mentioned, with a higher number of functions being mentioned for highly relevant and ambiguous objects, compared to irrelevant objects.

Figure 7

Mean number of functions for each relevance category

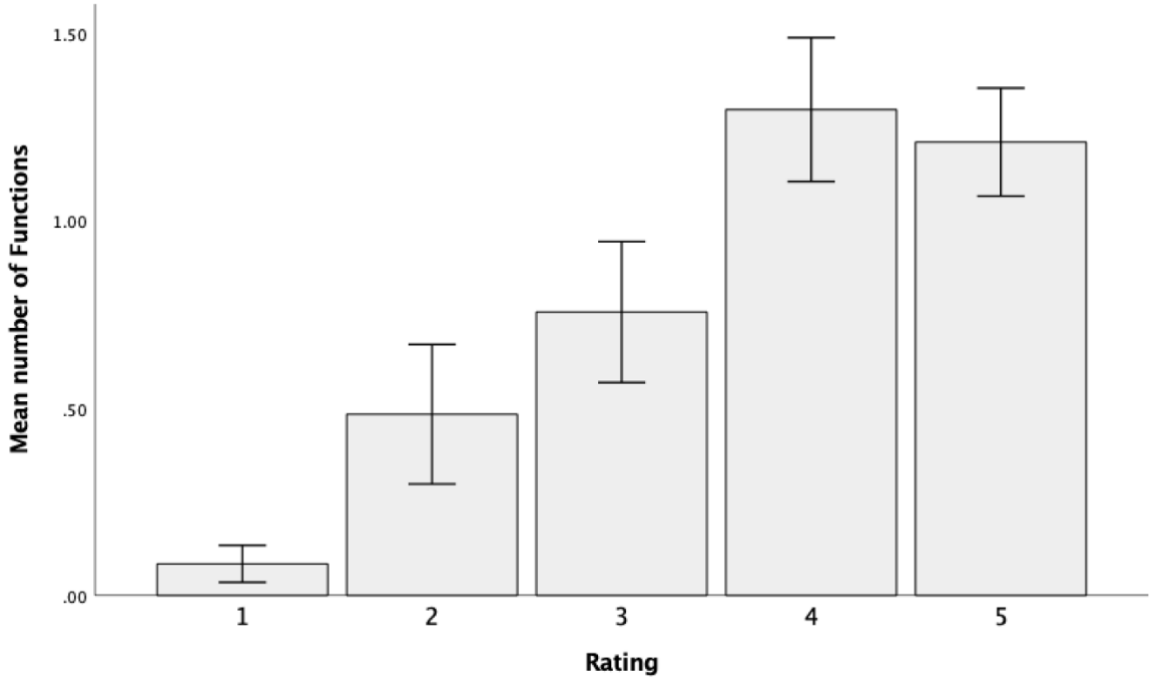


Note. Error bars represent 95% confidence intervals

Functions and Rating. Lastly, the rating of an object showed a significant relationship with the number of functions stated, X^2 (1, N = 12) = 282, $p < .001$, with participants stating more functions for the objects that had a higher rating (see Figure 8). Objects receiving a rating of 5 significantly differed in the number of mentioned functions from those receiving a rating of 3 ($p < .001$), those receiving a rating of 2 ($p < .001$), and those receiving a rating of 1($p < .001$), while they did not significantly differ from those receiving a rating of 4 ($p = 0.11$).

Figure 8

Mean number of functions, separately for each rating category



Note. Error bars represent 95% confidence intervals. Rating included a 5-point scale (1 = completely irrelevant, 5 = extremely relevant)

Other coding categories

In the following sections, we will analyze how other categories from the coding scheme related to the recall. Specifically, we will consider the data obtained for thought-reports of goals, self-references, and arguments for the irrelevance of the object (see Table 2).

Goals. Following the search-inference framework (Baron, 2008), goals were included in our coding scheme, yet their final conceptualization came very close to the category of functions due to the difficulty of separating references to goals from references to functions. Put differently, most functional thinking included goals explicitly or implicitly. However, some functions related to the same goal, which is reflected in the frequency analysis, where functions were mentioned 213 times out of 283 objects, and goals were mentioned 182 times out of 284 objects. Indeed, in a model of all scoring categories (total functions, goals, self-

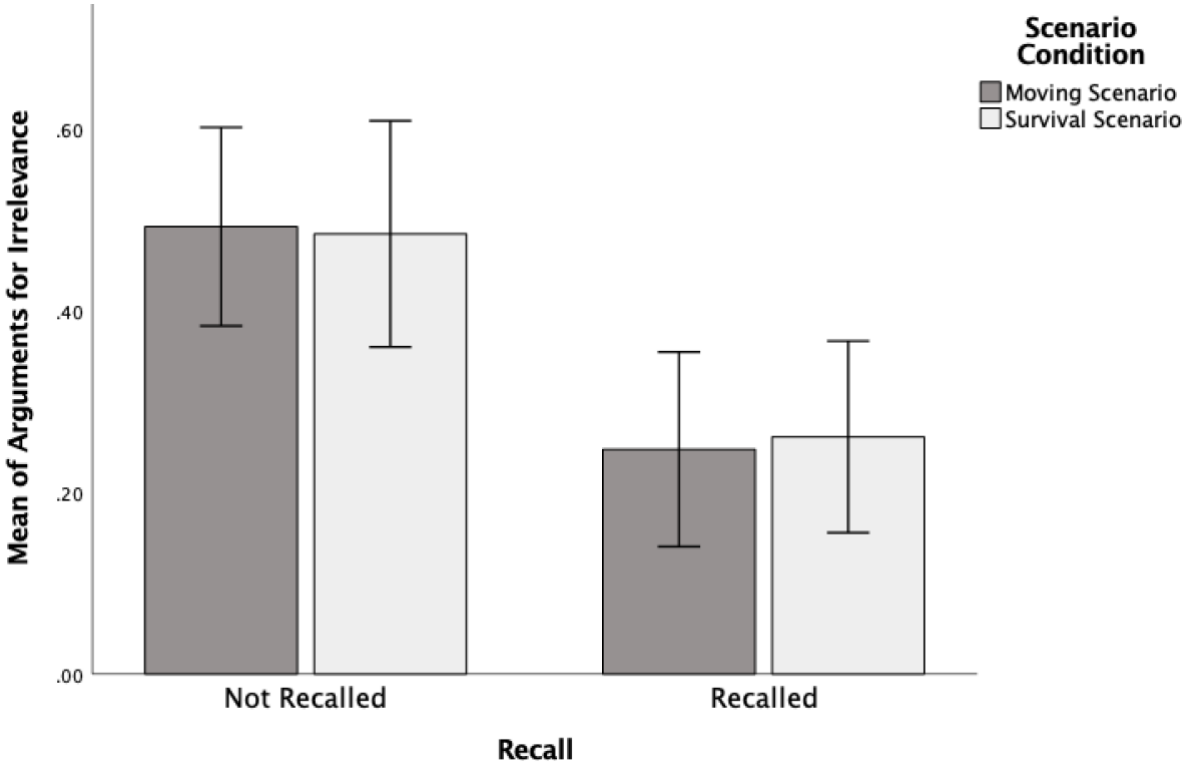
reference, arguments for irrelevance) being the predictors of the recall, total functions and goals showed a high correlation (r = -0.75), which indicates the multicollinearity of these two parameters. Due to multicollinearity, moderate ICC (α=0.69), and participants phrasing goals in terms of functions, the specific analysis of goals was excluded from further analysis.

Self-reference. Participants self-referenced significantly more often in the moving scenario compared to the survival scenario, X^2 (1, N = 12) = 12.93, $p < .001$. However, self-reference had no main effect on the recall, X^2 (1, N = 12) = 1.10, p = 0.29, and did not interact with the condition when predicting the recall, X^2 (1, N = 12) = 0.24, p = 0.62.

Arguments for the irrelevance of an object. Statistical analysis showed that there was no significant difference between the survival and the moving condition in how often arguments were mentioned for the irrelevance of an object, X^2 (1, N = 12) = 0.06, p = 0.81. Additionally, arguments for object irrelevance were significantly related to recall, X^2 (1, N = 12) = 5.84, p = 0.016, and did not interact with the scenario condition in predicting the recall, X^2 (1, N = 12) = 0.11, p = 0.74. Importantly, arguments for irrelevance predicted worse recall (see Figure 9), which corroborates the analysis showing a significant relationship between ratings and recall.

Figure 9

Mean number of arguments for the irrelevance of an object across two scenario conditions for the recall category



Note. Error bars represent 95% confidence intervals

The Imagining of the Scenario

Besides using the 'Type-aloud' method in the rating task, this method was also administered while participants had to think about the scenario, right after reading the description of the scenario. The exploratory analysis of these answers showed the following:

Survival Scenario. Common themes that appeared while imagining the survival scenarios were the need to build a shelter (8 participants out of 12), ways to get food (7 out of 12 participants), the potential of predators (9 out of 12 participants), and securing water (6 out of 12 participants). Other themes included goals of social contact (e.g., entertainment, keeping sanity, trying to see if anyone else is around), starting a fire (for either cold, predators, or food), washing and bathing, and protection from cold. Another noteworthy observation was

that participants reported only negative feelings in imagining the survival scenario, such as never feeling safe, being afraid for their sanity, panicking, and trying to move away from the grasslands.

Moving Scenario. Common themes that appeared while imagining the moving scenario were transporting belongings to a new place (7 out of 12 times), ways to find the best possible new home (7 out of 12 times), and meeting new people in the new place (4 out of 12 times). Other themes that appeared were finding a job in the new place, taking care of financial matters, securing VISA or passport, saying goodbye to family and friends in the current place, arranging healthcare, learning the language of the country they imagined moving to, taxation of the new place, and preferences for the new home, such as living near the nature or the art scene. In contrast to the survival scenario, participants reported both positive and negative emotions as part of imagining the moving scenario. Instances of positive emotions were being excited to move to the new place and thrilled to start afresh. Negative emotions were being stressed or anxious to move or find a new place, worried about getting new friends, and seeing moving as challenging.

Differences in thinking about the Scenarios. Generally, we noticed that the thought protocol answers for imagining the moving scenario were shorter, such that they typically only featured the names of the countries that participants imagined themselves moving to. On the other hand, multiple participants in the survival condition stated various details of the scenario they imagined themselves in, such as: “The area is a dense forest, stretching out as far as the eye can see. […] The trees are bustling with noise, the wind rustling the leaves, the birds tweeting throughout the day.”. Furthermore, in both scenarios participants referred to the three goals stated in the description of the scenario (survival: securing food, water, and avoiding predators; moving: locating and purchasing a new home, transporting the belongings). Specifically, we noticed that in the moving scenario all participants planned to

have a home arranged already before moving to a new place (e.g., “I will also have accommodation prepared on arrival.”). This resonated in a later rating task, where none of the participants referred to the goals of locating and purchasing a new home with relation to the object relevance. They only rated the relevance of an object in relation to the goal of transporting the belongings. Lastly, goals that were mentioned whilst imagining the moving scenario mostly did not demand thinking about the functions of any object, such as meeting new people, looking for prices, or learning the language. The only exception was the goal of transporting the belongings, where objects could be relevant (e.g., “I first need to get a few boxes and pack the most important things.”), which might be why only this goal was relevant for the rating task. On the contrary, goals that were mentioned while imagining the survival scenario often involved describing the tools or objects that are needed to achieve this goal (e.g., “I try to find something for defense, like a sharp glass or something that I can use against predators.”). In short, thinking about the survival and moving scenario differed in the level of elaborated description of the scenario, and the nature of the goals participants referred to. That is, in the survival scenario they needed more tools and objects to achieve the goals stated, while that was not the case in the moving scenario.

Discussion

The main purpose of the current study was to directly explore the underlying mechanisms of the survival-processing advantage using the ‘type-aloud’ protocol as an adaptation of the think-aloud protocol (Ericsson & Simon, 1984). One limitation of most previous findings is that their results about encoding processes relied on indirect inferences from performance on later memory tests. Through the ‘type-aloud’ protocol, we could directly test previous findings of the survival-processing advantage, asking participants to type their thoughts while (1) reading the description of the survival/moving scenario and (2) completing the rating task. Previous studies (e.g., Kroneisen & Erdfelder, 2011; Erdfelder & Kroneisen,

2014; Kroneisen et al., 2014) showed accumulating evidence in favor of the richness-of-encoding hypothesis playing a role in the survival-processing advantage. According to this hypothesis participants in the survival scenario come up with a large number of highly distinctive and unique ideas that later serve as a retrieval tool and lead to better memory recall of objects (Kroneisen & Erdfelder, 2011). Furthermore, it was found that these distinct memory representations might involve thinking about different possible functions of an object (e.g., Bell et al., 2015; Forester et al., 2020; Kroneisen et al., 2021). To test these ideas directly, we hypothesized that participants would come up with more possible functions in the survival scenario than in the moving scenario and that functional thinking will be able to predict a better recall on the surprise memory test. The time spent on the task was also shown to be an indicator of the amount of elaboration, (Craik & Tulving, 1975), which is why we predicted participants will take longer to rate the relevance of an object in the survival scenario compared to the moving scenario. Lastly, we looked at three different categories of objects based on relevance ratings where it was previously found that ambiguous objects allow for greater elaboration than high and low relevance category objects (Hansen-Manguikian, 2021). Therefore, we predicted that participants would come up with most functions for the ambiguous objects.

The results obtained in our study revealed that we could not find the survival-processing advantage, failing to replicate the results by Nairne et al. (2007), which was against our Hypothesis 1. Even though the difference between the survival and moving scenario was nonsignificant for recall, the survival scenario still showed a higher recall rate (48.59%) than the moving scenario (40.85%). The difference between scenarios possibly could not reach significance due to the low power of our study (below 0.80), as we only used 12 participants. Low power seems to be the most plausible explanation for the lack of survival-processing advantage in our experiment as we used the same survival-processing

paradigm as Nairne et al. (2007). Additionally, the survival-processing advantage showed to be a robust phenomenon, resistant to different measurement and methodological artifacts (e.g., Aslan & Bäuml, 2012; Nouchi, 2012, Otgaar et al., 2010). Despite having a low power to detect an effect, these findings still seem surprising, as we were nevertheless able to detect some other effects in our study. It was also surprising that, contrary to our second hypothesis, RT in the survival scenario did not significantly differ from the moving scenario. Again, this could be interpreted in a way that RT could not indicate the amount of elaboration due to low power. However, there might have been something about our study that erased the differences in elaboration between the two scenarios, which ultimately resulted in the absence of the survival-processing advantage.

While we discovered that the scenario condition could not predict the recall performance, we found that (1) functional thinking, (2) relevance category, and (3) Arguments Irrelevance had a significant effect on recall:

Thinking about Function

In Hypothesis 3 we predicted that participants would think about more possible functions of the objects in the survival compared to the moving scenario. In line with this hypothesis, results showed that there were indeed more functions mentioned in the survival scenario. Furthermore, the number of functions mentioned could significantly predict better recall, which was consistent with our Hypothesis 4. Yet, there was no interaction between the functions mentioned and the scenario condition for the recall, which means that even though participants thought of more functions in the survival condition, this did not translate into a significant survival advantage. The rest of this section discusses these results about functional thinking:

Firstly, the fact that participants reported a higher number of functions in the survival scenario was consistent with previous findings where participants produced a larger number

of ideas in the survival scenario compared to the fitness-irrelevant conditions (Röer et al., 2013). As previous studies did not specify the content of these ideas, apart from ideas being more creative in the survival condition (Bell et al., 2015), our findings showed that it is, in fact, the possible functions that participants came up with. Functions in the survival condition were possibly deemed as more creative as it was previously proposed that the survival scenario triggers thinking about the alternative uses of objects, whilst the moving scenario promotes thinking about primary uses (Wilson, 2016; Kroneisen et al., 2021; Forester et al, 2020). This finding connects to the idea of functional fixedness where the survival context benefitted more from the low functional fixedness of an object than did the moving scenario (Kroneisen et al., 2021) meaning that low functional fixedness offers more thinking about possible uses only in the survival scenario. In explaining why this is the case, we can translate these findings into the search-inference framework (Baron, 2008), where we previously reasoned that the survival-processing advantage might be based on the formed associations between the objects and the goals within the scenario – searching for uses of the objects and inferring object relevance to the possible goals. Results from the first part of the 'type-aloud' protocol where participants reported their thoughts about the scenario revealed that goals mentioned in the survival condition were more often connected to the use of objects leading to a subsequently higher amount of thinking about the object's functions (e.g., gathering materials to create a shelter). On the contrary, goals produced whilst thinking about the moving scenario often did not produce thinking about the function as object use was usually not necessary for achieving these goals (e.g., saying goodbye to the family members). These results can explain why the survival scenario benefits from low functional fixedness more than the moving scenario. They can also explain why the act of planning was found to mediate the survival-processing advantage (Klein et al., 2011) – planning how to achieve goals in the survival scenario involves thinking about the functions, while the function of an

object is not always part of the plan in the moving scenario. The same might be the case in studies that compare modern (city) versus ancestral (grasslands) scenarios – even if they set the same goal (e.g., finding the medicine or searching for food), this goal might be achieved differently in different scenarios. For example, finding food in the city might depend more on the price of food in the supermarkets or the kindness of other people to give you food, while you might need to use objects to be able to hunt or collect the food in the grasslands. In other words, we propose that participants came up with a higher number of functions in the survival scenario because the goals in this scenario stimulated searching for the functions of objects. Thus, the amount of elaboration is not restricted only by the properties of an object, such as functional fixedness, but also the nature of the goals that this scenario triggers.

Secondly, consistent with the richness-of-encoding hypothesis, results showed that the number of generated functions could significantly predict the performance of the surprise recall test. Similarly, Röer et al. (2013) found that the probability of successful recall increased as a function of a number of self-generated ideas. Considering the richness-of-encoding hypothesis this means that each generated idea or each possible function of an object could serve as a potential retrieval cue on a later memory test. Furthermore, an extra functional focus was previously shown to be able to even surpass the standard survival-processing instructions, meaning that functional focus proves to be an efficient deep-processing technique (Bell et al, 2015). Interestingly, as we separated the functions into two categories: (1) ‘Relevant Functions’ (functions relating to the three goals stated in the scenario), and (2) ‘Other Functions’ (functions relating to other goals), we found that it was only the ‘Other Functions’ that significantly predicted the recall. When participants reported their thoughts on the scenario, we found that goals that were mentioned besides the three goals already stated in the scenario only referred to functions in the survival condition. For example, the goal of sheltering was often mentioned in the survival scenario which is not one

of the goals already mentioned in the description of the scenario and requires the use of objects for its achievement. These extra goals created an additional opportunity for participants to find even more functions of given objects, while extra goals in the moving scenario did not help to generate more functions allowing for additional elaboration.

Lastly, as we found a higher number of functions stated in the survival scenario, we expected a higher recall in the survival condition. However, elaboration in terms of generated functions did not interact with the scenario condition in predicting the recall. This kind of result was surprising considering that there were significantly more functions mentioned in the survival scenario, which means that participants nevertheless elaborated more in the survival scenario. The reason why this elaborative thinking was not able to translate to the survival-processing advantage remains unknown besides the possibility that our study simply had too little power to detect the survival advantage. Additional analysis showed that participants never came up with more than two functions in the moving scenario, while they came up with the maximal number of four in the survival scenario. When the mean number of functions surpassed 2.67, this object was always recalled. Even though we cannot draw any radical conclusions from these findings due to a low number of participants and a lack of significance for the survival advantage, it appears obvious that results leaned towards a better recall depending on a number of functions in the survival scenario.

One possible reason for elaboration in terms of functions in the survival scenario not predicting a better recall could be that participants in the moving scenario compensated for the functional thinking with some other form of elaboration. However, this seems unlikely as answers from the ’type-aloud’ protocol in the rating task showed that participants also thought about the functions of objects in the moving scenario. It was even found that they related their answers to only one of the goals mentioned in the scenario, namely transportation of belongings. This made sense when looking at the ‘Type-aloud’ data from imagining the

scenario, where all participants predicted that the goals of locating and purchasing a new house will be arranged before actual moving, so they did not link these goals to the relevance of the object in the rating task. This means that despite an equal number of goals in each scenario, moving scenarios naturally allowed for lower elaboration as fewer goals were assumed. It was previously shown that when participants are restricted to fewer goals, this leads to diminished or even non-existent survival-processing advantage (Kroneisen & Erdfelder, 2011). Additionally, even the extra goals in the moving scenario that were not mentioned in the description of the scenario usually could not match the objects in the rating task, leading to low elaboration on these objects. Put differently, since objects in the moving condition could not be linked to the goals, there was no opportunity for elaboration on these objects, which means that these objects might have been processed based on low-level encoding characteristics, such as congruence or valence of the word. In line with this reasoning, Forester et al. (2020) found that the moving scenario indeed stimulates low-level encoding processes, while the survival scenario shifts away toward more elaborative encoding processes.

Relevance Category

Besides the number of functions generated during the rating task, we also found that the relevance category could significantly predict a better recall in the subsequent memory test. Importantly, the relevance category was found to interact with the number of functions when predicting the recall and could also predict the number of functions produced. Hypothesis 5 predicted the highest number of functions in the ambiguous category as proposed by the results from Hansen-Manguikian (2021). Ambiguous objects were postulated to provide the most opportunity for elaborative processing, as the link between the object and the goal cannot be immediately obvious. Instead, our results showed that the high-relevance category induced the most elaboration, as participants generated the highest number of

functions for the high-relevance objects. This finding is more in line with the congruity effect, stating that recall or recognition of objects is better when the objects are relevant or congruent with the type of processing (Schulman, 1974; Craik & Tulving, 1975; Butler et al., 2009). Likewise, there was a trend showing a better recall for words that had a higher rating (see Figure 2). Since the relevance category interacted with the number of functions generated, we could explain that congruity effect by the number of functions generated during the rating task. However, there was no congruity effect found for the scenario condition, as the ratings did not differ between the two scenarios. There was also no interaction effect between the relevance category and the scenario condition in predicting the recall, which runs counter to previous findings where participants generated more ideas in response to scenario-congruent objects than to scenario-incongruent objects (Röer et al., 2013). Since the rest of our findings indicate that the objects in the survival scenario showed to be more congruent with the goals of this scenario, we found it surprising that there was no effect of the scenario on the relevance rating as the goals, based on which the rating was made, were produced by the scenario. It is also generally known that the scenario is part of the encoding and the later retrieval as proposed by the encoding specificity hypothesis (Tulving, 1983) and transfer appropriate processing network (Morris et al., 1977; Roediger, Weldon & Challis, 1989).

Other Coding Categories

***Goals*.** Our final definition of goals ended up including both explicitly and implicitly stated goals. We found multicollinearity between the categories of goals and functions since most goals that were mentioned in the rating task provoked thinking about the functions. As we already mentioned, goals that did not trigger thinking about the functions (such as purchasing and locating a new home in the moving scenario) were not mentioned in the rating task. This intertwined nature of goals with functions was also seen in the low inter-rater reliability for goals since it was hard to decide whether to count something as a goal or a

function. On the other hand, functions were clearly stated and resulted in having excellent inter-rater reliability, which validates the fact that participants think about the functions of the objects whilst rating their relevance to the scenario. Taken together, goals in the rating task seemed to be expressed through the functions, so it was functions that were eventually expressed through the 'type-aloud' protocol.

Self-reference. Initially, we did not include any hypotheses about the self-reference effect on survival processing as it was previously shown that self-referential processing cannot explain the survival-processing advantage (Nairne et al., 2007). Yet, the pilot study revealed that participants often referred to themselves while rating the relevance of an object, so we wanted to see whether self-reference influences recall. Even though we did not find any effect of self-reference on the recall, results showed that participants self-referenced significantly more in the moving condition. This could be interpreted by the fact that most of the people have gone through some kind of moving experience, so they were able to share their personal experiences, while the survival scenario was mostly hypothetical.

Arguments for the irrelevance of an object. Results showed that the more 'Arguments Irrelevance' that were stated, the worse the recall performance was. According to the richness-of-encoding hypothesis, we could expect that also arguments for the irrelevance would serve as a potential retrieval cue, enabling deeper processing. Notwithstanding, we could also interpret this finding from the evolutionary point of view: due to the limited capacity of our memory, forgetting irrelevant information could help us to maximize the recall of relevant information. Generally, forgetting was found to ensure a statistically optimal match between the availability of information in memory and its probable current relevance (de Jong, 2021): therefore, our finding supports the view of memory not being a passive storage system, but rather an adaptive data-management system.

Limitations and Future Directions

One limitation of our study was the lack of statistical power since we only used 12 participants and reached the statistical power below the acceptable level of 80%. The reason for such a low number of participants was that we were primarily interested in exploring participants' thoughts and not rigidly testing previously set hypotheses. Still, setting our statistical power so low deprived us of possibly detecting some important effects. For instance, we could not detect the survival-processing advantage, which was previously shown to be a robust phenomenon (e.g., Aslan & Bäuml, 2012; Nouchi, 2012, Otgaar et al., 2010; Scofield et al., 2018). Even though the absence of these kinds of effects was likely due to low statistical power, we cannot claim so; therefore, future research would benefit from incorporating more participants when investigating the survival-processing paradigm (Nairne et al., 2007) through the think-aloud protocol.

Furthermore, we used the relevance categories that were predetermined based on the study by Yildirim (2020). However, we presented participants with the word of an object, while the study by Yildirim (2020) used pictures of objects. This adaptation might have changed some relevance ratings due to a different interpretation of an object when it was written as a word instead of presented as a visual image. For example, whilst the image of a window clearly represents a glass window, which is not always seen as relevant in the grasslands, the written word for a window was often interpreted as a hole in the shelter seen as highly relevant. This means that some of the objects written as a word could lower their functional fixedness as they allowed for more interpretations, possibly bending our results in Hypothesis 5, where we expected the most elaboration in terms of functions for the ambiguous objects. Taken together, even though the effects of using words instead of pictures are probably minor, we suggest that future research avoid this possible confounding effect by using pictures instead of words when investigating the relevance categories set by Yildirim (2020).

Lastly, since our study used the adaptation of the think-aloud protocol, all the limitations of this method naturally transfer to our experiment as well. Firstly, thinking aloud may produce different thinking than ordinarily. However, it has been found that in many verbalization tasks, thinking aloud does not produce an apparent effect (Ericsson & Simon, 1984). Secondly, verbal reports might not match the underlying determinants of the subject's behavior, since they might not get expressed verbally. Similarly, subjects might be unable to explain how they reached certain conclusions and attribute their decision to an arbitrary explanation (e.g., Nisbett & Wilson, 1977). Nonetheless, we were interested in the experiences and not the causes of one's conclusions (Ericsson & Simon, 1980). Thirdly, participants are usually not accustomed to verbalizing their thoughts at the same time as completing the task, so the administration of think-aloud protocol can be difficult (Smagorinsky, 1994). Overall, the think-aloud method is time-consuming and demands proper training on how to score the answers. However, verbal reports are argued to be reliable when there is relevant information to be reported as a subject of working memory (Ericsson & Simon, 1984), which was the case in our study.

Theoretical and Practical Implications

There are various theoretical and practical implications of our study. As far as theoretical implications are concerned, we found that thinking about the functions of an object plays a significant role in the survival condition but not the control moving condition of the survival-processing paradigm (Nairne et al., 2007). Even though previous studies already indicated towards the importance of functional focus (Röer et al., 2013; Bell et al., 2015; Kroneisen et al., 2021), our study demonstrated that through direct testing with the use of the 'Type-aloud' protocol. With this method, we were able to see the exact thoughts of participants while they read the description of the scenario and later rated the relevance of an object to that scenario. This enabled us to find some possible explanations for higher

functional focus in the survival scenario. We found that most goals that were mentioned in the survival scenario related to the use of objects and their possible functions, while goals in the moving scenario often did not relate to the use of any objects. Putting this rationale in the search-inference framework (Baron, 2008), objects in the moving scenario could not be related to the goals of that scenario. This means that objects in the rating task could not be elaborated on in the same way when thinking about them in the moving scenario as opposed to the survival scenario. Higher elaboration in the survival scenario was often proposed to be the underlying proximate mechanism of the survival-processing advantage, known as the richness-of-encoding hypothesis (e.g., Kroneisen & Erdfelder, 2011). However, our study was not able to find the survival-processing advantage despite higher elaboration in the survival scenario. Considering survival advantage as a robust phenomenon, we proposed that the most probable reason for not finding the survival effect was the lack of statistical power in our study.

Together, our results cast doubt on the notion that human memory is naturally tuned toward fitness-relevant information, meaning that it is unlikely that the ancestral scenario would induce a unique form of survival processing. Instead, we found that survival processing seems to invite more elaboration in terms of generating more possible functions of an object. More specifically, we found direct evidence for the amount of elaboration being an underlying proximate mechanism for the survival processing. This is in line with the richness-of-encoding hypothesis claiming that survival-processing advantage is not about the evolutionary significance of survival per se, but rather the degree of the distinctive and elaborative forms of thinking that survival processing invites. Put differently, elaboration, as a domain-general process, is simply co-opted by the survival processing in producing the mnemonic advantage, which categorizes survival processing as an exaptation instead of adaptation (Nairne & Pandeirada, 2016). However, this does not mean that there is nothing

adaptive about the survival-processing effect. The way that people are able to come up with more functions for an object in the survival scenario undoubtedly had an adaptive advantage for our ancestors to solve novel problems and increased the chances of manipulating the external environment and consequently survival. Similarly, we demonstrated that it is not any kind of elaboration that plays a role in the mnemonic advantage, but it is only the elaboration on the relevant information that plays a role. As producing arguments for the irrelevance of an object predicted worse recall, we found supporting evidence for our memory being an adaptive information-relevant system, where the primary function of learning and memory is to equip us with knowledge for effective future problem-solving (de Jong, 2021).

Conclusion

In conclusion, we found that the survival scenario might not induce a mnemonic advantage in itself, but rather have the ability to invite a highly elaborative and effective encoding in terms of producing more possible functions for the given objects. Generated functions could serve as potential retrieval cues for later recall, as proposed by the richness-of-encoding hypothesis. We did not only find direct evidence for a higher elaboration in terms of functional focus for the survival scenario but also showed what it is about this scenario that induces higher elaboration. Firstly, only the goals in the survival scenario required thinking about the functions of objects for their achievements, which means that objects in the rating task could be linked to the goals of the scenario only in the survival condition. Secondly, participants in the moving scenario ended up referring to only one of the goals (i.e., transporting their belongings) mentioned in the scenario description while rating the objects, which left them with fewer possibilities to link the objects to their goals. In contrast, participants in the survival scenario connected the objects to all three goals of the scenario, creating a higher chance of elaboration on this object. Furthermore, highly relevant objects possibly allowed for the highest elaboration, as most functions were produced for this

relevance category and progressively diminished as a function of lower relevance. Taken together, we propose that it is not just the relevance of an object that allows for higher elaboration but also the goals that have to be consistent with these objects. That idea is somehow similar to the congruity effect which was previously found to play a role in the survival-processing advantage (Butler et al., 2009).

References

Aslan, A., & Bäuml, K.-H. T. (2012). Adaptive memory: young children show enhanced retention of fitness-related information. *Cognition*, *122*(1), 118–122. https://doi.org/10.1016/j.cognition.2011.10.001

Baron, J. (2008). *Thinking and deciding* (Fourth). Cambridge University Press.

Bell, R., Röer, J. P., & Buchner, A. (2015). Adaptive memory: thinking about function. *Journal of Experimental Psychology.learning, Memory, and Cognition*, *41*(4), 1038–1048.

Bonin, P., Gelin, M., Laroche, B., & Méot Alain. (2020). "survival processing of the selfish gene?": adaptive memory and inclusive fitness. *Evolutionary Psychological Science*, *6*(2), 155–165. https://doi.org/10.1007/s40806-019-00220-1

Butler, A. C., Kang, S. H. K., & Roediger, H. L. (2009). Congruity effects between materials and processing tasks in the survival processing paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(6), 1477–1486. https://doi.org/10.1037/a0017024

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, *104*(3), 268–294. https://doi.org/10.1037/0096-3445.104.3.268

de Jong, R. (2021). *Learning and Memory: Part II* [PowerPoint slides]. University of Groningen

Duncker, K. (1945). On problem-solving (L. S. Lees, Trans.). Psychological Monographs, *58(5)*, i–113. https://doi.org/10.1037/ h0093599

Erdfelder, E., & Kroneisen, M. (2014). Proximate cognitive mechanisms underlying the survival processing effect. In B. Schwartz, M. Howe, M. Toglia, & H. Otgaar (Eds.), *What is adaptive about adaptive memory?* (pp. 172–198). New York, NY: Oxford University Press.

Ericsson, K. A. & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data*. Cambridge, MA: The MIT Press.

Forester, G., Kroneisen, M., Erdfelder, E., & Kamp, S.-M. (2019). On the role of retrieval processes in the survival processing effect: evidence from roc and erp analyses. *Neurobiology of Learning and Memory, 166*, 107083–107083. https://doi.org/10.1016/j.nlm.2019.107083

Forester, G., Kroneisen, M., Erdfelder, E., & Kamp, S.-M. (2020). Survival processing modulates the neurocognitive mechanisms of episodic encoding. *Cognitive, Affective, & Behavioral Neuroscience*, *20*(4), 717–729. https://doi.org/10.3758/s13415-020-00798-1

Hansen-Manguikian, L. (2021). Judging Object Relevance Under Time Pressure: evidence for a serial search of relevant uses. (Master's Thesis, University of Groningen, Groningen, Netherlands)

Kang, S. H. K., McDermott, K. B., & Cohen, S. M. (2008). The mnemonic advantage of processing fitness-relevant information. *Memory & Cognition*, *36*(6), 1151–6. https://doi.org/10.3758/MC.36.6.1151

Klein, S. B. (2012). A role for self-referential processing in tasks requiring participants to imagine survival on the savannah. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(5), 1234–1242. https://doi.org/10.1037/a0027636

Klein, S. B., Robertson, T. E., & Delton, A. W. (2010). Facing the future: memory as an evolved system for planning future acts. *Memory & Cognition*, *48*(1), 13–13.

Klein, S. B., Robertson, T. E., & Delton, A. W. (2011). The future-orientation of memory: planning as a key component mediating the high levels of recall found with survival processing. *Memory (Hove, England)*, *19*(2), 121–39. https://doi.org/10.1080/09658211.2010.537827

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Kostic, B., McFarlan, C. C., & Cleary, A. M. (2012). Extensions of the survival advantage in memory: examining the role of ancestral context and implied social isolation. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *38*(4), 1091–8. https://doi.org/10.1037/a0026974

Kroneisen, M., & Erdfelder, E. (2011). On the plasticity of the survival processing effect. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *37*(6), 1553–62. https://doi.org/10.1037/a0024493

Kroneisen, M., Kriechbaumer, M., Kamp, S.-M., & Erdfelder, E. (2021). How can I use it? the role of functional fixedness in the survival-processing paradigm. *Psychonomic Bulletin & Review*, *28*(1), 324–332. https://doi.org/10.3758/s13423-020-01802-y

Kroneisen, M., Rummel, J., & Erdfelder, E. (2014). Working memory load eliminates the survival processing effect. *Memory*, *22*(1), 92–102. https://doi.org/10.1080/09658211.2013.815217

Magliano, J. P., & McNamara, D. S. (2006). Typing versus thinking aloud when reading: implications for computer-based assessment and training tools. *Behavior Research Methods*, *38*(2), 211–217.

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. Behavior Research Methods, 44(2), 314-324. doi:10.3758/s13428-011-0168-7

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior*, *16*(5), 519–533. https://doi.org/10.1016/S0022-5371(77)80016-9

Nairne, J. S., Coverdale, M. E., & Pandeirada, J. N. S. (2019). Adaptive memory: the mnemonic power of survival-based generation. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *45*(11), 1970–1982. https://doi.org/10.1037/xlm0000687

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

Nairne, J. S., & Pandeirada, J. N. S. (2008b). Adaptive memory: is survival processing special? *Journal of Memory and Language*, *59*(3), 377–385. https://doi.org/10.1016/j.jml.2008.06.001

Nairne, J. S., Pandeirada, J. N. S., & Thompson, S. R. (2008). Adaptive memory: the comparative value of survival processing. *Psychological Science*, *19*(2), 176–180.

Nairne, J. S., Thompson, S. R., & Pandeirada, J. N. S. (2007). Adaptive memory: survival processing enhances retention. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *33*(2), 263–73.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: verbal reports on mental processes. *Psychological Review*, *84*(3), 231–259. https://doi.org/10.1037//0033-295X.84.3.231

Nouchi, R. (2012). The effect of aging on the memory enhancement of the survival judgment task. *Japanese Psychological Research*, *54*(2), 210–217. https://doi.org/10.1111/j.1468-5884.2011.00483.x

Olds, J. M., Lanska, M., & Westerman, D. L. (2014). The role of perceived threat in the survival processing memory advantage. *Memory (Hove, England)*, *22*(1), 26–35. https://doi.org/10.1080/09658211.2013.806554

Otgaar, H., Smeets, T., & van Bergen, S. (2010). Picturing survival memories: enhanced memory after fitness-relevant processing occurs for verbal and visual stimuli. *Memory & Cognition*, *48*(1), 23–23.

Roediger, H. L., III, Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger, III, & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 3–39). Hillsdale, NJ: Erlbaum.

Röer, J. P., Bell, R., & Buchner, A. (2013). Is the survival-processing memory advantage due to richness of encoding? *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *39*(4), 1294–302. https://doi.org/10.1037/a0031214

Schulman, A. I. (1974). Memory for words recently classified. *Memory & Cognition*, *2*(1), 47–52. https://doi.org/10.3758/BF03197491

Scofield, J. E., Buchanan, E. M., & Kostic, B. (2018). A meta-analysis of the survival-processing advantage in memory. *Psychonomic Bulletin & Review*, *25*(3), 997–1012. https://doi.org/10.3758/s13423-017-1346-0

Sherry, D. F., & Schacter, D. L. (1987). The evolution of multiple memory systems. *Psychological Review*, *94*(4), 439–454. https://doi.org/10.1037//0033-295X.94.4.439

Smagorinsky, P. (1994) Think-aloud protocol analysis: Beyond the black box. In P. Smagorinsky (ed.), *Speaking about writing: Reflections on research methodology* (pp. 3–19). Thousand Oaks, CA: Sage.

Smeets, T., Otgaar, H., Raymaekers, L., Peters, M. J. V., & Merckelbach, H. (2012). Survival processing in times of stress. *Psychonomic Bulletin & Review*, *19*(1), 113–118. https://doi.org/10.3758/s13423-011-0180-z

Soderstrom, N. C., & McCabe, D. P. (2011). Are survival processing memory advantages based on ancestral priorities? *Psychonomic Bulletin & Review*, *18*(3), 564–9. https://doi.org/10.3758/s13423-011-0060-6

Tulving, E. (1983). *Elements of episodic memory* (Ser. Oxford psychology series, no. 2). Clarendon Press.

Wilson, S. (2016). Divergent thinking in the grasslands: thinking about object function in the context of a grassland survival scenario elicits more alternate uses than control scenarios. *Journal of Cognitive Psychology*, *28*(5), 618–630. https://doi.org/10.1080/20445911.2016.1154860

Yildirim, B., (2020). Does survival processing affect attention allocation during encoding or retrieval? (Master's Thesis, University of Groningen, Groningen, Netherlands)