THESIS

EVOLUTION, MEMORY PROCESSES, AND THE SURVIVAL PROCESSING BENEFIT TO MEMORY: AN EXAMINATION OF THE UNPREDICTABILITY HYPOTHESIS

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ABSTRACT

EVOLUTION, MEMORY PROCESSES, AND THE SURVIVAL PROCESSING BENEFIT TO MEMORY: AN EXAMINATION OF THE UNPREDICTABILITY HYPOTHESIS

Nairne, Thompson, and Pandeirada (2007) found an advantage in recall for items that were earlier rated for their survival utility in a hypothetical grasslands scenario. This pattern has repeatedly been shown, typically when comparing survival utility ratings given using a grassland scenario to those given using a modern city scenario. This advantage has been attributed to a grassland setting being similar to the critical ancestral environment of early humans. However, recent work has found this effect in situations entirely unrelated to ancestral environments (e.g., outer space), suggesting that the grasslands scenario is not critical to the effect. Moreover, recent anthropological evidence suggests that early humans lived in a time of high climate variability that, in turn, led to a chronically unpredictable environment during the time period most critical to the evolution of modern humans. Thus, rather than having adapted to one specific environment (i.e., grasslands), early humans may have adapted to environmental unpredictability itself. The proposed series of experiments will investigate the hypothesis that uncertainty may be a modifying factor in the survival processing advantage in memory. In the first experiment, participants were given either a randomized or a blocked series of four rating tasks followed by a subsequent test of recall. The second experiment explored the effect of a task relevant background image that also functioned as a means of isolating trials (90% vs 10%) on recall. The third experiment examined the effect of changing biome images (45% vs 45% vs 10%) on recall.

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INTRODUCTION

The Survival Processing Benefit for Memory

In their seminal survival processing paper, Nairne, Thompson, and Pandeirada (2007), report an advantage at recall for words encoded within the context of a survival scenario. Nairne and colleagues had participants rate on a 1-to-5 Likert scale a series of words on their relevance to an imagined grasslands survival scenario:

> In this experiment, we would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival scenario materials. Over the next few months you will need to find steady supplies of food and water and protect yourself from predators. We are going to show you a list of words and would like you to rate how relevant each of the words would be for you in this survival scenario. Some words may be relevant and others may not – it's up to you to decide. (Nairne et al., 2007, p. 264)

This was compared to when participants had to rate words' relevance to a scenario in which participants envisioned moving to a foreign city:

> In this experiment, we would like you to imagine that you are planning to move to a home in a foreign land. Over the next few months, you will need to locate and purchase a new home and transport your belongings. We are going to show you a list of words and would like you to rate how relevant each of the words would be for you in accomplishing this task. Some words may be relevant and others may not – it's up to you to decide. (Nairne et al., 2007, p. 264)

Both of these scenario conditions were compared to conditions in which participants instead rated how pleasant the word was or the words' personal relevance (i.e., the self-relevance of the words). The pleasantness and the self-reference tasks represent well known and robust deep processing techniques and serve as exceptional comparison conditions.

After the word rating task, participants completed a distractor task for approximately two minutes. On a subsequent memory test for the words, memory was superior for those that were rated in terms of a survival processing scenario, whether the memory test was a free recall test or a recognition test. This finding has spawned many replications and follow-up studies that have aimed to determine the proximate mechanisms of this survival advantage.

In one of the first follow-up studies, Weinstein, Bugg, and Cohen (2008) compared grassland survival scenarios to city survival scenarios:

> In this task we would like you to imagine that you are stranded in the city 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 f attackers. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival situation. Some of the words may be relevant and others may not—it's up to you to decide. (Weinstein et al., 2008, p. 916)

They found higher recall rates for the grassland scenarios and posited that this was due to ancestral evolutionary pressures. Nairne and Pandeirada (2008b) describe these ancestral pressures as molding a "stone-aged" brain that has been passed onto people today. Nairne and Pandeirada went on to compare the survival scenario to an array of deep processing methods (pleasantness, imagery, self-reference, generation, and intentional learning) and demonstrated a reliable advantage of survival processing compared to all of these methods of encoding. These two articles set the stage for investigations of the proximal mechanisms of the survival processing advantage. Researchers have become very interested in what it is about the survival condition that promotes a "deeper" level of encoding than the other comparisons, especially the city scenarios as they only differ in two words, grasslands/city and predators/attackers. One prevalent hypothesis implicates the grasslands as an ancestrally relevant setting and this explains the increased recall.

Why a Grasslands Scenario?

Nairne and Pandeirada's (2008b) theory posits that humans evolved in a grassland biome and thus, have a memory that is tuned to those conditions. Presumably, this is why the original survival processing investigations involved participants envisioning grasslands scenarios in making their survival utility judgments (as opposed to other potential survival scenarios). There have since been a number of studies that have found an advantage for rating survival utility using a grassland scenario over rating moving utility using the same moving scenario as before (Kroneisen & Erdfelder, 2011; Kroneisen, Erdfelder, & Bucher, 2013; Kroneisen, Rummel, & Erdfelder, 2014; Nairne et al., 2007; Otgaar, Smeets, & van Bergen, 2010; Otgaar et al., 2011; Raymaekers, Otgaar, & Smeets, 2013; Röer, Bell, & Buchner, 2013; Smeets, Otgaar, Raymaekers, Peters, & Merkelbach, 2012; Weinstein et al., 2008). Additionally, the grasslands scenario has resulted in improved memory relative to a robbery scenario (Butler, Kang, & Roediger, 2009; Kang, McDermott, & Cohen, 2008; Nairne & Pandeirada, 2011) e.g.:

> In this task, we would like you to imagine that you are leading a heist of a well-guarded bank. Over the next few months, you'll need to find people to help you, make a plan, and gather any supplies you might need. What could help you to

> achieve this goal? We are going to show you a list of 30 items. Please rate how useful these items are in your situation. (Röer et al., 2013, p. 1299)

This scenario was used to specifically address the issue of emotionality of the standard survival scenario. Further, were the survival scenario an issue of hot cognition, we would expect lower recall in the more emotional state, as less emotional, "cool" states are associated with memory (Roiser et al., 2009).

The survival advantage of the grasslands scenario has also been found when compared to the city scenario presented earlier (Nairne & Pandeirada, 2010; Weinstein et al., 2008) and specific survival problems in a modern survival setting (Nairne & Pandeirada, 2010) e.g.:

> For the survival situation, please imagine that you are stranded in the city of a foreign land, without any basic survival materials. You have not eaten for several days and it's important for you to gain nourishment. You will need to search for and buy food to ensure your survival. We would like you to rate how relevant the word would be in your attempt to obtain nourishment. The scale of relevance ranges from one to five, with one (1) indicating totally irrelevant and five (5) signifying extremely relevant. Some of the words may be relevant and others may not—it's up to you to decide. (Nairne & Pandeirada, 2010, p. 11)

These are not the only comparisons that have been made that show an advantage to processing words in the context of their relation to a grasslands survival scenario, as many studies utilize pleasantness as a control condition as well (e.g., Burns et al., 2011; Nairne & Pandeirada, 2008a, and many others).

The Grasslands "Ancestral Setting" is Not Critical to the Survival Processing Effect

Although there is a vast amount of evidence that when rating survival utility with a grasslands survival scenario, people recall more words than in other conditions, including some very well-studied deep levels of processing (Craik & Tulving, 1975), the originally-used grasslands “ancestral setting” does not appear to be an essential component of the survival processing effect . A number of studies have demonstrated the survival processing advantage using scenarios that were not grasslands scenarios. For example, Kostic, McFarlan, & Cleary (2012) compared memory for items studied while rating the study items’ survival utility in a grasslands scenario with several other survival utility rating scenarios, including a jungle scenario, a desert scenario, a lost-at-sea scenario, and a lost in outer space scenario. Underlined sections differed between each rating task for the sea, jungle, and space scenarios respectively:

> In this task, we would like you to imagine that you are lost at sea/stranded in the jungle of a foreign land/stranded in a spaceship in space without any basic survival materials. Over the next few months, you will need to find steady supplies of food and water and protect yourself from predators/predators/danger. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival situation. Some of these words may be relevant, others may not—it’s up to you to decide. (Kostic et al., 2012, p. 3)

They found that the memory advantage shown in the grasslands scenario emerged to the same degree in all of the other scenarios as well. Most significant is the fact that the survival processing advantage happened even in the lost-at-sea and lost-in-outer-space scenarios, because while jungle and desert scenarios could be argued to potentially have been ancestral contexts, lost-at-sea and lost-in-outer-space scenarios cannot easily be argued to have played a role in human evolution.

In another study, Soderstrom and McCabe (2011) compared the usual grassland survival scenario with a commonly-used city scenario as a comparison, but replaced the words "predators" and "attackers," respectively, with "zombies:"

> In this experiment, we would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival scenario materials. Over the next few months you will need to find steady supplies of food and water and protect yourself from *zombies*. We are going to show you a list of words and would like you to rate how relevant each of the words would be for you in this survival scenario. Some words may be relevant and others may not – it's up to you to decide. (Soderstrom & McCabe, 2011, p. 565)

They found enhanced memory for the zombie condition compared to the others. Additionally, there was no benefit of survival processing in the grasslands scenario over the city scenario in either the original grasslands scenario or the zombie scenario.

Other studies have sought to parse out aspects of the survival advantage in an effort to explain it. When elaboration has been manipulated by requiring participants to generate a number of arguments for why each word belongs in a given category (1 vs 4 and moving vs survival respectively), the survival advantage is eliminated with only one argument (Kroneisen & Erdfelder, 2011). Thus, when elaboration is explicitly limited by experimental design the survival advantage disappears. Additionally, Röer and colleagues (2013) instructed participants to generate all the uses they could think of for each of the words in place of a rating task. They found a significant effect of generation, such that generating more uses led to better recall and participants generated more words in the survival condition (for a review on elaboration and memory see Reder, 1980). This ties in well with Kroneisen and colleagues' (2014) failure to produce a survival advantage in a high cognitive workload condition. In a related experiment, utilizing interactive imagery was shown to eliminate the survival advantage (Kroneisen et al., 2013). The common thread running through all these experiments is an emphasis on additional processing that is happening when participants are rating words in the context of the survival scenarios.

Given that grassland scenarios do not consistently confer an advantage over comparable non-ancestral contexts, the survival advantage is not likely driven by a "stone-aged brain" tuned to a specific environment (grasslands), as has previously been suggested (Nairne & Pandeirada, 2008b). It is possible that, as described above, having to judge items' survival utility using an elaborate, complex scenario (whether it is the grasslands scenario or lost in outer space), simply engages elaborative processing in a way that other types of processing do not. In turn, the differential degree or type of elaborative processing may account for the usual memory benefit shown. However, another possibility is that survival processing does confer a benefit that is rooted in what are often termed "ancestral priorities" (New, Cosmides, & Tooby, 2007), insofar as survival itself should always be evolutionarily relevant, but the specific relevant ancestral environment has been misidentified. Specifically, it is possible that the grasslands biome is not the specific environment to which modern humans evolved. To examine this more closely, it is necessary to consider current human evolution theory and more specifically, the specific environment surrounding it.

The Theory that Unpredictability of Environment Itself, Rather than a Grasslands Environment, Drove Human Evolution

Nairne and Pandeirada (2010) examine survival processing within the context of ancestral priorities, by which they mean comparing their grasslands scenario to a modern city scenario. These ancestral priorities refer to the challenges that Pleistocene period humans faced. This timeframe includes the proliferation of stone tools to the domestication of animals and cultivation of plants (Potts, 2012a). This period also includes the dispersal of *Homo* to Eurasia and beyond Africa (Potts, 2012a). In addition to an increase in technology this period also saw an increase in *Homo sapiens* brain capacity (Grove, 2014; Maslin et al., 2014; Potts, 1998; Potts, 2012a; Potts, 2012b; Shultz & Maslin, 2013).

However, rather than being a response to a specific environmental context (e.g., grasslands), Potts (1998) suggests that this expansion of brain size is a result of the unpredictable nature of the environment that *Homo sapiens* lived in. In other words, the increase in brain size was an adaptive mechanism to enhance survival while living in a highly variable environment, rather than an adaptive mechanism to enhance survival while living in one particular environment.

By surveying lakes and layers of sediment it is possible to evaluate and classify periods of time as either high or low climate variability intervals (Maslin et al., 2013; Potts, 2013; Shultz & Maslin, 2013). When grouped this way, most major historical events have been predicated by high climate variability, such as the first appearance of *Homo sapiens* or the Eurasian diaspora of *Homo* (Maslin et al., 2013; Potts, 2013; Shultz & Maslin, 2013). These high climate variability times also forced early humans to either adapt to the changing landscape, migrate, or go extinct (Potts, 2012a). The increase in brain size that characterizes Homo sapiens has also been shown to correlate with dramatic changes in climate variability (Maslin et al., 2013; Shultz & Maslin, 2013). Based on these types of findings, it would seem that the human brain was molded by environmental variability into a highly adaptive system, rather than a highly specialized system as would be predicted by a brain evolving to fit a grassland biome (Potts, 1998; Potts, 2013).

More importantly for the present purposes, however, is that this growing body of evidence from anthropological work suggests that humans evolved not to one particular environment (i.e., grasslands), but instead to environmental unpredictability itself. If this is true, perhaps one might expect to find memory advantages in scenarios that involve great unpredictability relative to judging survivability in mere grasslands scenarios. This is basically taking the idea presented by Nairne and colleagues in their original work with grasslands scenarios, and applying it to a different theory of human ancestral context. In short, if the most relevant human ancestral context to human cognition today is unpredictability itself, we might expect unpredictability itself to confer memory advantages over and above grasslands scenarios and other scenarios previously shown to give rise to survival processing benefits. Toward this end, the present study investigated whether survival processing in situations of unpredictability would confer a particular advantage over other known survival processing situations.

The Role of Unpredictability in Memory

There is reason to hypothesize that environmental unpredictability confers memory benefits relative to situations of greater predictability. Many well-established memory phenomena could be viewed as manifestations of an unpredictability benefit at encoding on later memory. In short, an abundance of evidence already suggests that human memory is particularly attuned to unpredictability, as described below.

The Von Restorff effect. One of the best known memory phenomena that could be viewed as an unpredictability benefit is the Von Restorff effect (Von Restorff, 1933). The von Restorff effect describes increased memory for items that are novel, or that have been isolated or made to stand out in some way. In Fabiani and Donchin's (1995) study, participants were shown a list of 20 stimuli, most of which were of a medium font size (13), some of which were in a small font size (6) and one of which was in a large font size. This large font size item was isolated from the other items in the experiment based on the unique size of the font in which it appeared. Superior recall for this item was found in a later memory task. Fabiani and Donchin (1995) also examined semantic, rather than perceptual, isolation and found the exact same pattern. The von Restorff effect has been found when isolating a word in a variety of ways: by font and size (Kelley & Nairne, 2001), by increasing or decreasing font size for target words (Fabiani, Karis, & Donchin, 1990; Karis, Fabiani, & Donchin, 1984) or by changing the color of the target object (Kishirama, Yonelinas, & Lazzara, 2004; Parker, Wilding, & Akerman, 1998). For further theoretical review see Wallace, 1965.

The P300 Effect and Subsequent Memory. The P300 is an electrophysiological signature of the brain's response to unpredictability, detectable via scalp electrodes. It tends to be modulated by predictability such that it is larger in situations of unpredictability and smaller in situations of predictability. For example, in what is called an oddball paradigm, participants might view stimuli that appear then disappear on the screen, and some of the stimuli appear frequently while others appear infrequently. This is similar to the von Restorff isolation effect, but in the traditional von Resorff paradigm multiple stimuli are isolated on one measure or another. In one particular variant of this paradigm, perhaps the stimulus that appears frequently is "X" and the stimulus that appears infrequently is "O". Generally, the less probable that "O" is in the context of the experiment, the larger the P300 amplitude is in response to its appearance (e.g., see Luck, 2005, for a review).

It turns out that the magnitude of the P300 effect that occurs in response to a stimulus' appearance is predictive of later memory for the stimulus (e.g., Donchin, 1981; Donchin & Coles, 1988). The larger the P300 effect in response to a stimulus at encoding, the better subsequent memory for that stimulus tends to be. This suggests that unpredictability within the context of an experiment can contribute to enhanced memory for the more unpredictable occurrences. In short, people have a tendency to better remember things that occur with less predictability.

Distinctiveness Effects. The traditional distinctiveness paradigm follows closely to experiments on the von Restorff effect. However, instead of one target word, the distinctiveness has a subset of words that are manipulated in, for example, their orthographic distinctiveness and case (upper vs lower) creating four groups with differing levels of distinctiveness (Hunt & Elliot, 1980). Human memory seems very sensitive to this distinctiveness and shows an enhanced recall for distinct stimuli across a broad spectrum of manipulations (for an extensive review see Hunt & Worthen, 2006).

Novelty and Encoding. How novel an item is when it is encoded has also been shown to increase recall (Tulving & Kroll, 1995). One way of testing this has been to expose participants to a series of stimuli repeatedly, then after a distractor task, show them (in a new study list) some of those old, familiarized stimuli with a set of new stimuli. After this second study phase, there is a second distractor task followed by a memory test for what was learned in that second study phase. The novel stimuli show enhanced memory relative to the stimuli that had already been pre-familiarized (Tulving & Kroll, 1995).

Kirchhoff and Wagner (2000) investigated the neural correlates of the response to novelty and subsequent memory. Participants either studied one of two repeating stimuli or a novel item in each trial. They found that regions that responded to novel stimuli are also predictive of subsequent memory. Regions of the prefrontal cortex and medial temporal lobe both were engaged at encoding for novel pictures and words more than familiar pictures and words. These areas were more active when the encoded word was going to be later remembered (Kirchhoff & Wagner, 2000). Kirchhoff and Wagner (2000) hypothesized that the increased activation to novel stimuli could be evidence for more elaborate or more effective encoding of these items (for a review of neural correlates of memory see Blumenfeld & Ranganath, 2007).

Varying Contexts at Encoding. A number of studies have suggested that exposure to information in multiple different contexts benefits learning relative to exposure to the same information for the same amount of time and for the same number or repetitions but in the same context every time. That is, there appears to be a memory benefit to experiencing the same thing in different contexts relative to experiencing it always in the same context. One of the first studies to show this was conducted by Smith, Glenberg & Bjork (1978), who showed that memory was better for items that were repeated in different contexts than for the same number of items repeated in the same context. All participants in their study were initially given a study list of 40 words in one particular classroom on campus. Later, the participants were all given the same list of words again, but half of the participants received this list in the same room as before, while half received them in a different room located in a different place on campus. Finally, all participants were given a free recall test in a completely different (i.e., new) context from any of the ones in which participants had studied the words. Even though all participants were tested in the same new room that was different from where the study words had been studied, those participants who studied the words in two different contexts retrieved many more words overall than those participants who studied the words in the same context both times (see Smith & Vela, 2001 for a review on context effects).

Related to this finding of mixed learning contexts is the finding that interleaved learning tends to lead to better learning and retention than blocked learning. Specifically, spacing one's studying across multiple study sessions over time confers memory benefits relative to blocking or massing one's studying in one session, known as the spacing effect (see Cepeda, Vul, Rohrer, Wixted & Pashler, 2008, for a review). To the extent that spacing one's studying involves more changes in learning context than massing ones studying all in one session, the existence of the spacing effect (or distributed practice effects) is consistent with the idea that mixing one's learning contexts is beneficial to overall learning. To the extent that spacing one's learning over time (and possibly places) involves some degree of unpredictability of context relative to massing one's learning in one place and time, the spacing effect itself is consistent with the idea that unpredictability leads to later memory advantages.

Variable Practice in Learning. Related to the above type of finding with learning context is the finding the varying the practice circumstances during training seems to confer advantages over training the same way over time, or blocking the training sessions instead of varying them across trials. There are many ways that the benefits of variable practice have been shown. For example, Shoenfelt, Maue, McDowell, and Woolard (2002) examined participants' accuracy of basketball free throws after training. Some participants were trained in a constant fashion (continually making free throws from the same line during practice). Others were trained in a variable manner whereby some practiced from in front of and behind the line, some practiced in front of, behind, and on the line, and some practiced from random locations on the court.

Participants who were trained in the constant manner performed less well on the later basketball free throw test than participants who had been trained in a variable manner. Ste-Marie, Clark, Findlay, and Latimer (2004) showed that children learned handwriting better when they learned to write each letter along with other letters rather than learning one letter at time by writing it repeatedly in isolation for a sequence. Others have found similar effects of interleaved practice relative to blocked practice. For example, Hall, Domingues, and Cavazos (1994) have benefits of interleaved relative to blocked practice with baseball swings and Goode and Magill (1986) have shown similar findings with badminton serves. To the extent that interleaved practice and changing up the type of practice involves less predictability than constant practice circumstances, these studies relate to the idea that unpredictability helps learning.

Unpredictability as a Possible Factor in Survival Processing

Given that 1) grasslands scenarios are not critical to the survival processing effects in memory research, 2) humans are thought to have evolved to unpredictability itself rather than to a specific environment like grasslands, and 3) human memory consistently shows benefits for information that was either itself unpredictable at encoding or was encoded under relatively unpredictable circumstances, the proposed study seeks to examine whether unpredictability might lead to advantages over and above the usual survival processing effects that are shown with grasslands scenarios. To the extent that thinking of information in terms of survival utility should always be evolutionarily relevant to a person (insofar as survival is important to fitness), survival processing should confer benefits to memory. Our question was whether unpredictability would enhance this effect relative to standard grasslands scenarios.

It should be noted that it is also possible that the anticipated unpredictable nature of the survival scenarios used in prior research created a somewhat more perceived unpredictable encoding context than the comparison scenarios that have often been used. For example, perhaps rating survival utility in a grasslands scenario seems more unpredictable to a research participant than rating moving utility in a moving scenario. While it may be that such perceived unpredictability at encoding plays a role in the usual survival processing advantages that was not the main question for the present study. The present study was concerned with whether unpredictability at encoding would show survival processing advantages above those usually shown.

Experiment 1 seeks to examine the hypothesis that a randomly arranged array of rating tasks will lead to a greater survival processing benefit than the usual blocked format for examining survival processing effects. Toward this end, recall will be compared for participants who received the rating tasks in a random, mixed format with those who received them in a blocked format. Not knowing which rating task will be required next can potentially decrease the predictability of the task and in turn, potentially enhance memory and interact with survival processing to lead to better memory than in the usual survival processing condition in which the task is more predictable by virtue of being blocked.

Alternatively, blocking stimuli rather than intermixing them may lead to better memory due to schematic processing (Bartlett, 1932). This schematic processing gives additional structure and forms connections between the different items which is associated with higher recall (Alba & Hasher, 1983). Finally, when rating tasks are blocked each word can become a prime for the following words, whereas we would not expect that to happen within the intermixed condition (Conway, 1990)

Further, we expect that survival processing will outperform the other three tasks based on previous research (Nairne et al., 2007; Nairne & Pandeirada, 2008b)

Experiment 2 will examine the effects of unpredictability in a different way. Specifically, Experiment 2 will use an oddball task with survival relevant context. The standard background (occurring 90% of the time) will be either a summer scene or a winter scene counterbalanced across participants. The oddball background will be the other scene (10% of the time). Participants will be instructed to use the background image as additional context for their rating (survival or moving in either summer or winter). The background images also serve as another instance of unpredictability that is task relevant. Whether moving or surviving in summer vs winter drastically changes the problem. These season stimuli were chosen over structural isolation methods (e.g., font size or color), as they were easily related to the task at hand (imagining a moving or survival scenario). We expect the oddball condition to enhance recall along with the standard survival advantage.

Experiment 3 extends the methods used in Experiment 2 to different biomes rather than seasons. Participants will view three distinct biomes as added context for their scenario (i.e., arid desert, tropical rainforest, and grass savanna). Again, participants will see less of one biome to create an oddball task. Each participant will view all biomes with a 45%, 45%, 10% break down. The logic behind isolation method selection followed from Experiment 2 with the exception that biome was chosen over season to create more distinct backgrounds. The impact of a changing biome has molded the human brain into what it is today (Potts, 2012b). Thus, multiple biomes were selected based on prior survival advantages being found using a text description of these biomes (Kostic et al., 2012). The idea was that biomes should help to maximize the likelihood of finding an evolutionary-based unpredictability effect, should one exist. The biomes selected to be the oddball was counterbalanced across participants. Again we expect to see superior recall for the isolated trials.

EXPERIMENT 1

In Experiment 1, the impact of unpredictability on the survival processing advantage was assessed. Participants studied a list of 128 words and rated how relevant a word is to the survival or moving scenarios they had read previously, how pleasant the word was, or if the word brought a personal experience to mind. The scenarios were taken from Nairne et al. (2008) and participants were randomly assigned to either the intermixed group (more unpredictable) or the blocked group (more predictable). For the intermixed group, words were randomly paired with one of the rating conditions while the blocked group had four separate blocks of rating. The order of the blocks was randomized for each participant. By randomizing the rating condition participants should be limited in their ability to elaborate on the rating tasks. After rating the words, participants completed a brief distractor of math problems and finally completed a recall task for all words.

Method

Participants. A priori power calculations required 60 participants (30 per group) for a medium effect size. Participants were students at Colorado State University (n = 67). Three participant's data was excluded: two for not following recall directions, and one for failing to complete the rating task.

Materials. Participants were presented with 128 study words (see Appendix A) taken from Nairne et al. (2007). They were given multiple rating task instructions to read before the rating task that they performed with these words. Each word had a corresponding cue presented with the word during the rating task. Participants had five seconds per word to provide a rating.

Failing to rate a word happens rarely in previous literature (e.g., Nairne & Pandeirada, 2010), but if a participant displays a pattern (three or more failures to rate in a row) their data was excluded.

The rating task instructions for each cue condition are as follows:

Survival. In this task, 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. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival situation. Some of the words may be relevant and others may not—it's up to you to decide.

Moving. In this task, 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. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in accomplishing this task. Some of the words may be relevant and others may not—it's up to you to decide.

Pleasantness. In this task, we are going to show you a list of words, and we would like you to rate the pleasantness of each word. Some of the words may be pleasant and others may not—it's up to you to decide.

Self-reference. In this task, we would like you to think of personal experiences you have had in your life. We will present you with a series of words, and for each word we would like you to rate how easily the word brings to mind an important personal experience.

Following the presentation of the study list and the accompanying rating task, participants were given a list of 100 basic math problems (e.g., 2+9-4=?).

Design and procedure. The rating tasks (intermixed vs blocked) were manipulated between groups. Each participant completed four blocks of 32 words. For the intermixed group words were randomly paired with a rating task in each block. The blocked group were randomly assigned an order of rating tasks and completed each rating task in one block before moving on to the others.

In both conditions the participants were prompted on each trial with the specific rating task that they were using for that word. The single word keyword for each rating task (i.e., survival, moving, pleasantness, and self-reference) were presented at the top of the screen with the rating task and 1-to-5 Likert scale displayed below.

After completing the rating task, participants were given a series of basic math problems to solve for five minutes. Finally participants completed a free recall task for all blocks. Participants were presented a blank screen with a cursor and given ten minutes to recall as many of the words that they rated earlier as they can within that time frame. Participants were instructed to separate each word with a ",” to facilitate data processing.

Results

A 2 Study Presentation Format (intermixed vs blocked) x 4 Processing Condition (survival vs moving vs pleasantness vs self-reference) mixed factorial ANOVA was run to compare the number of correctly recalled words for each group based on study condition. Contrary to our hypothesis, there was no reliable main effect of study presentation format, $F(1,62) = 0.86$, $MSE = 15.63$, $p = .36$ and also no significant interaction between study presentation format and processing condition $F(3,62) = 0.88$, $MSE = 4.46$, $p = .57$. There was, however, a significant main effect of processing condition, $F(3,62) = 15.20$, $MSE = 99.78$, $p <$

.001 as we hypothesized. See Table 1 for a comparison of means for each processing condition by study presentation format.

Since there were no significant effects of study presentation format, both groups were combined. Post hoc tests on these combined data revealed a number of significant differences. As anticipated, the survival group outperformed the moving, $t(63) = 3.51$, $SE = 0.49$, $p = .001$; self-reference, $t(63) = 6.20$, $SE = 0.48$, $p < .001$; and the pleasantness group, $t(63) = 2.59$, $SE = 0.46$, $p = .012$. Those in the pleasantness condition recalled significantly more than those in the self-reference group, $t(63) = 4.06$, $SE = 0.45$, $p < .001$; but it was not significantly better than recall of participants in the moving condition, $t(63) = 1.24$, $SE = 0.43$, $p = .22$. Finally, participants in the moving condition outperformed participants in the self-reference condition, $t(63) = 3.23$, $SE = 0.40$, $p = .002$. See Figure 1 for a comparison of combined means.

Discussion

While we found no consistent effect of study presentation format, there was an advantage of blocked over random presentation for the self-reference condition. One possible explanation is that people were likely better able to think autobiographically when they have 32 consecutive trials to make these judgments than those same 32 trials scattered throughout 128 trials.

Overall, the standard pattern of results for the survival paradigm discovered by Nairne et al. (2008) was shown in Experiment 1. However, except for in the self-reference condition (as discussed above), there was no overall effect of study presentation format. Perhaps randomizing the study conditions was not a sufficiently strong manipulation of uncertainty. Alternatively, perhaps blocking them facilitates schematic processing which in turn, helps memory. It is possible that together the uncertainty effects and the schematic processing effects work to counteract each other. If so, then comparing study presentation format at encoding may not be the best way to investigate the uncertainty hypothesis. Therefore, another method of inducing uncertainty and unpredictability at encoding was used in Experiment 2. Specifically, Experiment 2 utilized an oddball paradigm to determine if manipulating uncertainty impacts the survival advantage.

EXPERIMENT 2

In Experiment 2, the effect of unpredictability on the survival processing advantage was examined by isolating 10% of trials through a change in background image rather than a study presentation format order of rating tasks. Participants rated 128 words presented on either a background of a winter scene on the screen or on a background of a summer scene, rating each word for its relevance to a single scenario – either a moving or a survival scenario. Summer and winter scenes were used as a plausible difference in context and to differentiate the isolated trials from the standard trials visually. However, because it is possible that particular background scenes are conducive to better memory than others, memory performance in the specific scene-type conditions was also examined to determine if the type of scene made any difference to memory. The words were drawn from Nairne et al. (2007).

Method

Participants. A priori power calculations called for 128 participants with 32 in each group. Participants were students at Colorado State University (n = 128). Participants from Experiment 1 were excluded. One participant's data was excluded for failing to complete the rating task.

Materials. The moving and survival scenarios as well as the word list were the same as those in Experiment 1. Additionally, a summer scene and a winter scene were used to add additional context to each word (e.g., how relevant the word fire is in winter vs in summer). Both photos were gathered from an internet search and are used per fair use guidelines. The scenes depict the same landscape, but one shows the landscape during summer and the other during winter. The summer and winter scenes can be seen in Figure 2 and Figure 3, respectively.

Modifications to the scenario instructions to account for the added task have been italicized:

Survival. In this task, 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. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival situation *within the season presented*. Some of the words may be relevant and others may not—it's up to you to decide.

Moving. In this task, 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. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in accomplishing this task *within the season presented*. Some of the words may be relevant and others may not—it's up to you to decide.

Design and procedure. The design and procedure for Experiment 2 was largely the same as Experiment 1 with some key differences. Moving and Survival conditions were contrasted between groups. Participants were asked to rate the relevance of a given word to either the moving or survival scenario, and in the context of winter or summer as indicated by a background image. The words were superimposed upon the image, with a white background for the word to ensure participants were able to read every word, regardless of background. Participants were given three practice words to ensure they understood the task and were able to incorporate the added context of the background. The proportion of winter to summer images was manipulated between groups. The two counterbalanced groups will see either 90% winter/10% summer or 90% summer/10% winter at encoding.

Results

Within the moving condition, no significant differences were found between the 90% summer and the 90% winter groups ($t(67) = .13$, $SE = 0.02$, $p = .90$), nor were any differences found between the 10% summer and 10% winter groups ($t(67) = .22$, $SE = 0.03$, $p = .83$). There was also no difference found between the 90% summer and 90% winter groups for the survival condition ($t(56) = .26$, $SE = 0.02$, $p = .80$) nor the 10% summer and 10% winter groups ($t(56) = .89$, $SE = 0.04$, $p = .38$). Since there was no effect of scene context (winter vs. summer) the data were collapsed into 90% vs 10% for survival and moving.

A 2 Probability Condition (90% vs 10%) x 2 Scenario (moving vs survival) mixed factorial ANOVA comparing words recalled by condition was run to assess the effect of oddball trials on the survival processing effect. There was a significant main effect of scenario with survival processing leading to significantly higher recall $F(1,125) = 5.85$, $MSE = 0.09$, $p =.017$. No main effect was found for the probability comparison, $F(1,125) = 0.70$, $MSE = 0.006$, $p = .41$. Additionally, there was no significant interaction between probability condition and scenario, $F(1,125) = .99$, $MSE = 0.009$, $p = .32$. See Figure 4 for a comparison of combined means.

Post-hoc tests indicate that the oddball ($M = 0.28$, $SD = 0.14$) vs standard ($M = 0.26$, $SD = 0.09$) comparison within the survival scenario condition was non-significant, but trended in the direction of an oddball effect, $t(57) = 1.18$,$SE = .02$, $p = .12$; while there seems to be no difference between the oddball and standard conditions, $t(57) = 0.12$, $SE = .02$, $p = .45$.

Discussion

The standard survival advantage was observed. The oddball condition trended towards significantly higher recall within the survival condition, but there was no effect within the moving condition. It is worth mentioning that the current experiment was only powered to detect a medium effect and is underpowered to detect a small effect.

One possible explanation for the lack of enhanced recall for oddball trials is the lack of distinctiveness between the summer and winter scenes. In an effort to test this, Experiment 3 involved a series of oddball trials with three scenes of distinct biomes. The visual depictions of different biomes were selected due to their previous (though strictly conceptual) use in examining the survival advantage (Kostic et al., 2012). By using potentially evolutionarily relevant contexts in the background, the likelihood of finding an oddball effect interacting with the survival processing effect could be maximized.

EXPERIMENT 3

Experiment 3 involved elements from both Experiment 1 and Experiment 2. Participants were again shown scenes to provide added context to the scenarios however instead of seasons participants will view different biomes (i.e., arid desert, tropical rainforest, and grass savanna).

Method

Participants. A priori power calculations call for 40 participants with 20 in each group. Participants were students at Colorado State University (n = 42). Participants from Experiment 1 and 2 were excluded.

Materials. The moving and survival scenarios as well as the word list were the same as those in Experiment 2. Following from Experiment 2, participants were again given a background picture to give added context for each scenario (e.g., how relevant the word fire is within an arid desert vs grass savanna). Photos were gathered from an internet search and are used per fair use guidelines. The scenes depict the salient elements of each biome (e.g., the sand dunes of an arid desert vs the flora of a tropical rainforest). The arid desert, tropical rainforest, and grass savanna backgrounds can be seen in Figures 3, 4, 5, and 6 respectively. These scenes were selected based on previous research which has found a survival advantage for the selected biomes (Kostic et al., 2012).

Modifications to the scenario instructions to account for the added task requirements have been italicized:

Survival. In this task, we would like you to imagine that you are stranded in 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. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival. Some of the words may be relevant and others may not—it's up to you to decide.

The background of each slide will be a different climate. It will either be a desert, a savanna, or a rainforest. Please rate how relevant the word is to moving to the presented climate.

For example, when there is a rainforest, rate how relevant the word is to surviving in a rainforest climate.

Moving. In this task, 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. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in accomplishing this task. Some of the words may be relevant and others may not—it's up to you to decide.

The background of each slide will be a different climate. It will either be a desert, a savanna, or a rainforest. Please rate how relevant the word is to moving to the presented climate.

For example, when there is a rainforest, rate how relevant the word is to moving to a rainforest climate.

Design and procedure. The design and procedure for Experiment 3 was drawn largely from Experiments 1 and 2 with some key differences. As in the previous experiments, participants were asked to rate the relevance of a given word to either the moving or survival scenario, but in this experiment they were doing so in the context of a specific biome as indicated by a background image. The words were superimposed upon the image, with a white background for the word to ensure participants were able to read every word, regardless of background as was done in Experiment 2. Participants were given three practice words to ensure they understand the task and have been exposed to each of the backgrounds. The proportion of each biome shown was counterbalanced across participants with a 45%, 45%, 10% split (e.g., 45% arid desert, 45% tropical rainforest, and 10% grass savanna) and the order was randomized within each participant.

Results

For each counterbalanced version, the two standard stimuli (the stimuli that were presented 45% of the time) were compared and no significant differences were found (all *p*'s >.4); therefore, the standard data were averaged for each participant. In order to determine whether certain biome scenes were conducive to better memory than others, memory performance in the specific scene-type conditions was examined to determine if the biome chosen as the oddball impacted recall. A 2 Survival (survival vs moving) x 2 Proability Condition (90% vs 10%) x 3 Biome (desert vs rainforest vs savanna) mixed factorial ANOVA was run to determine if there was an interaction dependent on which scene was the oddball. There was no main effect of biome, $F(2,36) = 0.78$, MSE = 0.01, $p = .47$. There was no interaction between survival and biome ($F(2,36) = 1.2$, MSE = 0.02, $p = .33$), nor between biome and probability condition ($F(2,36) = 2.4$, MSE = 0.02, $p = .11$), and finally there was no three way interaction between biome, probability condition, and survival ($F(2,36) = 0.24$, MSE = 0.002, $p = .79$). Since it did not matter which scene was the oddball, data were combined across rating tasks to maximize statistical power.

A 2 Survival (survival vs moving) x 2 Probability Condition (90% vs 10%) mixed factorial ANOVA was run to compare the number of correctly recalled words for each group based on stimulus type. Unexpectedly, there was no main effect of survival, $F(1,40) = 0.21$, MSE

= 0.003, p = .65, nor was there a significant effect of probability condition as we had anticipated, though it approached significance when powered to detect a medium effect, $F(1,40) = 2.37$, MSE = 0.02, p = .13. Finally, there was no significant interaction observed between survival and probability condition, $F(1,40) = 0.07$, MSE = 0.001, p = .79. See Figure 8 for a comparison of means with standard representing the average of both standard stimuli.

Discussion

While there were no significant differences between groups, the difference between the oddball and the standard stimuli approached significance. One factor could be the high standard error for the oddball condition which is due to the low number of trials needed to create the oddball trials. Since the oddball condition consisted of 10% of the trials, there were only 14 per participant. Experiment 3 did not have enough power to detect a small effect, and based on the trend towards significance the memory advantage conveyed by the oddball trials is assumed to be small.

What differentiates Experiment 3 from the previous two experiments is the lack of a survival advantage. The survival processing advantage is a robust finding in word learning tasks, but we were unable to detect an effect of survival processing when using an oddball task with two standard pictorial stimuli. This is unlikely to be due to the participant pool, to the use of background images during encoding, or the chosen biomes. This will be discussed in more depth in the General Discussion.

GENERAL DISCUSSION

The primary goal of the current study was to assess the potential role of unpredictability in the survival processing paradigm. Unpredictability was manipulated in three ways: randomization of rating task (Experiment 1), by two stimuli isolation/oddball (Experiment 2), and finally, a three stimuli isolation/oddball with two equal standard stimuli (Experiment 3).

Broadly, it seems that increasing uncertainty had little positive impact on recall and in some cases lowered recall. In Experiment 1, the results of Nairne et al. (2008) were replicated where the survival rating task consistently outperformed the other rating tasks. However, when unpredictability was increased through rating task randomization there was a deficit in recall in the self-reference task when compared to the blocked condition.

The self-reference task requires participants to reflect on their own experiences and rate how much a given word brings to mind a personal event. When this task is blocked together, each word can function as a prime for the subsequent word which would make relating a word to personal experience easier than when the words are interspersed with other tasks promoting recall (Conway, 1990). Based on this finding, manipulations that involve self-reference interspersed with other tasks may see lower rates of recall in the self-reference condition due to the way an experiment was designed. Blocking the self-reference task may also promote schematic processing of items. One key aspect of schematic memory is prior knowledge (Alba & Hasher, 1983) and by asking participants to reflect on an important personal experience we are asking participants to relate the presented word to prior knowledge.

Additionally, in the moving condition of Experiment 2 there seemed to be no benefit for oddball trials. It is unclear as to why there was no benefit, as the enhanced recall for oddball trials is well documented (e.g., Fabiani & Donchin, 1994; Fabiani et al., 1990; Karis et al., 1984). Perhaps integrating the meaning of the image (i.e., the season) minimized the isolation of the trials. However, we see a trend of increased recall for the survival scenario so this does not fully explain the lack of effect. Another explanation could be a lack of statistical power, as a priori power calculations were set to detect a medium effect. This seems likely, as the means for the oddball and standard groups follow a trend of enhanced recall for the oddball condition.

Experiment 3 demonstrated a trend towards higher recall for the oddball trials, but the more interesting finding is an elimination of the survival processing advantage, which shows a very robust effect in word learning paradigms. A number of factors could be at work here, but some possibilities can be ruled out due to the previous experiments. First, since there were significant survival advantages in Experiment 1 and Experiment 2 it is unlikely that the lack of effect is due to the participant pool. Second, using background images as a means of adding context to the survival paradigm can be ruled out based on finding a significant survival advantage in Experiment 2. Third, the choice of biomes likely isn't the underlying cause either, as these biomes have been used in previous research to generate a survival advantage, albeit through text as opposed to pictorially (Kostic et al., 2012).

If not for the reasons described above what can explain the findings? The first possibility is that switching between three different biomes at random was confusing and prevented effective encoding. Since we found a survival advantage in Experiment 2, it might be the added standard stimuli that minimized the advantage. Because each of the two stimuli made up 45% of the trials, very few trials had the same context of the scenario back-to-back. A future study could compare a blocked, counterbalanced version of Experiment 3 (e.g., all the desert trials, then all the rainforest trials, and finally all the savanna trials) and compare that to the current, randomized version to test whether this rapid switching between contexts of the scenario is responsible for the lack of a survival advantage. This idea is in line with the effect of elaboration found by Röer and colleagues (2013), such that switching between different contexts of the scenario inhibits the elaboration on a given word. Additionally, when comparing the percentage recalled from Experiments 1 and 2, it seems possible that something about the different biomes is not reducing recall in the survival scenario, but rather enhancing recall for the moving scenario. Short of doing a meta-analysis or Baysian statistics, there isn't a way to empirically measure the impact each set of instructions had on survival and moving.

Further, there has been work done on processes that interfere with mental imagery. Brooks' (1968) found that when participants are asked to perform multiple tasks that draw on the same domain (e.g., visually tracing a letter and pointing to yes/no) their performance is impaired compared to a mixed domain task (e.g., visually tracing a letter and saying yes/no). This impairment has been found across a variety of tasks and performance is consistently impaired when both tasks rely on the same sensory modality (Segal & Fusella, 1970). The exact mechanisms that underlie this finding have been contended, but the same interference was observed (Phillips & Christie, 1977). This may explain why we did not see any benefit of survival in Experiment 3. Showing participants images of the different biomes may have interfered with their ability to imagine or form an image of the scenario. Though previous work has not shown a direct effect of imagability and recall (Nairne & Pandeirada, 2010) perhaps interfering with imagining the scenario reduced recall.

Limitations

The single largest limitation of the current study is power. All three experiments were powered a priori to detect a medium or larger effect. The current results implicate a number of contrasts as having a small effect and based on the findings from Experiment 2 and 3, it seems that the oddball vs standard comparison is a small effect.

Additionally, many von Restorff paradigms (Fabiani & Donchin, 1995; Fabiani et al., 1990; Parkeret al., 1998; von Restorff, 1933) use a single oddball whereas Experiment 2 used 13 and Experiment 3 used 14; however using more and still finding an advantage for isolated items is not unheard of (e.g., Karis et al., 1984; Kelly & Nairne, 2001; Kishiyama et al., 2004). In other isolation experiments stimuli lists were constructed into multiple blocks, such that there was only one isolated word per block. Using multiple oddball items may have contributed to the reduced effect observed in Experiments 2 and 3. Further, since the magnitude of the P300 is correlated with recall (Fabiani et al., 1990) and inversely correlated with number of presentations (Squires, Squires, & Hillyard, 1975) this could partially explain the pattern of results found in the present studies.

Conclusions and Future Directions

Overall, we were able to replicate the survival advantage independent of two of our uncertainty manipulations (randomizing rating task and a two item oddball task). Within that, it seems that randomizing or blocking rating tasks has little effect on the overall pattern found for the survival advantage. In Experiment 2 when isolating 10% of the trials with a different background, we observed no memory advantage for these oddball trials relative to the standard trials; however, we were able to maintain the survival advantage in both the isolated and the standard groups.

Future research should build on Experiment 3 as was mentioned in the general discussion – compare a blocked oddball paradigm to a randomized oddball paradigm to test rapid context switching within a given scenario as moderating the survival advantage. An additional interesting test would be to attempt to determine what is changing; is recall in the survival condition being reduced or is memory in the moving condition being boosted? Additionally, replication of Experiment 2 to determine if the pattern of results found in the moving condition persists. Finally, a three stimulus oddball task might provide additional information on what is minimizing the survival advantage – especially when paired with EEG measurements to examine the P300 component. Additionally, the experiment should be run without the scenes as backgrounds to determine if the presences of the biomes prevented people's ability to imagine the scenario.

Table 1

Words recalled for each task in blocked and randomized rating conditions

	Survival	Moving	Pleasantness	Self-Reference
Condition	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Blocked	8.41 (3.74)	6.35 (2.18)	7.26 (3.2)	5.76 (1.96)
Randomized	7.87 (3.67)	6.53 (3.17)	6.70 (3.43)	4.60 (2.90)

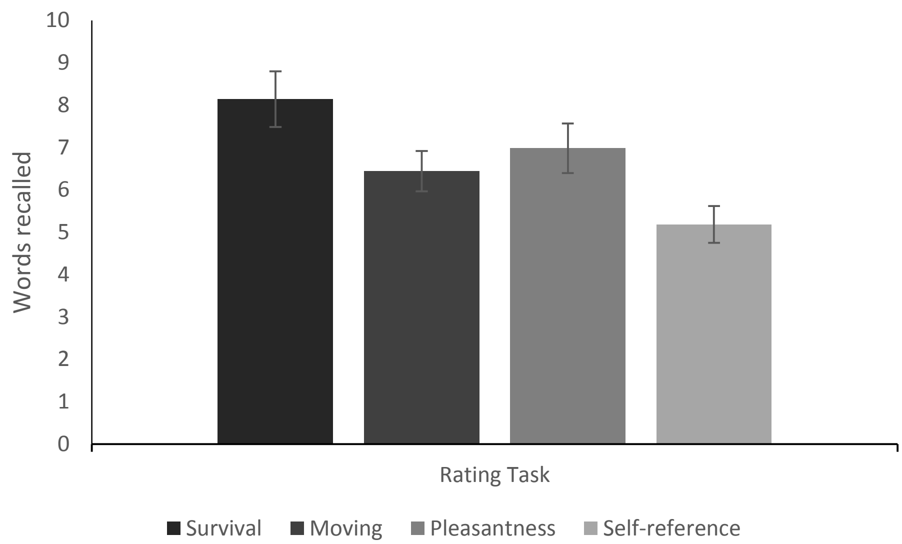

Figure 1. Mean words recalled for each rating task, combined across presentation organization. Error bars indicate SEM.

Figure 2. Background image for Experiment 2 representing the summer scene.

Figure 3. Background image for Experiment 2 representing the summer scene.

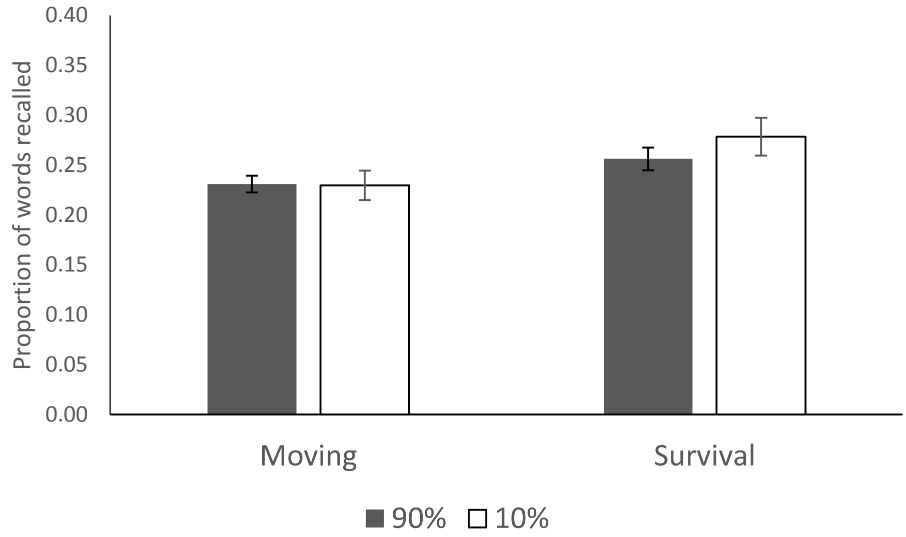

Figure 4. Mean proportion of words recalled, combined across background image type. Error bars indicate SEM.

Figure 5. Background image for Experiment 3 representing the arid desert scene.

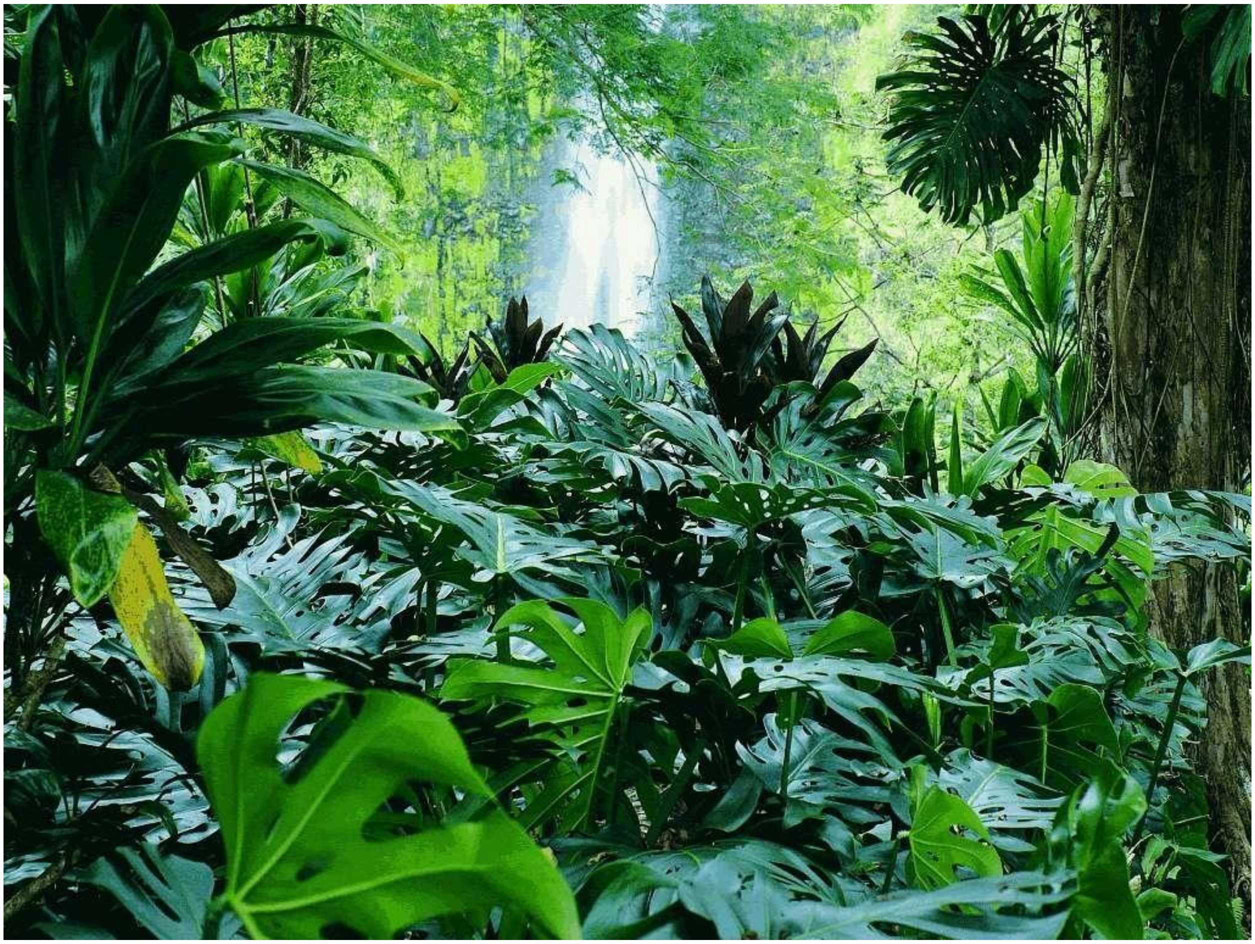

Figure 6. Background image for Experiment 3 representing the tropical rainforest scene.

Figure 7. Background image for Experiment 3 representing the grassland savanna scene.

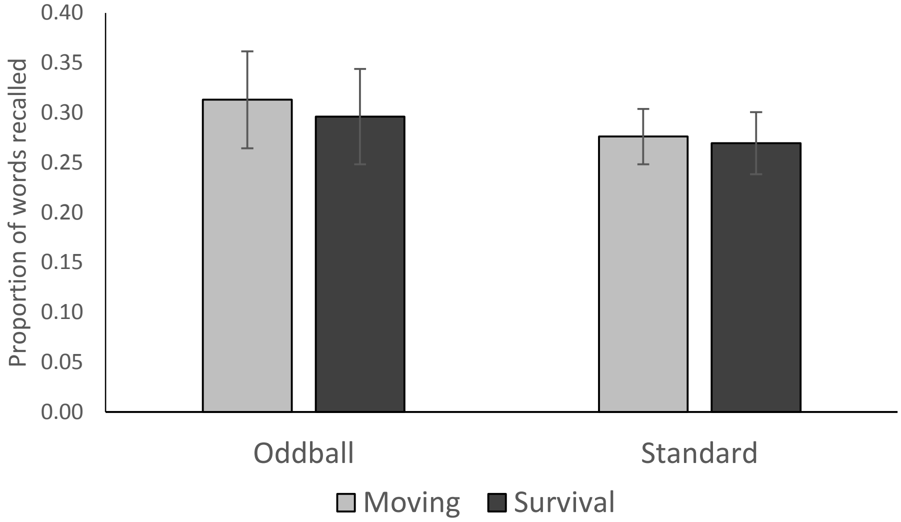

Figure 8. Mean proportion of words recalled with averaged standard conditions. Error bars represent SEM.

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Appendix I

Appendix I

stone	vapour	python	home	boy	soil
madame	storm	mother	rod	snake	prairie
bowl	soldier	monk	fur	husband	queen
liver	salt	man	corn	clothing	bath
lime	cabin	leader	troops	workers	needle
girl	insect	speaker	person	sea	gentleman
mountain	shore	king	chair	master	camp
victim	flood	lumber	chief	army	weapon
lemon	colony	horse	river	cottage	dust
bird	lord	fiber	cotton	board	metal
baby	artist	water	dirt	son	landscape
iron	meadow	ocean	valley	dinner	bed
fox	tree	string	dogs	woods	grass
bear	bread	woman	family	blood	settlement
snow	jungle	disease	parents	fire	butter
house	summit	liquor	shoes	forest	rock
ladies	client	builder	potato	child	drink
veteran	garden	people	musician	formation	children
wife	doctor	cane	meat	cattle	cat
fabric	physician	lake	village	fruit	coast
sheep	tobacco	lion	stem	alcohol	sugar
friend	tool				