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RESEARCH REPORT

Adaptive Memory: Enhanced Location Memory After Survival Processing

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Two experiments investigated whether survival processing enhances memory for location. From an adaptive perspective, remembering that food has been located in a particular area, or that potential predators are likely to be found in a given territory, should increase the chances of subsequent survival. Participants were shown pictures of food or animals located at various positions on a computer screen. The task was to rate the ease of collecting the food or capturing the animals relative to a central fixation point. Surprise retention tests revealed that people remembered the locations of the items better when the collection or capturing task was described as relevant to survival. These data extend the generality of survival processing advantages to a new domain (location memory) by means of a task that does not involve rating the relevance of words to a scenario.

Keywords: memory, spatial location, survival processing, evolution

Human memory systems evolved subject to the constraints of nature's criterion—survival en route to successful reproduction. Nature sculpts physical and psychological systems, via the processes of natural selection, when new heritable traits increase the probability of survival and successful sexual selection. It is not surprising, as a result, that the "footprints" of nature's criterion remain apparent in the operating characteristics of modern memory systems (see Nairne, 2010, for a review). For example, there is now considerable evidence that processing information for its survival value increases its later retention—more so, in fact, than most traditional memory-enhancing techniques (Nairne, Pandeirada, & Thompson, 2008).

In the survival processing paradigm, participants are asked to rate the relevance (or usefulness) of information in an imagined survival scenario. Participants are asked to imagine themselves stranded in the grasslands of a foreign land without basic survival materials. Over the coming months they must seek out sources of food and water and escape from potential predators. Individual words are then presented for relevance ratings followed shortly thereafter by a surprise memory test. Compared with a variety of control scenarios, survival processing produces superior retention (Nairne, Thompson, & Pandeirada, 2007; Weinstein, Bugg, & Roediger, 2008). The survival processing advantage has been found when using related and unrelated word lists (Burns, Burns, & Hwang, 2011; Nairne & Pandeirada, 2008) and pictorial stimuli (Otgaar, Smeets, & van Bergen, 2010), and for both recognition and recall (Kang, McDermott, & Cohen, 2008).

From an adaptive perspective, it makes sense that people remember information that has been processed for its fitness consequences. For example, remembering that food has been located in a particular area, or that potential predators are likely to be found in a given territory, should increase the chances of subsequent survival. New, Krasnow, Truxaw, and Gaulin (2007) found that memory for the spatial locations of food items depended importantly on the nutritional value of the food; Wilson, Darling, and Sykes (2011) recently found that the locations of evolutionarily relevant stimuli, such as snakes, were learned more quickly than the locations of evolutionarily irrelevant stimuli that were matched for arousal (the image of a gunman). Surprisingly, though, early work in our laboratory failed to find any consistent survival advantages when memory for location was specifically tested (Nairne, Pandeirada, Smith, Grimaldi, & Bauernschmidt, 2010). In these experiments, words appeared on either the left or the right side of a computer screen, and participants were asked to rate each word either for its relevance to a survival scenario or for pleasantness. At test everyone was asked to recall the presented words and then to indicate, for each recalled word, whether it had appeared on the left or the right side of the screen. Across several experiments, strong survival advantages were found for overall recall but not in memory for location.

The data from one of our experiments are presented in Figure 1. The left side of the figure shows the free recall data—again,

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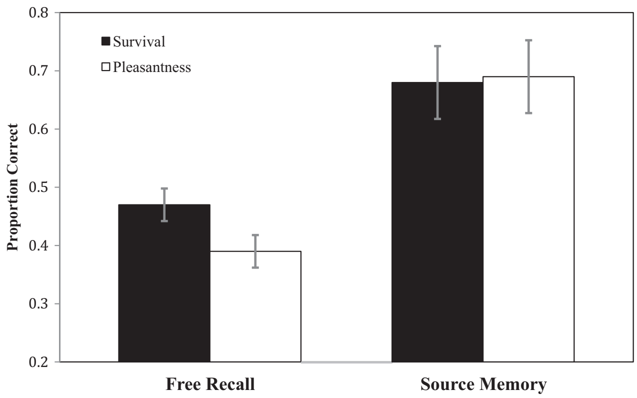

Figure 1. Results from Nairne et al. (2010): average proportion correct free recall and location memory for the survival and pleasantness conditions. Error bars indicate 95% confidence intervals.

participants were more likely to recall words that had been rated for survival, replicating previous work (e.g., Nairne et al., 2007). The right side shows location memory performance. Here the data are conditionalized on correct recall: What proportion of the recalled items from a given condition (e.g., survival) were assigned to the correct presentation location (e.g., left side of the screen)? Location memory performance was well above chance (50%), but no differences were found between conditions. Survival processing enhanced participants' ability to recall an item but not its prior location. Given the adaptive significance of location memory, especially in a survival situation, this null effect was surprising and unanticipated.

Yet in each of the experiments reported by Nairne et al. (2010), the location of the to-be-rated word was unrelated to the main rating task. Participants were asked to rate the relevance of the word to a survival situation (or rate the word's pleasantness), and the fact that the word occurred on either the left or the right side of the screen was irrelevant to the rating decision. Participants did encode and remember position, but the processes controlling those memories may not have been engendered by the orienting task; for example, the encoding of spatial position may have been controlled, in part, by automatic processes (e.g., Hasher & Zacks, 1979).

The current experiments were designed to test location memory when the item's initial location was directly relevant to the rating decision. To accomplish this end, several important changes were made to the typical survival processing paradigm. Rather than present words to be rated for survival relevance, we displayed pictures of food (Experiment 1) or animals (Experiment 2) individually at various locations relative to a central fixation point. Some of the items appeared relatively close to the fixation point; others were farther removed. The participant's task was to decide, using a 5-point scale, how easily the food or animal could be collected or captured. Location, or the distance of the item from the fixation point, was therefore likely to be a central feature of the rating decision. Following the rating task, and a short distractor period, participants were asked to remember the specific locations of the previously presented items.

The critical processing manipulation varied whether the collection or capturing task was vital for survival. In keeping with Nairne, Pandeirada, Gregory, and VanArsdall (2009), participants in Experiment 1 were told they were gathering food items to help ensure their personal survival or to win a scavenger hunt; in Experiment 2, the capturing task was necessary either to guarantee survival of the tribe or to win a hunting contest. In Nairne et al., the fitness relevance of the processing scenario importantly influenced later free recall: Participants who processed words in a survival context remembered more words than those who received one of the contest scenarios. In the present case, it was predicted that location memory would be enhanced when the initial collection or capturing tasks were deemed relevant to survival.

Experiment 1

In Experiment 1, participants were asked to rate and remember the same set of eight food items. The items (pictures of food) were presented individually, at eight locations, and participants had to decide how easily the item could be collected (using a 5-point scale). After they completed the eight rating trials, each item was presented again, and the participants were asked to click on the item's original presentation location (using a computer mouse).

Processing condition was manipulated between subjects. One group received instructions stating that collecting the food was important for survival in the grasslands of a foreign land; the other group was told that food collection was needed to win a scavenger hunt contest. Importantly, both groups of participants imagined themselves performing essentially the same activity—collecting food items; the only significant difference was whether the activity was described as fitness relevant. The critical dependent variable was the accuracy of the final location judgments.

Method

Participants and apparatus. Fifty-two undergraduates (26 women and 26 men) participated in exchange for partial credit in an introductory psychology course. Participants were tested in groups ranging from one to four in sessions lasting approximately 30 min. Stimuli were presented and controlled by personal computers.

Materials and design. Eight line drawings of food items taken from the Snodgrass and Vanderwart (1980) norms were used as the target stimuli (see Appendix). Four additional food items were used in a practice phase. The experiment employed a simple between-subjects design: All participants were asked to rate the same pictures, in the same random order.

Picture location was balanced such that two pictures occurred across trials in each quadrant of the screen. Within each quadrant, location was randomly chosen; the only restriction was that one picture would occur closer to the center of the screen ("near" position; 167 pixels from center) and the other would occur farther from the center of the screen ("far" position; 309 pixels from center).

Each participant rated the pictures using one of the two scenarios; across participants, each line drawing was rated equally often under both scenarios. The rating task was followed by a 1-min distractor task—rapidly deciding whether single digits were even or odd—and then the surprise location memory task. Except for the rating scenario, all aspects of the design, including timing, were held constant across participants.

Procedure. On arrival participants were randomly assigned to one of the two rating scenarios: survival or scavenger hunt. Participants in the survival condition received the following instructions:

> 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 in order to survive. We are going to show you pictures of food items that will be displayed in various locations of the screen and we would like you to rate how easy/difficult it would be for you to collect each food item. You should consider that your initial position is the center of the screen, as will be indicated by a circle. Therefore, you might think that if a food item is further away from your position it will be harder to collect. However, you might also take into account other aspects such as characteristics of the food item that might affect how easy/difficult it would be for you to collect it; for example, you might need to climb trees or dig in order to get some of those items. Remember, your goal is to collect as many food items as you can to help you survive.

Instructions for the scavenger hunt condition were as follows:

> In this task, please imagine that you have been invited to participate in a scavenger hunt contest in which you have to collect food items. Your goal is to win this contest. You will need to collect as many food items as you can to win the contest. We are going to show you pictures of food items that will be displayed in various locations of the screen and we would like you to rate how easy/difficult it would be for you to collect each food item. You should consider that your initial position is the center of the screen, as will be indicated by a circle. Therefore, you might think that if a food item is further away from your position it will be harder to collect. However, you might also take into account other aspects such as characteristics of the food item that might affect how easy/difficult it would be for you to collect it; for example, you might need to climb trees or dig in order to get some of those items. Remember, your goal is to collect as many food items as you can to win the contest.

Each to-be-rated food item was presented in a unique location for 5 s. The item then disappeared, and a scenario-dependent prompt appeared above a rating scale ranging from 1 (*very difficult to collect*) to 5 (*very easy to collect*). Survival participants were prompted to decide "How easy/difficult would it be to collect this food item to help you survive?" Participants in the scavenger hunt condition received "How easy/difficult would it be to collect this food item to help you win the contest?" The rating scale and prompt were displayed for 5 s, and participants responded by pressing the key corresponding to their value of choice. Everyone was cautioned to respond within the 5-s rating window. No mention was made of the subsequent retention test. A short practice session preceded the actual rating session.

After rating the eighth item, instructions for the even–odd decision task appeared. In succession a single-digit number ranging from 1 to 9 was presented, and participants were asked to respond by pressing the letter *E* on the keyboard if the number was even and the letter *O* if the number was odd. Participants had 2 s to respond for each digit; this task lasted for 1 min.

Instructions for the location memory test followed. Participants were told they would be seeing each of the previously rated pictures. The task was to decide where each food item had appeared during the initial rating task. Items appeared for 2 s, in the center of the screen, and were followed by a blank screen (with the center circle from the rating task as a reference point). The participant was told to move the mouse to the point on the screen where he or she believed the food item had originally occurred and then to click the mouse. The response was logged as an (X, Y) coordinate. The eight food items appeared in succession in a new random order. The location memory test was self-paced.

Results and Discussion

The level of statistical significance, unless otherwise noted, was set at $p < .05$ for all comparisons.

Table 1 shows the mean rating values for each group as a function of whether the food item had appeared initially at a location near or far from the central fixation point. An overall analysis of variance (ANOVA) revealed a main effect of position (near vs. far), $F(1, 48) = 34.43$, $MSE = 0.445$, $\eta_p^2 = .418$, confirming that item location was considered relevant during the rating task. Not surprisingly, participants rated items farther from the central fixation point as harder to collect. Neither group (survival vs. scavenger hunt), sex of the participant, nor any of the interactions approached statistical significance in the rating data (Fs < 1).

The results of main interest—the accuracy of location memory—are presented in Figure 2. Location accuracy was defined as the Euclidean distance between the point where the participant clicked his or her test response ($X_{response}$, $Y_{response}$) and the center of where the picture had actually occurred (X_{actual}, Y_{actual}). Thus, the smaller the distance between remembered and actual location, the better the location memory. These distance values are plotted in Figure 2 as a function of scenario group and presentation position. An ANOVA revealed a main effect of position, $F(1, 48) = 17.62$, $MSE = 2657.34$, $\eta_p^2 = .268$, and, as predicted, a main effect of group, $F(1, 48) = 5.22$, $MSE = 10883.63$, $\eta_p^2 = .098$, $p < .03$. Participants given the survival scenario showed the best location memory. Participants were also more likely to remember the locations of items that appeared closer to the central fixation point. This position effect replicates earlier work showing that people are better at reproducing the locations of items that occur near a border or landmark (e.g., Nelson & Chaiklin, 1980). Neither the main effect of sex ($F < 1$) nor any of the interactions approached significance (Fs < 1).

These data confirm our main prediction, namely, that location memory should be enhanced when the food collection task is relevant to survival. It is certainly adaptive for people to remember the locations of potential food sources, especially when food is necessary for continued survival. Note that the fitness relevance of the task—collecting food for survival or to win a contest—was the main difference between the groups. The rating task itself, along with the food items and their locations, was held constant across participants. In addition, unlike in previous work on survival

Table 1
Average Item Ratings (and Standard Deviations) in Experiment 1

Group	Near position	Far position
Survival	3.66 (0.63)	3.03 (0.65)
Scavenger contest	3.93 (0.69)	3.03 (0.86)

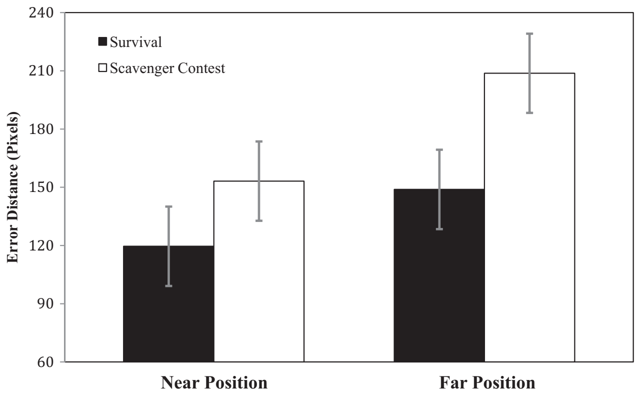

Figure 2. Results from Experiment 1: average error distance (in pixels) for the survival and scavenger contest groups. Position level (near vs. far) was manipulated within subjects. Error bars indicate 95% confidence intervals.

processing, participants were not asked to rate the relevance of the stimuli to an imagined scenario (e.g., survival grasslands or moving to a foreign land) but rather to rate how easily an item could be collected; this rating was presumably based on the item's location, and perhaps on its idiosyncratic characteristics, rather than on the scenario content itself. As a result, it seems unlikely that the fit (or congruity) between the item and the processing scenario was an essential determinant of the survival processing advantage (Butler, Kang, & Roediger, 2009; Nairne & Pandeirada, 2011).

Experiment 2

Our second experiment replicates Experiment 1 using a different set of stimuli (animals rather than food items) and somewhat different scenarios. Instead of a food gathering task, a hunting scenario was used. Participants were asked to rate the ease of capturing an animal for survival or winning a hunting contest. In all other aspects, Experiment 2 was an exact replication of Experiment 1.

Method

Participants and apparatus. Seventy-two students (36 women and 36 men) participated in exchange for partial credit in an introductory psychology course. Participants were tested in groups ranging in size from one to four in sessions lasting approximately 30 min. Stimuli were presented and controlled by personal computers.

Materials and design. Eight line drawings of animals taken from the Snodgrass and Vanderwart (1980) norms were used as the target stimuli in Experiment 2 (see Appendix). Four additional animals were used in a practice rating phase. Except for the processing scenarios, which were once again manipulated between subjects, the design was identical to Experiment 1.

Procedure. On arrival participants were randomly assigned to one of the two rating scenarios: survival or hunting contest. The instructions for the survival group read as follows:

> In this task, please imagine that you are living long ago in the grasslands of a foreign land. As a part of a small group, you are in charge of contributing meat to feed your group. You will need to hunt as many animals as you can to help your group survive. We are going to show you animal pictures that will be displayed in various locations of the screen and we would like you to rate how easy/difficult it would be for you to capture each animal. You should consider that your initial position is the center of the screen, as will be indicated by a circle. Therefore, you might think that if an animal is farther away from your position it will be harder to capture. However, you might also take into account other aspects such as the animal's characteristics; for example, some animals are faster at escaping, which might affect how easy/difficult it would be to capture. Remember, your goal is to capture as many animals as you can to help your group survive.

During the rating task, a scenario-dependent prompt appeared above the rating scale ranging from 1 (*very difficult to capture*) to 5 (*very easy to capture*). Survival participants were prompted to decide "How easy/difficult would it be to capture this animal to help your group survive?"

Participants in the hunting contest group received the following instructions:

> In this task, please imagine that you have been invited to participate in a hunting contest. As a part of a team, you are in charge of contributing captured animals to the team effort. You will need to hunt as many animals as you can to help your team win the contest. We are going to show you animal pictures that will be displayed in various locations of the screen and we would like you to rate how easy/difficult it would be for you to capture each animal. You should consider that your initial position is the center of the screen, as will be indicated by a circle. Therefore, you might think that if an animal is farther away from your position it will be harder to capture. However, you might also take into account other aspects such as the animal's characteristics; for example, some animals are faster at escaping, which might affect how easy/difficult it would be to capture. Remember, your goal is to capture as many animals as you can to help your team win the contest.

During the rating task, participants in the hunting contest condition were prompted to decide "How easy/difficult would it be to capture this animal to help your team win the contest?"

All other procedural aspects mimicked those of Experiment 1 including the presentation parameters (e.g., half the animals appeared near to the fixation point, and half appeared at a far position), the odd–even distractor task, and the location memory test.

Results and Discussion

The results of Experiment 2 replicated the main findings of Experiment 1 in virtually all respects. The rating data are shown in Table 2. As in Experiment 1, an ANOVA revealed a significant effect of presentation position, $F(1, 68) = 42.02$, $MSE = 0.335$, $\eta_p^2 = .382$, but no main effect of group or sex of the participant (Fs < 1). Participants rated the animals in the near condition as easier to capture, confirming that location was actively processed during the rating task, but no rating differences were detected between groups.

The location memory data are shown in Figure 3, plotted as a function of position and scenario group. Once again, an ANOVA revealed a significant main effect of scenario, $F(1, 68) = 5.84$, $MSE = 6686.75$, $\eta_p^2 = .079$, $p < .02$, demonstrating better location memory for the survival group. Although the pattern was similar to

Table 2
Average Item Ratings (and Standard Deviations) in Experiment 2

Group	Near position	Far position
Survival	3.07 (0.63)	2.38 (0.55)
Hunting contest	3.00 (0.79)	2.44 (0.57)

the one found in Experiment 1, the main effect of presentation position (near vs. far) was only marginally significant in Experiment 2, $F(1, 68) = 3.93$, $MSE = 3315.93$, $\eta_p^2 = .055$, $p = .051$. Neither sex, $F(1, 68) = 1.49$, $MSE = 6686.75$, $\eta_p^2 = .021$, nor any of the interactions approached statistical significance (Fs < 1).

General Discussion

As a product of natural selection, people's capacity to remember was sculpted over generations using nature's criterion—the enhancement of fitness. Memory systems evolved because they increased the chances of survival or, more directly, the capacity to reproduce successfully. It is reasonable to anticipate, therefore, that people should be particularly good at remembering information pertinent to fitness situations. Indeed, substantial evidence now shows that processing information for its survival relevance makes it easier to recall or recognize at a later time (Nairne, 2010).

It was somewhat surprising, therefore, when early work from our laboratory failed to find enhanced location memory after survival processing (Nairne et al., 2010). In some sense, location memory is the sine qua non of adaptive memory (e.g., remembering the location of a food source or the appearance of a predator in a given territory). In this earlier work, however, the location of the item was irrelevant to the main processing task, which involved rating the survival relevance of words. In the current experiments, location was central to the rating task—a conclusion verified by the rating data—and a different outcome was obtained. Although it is not possible to conclude definitively that location relevance was responsible for the different outcomes, because the experiments differed in other ways as well, it is certainly a reasonable conclusion.

Both of the present experiments showed enhanced location memory when the initial collection (Experiment 1) or capturing (Experiment 2) task was critical for individual or group survival. The important factor controlling performance is likely to have been fitness relevance because, in most other respects, the survival and contest groups received the same task and instructions. Participants processed and remembered the locations of the same stimuli (food items or animals) and performed the same rating task. In other work on survival processing, the control conditions have usually involved either different rating tasks (e.g., pleasantness) or quite different scenarios (e.g., moving or vacationing in a foreign land).

Of course, it is not possible to determine exactly what dimensions controlled performance in the survival condition. For example, one might argue that participants treated the survival scenarios as more realistic, important, or even more self-relevant than the scenarios that were contest based. However, there were no significant differences in either the overall ratings or the rating response times between the survival and control scenarios suggesting that participants were not simply trying harder in the survival condition. Moreover, hunting trips and scavenger contests are more familiar to undergraduate participants than grasslands-based survival situations and, thus, probably were more likely to generate self-relevant associations or elaborations. It also seems unlikely that increased arousal in the survival condition is the controlling factor: Kang et al. (2008) controlled for arousal by using a control scenario (a bank heist) that was rated as equally "exciting" by participants; significant survival advantages were still obtained. Others have argued that survival processing has a "planning" component that is particularly beneficial to recall—one that induces participants to adopt an orientation toward the future (Klein, Robertson, & Delton, 2010). Planning scenarios do benefit recall in some situations, but it is difficult to see how planning could contribute to the survival advantages seen in the present experiments. Again, everyone performed the same rating task—rating the ease of capturing or collecting items—and the task was not planning based.

The current experiments also document survival processing advantages in a completely new domain. Research on survival processing has typically used words as stimuli, usually unrelated word lists, as well as the established survival processing paradigm (Nairne et al., 2007). No words were used in the present experiments, nor were participants asked to rate the relevance of information to an assigned scenario. The elimination of relevance ratings lowers the chances that survival advantages can be attributed to the fit (or congruity) between an item and its processing scenario (Butler et al., 2009; Nairne & Pandeirada, 2011). There are situations in which survival processing advantages seem not to occur (e.g., when processing faces, Savine, Scullin, & Roediger, 2011; implicit retention tests, Tse & Altarriba, 2010), but the present experiments help establish that survival advantages do generalize across a range of tasks and stimulus materials. Identifying the boundary conditions for survival effects is important, in part, because those conditions help us understand the proximate mechanisms that control performance. For example, as Savine et al. (2011) noted, memory for faces benefits from increasing the depth of processing, but similar benefits are not found after survival processing. Such data suggest that survival processing cannot be easily categorized as just another form of deep processing.

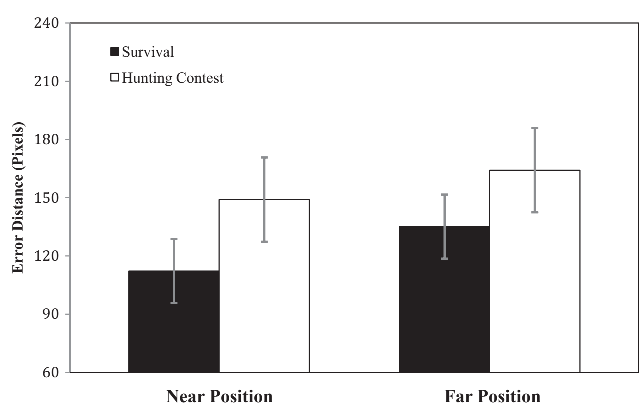

Figure 3. Results from Experiment 2: average error distance (in pixels) for the survival and hunting contest groups. Position level (near vs. far) was manipulated within subjects. Error bars indicate 95% confidence intervals.

Overall, our research further reinforces the value of adopting a functional perspective on the study of remembering (Klein, Cosmides, Tooby, & Chance, 2002; Nairne, 2005; Paivio, 2007). The crux of the functionalist agenda is the assumption that our memory systems are purposive—that is, we possess the capacity to remember because memory helps us solve critical adaptive problems. In the present case, our data document a role for fitness relevance in an important and ecologically relevant context—remembering the locations of possible food sources. In evolutionary analysis, form is assumed to follow function, so investigating the problems that our memory systems evolved to solve is key to understanding how those systems ultimately operate.

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Appendix

Line Drawings

Table 1A
Experiment 1: Food Stimuli

			
Apple	Banana	Carrot	Grapes
			
Mushroom	Pear	Pineapple	Pumpkin

Note. Word labels were not presented to the participants.

Table 1B
Experiment 2: Animal Stimuli

			
Cow	Deer	Duck	Fox
			
Goat	Pig	Rabbit	Squirrel

Note. Word labels were not presented to the participants.

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