Judging Object Relevance Under Time Pressure: evidence for a serial search of relevant uses

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Abstract

Objects rated with relevance to a survival scenario are more likely to be remembered than those same objects rated with relevance to a moving scenario. The survival processing advantage has been replicated many times, yet the mechanism behind this advantage is still unknown. This project attempts to elucidate the process of making a relevance judgment by testing a theory that we make a serial or parallel search for possible uses of the object and match them to our goals. First participants rated the object under time pressure, and then they were given a second chance to rate the same objects with no time limit. We categorized the objects into 3 different types: highly relevant, ambiguous, and irrelevant. We found that participants were able to make accurate judgments in on average 669 ms, and that they changed their judgment mainly for ambiguous objects. This indicates that the added time was used to consider more possibilities and thus more relevant matches were found. In a broader perspective, this provides evidence for a serial search for possible uses and matches to possible goals, and that the act of searching should be investigated as a possible mechanism for the memory advantage.

Keywords: Survival processing, relevance, judgment, decision making

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The way we recognize and use objects in our daily lives is seemingly effortless. While making a sandwich, our eyes are automatically guided to the objects we need first, second, and so on (Hayhoe and Ballard, 2005) and we perform the required action without much conscious thought (Van Elk et al., 2014). While this indicates the brain is very good at judging the function of objects and determining their relevance to our behavioral goals, the process underlying this type of judgment has yet to be investigated. The aim of our study is to investigate how we judge which objects are relevant to our goals.

Survival processing

One well-studied paradigm in which participants judge the functional relevance of objects to behavioral goals is that used to test the survival processing advantage (Nairne et al., 2007). In this task, participants imagine that they are stranded in the grasslands of a foreign land and are asked to rate the relevance of words or pictures to that scenario. This paradigm was introduced to test the idea that memory evolved to enhance fitness and improve survival (Tooby & Cosmides, 2005). If so, relating words to a survival scenario similar to one our ancestors faced, such as having to find food, water, and protection from predators, should provide a strong mnemonic effect. This idea was called the survival-processing advantage, and the idea that it indeed pertains to a mnemonic mechanism related to our own survival is supported by several findings. To start, when participants rate objects with relevance to one's own survival, the objects are remembered better than when they are judged in terms of their relevance for a similarly constructed moving scenario (Nairne et al., 2007). Nairne and Pandeirada (2010) also tested a modern survival scenario within a city to the ancestral survival scenario of the grasslands. There they found a memory advantage for the ancestral survival scenario, supporting their original hypothesis that ancestral priorities are the driving force behind the evolution of memory. In addition, the survival-processing advantage has been observed compared to other types of deep encoding techniques such as rating the pleasantness of items, or imagining items (Nairne et al., 2007). Taken together, these findings show that relating objects to survival provides a strong mnemonic effect.

Richness of encoding hypothesis

While many studies have found evidence for the survival-processing advantage (Scofield et al., 2018), they have been primarily focused on answering the question of *why* it exists. Another key question, however, is *how* the advantage works; i.e. what is the mechanism behind the advantage? As Nairne and Pandeirada (2008a, p. 378) put it, “these experiments have revealed very little about the proximate mechanisms that actually produce the survival benefit. Is the survival processing special, arising from the action of some kind of special mnemonic adaptation, or can we explain the advantage using traditional explanatory tools? For example, one might claim that survival processing is simply another form of ‘deep processing,’ albeit a particularly good one, leading to enhanced elaboration or distinctive encodings.”

The 'deep processing' account refers to the depth of processing framework first put forth by Craik and Lockhart (1972), whose work emphasized the importance of semantic and structural encoding. A memory trace is a product of perceiving the stimulus, and that perception can be broken down into component parts: early sensory processing and semantic associative operations. The strength of the memory trace would be dependent on the number and qualitative nature of these perceptual analyses. Craik and Tulving (1975) expanded upon this to argue for the richness and distinctiveness of information encoding to be most important for deep processing rather than processing time. In their experiment, they compared three tasks with increasingly elaborate levels of processing: an uppercase versus lowercase task, a rhyming task, and a sentence-word matching task, all of which required a 'yes' or 'no' answer, they found the largest mnemonic effect for the high-level processing task (sentence-word matching task), then the response within the task ('yes' eliciting better memory than 'no' responses). Craik and Tulving inferred from these results that when participants responded 'yes' to whether X word fits in Y sentence, they formed an integrated unit between the word and the sentence, which allowed better recall for that same word compared to responding 'no' (less integrated) or in a less elaborate task (does X rhyme with Y?). They concluded the 'richness' of the encoding comes from the integrated unit that is formed when the target word and the encoding question are matched in an elaborate task (Craik & Tulving, 1975).

It is not hard to imagine that the level of processing needed for determining whether a word fits within a sentence and determining whether an object fits into a scenario might be similarly high. When applied to the survival-processing paradigm, the results of Craik and Tulving's (1975) experiments suggest that relating words to an imagined scenario is a task that requires a high level of processing, making it perfect for deep encoding. Within the high-level processing 'relevance task', manipulations of aspects of the task could easily change the depth of processing in a similar way that congruency changes the depth of processing within a single task. Regarded in this light, survival scenarios may manipulate depth of processing compared to moving scenarios, even though they are both relevance tasks, increasing subsequent recall. It seems possible to manipulate the depth of processing further: what about adjusting the elaborateness of the scenario, or the stimuli themselves?

Adjusting the ability to elaborate on the scenario or stimuli

Kroneisen and Erdfelder (2011) tested this by using a similar but less elaborate version of the survival scenario originally used by Nairne et al. (2007). They only included one goal -the need for water- rather than the three goals of food, water, and protection from the original experiment. When comparing both the 1-goal and the 3-goal survival scenarios to original moving scenario, they found that the simplified survival scenario did not promote better recall than the moving scenario. This supports the idea that manipulating depth of processing within a task by manipulating the ability to elaborate does decrease subsequent recall.

Kroneisen et al. (2020) followed up with another unique way of manipulating depth of processing: by using stimuli with varying degrees of functional fixedness. In this experiment some objects had only one obvious function (e.g. watering can), whereas others could be used in many different ways (bucket). An object with many possible uses (low functional fixedness) would have more possibilities for elaboration compared to an object with one or two possible uses (high functional fixedness). Consistent with the hypothesis that depth of encoding drives the memory advantage, the results showed that objects with high functional fixedness were less likely to be recalled but objects processed in the survival scenario were still more likely to be recalled than the objects processed in the moving scenario regardless of functional fixedness. However, there was an interaction between functional fixedness and scenario, such that the survival- processing advantage was greatest for objects that were low in functional fixedness. Taken together, Kroneisen et al.'s (2011; 2020) findings show that the depth of encoding within the relevance task can be modulated by the number of goals in the scenario (1 or 3), and the possible of uses of the object (many or few). That these manipulations influence subsequent recall suggests that they are all involved in the formation of the memory trace. If we take the memory trace to be the "record of encoding operations carried out on the input; (and that) the function of these operations is to analyze and specify the attributes of the stimulus" as Craik and Tulving (1975) put it, we can infer that the operations carried out on the input would be assessment of these possible goals and possible uses within each scenario. This indicates a need for a framework in which the uses, goals, and scenario are all integrated into a form of assessment.

Search-inference framework

The search-inference framework posited by Baron (2008) proposes that the process of thinking can be described in terms of search and inference. When making a decision, we first search for possibilities, and then make inferences about how these possibilities might help us reach our goals. Related to the survival-processing paradigm, the participant receives predetermined goals (food, water, and protection), and then must make inferences about the extent to which each object presented could help achieve those goals. Interpreted in this framework, Kroneisen et al.'s (2011; 2020) findings that increasing the number of goals or decreasing functional fixedness improves recall can be interpreted as evidence that depth of encoding can be understood in terms of the amount of search and inference that is needed to make a judgment.

What remains unclear, however, is whether increasing elaboration leads to more time spent thinking. In some cases elaborate encoding manipulations do seem to increase the time spent on responding, as the survival scenario usually invokes longer decision times than the moving scenario (Kroneisen & Erdfelder, 2011, Nairne et al., 2007), but not always (Kroneisen et al., 2020). Typical survival processing studies give participants 5 seconds to rate the object, and do not ask participants to respond as quickly as possible, meaning their reaction times may not be indicative of the time spent processing. In Craik and Tulving's (1975) experiments, they found that tasks designed to produce more elaborate encoding took more time than more shallow tasks, until they tested this by creating a very complicated but shallow task that took much time but produced little recall. Within the same task, Craik and Lockhart (1972) postulated that study time would be a metric of deep processing and predictor of memory strength. However, Craik and Tulving (1975) found no relationship between response time and subsequent recall within their tasks. In fact, 'yes' responses elicited much higher recall than 'no' responses but took the same amount of time. They concluded that reaction times cannot be used to confirm a manipulation designed to induce deep encoding, but can be an indicator.

Searching, Fast and Slow

How is it possible that deep encoding could occur without an increase in response time? Does a deeper hole not take longer to dig? This is why Craik and Tulving preferred the term 'richness of encoding' hypothesis rather than 'deep encoding.' This can be reconciled by looking at fast and slow responses as two different systems (Kahneman, 2011). A fast, intuitive response is produced by system-1, while system-2 as a slow, deliberative process. But system-2 requires cognitive resources and time, and prefers to hand over the work to system-1 when possible. With enough practice, difficult system-2 decisions can be made by system-1, because our intuitions are nothing more than recognition (Simon, 1996; Gladwell, 2005; Kahneman, 2011). While an expert chess player may be able to intuit the right move 100x faster than a novice, it is simply because they have played the game so many times that they can recognize patterns much faster (Simon, 1996). Thus, it is not that the conclusion an expert reaches is so different, or less complicated than the conclusion a novice reaches at a much slower pace, it is just that the system has been honed to recognize something complex, instead of having to think to reach it. We can think of rich encoding as possible within a fraction of a second to someone who has the power to recognize those rich associations quickly. When those associations require system-2, more thinking would indeed be an indication of more associations, and thus richer encoding.

A task which uses recognition, and hence system-1, can be considered a parallel thinking process, whereas a process which uses system-2 can be considered a serial process in which associations have to be made one by one. A task can elicit deep encoding whether it uses system-1 or system-2, but a task that uses system-1 will not increase response time based on the depth of encoding. A task that requires system-2, however, because each association requires thoughtful analysis, would increase response time with each association, and thus response time would be a predictor of subsequent recall on that task.

A task can be performed with system-1 or system-2, but some tasks are more likely to activate one than the other. For example, given time pressure, only the fast system-1 will be able to provide an answer. So, what remains to be seen is whether we are experts on judging the relevance of objects to a survival scenario, or whether making the required associations to answer this question requires a serial process. In the case of judging objects for their relevance to daily use, we may be experts and thus use a parallel process to decide to first get bread, then jam, then a knife to make a sandwich. In the case of an imagined survival scenario, we may require system-2 to step in and make the associations in a serial process.

Evidence for parallel or serial

Why might our intuitions succeed in this case? Judging object relevance involves fast processes, such as object recognition. We can categorize an object in less than 200 ms (Potter, 1976; Thorpe et al., 1996). It involves activation of sematic information, which has been seen to cross nodes in neural networks very quickly (Hoedemaker & Gordon, 2017). The final piece, is how quickly the possible uses of an object can be retrieved, and inferences of relevance be obtained. This could be done quickly and intuitively, or it may require time and deliberation. The controversy in the field of decision-making tasks over the utility of our intuition leaves this an open question.

Writers like Malcolm Gladwell in his 2005 book ‘Blink’ have popularized the rationality of our intuitions. He explains we are all experts at reading faces, which is why we can immediately perceive the emotions of others. The large number of physiological indicators is too much for our conscious mind to process, yet we are accurate in our intuitions from the smallest of facial expressions. Our intuitions can even provide us with the knowledge that there is a correct answer, even without knowing what the answer is (Bolte et al., 2003). When three words are presented that may or may not have a relationship, people can respond under time pressure with much greater than chance accuracy that they are related, without having time to determine *how* the words are related (Bolte et al., 2003). The difference between recognizing that they are related, and determining how they are related, could be the difference between system-1 and system-2. In an even more complicated task, Bago & DeNeys (2017) tested whether people can respond correctly under time pressure to a task in which considering multiple possibilities is necessary to achieving the right answer. They again found that judgments under time pressure were correct more often than expected. These findings, taken together, would suggest that intuitions might provide correct answers even to complex problems.

Our intuitions are not always so useful, and can sometimes lead us astray. Indeed, Kahneman (2011) cites many examples in which type-1 thinking can have negative consequences, such as with cognitive biases. Frederick (2005) designed a 'cognitive reflection task' in which the question is designed to have an instinctive (but incorrect) first answer, while the right answer can be reasoned to. In one such task, Galotti and colleagues (1986) tested both good reasoners and poor reasoners in a logical syllogism task. They used syllogisms that first indicated a single model but required thinking of alternative models to answer correctly. Participants were first asked to respond under time pressure then given time to rethink their decision. They found that good reasoners were more likely to correct initial answers that were incorrect. In addition, they took twice as much time between the first and final answer. This led them to conclude that good reasoners were more thorough in their search. System-2 is clearly needed to find the right answer in this case, where thinking of alternative models increases the time needed to respond. These findings suggest that some tasks require a deliberation process to respond correctly, indicating a serial search for possibilities.

Why test whether the survival-judgment task is serial or parallel?

Relating these findings to the survival processing task, one might wonder if a survival relevance judgment is similar to such a cognitive reflection task, in which the first instinct is usually wrong but given time for deliberation, people can reach the right answer. Participants are typically given 5 seconds or more to rate the relevance of items, and has not yet been studied how they respond under time pressure, when forced to use their first instinct. This leaves an open question as to whether a relevance judgment can be made correctly with instinct alone, and how long this process takes.

Craik and Tulving (1975) used tasks which required a yes or no answer, and whose answer involved a recognition process. They asked participants questions such as: 'does this word fit in this sentence?' or 'does __ rhyme with ___?' without trying to trick participants with a misleading but incorrect intuitive answer. This leaves open the possibility that their experiments focused on system-1 processes, explaining why they did not find a relationship between richness of encoding and reaction time. It is necessary to determine whether the survival-judgment task elicits a parallel or serial search for possibilities, in order to further examine the utility of reaction time as a metric for richness of encoding.

Additionally, by adjusting possibilities for elaboration using the stimuli within the same task, such as Kroneisen and colleagues (2020) did with functional fixedness, a serial processing account would implicate that objects with more possibility for elaboration would take more time. This would allow us to use reaction time as an indicator of richness of encoding, a theory which could be tested in a follow-up experiment including a memory component.

The paradigm

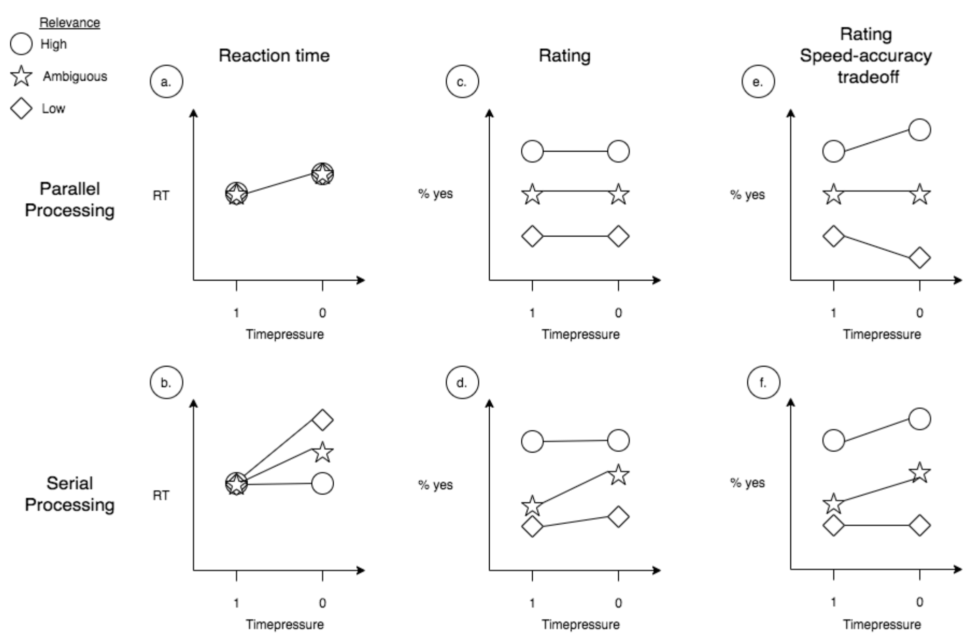
By combining insights from intuition research with the search-inference framework (Baron, 2008) we can thus consider the survival relevance-judgment task as a search-inference process that could be serial or parallel. The current study used a paradigm that combines the survival-relevance task with an initial, intuitive judgment and a second, deliberative judgment. To test how the uses of objects affect the search, an array of objects with predetermined degrees of relevance were used. These objects were from a previous study in which participants rated the objects on a 1-5 scale (Yildirim, 2020). The objects most often rated highly were assigned to the 'high relevance' object type. Those most often rated low were assigned to the 'low relevance' object type. Those that had a large variety of ratings were assigned to the 'ambiguous' object category. We can infer that each object has a primary use (e.g. a hat is used for sun protection) that comes to mind first, and then various other uses (e.g. hat could be used to carry food) which are less obvious. Similar to the idea of the functional fixedness rating, these categories represent how likely someone is to find a use for that object that matches the scenario. The fact that the 'high relevance' category mainly contains food items, and food items are directly related to the goal of finding food, supports this idea.

First participants are asked to imagine they are in the survival scenario, then they are asked to judge whether each object is relevant ('yes' or 'no') under time pressure, based on their first instinct. They are then given a second chance to rate the same objects with unlimited time. This allows us to test whether the relevance of each object is available immediately (parallel) or takes time to infer (serial). According to a strictly parallel account, all possible uses for the object become available at once so it can be immediately inferred whether the object is relevant or not. Alternatively, a serial-processing account would describe searching for possible uses of the object and judging them one at a time with relevance to each goal.

The current paradigm allows us both to explore the search-inference theory for how we think, as well as lend support to either parallel or serial processing theory for making relevance judgments. The following hypotheses (Figure 1) were preregistered on OSF (https://osf.io/t8rv3):

Figure 1

Overview of predictions for response time and response based on parallel or serial processing



Predictions for reaction time

If all information needed to make the judgment were available and processed at once, it would be expected that extra time for deliberation would not necessarily be needed to make a meaningful judgment. Thus, in a parallel processing account, it would be expected that extra time would be taken as instructed, but that extra time would not change depending on object type (Figure 1a).

If, in the case of serial processing, each possible use needs to be considered with relevance to possible goals one at a time, one would expect an interaction effect for time pressure and object type (Figure 1b). In the condition with time pressure, only the first use that comes to mind will be considered with relevance to the scenario, a process that we expect to take the same amount of time for each object type. Given unlimited time to deliberate, however, objects with a primary relevant use (high relevance objects) should be able to be rated 'yes' immediately, whereas objects with secondary or tertiary relevant uses (ambiguous objects) would take longer to rate. We expect objects that do not have a relevant use (low relevance objects) to take the longest to rate because many possible uses would have to be considered before finding a match or giving up. This prediction is derived from the notion that the process of searching for possible uses may operate similarly as the process of visual search, for which it is known that target-absent arrays take longer to be rated correctly than target-present arrays, given an equal chance of each (Wolfe, 2010). In our paradigm it could be analogous to having 1/3 target present, 1/3 target absent, meaning the ratio of target-absent to target present would be the same, following target-absent trials should take longer to rate.

Predictions for ratings

If all matches of possible uses to possible goals were available immediately, one would expect the relevance ratings given on first instinct to be equal to the ratings given with time to deliberate (Figure 1c).

If each use needs to be considered one at a time, deliberation should allow for more uses to be considered, and thus, more possible matches to be found. Given only enough time to consider the primary use of the object, we would expect high relevance objects to be rated highly, but little difference between ambiguous and low relevance objects. This is because given only enough time to consider the first option; an object with a relevant secondary use is just as irrelevant as an object with no relevant use. Given time to deliberate, objects with a relevant secondary use would be rated as relevant. Accordingly, we expect an interaction effect of time pressure and object type, such that the ratings of ambiguous objects would show the most change towards relevant, whereas relevant and irrelevant objects would show little to no change in ratings (Figure 2d).

Predictions given speed-accuracy tradeoff

Finally, speed accuracy tradeoff may play a part if the processing is serial or parallel. For example when trying to produce a speeded response, even if all matches are available after processing the image (a parallel process), a quick motor response can come before the processing finishes. In this case a speed accuracy tradeoff could account for a change in responses from the timed to the untimed condition if the change goes towards the normative response for that object type (Figure 1e). If a speed accuracy tradeoff is present but the process is serial, we might see a small increase in yes responses for the untimed condition, which is correcting for mistakes made in the timed condition (Figure 1f). We would see a similar decrease in yes responses for the low relevance condition, which could be counteracted by the search for tertiary uses, leading to little to no change in the mean of rating for this object type. It is for this reason that the ambiguous category is the most important indicator of serial or parallel processing.

Method

Ethics Statement

Ethical approval for this study was granted by the Ethical Committee Psychology (ECP) affiliated with the University of Groningen, the Netherlands. The study was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants included in the study.

Participants

A total of one hundred participants were collected using Prolific (www.prolific.co). Our sampling plan used optional stopping to decide the number of participants: if we reached sufficient evidence for or against our effects of interest, or we reached 100 participants (see Bayesian analysis below). As participants were collected, 10 were excluded and replaced for not following instructions (see Participant Exclusion below), so a total of 110 participants were paid to participate on Prolific in order to reach 100 usable participants. Criteria for participation were that they have English as a first language, be between the ages of 18-33 years old, and be using a computer rather than a phone or tablet. Out of the final 100 participants, 53 were female and 47 were male. The mean age was 24.6, with a range from 18 to 32. Fifty-two were students. The majority of participants were from the United Kingdom, with 60 stating their country of residence was the UK. Eleven stated their country of residence as the United States, 6 from Canada, 5 from South Africa, 4 from Ireland, 3 from New Zealand, 3 from Australia, 2 from Poland, and 1 from each of the following countries: Hungary, Israel, Spain, Greece, and The

Netherlands. Participation was on a voluntary basis and participants were paid £1.88 for 15 minutes, the maximum time the experiment was expected to take.

Materials

Open Sesame was utilized for stimulus presentation and data collection (Mathôt et al., 2012). The images used were selected from the Snodgrass and Vanderwart Picture Drawings in Color Database (Rossion & Pourtois, 2004). The images of the objects displayed against a rectangular white background, sized 281 pixels wide x 197 pixels high or 187 wide x 281 high (Figure 1). Image selection was based on data obtained in an earlier study (Yildirim, 2020). In this study, two groups of participants rated a total of 80 object images on a scale of 1-5 with regards to their relevance to the same survival scenario as used in the current study. One group (N = 42) rated 40 of these objects, and the other group (N = 40) rated the other 40 objects. Based on these data, we selected three sets of 16 objects. The “low relevance” set had ratings skewed towards a low value of 1, indicating most participants judged these objects as being irrelevant to the survival scenario. The “high relevance” set had ratings skewed towards a high value of 5, indicating most participants judged these objects as highly relevant. Lastly, the third set of “ambiguous” objects had a relatively flat distribution of ratings, indicating that participants judged the relevance of these objects very differently.

Table 1

All objects used in the experiment, according to category

High Relevance	Ambiguous	Low Relevance
		

Design and Procedure

A within-subjects design was used. Factors included object type with 3 levels: high relevance, ambiguous, and low relevance, and time pressure with 2 levels: time pressure and deliberation. All participants were instructed to make a survival relevance rating for each of the

48 objects using their first instinct, under time pressure. Then they were instructed to make a survival relevance rating again for each of the 48 objects with unlimited time. The rating variable was binary, with only a choice of 'yes' or 'no' to rate relevance. In both blocks, the objects from Table 1 were presented in random order.

Participants were first informed about the general requirements of the study, and then asked to provide informed consent to participate. Next, participants were presented with the following instruction:

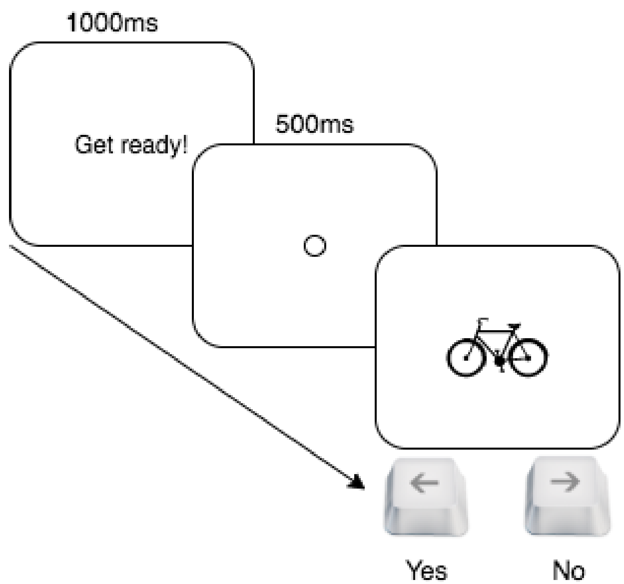
> "*In this task, we would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival materials. Over the next few months, you'll need to find steady supplies of food and water and protect yourself from predators. Please take a moment to imagine that you are in this situation. After you have done this, you can continue by pressing 'Spacebar'.*
>
> *We are now going to show you a series of objects. For each object, you need to indicate whether you think it would be relevant to you in the survival scenario. Some of the objects may be relevant and others may not —it's up to you to decide. You should respond as quickly as possible, based on your first instinct."*

Following this instruction, participants were informed that they should press the left or right arrow key to rate images as relevant or not to this scenario (Figure 2). Participants were specifically instructed to keep the index finger of their right hand positioned on the left arrow key and middle finger on the right arrow key in order to respond quickly. The assignment of these response keys to the relevant and irrelevant judgments was counterbalanced between subjects.

Next participants were shown two example objects, with the response keys indicated below the objects. After these two examples, there were 20 trials to practice the task. The objects used in the practice trials were different from those used in the actual experiment, and they were selected in such a way to include an equal number of relevant, irrelevant, and ambiguous objects.

Figure 2

Illustration of a trial



On each trial, participants were first presented an instruction to 'Get Ready' for one second, a fixation dot for 500ms, and then the image (Figure 2). The image remained on the screen until a response was made.

After completing the practice trials, participants continued with the 48 trials for the time-pressure condition. At the end of this block, participants were given the following instruction for the condition without time pressure:

"*In the second part of the experiment, you will again be asked to determine the relevance of objects to the survival scenario. The difference is that you should now take your time to* *think about your answer before giving it, instead of responding as quickly as possible based on your first instinct. The objects are the same as before, and your judgment may change from your previous judgment, or it may stay the same. It is up to you. Press R if you would first like a reminder about the scenario."*

The second block used the same items as the first block, in a new random order, but without the 'Get Ready' screen or the fixation dot.

Bayesian analysis

The primary analyses were Bayesian repeated measures analyses of variance performed using JASP (JASP team, 2020). The default *Cauchy* prior width of .707 was utilized in all analyses. Bayesian analysis was chosen because it allows for the quantification of evidence for the null and alternative hypothesis. Additionally, Bayesian analysis methods are immune to the problems associated with optional stopping (Rouder, 2014), so we did not rely on a power calculation to determine the number of participants. We preregistered that we would continue to test participants until we had reached a Bayes factor of 10 or higher for or against the interaction effect of time pressure and object type for both response time data and rating data. A Bayes factor of 10 means that the sampled data is ten times more likely under the alternative hypothesis than the null, or vice versa, and is considered 'strong evidence' for the effect (Jeffreys, 1961).

Participant Exclusion

Three exclusion criteria were preregistered on OSF to determine if the participant did not follow instructions. Participants were excluded if they rated objects non-sensibly; that is, if low-relevance objects as relevant more often than high-relevance objects. Since this may not be possible under time pressure, if the rating process is serial, we only assessed this in the condition without time pressure. Participants were excluded if they did not follow instructions for deliberation: if their average response time was higher while under time pressure. In determining whether response time criteria were met, we calculated average response time after outlier exclusion so that extremely long outlier times did not skew the averages. While not preregistered, we decided to keep participants whose average response time under time pressure was higher, as long as it was less than 100ms. This was because such a small difference in response time could indicate they spent the same amount of time in both conditions. Out of 110 participants who participated, 10 were excluded. One participant rated all objects as relevant, which means they did not have a higher average rating for high-relevance objects than low-relevance objects. Despite this, we included this participant because it is possible this was a reasonable judgment. They did not judge all objects as relevant under time pressure, which indicates a thoughtful rather than thoughtless type of response.

Outlier Exclusion

Outlier trials were excluded on the basis of response time only. Outliers were removed using the Van Selst and Jolicoeur (1994) method. This method calculates the standard deviation based on the number of observations per cell, then iteratively analyzes the data to exclude outliers 3 standard deviations from the mean. This method was used per participant, per time pressure condition, per object type. Out of 9,600 trials, 318 outliers (3.31%) were excluded, totaling 9,282 trials for analysis.

Results

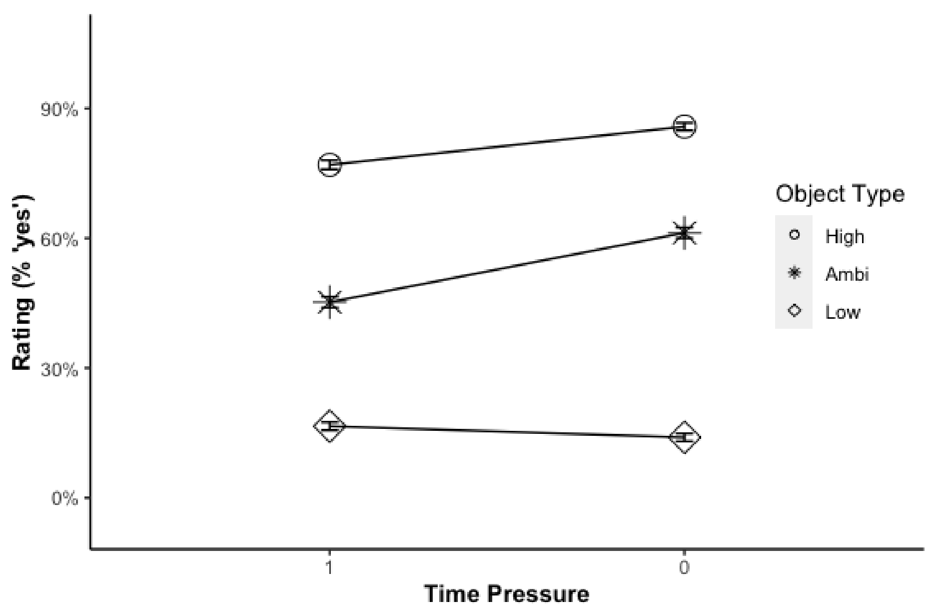
Descriptive plots of response times and ratings can be seen in Figure 3 and Figure 4, respectively. On average, response times were 425 ms shorter under time pressure, and objects were still rated according to their type (Figure 3). This indicates that participants are still able to make meaningful judgments without the 5 seconds given in most survival processing experiments. Indeed, participants took on average only 669 ms to respond using their first instinct. When given the opportunity to reconsider, participants only changed their mind on 19.6% of deliberation trials, and mostly for ambiguous objects - showing that their first instinct often matched their deliberative judgment.

In order to examine the effects of time pressure and object type on rating and response time, two Bayesian repeated measures analyses of variance (RM-ANOVAs) were performed.

Rating

Figure 3

Descriptive plot of mean rating for each object type



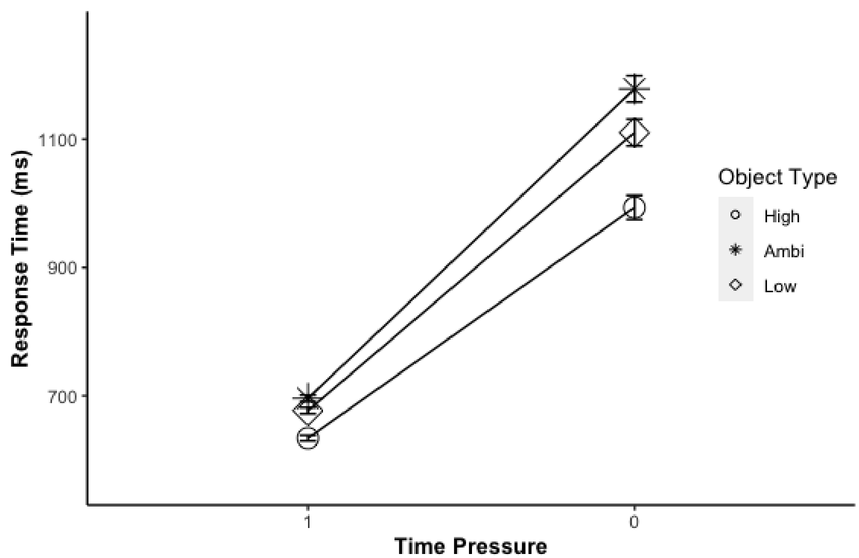
Note: Error bars represent standard error of the mean (SEM). SEM is defined as the standard deviation of the distribution of sample means.

Results revealed evidence for the interaction effect of time pressure and object type on ratings with a BF_{incl} = 4.14e^8, meaning the data are 4.14e^8 more likely in the model with the interaction than the model with solely the main effects of time pressure and object type (all model comparisons were performed using matched- models, meaning all models with the interaction were matched with the same models without the interaction for comparison, as suggested by Sebastian Mathôt). The model with the interaction was also more likely than the null model with BF_{10} = 1.60e^196 and an error percentage of 2.11%.

To explore the cause of the interaction further, follow-up paired-samples T-tests were conducted. For low relevance objects, moderate evidence was found for the null hypothesis that they did not change their ratings with BF_{10} = 0.31. The ratings for high relevance objects were 8.9% higher in the condition without time pressure compared to the condition with time pressure. The follow-up paired-samples T-test found evidence with BF_{10} = 3.2e^8 that participants increased their rating for high-relevance objects when deliberating. Similarly, the ratings for ambiguous objects were 16.1% higher in the condition without time pressure, and evidence was found with BF_{10} = 8.7e^11 for the difference in means. These tests indicate evidence for a positive effect of more time on rating for high-relevance objects, an even more positive effect for ambiguous objects, and no effect for low-relevance objects. To determine if the positive effect of deliberation was indeed larger for ambiguous than for high relevance objects, a 2x2 RM-ANOVA was conducted using only relevant and ambiguous object types. Results show evidence with BF_{10} = 6.45 in favor of the alternative hypothesis that the increase in ratings when given time to deliberate is greater for ambiguous objects than high relevance objects. This indicates the interaction effect is still present even with low-relevance objects removed.

Figure 4

Descriptive plot of mean response time for each object type



Note: Error bars represent standard error of the mean (SEM). SEM is defined as the standard deviation of the distribution of sample means.

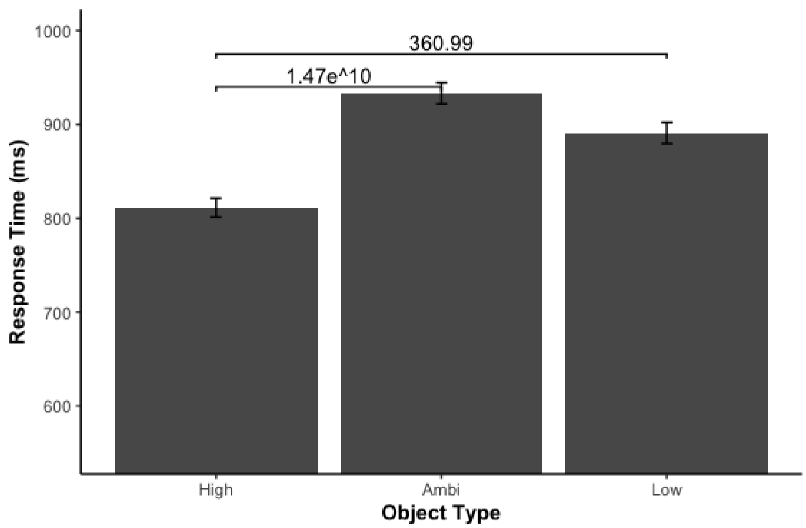
Response Time

Due to model misspecification (i.e., non-normality, and unequal variances), we applied a $\log_{10}$-transformation to the response times. This did not remedy the violation of normality, but given that an ANOVA is relatively robust against violations of this assumption with sample sizes such as the current sample of 100 participants, we decided to use the untransformed data and go ahead with the analysis.

Results of the Bayesian RM-ANOVA found moderate evidence against the interaction effect of time pressure and object type with $BF_{incl} = 0.227$. A main effect of object type was found with a $BF_{incl} = 49.42$. Post-hoc tests found the difference to be between high relevance and ambiguous objects, as well as high relevance and low relevance objects, with a BF_{10} = 1.47e^10, and BF_{10} = 360.98, respectively. This indicates that participants took less time to rate high-relevance objects than the other two types of objects (Figure 5).

Figure 5

Bar graph of the means per object type, including the Bayes Factors > 10 for the differences in means



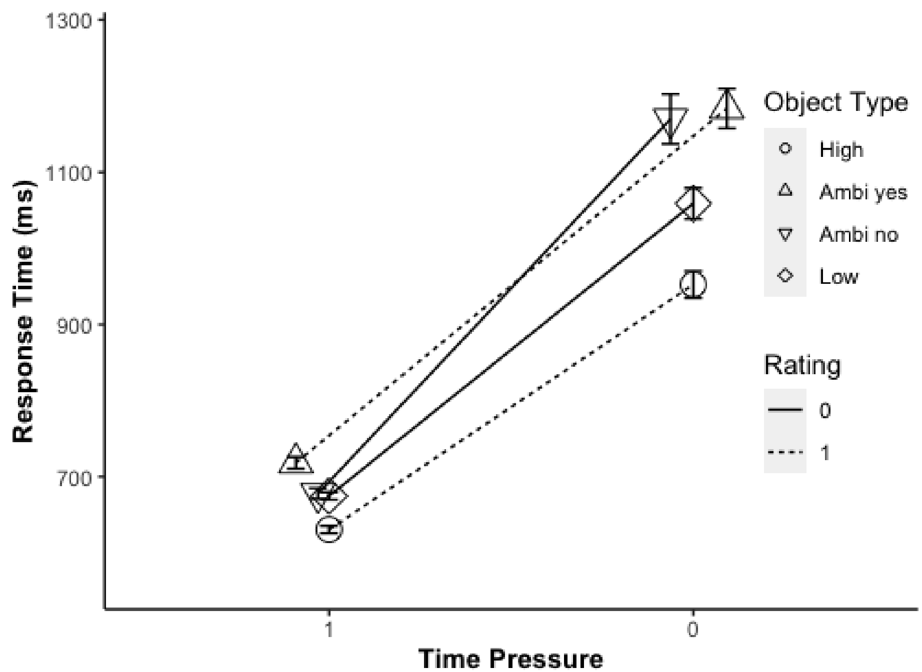
Note: Error bars represent standard error of the mean (SEM). SEM is defined as the standard deviation of the distribution of sample means.

In a follow up analysis, we examined the response times using on those trials in which the participant's relevance judgment conformed to the object's type. This involved excluding trials on which participants chose relevant when the object type was low relevance, or irrelevant when the object type was high relevance. This exclusion removed 11.4% of trials. Since ambiguous objects do not have a 'correct' choice, this object type was split into two groups, one where the trial was rated as relevant, and one where the trial was rated as irrelevant. An RM-ANOVA was performed on this data and evidence was found for the interaction effect with BF_{incl}

= 22.36. Figure 6 gives visual indication that ambiguous objects rated as irrelevant showed a higher increase in response time from the condition with time pressure to the condition without time pressure than the other object types.

Figure 6

Descriptive plot of response time with 'errors' removed and ambiguous split



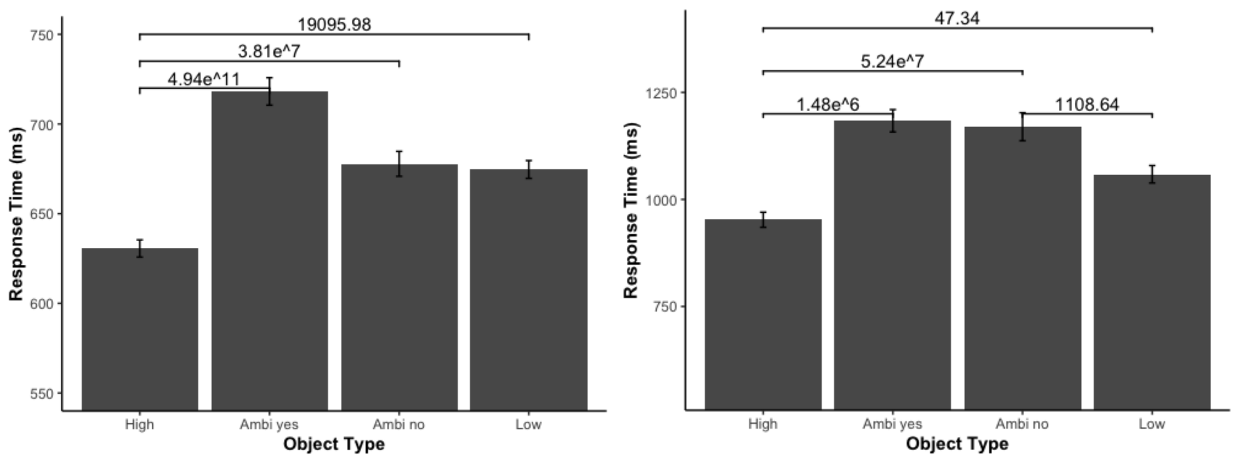
Note: Error bars represent standard error of the mean (SEM). SEM is defined as the standard deviation of the distribution of sample means.

Follow-up tests on the main effect of object type

To examine the cause of the interaction of time pressure and object type, two 1-way ANOVAs were performed, one on the trials with time pressure, and one on the trials without. Both tests showed evidence for the effect of object type with BF_{10} = 2.664e^11 and BF_{10} = 3.754e^10, respectively. Post-hoc tests showed that under time pressure, the high relevance objects were rated as relevant faster than all three other types, while the other types did not differ from each other (Figure 7). In the condition with time to deliberate, we see the same pattern but with the addition of evidence that ambiguous objects rated as irrelevant took longer than rating a low relevance object as irrelevant (Figure 8).

Figures 7 and 8

Response times per object type using the data with ambiguous split and 'errorless' trials. Left is under time pressure and right is with time to deliberate. Bayes Factors included if $BF_{10} > 10$.



Note: Error bars represent standard error of the mean (SEM). SEM is defined as the standard deviation of the distribution of sample means.

Object Level Analysis

By examining the relationships between rating, change-in rating, and response time at the level of individual objects we hoped to get a better idea of how participants were thinking about this task. Also, by looking at individual objects we can examine how well our expectations for ratings (based on category) matched participants' responses for each object.

Figure 9 shows the change of judgment for each individual object, color-coded for whether it belonged to the ambiguous, high or low relevance group. We can see the objects that showed the most change (whistle, wagon, basket, and hat) were indeed ambiguous objects as we expected. However, by looking at the next four objects which changed the most (candle, coat, scissors, boot) we see that they were in the high-relevance category of objects, defying our expectations that high-relevance objects would be most often rated as relevant on first instinct. Low relevance objects, as expected in the case of a speed-accuracy tradeoff, were most likely to change negatively, but we do see some objects that defy this trend (door, couch, dress, and vase).

Figure 10 visualizes the relationship between the likelihood of a change of judgment and reaction time in the condition without time pressure. Trials where the change was from 'yes' to 'no' appear to be slower than when the change was from 'no' to 'yes' for the same object.

Figure 9

Objects ranked by degree of change

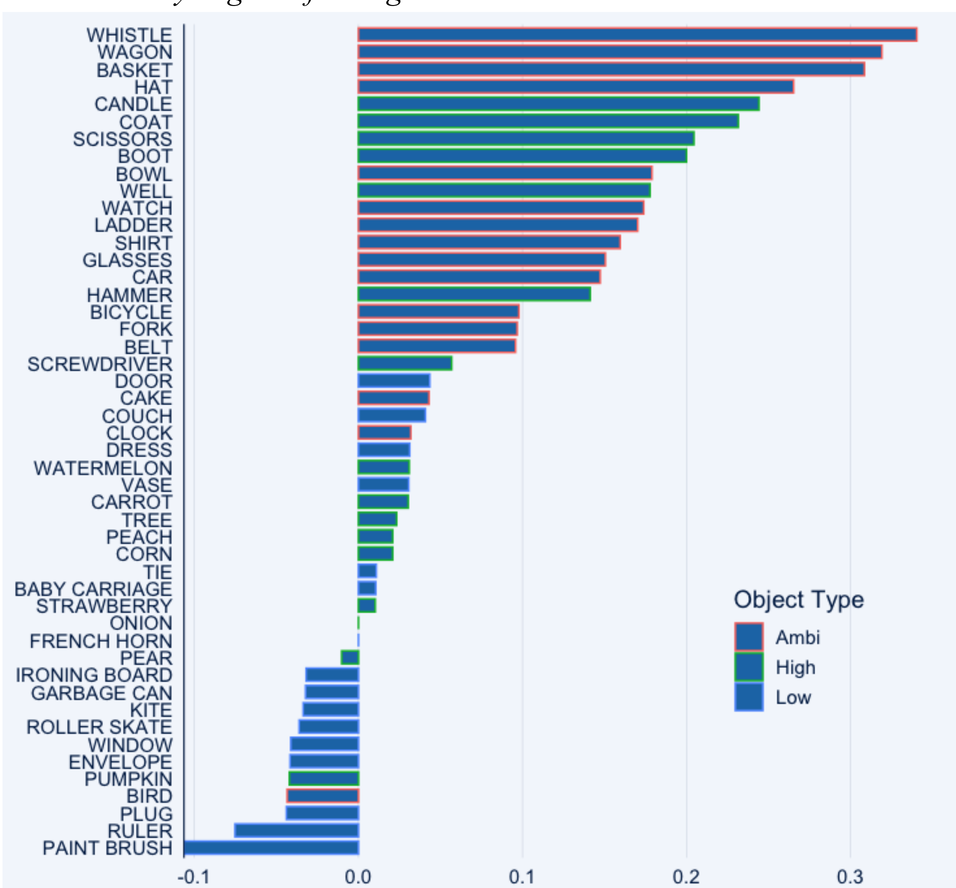


Figure 10

Trials in the deliberation condition grouped by how the object rating changed

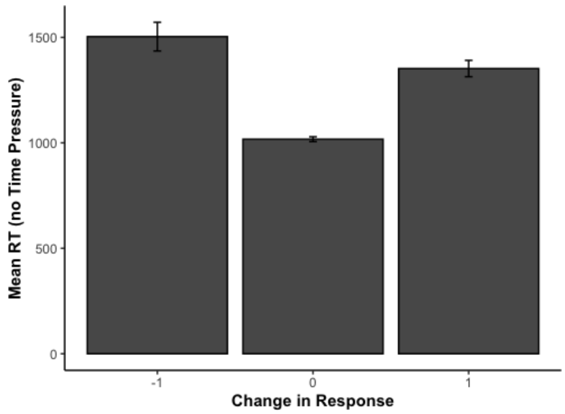
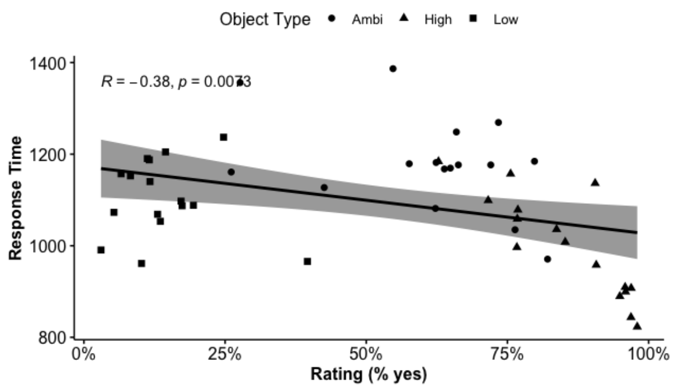


Figure 11

Pearson correlation between response time and rating when deliberating

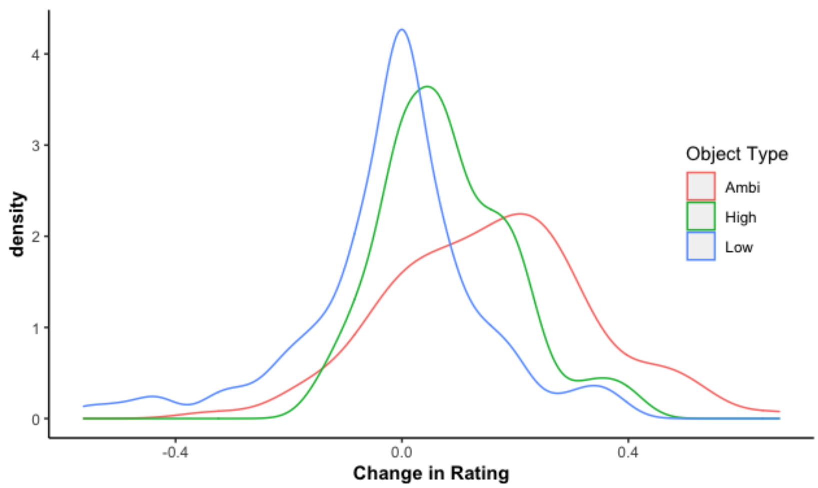


Results of a Pearson's correlation test between response time and rating in the condition without time pressure can be seen in Figure 11. A significant negative correlation (R= -0.38, p = 0.0073) was found such that objects rated as relevant were more likely to have shorter response times. Ambiguous items can be seen in the center with the higher response times and as expected, mixed ratings.

We hypothesized this task involves a creative act of searching for possible uses for objects, thus, we explored whether participants differ in this creative act, and on which object types. This can be represented by how often participants changed their mind on the relevance of an object. Individual differences were explored with a density plot (Figure 12). Results show participants varied the least on rating low relevance objects, with most not changing their rating at all. But participants varied much more in how much they changed their mind for ambiguous objects, with some changing not at all and some changing their mind on these objects as much as 50% of the time.

Figure 12

Density of how many participants changed their rating for each object type



Discussion

The aim of this study was to compare how people judge the relevance of objects for a survival scenario when these judgments need to be made with and without time pressure. We reasoned that this task involves searching for possible uses of an object and inferring their relevance to possible goals, and that the formation of these associations may be the key behind the survival processing advantage (Nairne et al., 2007). By turning the survival relevance task into a cognitive reflection task (Frederick 2005) that forces system-1 at first, then allows room for system-2 to work (Kahneman, 2011), we can see if this judgment changes. A change in judgment would implicate a serial search for possibilities, in which participants consider additional uses in the condition without time pressure. By integrating 3 types of objects we can further determine a theory of how such a serial search might move forward with time - based on finding uses for the object one by one, and matching them to goals one by one.

Results showed that participants changed their judgment 19.6% of the time. This indicates evidence for a serial search - more time was needed to assess the possibilities that led to a relevant rating. While high relevance objects were deemed relevant 8% more often with deliberation, the increase for ambiguous objects was 16.1%, with evidence for this increase being higher for ambiguous than high relevance objects. Participants did take more time with their second judgment, with an average increase of 425 ms. According to our hypotheses, an increase in response time would have been expected for a parallel or a serial search, so we tested for the presence of an interaction between object type and response time. This was not found when the objects were sorted based on type alone, but when the object types were sorted based on response type (yes or no), an interaction was found. In both analyses of response time, high relevance objects were rated faster than the other types of object both under time pressure and with deliberation. When the ambiguous objects were split by response, however, a difference was found between ambiguous objects judged as irrelevant and low relevance objects judged as irrelevant that was not present under time pressure. This provided evidence that the time needed to judge ambiguous objects as irrelevant increases more with deliberation than for low relevance objects judged as irrelevant, despite an increase in response time for all object types.

Despite the popular idea that our instincts are often correct (Gladwell, 2005), we can see here that they were not enough to take into account all the ways in which an object might be relevant to survival. Instinctual judgments were, however, the same as the deliberative judgment about 80% of the time, providing support for how accurate our fast (669 ms) instincts can be. In light of the search-inference (Baron, 2008) framework we can deduce that objects in the high-relevance category were decided fastest because their first use was relevant to a goal, whereas ambiguous objects may have required consideration of multiple uses before arriving at a match.

By ranking the objects based on their degree of change (Figure 9), we can see that the high relevance objects which were food items (carrot, peach, corn, strawberry, onion) were among the objects that changed the least - indicating they had a primary use (food) and a direct relevance to a goal (finding food), requiring little time to make this association under time pressure. The high relevance objects that were not food (candle, coat, scissors, boot) were among the objects that changed the most, indicating they were the source of the 8% change in high relevance objects from fast to deliberate responses. These objects may have been more similar to ambiguous objects in that their primary use (light, warmth, cutting, and walking) was not directly related to a goal of finding food, water, or protection from predators. This may have required a more creative inference process (light can help one find food or water during the night). Indeed we see from Figure 12 that the most variation in how much participants changed their rating came from ambiguous objects. Some participants were lacking in creativity and did not change their judgment even for ambiguous items, whereas others changed as much as 50%. High and low relevance objects did not see such variation in participants' change in judgment, with most participants changing not at all or very little on these objects.

It was predicted that ambiguous objects would take longer to rate than high-relevance objects, but not than low relevance objects. Low relevance objects were predicted to take the most time because judging an object to be irrelevant would seem to require an exhaustive search in which all possible uses need to be considered before one can conclude that an object is not relevant (see also, Wolfe, 2010). We predicted that participants would search through all possible uses of irrelevant objects and infer the lack relevance to each goal before finally responding - with this taking the most time if it is a serial search. However, our results were not in line with this prediction: before splitting data based on responses (Figure 4) we see that irrelevant objects did not take longer to rate than ambiguous objects. Even after splitting the data based on response (Figure 6), irrelevant objects were judged irrelevant much *faster* than ambiguous objects were judged as irrelevant. This leads to an interesting question: why did participants not perform an exhaustive search for relevant possible uses?

One possible explanation for this is that low relevance objects have only one use, or at least fewer uses to go through than ambiguous objects. Let us compare two objects from Figure 9. A low relevance object, 'baby carriage', changed very little, but an ambiguous object 'wagon' changed the second most. But what is a baby carriage other than a more specific type of wagon? By relating an object to a specific use (carrying babies), one narrows down the possible uses of an object. In this way, an object can go from having many possible uses, to having a very fixed use. Participants were able to go from 'no' to 'yes' very often for their judgment of the wagon, but almost never for the baby carriage. This shows how two similar objects, but one with a fixed common use, can be judged very differently in this task.

This means we might be able to infer the functional fixedness (Kroneisen et al., 2020) of ambiguous and low relevance objects. If different people rated objects differently (as they did for ambiguous objects in Yildirim, 2020), it means there are different ideas about uses for the object. If there are different ideas about the uses for the object, one person could imagine multiple uses for that object. With this line of reasoning, we can infer that ambiguous objects are not high in functional fixedness, and may even be quite low in such a metric. If the judgment process involves a serial search for uses and inferences to goals, objects with few uses would take less time to judge than objects with more uses to go through. An object with many possible uses would take more time because each possible use would have to be considered with relevance to one's goals, one by one.

Another possible explanation for this result is that a participant's *willingness to search* was involved in the process, rather than just a search through fewer uses. Participants may have deemed the task of searching through the possible uses of a low relevance object for a relevant use too difficult or bothersome to continue trying, despite an initial effort. If the process required to find a match is serial, this means system-2 is involved, but system-2 requires the investment of cognitive resources and time, and passes the job off to system-1 when possible. The task of actually searching through all possible uses and inferring relevance to the three goals is lengthy and daunting, so system-1 may step in to answer the easier, heuristic question "am I likely to be able to find a relevant use for this object?" To which, for irrelevant items, the answer is 'no.' This could also be an instance of participants relying on the availability heuristic (Tversky & Kahneman, 1973), in which they estimate the likelihood of finding a relevant use by assessing how easily other uses come to mind. As Kahneman (2011) writes "System-1 often makes this move when faced with difficult target questions if the answer to an easier and related heuristic question comes readily to mind." Just because we give participants the opportunity to deliberate for as long as they want, does not mean they take it. For the irrelevant category of objects, it may be obvious that the task of finding a relevant use is more difficult than the other objects. Clearly, for ambiguous objects, system-2 is willing to step in to expend resources and time to search for a relevant use.

These two possibilities are not opposed to each other, and could both be involved in why ambiguous objects take longer to be judged as irrelevant than low relevance objects. It may be that the functional fixedness of an object is apparent before its relevance is apparent. The high functional fixedness of low relevance objects makes the difficulty of creatively analyzing these objects clear to the participant - leading to a 'giving up' reaction. If this is the case, the ambiguous objects' low functional fixedness inspires the participant to keep looking, even when they have not found a match yet. This might explain why we see response times indicative of an exhaustive search for ambiguous objects, but not low relevance objects.

Implications for rich encoding and a memory advantage

From the results of this experiment, we find evidence for a serial process behind a judgment of relevance. From the response time data, we see that ambiguous objects trigger the most time consuming search for possible uses and inference to goals. This indicates that these ambiguous objects allow for greater elaboration - a process necessary for rich encoding and associated with a memory advantage.

This connection between ambiguous objects and elaboration allow for predictions about further experiments. Nairne and colleagues (2009) found a memory advantage to processing objects with relevance to survival, inspiring experiments that sought to find the mechanism behind this effect. Kroneisan and colleagues (2020), inspired by Nairne and colleagues (2009) as well as Craik and Tulving (1975), found that objects low in functional fixedness had a memory advantage in subsequent recall, and this effect was amplified by the survival processing effect. They attribute the advantages to richness of encoding, in which the number of associations generated during encoding is linked to memory advantages. According to Craik and Tulving (1975), elaboration and congruency are the most important factors for rich encoding. Although they did not find response time to be a predictor of rich encoding between tasks or within the same task, they did find a small advantage to higher response time within task and within the same response. All of this research on rich encoding, taken together and combined with the results of this experiment, would predict that (1) ambiguous objects (2) judged as relevant, (3) within the survival scenario, and (4) with the highest response times, would be the most remembered.

Similarly, because such a cognitively demanding process is required to judge ambiguous objects, another prediction can be made for the influence of time pressure. By preventing the full processing of the object with time pressure or a cognitive load manipulation, this would predict a decrease in the memory advantage for ambiguous objects but not the advantage for low or high relevance objects. Additionally, this would predict that this memory advantage would be directly correlated with the amount of additional time spent on response for ambiguous objects. Future experiments containing all of these variables could test these predictions.

Conclusion

We find that the search-inference framework, with a search for possible uses with inference to possible goals in a serial fashion is supported by these results. We find that people can make accurate judgments very quickly, but that deliberation still induces further change, especially for ambiguous objects. These objects may be low in functional fixedness, and allow consideration of multiple uses - a form of elaboration indicative of rich encoding. This study both supports the utility of our intuitions, and yet still indicates we judge relevance in a serial process, considering possible uses with relevance to our goals. The fact that we used the survival paradigm is beneficial for examining the mechanism behind the survival processing advantage, but we do not often imagine ourselves in such a survival scenario nor judge an assortment of random objects. How can we extrapolate these results to our everyday judgments of object relevance? What we can say is, that when faced with an unusual decision and an object that has many possible uses we likely perform a serial search through possible uses - inferring relevance to our goals. This elaborative process will be memorable - allowing us to perform this decision faster in the future. By repeating this process we become experts at achieving our goals with the objects we are familiar with, explaining why making a sandwich is so effortless despite involving so many objects with various possible uses.

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