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ORIGINAL ARTICLE

Is there a survival processing effect in metacognition?

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Abstract

Memory systems serve an adaptive function for the fitness of organisms. A good example of this is the Survival Processing Effect (SPE) which points to increased retention of information when it is processed in a survival context compared to other contexts. Survival processing may also affect metacognitive processes, by increasing confidence judgments as well as increasing metacognitive sensitivity. No previous study, however, has directly examined whether processing information for survival also has an effect on metacognitive processes. Here we ask whether SPE extends to the metacognitive system in terms of both metacognitive sensitivity and confidence bias. In Experiment 1 participants were asked to rate a list of words in terms of relevance in a survival scenario or a moving scenario. In a surprise old/new recognition test, they were given one word at a time and asked to indicate if they have rated the presented word before and state how confident they are in that choice. Surprisingly, the results did not reveal a SPE, which may have been due to high overall performance in the recognition task. In Experiment 2 we increased the level of difficulty of the memory task, which resulted in a robust SPE, but could not find this effect in metacognitive monitoring. Together, these results suggest that survival processing may not affect metacognitive processes in a reliable fashion.

Introduction

Memory systems, including human memory, are likely to have evolved to enhance fitness of the individual by increasing the chances of survival and reproduction (Kazanas & Altarriba, 2015; Nairne & Pandeirada, 2016). Given that some information, such as location of food or predators, carries higher fitness-related value, the storage and retrieval of such information may be more efficient compared to other information. Consistent with this idea, previous studies showed that encoding information in a survival context, where information is evaluated based on their survival value, increases retrieval of this information, termed the survival processing effect (Burns et al., 2014; Nairne & Pandeirada, 2010; Nairne et al., 2007).

In addition to increasing recall and recognition performance, survival processing may also be expected to prevent false memories (Otgaar & Smeets, 2010). False memories are defined as the memory trace of an experience that in fact did not happen or remembering it in a different way than the fact (Roediger & McDermott, 1995) and can arise due to various factors, including inferences that a person makes regarding the event (Roediger & McDermott, 1995), which can be influenced by interference of events that happened afterward (e.g., Loftus et al., 1978, Schooler et al. 1990, Goff et al. 1998, Tversky et al. 2000), sleep deprivation (Chatburn et al., 2017), and similarity between to be remembered information (Coane et al., 2021), or general metacognitive beliefs about how memory works (Mazzoni & Kirsch, 2002).

In a study that investigated if survival processing acts as a safeguard against false memories, Howe and Derbish (2010) compared recall rates after words were rated either for their survival value or, in the control condition, for their pleasantness. Contrary to predictions, they found that survival processing resulted in higher false memories compared to the control condition. Similarly, Otgaar and Smeets (2010) found that when given a recognition test after rating relevance of words to a survival or a house-moving (control) scenario, survival processing resulted in not only higher true recall performance but also in higher false memories in both adult participants and children. Taken together, these findings suggest that survival processing effect, while enhancing

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retrieval of information overall, may also make people more prone to false memories.

These findings of higher rates of false memories associated with survival processing are compatible with theories focusing on activation spread between associated items stored in memory (Otgaar & Smeets, 2010). These theories state that an increase in true recall comes with an increase in false memories due to the activation spread along the memory networks which causes related but not exposed items in the system to be activated. Associative Response Theory (Underwood, 1965), for instance, posits that memory system is, in fact, a network in which all components are linked semantically. Due to the connections between related components, during the encoding of a piece of information, other semantically related ones are also activated in the system. This activation, in turn, leads people to mistakenly assume that they have seen the word previously. Thus, as the activation of the words presented increases (such as when words processed in survival context are retrieved), false recognition rates also increase since the activation of related words will also increase (Anastasi et al., 2005).

Although increased rates of false memories may seem to be not adaptive at first glance, they may in fact provide the person with an increased chance of survival. Previous studies, for instance, showed that false memories may be beneficial by facilitating problem solving (Howe et al., 2011) and visual identification (Otgaar et al., 2015a, 2015b). If false memories can be beneficial in certain instances, then one may ask if they have an adaptive value in survival contexts. Indeed, Howe and Derbish (2010) argued that incorrectly remembering the presence of a survival threat (such as a predator) in a location may alert the individual to be particularly cautious, ultimately protecting them from any possible threat in that location. The idea that some errors are less costly than others has been formalized by Error Management Theory (EMT) (Haselton & Buss, 2000). Under this theory, decisions under ambiguous circumstances are made in a way to balance the trade-off between costs and benefits (Johnson et al., 2013), and natural selection favors biases that result in the least costly error in case of an asymmetry between the costs of false positives and the costs of false negatives (Haselton & Buss, 2000). For example, suppose that one has to remember whether they saw a predator in a given location before or not. Remembering that there was a predator there when there was not would be a false-positive error (a.k.a Type-1 error), while forgetting about a predator when there was one would be a false-negative error. EMT proposes that under uncertainty, people are biased to make the less costly error, which in this example would be the false positive. Assuming there was a predator in the location and avoiding it might be a less costly error than approaching it when in fact there was a predator. From this perspective, people might be expected to produce more false positives (Type 1 errors) when processing information in the survival context compared to other contexts, since it would be less costly to do so. Therefore, the increased false memory rate observed in survival scenarios might in fact be an adaptive strategy (Howe & Derbish, 2010). Howe and Derbish (2010) also showed that this increase in false memories in survival processing is independent from the word's relation to survival, indicating that this bias may extend to seemingly illogical cases as well.

A related question is if the metacognitive system also commits such survival-driven errors like the memory system. Metacognitive processes allow people to monitor and judge the outcomes of their cognitive operations (Fleming et al., 2014). To study metacognitive processes experimentally, researchers often use retrospective or prospective confidence judgments about decisions made in perceptual, memory, or problem-solving tasks (Kepecs & Mainen, 2012). These confidence judgments can be asked prospectively or retrospectively, before or after providing an answer, explicitly, and be probed in different forms, such as ratings of confidence (retrospective), feeling of knowing judgements (FOK; retrospective; Hart, 1965), and judgements of learning (JOL; prospective; Arbuckle & Cuddy, 1969).

The decision of being highly confident or not in a previously given answer is a second-order task where one discriminates whether their response in the first-order task was correct or incorrect. Given that metacognitive judgements are also decisions, Maniscalco and Lau (2014) proposed that principles of Signal Detection Theory can be applied to analyze the accuracy of metacognitive confidence judgements. Thus, it is possible to make a metacognitive false-positive error by having high confidence in a wrong first-order answer and a metacognitive false-negative error by having low confidence in a correct first-order answer. By extension, correct metacognitive responses would be to give high confidence ratings to a correct response and low confidence rating to a wrong answer.

Metacognitive sensitivity refers to the degree of an individual's correctness while evaluating their performance through these confidence decisions. High metacognitive sensitivity means that the one can correctly distinguish and state the variations in their performance (Fleming et al., 2014). Importantly, metacognitive sensitivity is dissociable from the objective performance; such that an individual with objectively low performance in the first-order task might have high metacognitive sensitivity regarding their performance level, while an individual with objectively high performance might have low metacognitive sensitivity (Fleming & Dolan, 2012). Metacognitive sensitivity for memory, too, is dissociable from the objective performance as well (see Dodson et al., 2007; Tolin et al., 2001).

Little is known whether the human metacognitive system also shows putatively adaptive patterns, such as the survival processing effect. To our knowledge, only one other study looked into this possibility. Although not framed in metacognitive terms the study by Palmore et al. (2012) asked their participants to report judgements of learning (JOL) on words they previously rated for their survival value. The results revealed a lack of survival processing effect on memory performance, but overall higher JOLs for words encountered in the survival condition. This suggests that encountering items in a survival context gives participants a false sense of confidence in how well they will remember these items. Although this study was not designed to examine the survival processing effect in the metacognitive system, it suggests that the human metacognitive system is sensitive to processing of fitness-relevant information. Previously Mazzoni and Kirsch (2002) described a role of metacognition in memory; such that one's explicit metacognitive beliefs can result in false memory reports. Here, we investigate a different link between metacognition and memory. Specifically we ask whether metacognitive confidence judgments regarding the decisions based on survival-related information will be different from those regarding the decisions based on information not related to survival. Although the exact mechanisms underlying survival processing effect are still not fully understood, it is generally thought to rely on implicit processes, i.e., an explicit knowledge of such an effect is not required to observe the survival processing effect.

From a fitness point of view, the survival processing effect extending to the metacognitive system is plausible. Consider the following example. Imagine that an individual remembers that she saw a dangerous snake in a location. She must evaluate the reliability of her memory in order to make the least costly decision about revisiting that location. If she is highly confident that she saw a snake there, she will likely avoid the location. However, if her confidence for this memory that she saw a snake there is low, she may choose to go to that location. At this point, confidence in the memory becomes crucial for the survival of the person. Given the significance of the confidence decision for survival, we propose that the human metacognitive system has also been selected and shaped by natural selection. In the example given above, there are two possible outcomes of this memory decision about the presence of a snake in the location: she may be right or wrong. Logically, in the cases where she is right about the presence or the absence of the snake, having a high confidence would be optimal since it will mean correctly monitoring the performance. For other cases, i.e., the cases where she is wrong (either through a false positive or a false negative), we believe that having a high confidence in false positives would be less costly than having high confidence in false negatives. Specifically, if people are inclined to make more false positives in survival memory situations, and this is adaptive, then being highly confident in this assumption of presence of the items would be more beneficial. In other words, if assuming that there is a predator in a location even if there is no predator there might be adaptive, being highly confident in this memory would also be adaptive. Simply put, making a false-positive error by being confident that there is a snake in a location (when there is not) would be less costly since it will make one extra cautious about going to that location than being less confident. For false-negative errors, on the other hand, we claim that having low confidence in the memory would be the less costly choice. If someone remembers that the location is free of danger when in fact it is not, and has a high confidence in this memory, then the chances of going to that location and getting hurt would be high. Therefore, having low confidence in false-negative errors and practicing caution would be the least costly decision. Therefore, while one can be expected to give higher confidence ratings to false-positive errors in survival situations, they can also be expected to give lower confidence ratings to false-negative errors.

In two experiments, we employed an adapted version of the classical survival processing paradigm (Otgaar et al., 2015a, 2015b) and presented participants with imaginary scenarios, e.g., being in a grassland without any material needed for survival. Afterward, participants were shown words and asked to rate their relevance for their survival in the imagined scenario. Following this a distractor task is presented right before a final surprise memory test. In our study a surprise recognition test followed the distractor task and participants evaluated their confidence in their responses. Our first prediction was that people will show higher recognition memory performance when they learn information in an ancestral survival-related context (i.e., the survival processing effect). In addition to this prediction, based on EMT (Haselton & Buss, 2000) and previous studies (Howe & Derbish, 2010; Otgaar & Smeets, 2010), we expected to find higher first-order false positives in survival-related contexts. Our second prediction was that people will be more confident in their memories regarding information learned in a survival-related context as compared to a house-moving context. Finally, we predicted that those who learned information in an ancestral survival-related context will show higher confidence in their first-order false-positive answers while showing less confidence in their first-order false-negative answers. Given that we had different predictions regarding the confidence levels in different first-order answers, we did not have a prediction regarding how survival processing will affect overall metacognitive sensitivity levels of participants. Although we had no predictions, we also looked whether survival processing effect influences metacognitive sensitivity as an exploratory analyses.

Besides examining whether survival processing also affects metacognitive processes, we also aimed to contribute to the ongoing domain-generality debate of metacognitive systems, such that metacognitive sensitivity of an individual is correlated across different tasks. The evidence on this debate is mixed. While there are some studies finding a correlation between metacognitive sensitivity levels in different tasks (see Song et al., 2011; Veenman et al., 1997; Schraw, 1998), other studies could not find support for the domain generality of the metacognitive system (see Baird et al., 2014; Fleming et al., 2014). For the purpose of contributing to this debate, we used a perceptual task as our distractor task to examine the correlation between the metacognitive sensitivity levels in our different cognitive tasks as an exploratory analysis.

Methods

Participants

The required number of participants for an independent samples t-test was found to be 102 by using G*Power 3.1.9.2 (Faul et al. 2007) to achieve an effect size (Cohen's d) of 0.5 and error probability of 0.05. We collected data from 103 participants who were either Koç University undergraduate students, who completed the study in exchange for course credit, or volunteers who received no compensation for their participation. A total of six out of 103 of participants were excluded from data analysis due to either poor performance in the surprise recognition task (<50%, $N=4$); rating almost all words as old ($N=1$); or using only the low end of the confidence rating scale ($N=1$). We thus included data from 97 participants to our final analyses ($N_{survival}=49$, $N_{moving}=48$). The age range of the final sample was between 18 and 30 ($M=21.56$, SD = 1.859). 68 of the participants identified as women and 29 identified as males. Prior to study, ethical approval was obtained from the Ethics Committee of Koç University.

Tasks and stimuli

Scenario reading and usefulness rating task

We used survival and moving scenarios that were translated from Nairne et al. (2007) into Turkish by Mısırlısoy et al. (2019) (see Appendix). The survival scenario asked the participants to imagine themselves in a grassland without any resources needed for survival. The moving scenario asked them to imagine themselves moving to a new city where they will need to find a new home and move in there. Afterward, we presented participants with 50 words and asked them how useful these words would be in the imagined scenario (see Fig. 1a). The words to be rated for their usefulness in the scenarios were selected randomly from Aksan et al. (2016). We made two lists of 50 words matched for frequency and category (see Appendix).

Distractor task

The task was adapted from Fleming et al. (2014). Participants saw a pair of circles side by side. Each circle contained a different number of dots in it. One circle, randomly appearing on the left or right, always contained 50 dots and the other contained varying numbers of dots. Participants' duty was to indicate which circle contained more dots. Metacognitive sensitivity and task performance are dissociable from each other but task performance can still act as a confounding variable in metacognitive sensitivity in such a way that as the task gets easier, metacognitive sensitivity levels get higher (Fleming et al., 2014). With this design, performance is held constant at a previously defined value for all participants. This is achieved by increasing or decreasing the task difficulty after each trial depending on the performance of the participant. Therefore, it eliminates the variation in metacognitive sensitivity caused by the task performance and allows us to estimate a metacognitive sensitivity more properly (Fleming et al., 2012). The difference in the number of dots was adjusted by the staircase method in which the difference increases by one after each wrong answer and decreases by one after two consecutive correct answers (Fleming et al., 2014). After each answer, participants were asked to rate how confident they are in their answers (see Fig. 1b).

Surprise memory tasks

One hundred words, half of which were from the list used in the usefulness rating task and the other half were from the other list, were shown one at a time. After the presentation of each word and obtaining an answer whether they remember rating the word in the usefulness rating task, participants were asked to rate how confident they are in their answers (see Fig. 1c).

Procedure

The experiment was run on the online platform Pavlovia (Peirce et al., 2019; https://pavlovia.org/). Prompts and instructions were given in Turkish. Participants were informed that the goal of the study was to investigate which items people find useful in certain situations. Before the study and each trial, they were given detailed instructions on how to complete tasks. It took nearly 45 min to complete the experiment (see Fig. 1d).

Participants were randomly assigned to either survival condition or moving condition; the only difference was the scenarios they read. At the beginning of the experiment,

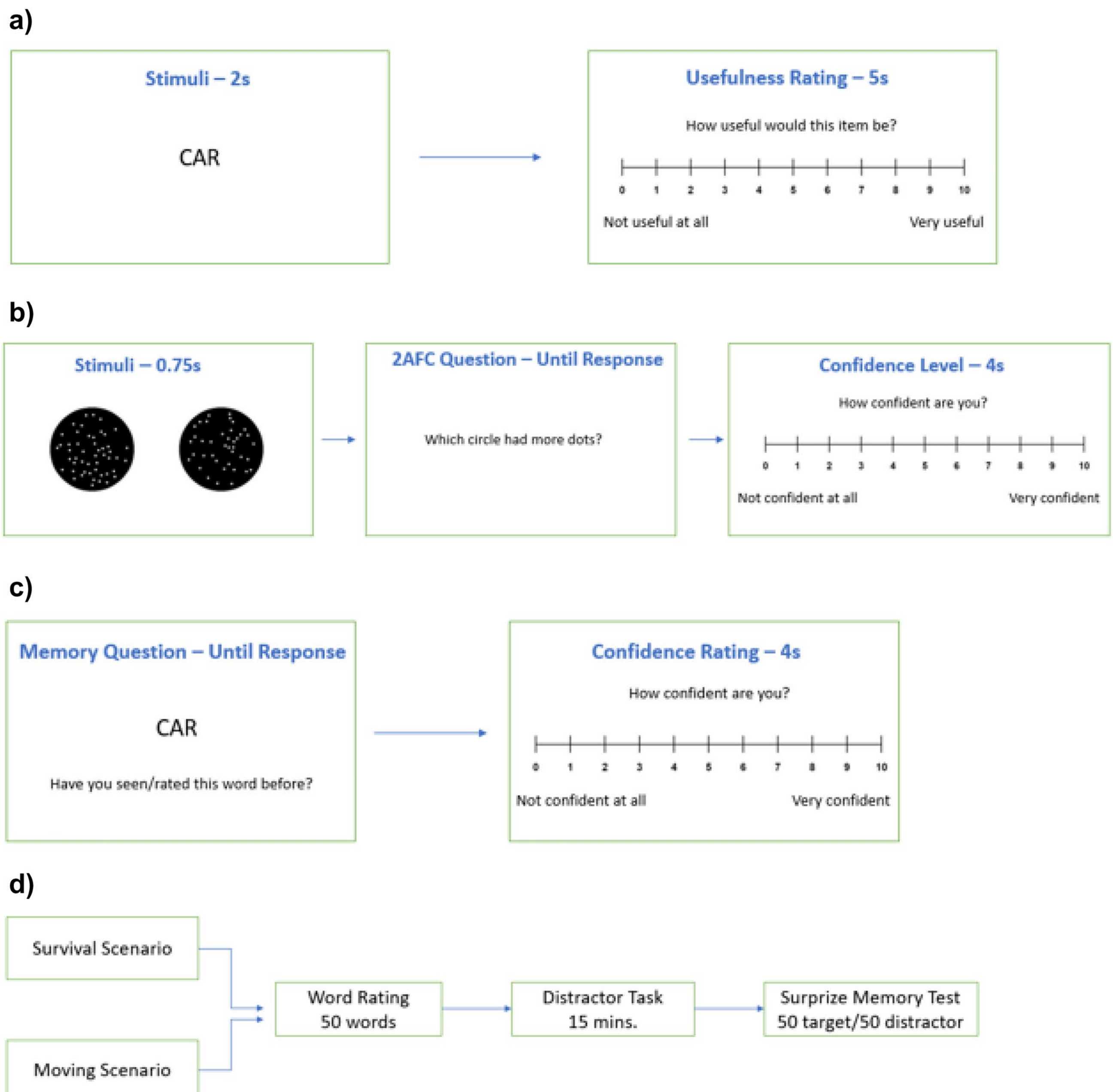

Fig.1 **a** An example trial from the usefulness rating task. **b** An example trial from the distractor task. **c** An example trial from the surprise memory task. **d** The procedure of this study

participants read the scenario and asked to imagine themselves in that condition. Afterward, they were presented with randomly selected one of the previously constructed lists of 50 words (shown one word at a time on the screen). After seeing the item for two seconds, they rated how useful the word would be in the scenario in five seconds on a scale of 0 to 10: “10” referring to “very useful” and “0” referring to “not useful at all.” The usefulness rating and the reaction times were recorded.

After completing this part, they were presented with the distractor task for approximately 15 min. In the distractor task, participants saw two circles on the screen, each containing varying numbers of dots. After seeing the circles for 0.75 s, they were asked to indicate whether the circle on the right or left had a greater number of dots. After providing their answer, they were asked to rate their confidence in their response in a maximum of four seconds on a scale of 0 to 10: “10” referring to “very confident” and “0” referring to "not confident at all." They were encouraged to use all the scales. The task lasted for 15 min. As the task lasted for 15 min, each participant completed a different number of trials based on their pace. To equate the number of trials that we based our analyses on and the number of trials used in the distractor task and the surprise memory task, we used the first 100 trials for our analyses. The distractor task was followed by a surprise memory and confidence rating task. In this task, they were shown 100 words, presented on the screen one at a time. 50 of the words were words that they have rated for their usefulness before and 50 of which were new words from the second list that they have not seen. The participants indicated whether they had seen the word before or not by pressing "D" on their keyboard if they had seen it, "K" if they had not seen it. After each answer, they also stated how confident they were in their response by using an 11-point sliding scale.

Results

Hypothesis 1: survival processing effect

To test our first hypothesis expecting a survival processing effect, we compared the performance of two groups (moving vs survival) in the surprise memory task. We defined performance as the percentage of correct first-order answers given in the task. An independent samples *t* test showed no significant difference between the proportion of correct answers of survival group ($M = 0.87$, SD = 0.09) and moving group ($M = 0.87$, SD = 0.09), $t(95) = 0.13$, $p = 0.90$, $d = 0.03$, 95% CI [− 0.03, 0.04]. Thus, there was no survival processing effect in the present sample.

In addition to the performance difference between the groups, we also examined if the survival group had higher first-order false positives compared to the moving groups as it was found in previous studies. We coded first-order answers where the participants mistakenly classified a word as "old," when in fact it was "new." An independent samples *t* test showed that the number of first-order false positives was not higher in the survival group ($M = 7.06$, SD = 5.33) compared to the moving group ($M = 7.27$, SD = 4.65), $t(95) = - 0.21$, $p = 0.80$, $d = - .04$, 95% CI [− 2.23, 1.81].

Hypothesis 2: memory confidence and metacognitive sensitivity

To test if the survival group gave higher overall confidence ratings in their answers, we compared the mean confidence level of two groups with an independent samples *t* test. There was no difference between mean confidence ratings ($M_{survival} = 9.10$, $SD_{survival} = 0.84$, $M_{moving} = 8.80$, $SD_{moving} = 1.06$), $t\ (95) = 1.57$, $p = 0.12$, $d = 0.32$, 95% CI [− 0.08, 0.69]).

To test if groups' metacognitive sensitivity levels were different from each other, we conducted an independent samples *t* test on the mean metacognitive sensitivity levels calculated as *meta-d'* and *meta-d'/d'* using data from surprise memory and confidence rating tasks. *Meta-d'* is an index of metacognitive sensitivity calculated within the Signal Detection Theory framework. It indicates one's ability to discriminate between their correct and incorrect decisions. This measure, however, is influenced by the performance in the first-order decision task. *Meta-d'/d'* has been developed as a measure of metacognitive efficiency that is free from the influence of first-order performance. An optimal level of metacognitive sensitivity would be where *meta-d*' and *d'* would be equal, and meta-d'/d' would be equal to 1 (Fleming & Lau, 2014). Relevant parameters were calculated using Alan Lee's python adaptation of the code written by Maniscalco and Lau (2014; http://www.columbia.edu/~bsm2105/type2sdt/).

Our results showed that metacognitive sensitivity levels of groups measured as *meta-d'/d'* was not significantly different ($M_{survival} = 0.97$, $SD_{survival} = 0.57$, $M_{moving} = 1.03$, $SD_{moving} = 0.53$), $t(95) = - 0.54$, $p = 0.59$, $d = 0.11$, 95% CI [− 0.28, 0.16]. Overall, our results suggest that survival processing did not affect participants' metacognitive processes in a reliable fashion.

We also compared the two group's metacognitive sensitivities on the distractor task. For these analyses, we excluded 2 participants because their performance in the task was lower than 0.6. For the remaining 95 participants, metacognitive sensitivity levels of the survival group measured as *meta-d'/d'* were higher for the survival group compared to the moving group ($M_{survival} = 0.76$, $SD_{survival} = 0.41$, $M_{moving} = 0.59$, $SD_{moving} = 0.39$), $t\ (93) = 2.16$, $p = 0.03$, 95% CI [0.01, 0.34].

To provide a contribution to the ongoing debate on the domain specificity or domain generality of the metacognitive system, we looked if metacognitive sensitivity of the participants in the distractor task (perceptual task) was correlated with the metacognitive sensitivity levels in the surprise memory task. The correlation between metacognitive sensitivity levels of participants in the distractor task and the surprise memory task was not statistically significant, $r\ (93) = 0.16$, $p = 0.11$, not supporting the domain generality of the metacognitive system.

Hypothesis 3: confidence in first-order false positives and first-order false negatives

Our third prediction was that the survival group would have higher mean confidence levels in their first-order false-positive answers compared to the moving group. The results of an independent samples t test showed that participants in the moving group and the survival group did not differ in terms of their mean confidence levels given to first-order false-positive answers ($M_{\text{survival}} = 7.06$, $SD_{\text{survival}} = 2.35$, $M_{\text{moving}} = 6.79$, $SD_{moving} = 2.45$), t (94) = 0.55, $p = 0.59$, $d = 0.11$, 95% CI [− 0.71, 1.24].

For our fourth prediction stating that the survival group will have lower confidence levels in their first-order false-negative answers, we conducted another independent samples t test. We coded first-order answers where the participants mistakenly classified a word as "new," when in fact it was "old," Our results showed that contrary to our prediction, survival group had higher confidence in their first-order false-negative answers ($M = 7.574$, $SD = 2.4774$) compared to the moving group ($M = 6.29$, $SD = 2.64$), $t(91) = 2.42$, $p = 0.02$, $d = 0.50$, 95% CI [0.23, 2.34] (see Fig. 2).

As a post hoc analysis, we also asked if the mean confidence ratings given to incorrect answers in general differed between the groups to see if the inclination to give lower confidence ratings in the wrong questions is the reason for observing a confidence level difference in the first-order false-negative answers. The results of independent samples t-test showed that moving group gave lower confidence levels ($M_{\text{moving}} = 6.57$, $SD_{moving} = 1.78$) when their answers were incorrect compared to survival group ($M_{survival} = 7.32$, $SD_{survival} = 1.90$), t(95) = 2.02, p = 0.047, $d = 0.41$, 95% CI [0.011, 1.49], indicating that despite the lack of difference between the mean confidence ratings of the groups given to first-order false-positive answers, survival group had higher confidence in their overall first-order wrong answers (see Fig. 3).

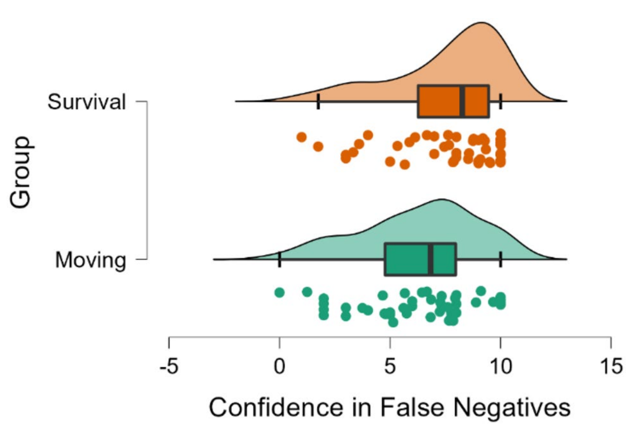

Fig. 2 The figure is created by using Jasp (2022). Mean confidence ratings given to first-order false-negative answers in the surprise memory test. Dots indicate each participant's mean confidence rating given to first-order false-negative answers. The boxes indicate interquartile ranges; the line in the middle indicates the median

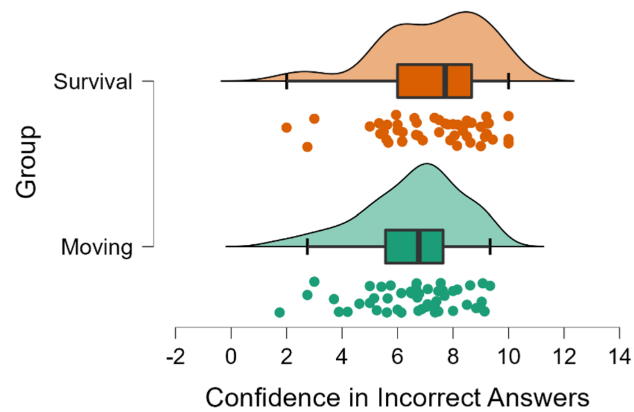

Fig. 3 The figure is created by using Jasp (2022). Mean confidence ratings given to first-order incorrect answers in the surprise memory test. Dots indicate each participant's mean confidence rating given to first-order incorrect answers. The boxes indicate interquartile ranges; the line in the middle indicates the median

Experiment 2

In the first study, the groups did not differ in terms of their memory performance, showing that there was no survival processing effect. We also could not replicate the previous studies' finding of higher first-order false-positive answers in the survival group. Our further analyses showed that the survival group was not inclined to give higher overall mean confidence ratings to their answers. Survival group, however, showed a tendency to give higher confidence ratings to their incorrect answers in general and first-order false-negative answers in specific. This tendency was not observed when confidence ratings given to first-order false-positive answers were examined separately. It is, however, important to note that the absence of survival processing effect may pose a problem since it was the main expectation on which other predictions were built. We believe that high performance rates in the memory task may have caused a ceiling effect, which resulted in no effect of survival processing. In a second study, we aimed to increase the task difficulty to overcome the ceiling effect.

Method

To increase the task difficulty, we added more distractor words to the surprise recognition memory test. All the stimuli and procedure were the same as study 1. The only difference was that the final memory test consisted of 100 items of which randomly selected 30 were "old" words while the remaining 70 were "new" words (see Appendix C for newly added words).

Results

Of the initial 108 participants who took part in the study, four were eliminated for having performance scores in recognition task equal to or below 50%. 52 of the remaining participants were in the survival group and 52 were in the moving group. Age range of the final sample was between 18 and 31 (M = 20.52, SD = 1.71). 79 of the participants identified themselves as female and 25 identified themselves as male.

Hypothesis 1: survival processing effect

Independent samples t test analysis comparing the performances of groups on surprise memory test showed that survival group ($M_{survival}$ = 0.91, $SD_{survival}$ = *0.06*) had higher overall performance compared to moving group (M_{moving} = 0.87, SD_{moving} = 0.080), indicating that there was a survival processing effect, t (102) = 3.01, p = 0.00, d = 0.59, 95% CI [0.01, 0.07] (see Fig. 4). Comparing if the groups differed in terms of the number of false alarms they made, we found that those in the moving group (M = 10.10, SD = 7.00) had higher false alarms compared to those in the survival group (M = 6.85, SD = 5.04), t(102) = – 2.72, p = 0.01, d = – 0.53, 95% CI [– 5.62, -0.88].

Hypothesis 2: memory confidence and metacognitive sensitivity

Independent samples t test showed that groups' overall mean confidence ratings given in the surprise memory task did not significantly differ from each other ($M_{survival}$ = 8.64, $SD_{survival}$ = 1.01, M_{moving} = 8.31, SD_{moving} = 1.25), t (102) = 1.53, p = 0.13, d = 0.30, 95% CI [– 0.10, 0.78]. Most of the time higher performance is accompanied by higher confidence ratings (see McCurdy et al., 2013; Rouault et al., 2018). In the present experiment, however, despite showing higher performance in the surprise memory task, the survival group did not have higher mean confidence levels. This finding raises the possibility of a confidence bias in the survival group such that they are becoming underconfident in their first-order decisions.

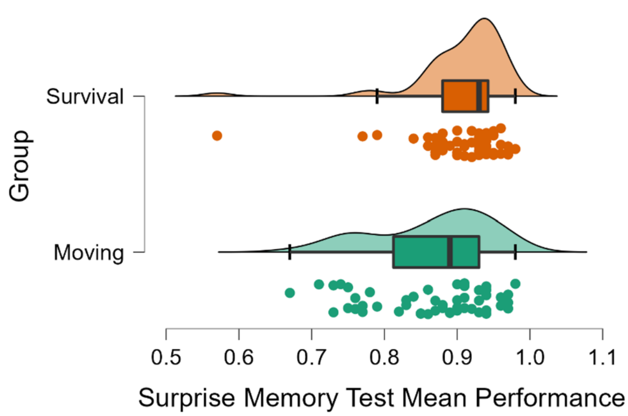

Fig. 4 The figure is created by using Jasp (2022). Performance on the surprise memory task for the survival and moving groups. Dots indicate each participants' performance in the surprise memory task. The boxes indicate interquartile ranges; the line in the middle indicates the median

Metacognitive sensitivity of the groups calculated as *meta-d'/d'* was not statistically different ($M_{survival}$ = 1.04, $SD_{survival}$ = 0.37 M_{moving} = 1.07, SD_{moving} = 0.36), t (102) = – 0.49, p = 0.62, d = – 0.10, 95% CI [– 0.18, 0.11]. Taken together, these results suggest that survival processing did not affect the metacognitive sensitivity of the participants in the expected way, while it may possibly have an influence on the confidence bias.

Further examination of the difference between the groups' metacognitive sensitivity for the distractor task calculated as meta-d'/d' showed that there was no difference between the metacognitive sensitivity of the groups in the distractor task ($M_{survival}$ = 0.69, $SD_{survival}$ = 0.32 M_{moving} = 0.75, SD_{moving} = 0.42), t (102) = – 0.83, p = 0.41, d = – 0.16, 95% CI [– 0.21, 0.08], indicating that there was no initial difference between the metacognitive sensitivity levels of the groups.

For our additional examination of whether the metacognitive system is domain general or domain specific, we again tested if metacognitive sensitivity levels in the distractor task were correlated with the metacognitive sensitivity levels in the memory task. The correlation between metacognitive sensitivity levels in dot task and word task was statistically significant, r (102) = 0.22, p = 0.03. This correlation, unlike the corresponding result in Experiment 1, supports the possibility of a domain-general metacognitive system.

Hypothesis 3: confidence in first-order false positives and first-order false negatives

The results of independent samples t-test showed that there was also no difference between groups' mean confidence ratings given to first-order false-positive answers ($M_{survival}$ = 6.54, $SD_{survival}$ = 2.03, M_{moving} = 6.53, SD_{moving} = 1.61), t (101) = 0.03, p = 0.97, d = 0.01, 95% CI [– 0.70, 0.73]. Similarly, groups' confidence levels in first-order false-negative answers did not differ significantly ($M_{survival}$ = 4.66, $SD_{survival}$ = 3.32, M_{moving} = 5.60, SD_{moving} = 2.32), t (83) = – 1.52, p = 0.13, d = – 0.33, 95% CI [– 2.17, 0.29].

Further examination of difference between the groups' confidence ratings given to incorrect answers also did not reveal a significant difference ($M_{survival}$ = 6.02, $SD_{survival}$ = 1.92, M_{moving} = 6.30, SD_{moving} = 1.58), t

(102) = − 0.82, p = 0.41, d = − 0.16, 95% CI [− 0.97, 0.40]. These results indicate that those in the survival groups were inclined to give higher confidence ratings neither to their incorrect answers in general nor to the first-order false-positive answers.

Discussion

Previous studies found that memory performance is enhanced when the recalled information is encoded in a survival context, termed the survival processing effect. Since evaluating the reliability of one's own memory is crucial to survival, in the present study we asked whether the metacognitive system was also susceptible to this effect. Our first aim was to replicate the survival processing effect and see if survival processing also makes people more prone to making first-order false-positive errors as it was found in the previous studies. Secondly, based on Error Management Theory, we expected people to have higher overall mean confidence in memories of survival-related information compared to memories of moving information, as it would be less costly. In addition to that, we also predicted higher mean confidence ratings in the first-order false-positive trials when information is encoded in a survival context compared to a moving context while expecting lower confidence ratings in the first-order false-negative trials. Despite the lack of a survival processing effect in the first experiment, we observed this effect in our second experiment. For our hypotheses regarding the metacognitive system, the findings presented a mixed picture.

Surprisingly, in the first experiment we found no evidence of a survival processing effect. Given that mean performance of both groups were very high, we believe that the difficulty level of the memory task might have caused a ceiling effect, which may in turn conceal a possible survival processing effect. Indeed, in the second experiment, when we increased the difficulty of the recognition task by decreasing the target/distractor ratio, we obtained a significant survival processing effect. Whether this is due to an increase in the difficulty of the task is unclear however, since the performance in the second experiment was also very high and comparable to the performance in the first one.

The presence of survival processing effect in the second study but not in the first study also provides a possible explanation in need of further testing for the proximate mechanisms of survival processing effect. The timing of the first experiment, for example, coincided with the beginning of COVID-19 pandemic, which may have influenced the results. In particular, even our control scenario of moving may have elicited some survival-related worries and thoughts during the initial stages of pandemic. Some previous experiments found that the survival processing effect disappears relative to a control condition involving a dying scenario (Burns et al., 2014), indicating that death-related thoughts contribute to the memory performance in the same way as survival processing. Therefore, the present study also raises the question of the importance of anxiety or death-related thoughts in explaining the proximate mechanisms of survival processing effect. As we did not ask participants about their anxiety or death-related thoughts we do not currently have evidence for this hypothesis.

Importantly, our second hypothesis that we would see a higher overall confidence in survival condition since it would be more beneficial compared to having low confidence, which would indicate that the metacognitive system was also influenced by survival processing, received mixed support at best. While in Experiment 1 we observed a modest effect of survival condition on confidence ratings given to incorrect trials, this was in the absence of a survival processing effect in the recognition performance. Then, in Experiment 2, we observed no effect of survival processing on overall mean confidence ratings even though we found a significant survival processing effect in recognition. This finding was particularly interesting since there generally is a correlation between performance and average confidence ratings (see McCurdy et al., 2013; Rouault et al., 2018). Given that we could not find a difference between the groups' overall mean confidence levels, this raises the possibility of a confidence bias in the survival group that needs to be examined further in the future studies. Moreover, we failed to find higher confidence ratings in first-order false-positive trials for those who learned information in a survival context. Overall, these results suggest that there is a possibility of the metacognitive system being susceptible to survival processing, but this possibility needs further testing.

The finding that survival processing effect being observed only in the first-order performance while not affecting the second-order performance in terms of metacognitive sensitivity supports the previous findings, indicating that first-order performance and metacognitive abilities are dissociable (see Dodson et al., 2007; Tolin et al., 2001; Song et al., 2011). Therefore, our results highlight the importance of being cautious while applying the findings of first-order decision making systems to the second-order decision making system and testing the possible effects of a given condition on these systems separately.

One important finding in our studies was that although we could not find a correlation between the metacognitive sensitivity in the perceptual task and memory task in the first experiment, we found a correlation between them in Experiment 2. The ongoing debate on the domain generality of the metacognitive system has not reached a conclusion yet. Metacognitive systems being domain general means that different cognitive domains, such as perception and memory, share and rely on one comprehensive metacognitive system that supports all cognitive domains (Carpenter et al., 2019). Given that we found support for the domain generality in our second study where we found a survival processing effect too raises the possibility of the metacognitive system being resistant to the survival processing effect since it only affects the memory system–at least in the present study's paradigm. It can thus be claimed that the metacognitive system is not affected by the interventions in the first-order system because of its domain independent general nature.

Possible limitations of the study

The present study has several limitations. The first one is that it was not conducted in a controlled lab environment due to the COVID-19 restrictions. Instead, the experiments were conducted online where each participants took the study at the time that was the most suitable to them and at the place of their choice. The lack of control over the external factors may have created noise that we could not detect and control. Some participants, for instance, may have completed the experiments in an environment that does not enable them to give all their attention to the task at hand. The importance of attention for the survival processing effect has been shown in previous studies such that survival processing effect diminishes when participants are required to rate the words presented according to their survival relevance under a divided attention paradigm (Yang et al., 2021). Other factors that could not have been held constant, such as the size of the computer screen or the used keyboards characteristics, may have some effects that could not be detected as well.

Secondly, increasing the amount of uncertainty of the participants in their answers may also yield different results. There are two factors that are highlighted for a decision to be biased in the Error Management Theory. First one is that the decision should be made under uncertainty, i.e., the chance of possible outcomes to occur should be vague to anticipate, and the second one is that there must be a difference between the possible costs of false-positive and false-negative errors (Johnson et al., 2013). Our study, however, may not fulfill the first factor of uncertainty. Given that the participants' showed a very high performance in both studies and the mentioned relationship between performance and metacognitive processes, one may speculate that participants were able to predict whether their answers were correct or incorrect with a certainty. In fact, the finding that the survival group was inclined to show under confidence bias in the first study when their answers were incorrect, i.e., when there was a room for uncertainty, can be considered as an indicator of the important role of uncertainty. Therefore, creating a task where there is more room for uncertainty may reveal different results.

One other important factor to consider is the survival relatedness of the confidence rating task used to assess metacognitive procedures. The used task's relation to survival is a crucial factor for the survival processing effect to take place. While some studies show that survival-threat scenarios in the modern context does not yield as good retention as the ancestral contexts (Nairne & Pandeirada, 2010), there are also studies showing that modern survival scenarios are as effective as the ancestral scenarios (Kazanas & Altarriba, 2017; Soderstrom & McCabe, 2011). Some studies even found better memory retention in modern scenarios (Bugaiska et al., 2015). Looking at the role of both context and the threat level of the presented scenarios on survival processing effect, Olds et al. (2014) found that recall rates were higher when the threat was high, independent from the context of the scenario. In line with these studies a recent review (Tay et al., 2019) showed that the presence of survival threat during encoding has a stronger effect on memory then the nature of the threat, whether it is modern or ancestral. Therefore, the presence of survival threat is crucial for survival processing to take place compared to other factors, such as the context where the threat happens. Metacognitive judgements in our study, however, were made under no particular survival threat, unlike the encoding part of the memory task where participants rated words in relevance to survival. Thus, a design incorporating survival threat not only during information encoding but also during the retrieval stage when metacognitive processes are assessed may produce different results than ours.

Summary and conclusions

The present study asked if the metacognitive system is also affected by the processing of survival-relevant information like the memory system. The results of our studies indicate that the metacognitive system may not be as susceptible to the survival processing effect as the memory system, at least in terms of metacognitive sensitivity. It is possible, however, that confidence bias may be susceptible to this effect—though this claim requires further testing.

This study bears importance since it is one of the first studies to investigate the relation between survival pressures and metacognitive processes. The absence of survival processing effect in the metacognitive systems raises the question of what it is about the metacognitive system that makes it resistant to the survival processing effect. Moreover, although our results indicate a resistance of metacognitive processes to the survival processing effect, future studies can obtain different results by increasing the uncertainty or creating a survival-related task to assess metacognition.

Appendix A

Survival Scenario: Yabancı bir yerde, uçsuz bucaksız çayırlık bir alanda, yanınızda hayatta kalmanıza yardımcı olacak hiçbir.

malzeme olmadan mahsur kaldığınızı hayal edin. Önünüzdeki birkaç ay boyunca, düzenli olarak yiyecek ve su bulmanız ve kendinizi.

yırtıcı hayvanlardan korumanız gerekecek. Şimdi size bazı kelimeler sunulacaktır. Lütfen bu hayatta kalma bağlamında, her bir kelimenin.

ne kadar ilgili/gerekli olacağını derecelendirin. Bu kelimelerden bazıları ilgili/gerekli, bazıları ilgisiz/gereksiz olabilir. Bu derecelendirme için doğru/yanlış bir cevap yoktur, karar tamamıyla size kalmıştır.

Moving Scenario: Yabancı bir yerde yeni bir eve taşınmayı planladığınızı hayal edin. Önünüzdeki birkaç ay içinde yeni bir ev bulmanız, satın almanız ve eşyalarınızı taşımanız gerekecek. Şimdi, size bazı kelimeler sunulacaktır. Lütfen bu taşınma görevini yerine getirirken her bir kelimenin ne kadar ilgili/gerekli olacağını derecelendirin. Bu kelimelerden bazıları ilgili/gerekli, bazıları ilgisiz/gereksiz olabilir. Bu derecelendirme için doğru/yanlış bir cevap yoktur, karar tamamıyla size kalmıştır.

Appendix B

Word	Frequency	List
YUMURTA	5383	1
ZEYTİN	1744	1
SOĞAN	2342	1
ŞEKER	5206	1
ÇAY	10,740	1
KÜLOT	192	1
TERLİK	706	1
BERE	316	1
BİLEZİK	539	1
OTOBÜS	6007	1
PETROL	7217	1
ÇELİK	3282	1
BİTKİ	13,249	1
AĞAÇ	10,212	1
GÖL	4112	1
KARABİBER	959	1
KEK	550	1
KÜPE	527	1
CEKET	1787	1
BULVAR	458	1
MİNİBÜS	1288	1
MERMER	1222	1

Word	Frequency	List
KÖMÜR	2384	1
GECELİK	652	1
UÇAK	8093	1
ÇALI	842	1
HİNDİ	361	1
KAPLUMBAĞA	896	1
AKREP	1020	1
SALEP	81	1
ÇEKİÇ	772	1
TENCERE	1463	1
ÇANTA	4697	1
SANDALYE	2993	1
KİLİM	592	1
YORGAN	1068	1
PAMUK	2077	1
METRO	915	1
KUTU	4875	1
KABLO	1173	1
FENER	1483	1
TABAK	2918	1
DEFTER	4964	1
BETON	2633	1
DOLAP	2342	1
GİTAR	917	1
BELGE	9648	1
HEYKEL	3368	1
KİTAPLIK	1081	1
PLAK	1558	1
EKMEK	6576	2
PEYNİR	2180	2
PATATES	2000	2
TUZ	4664	2
KAHVE	7200	2
BİKİNİ	203	2
BOT	695	2
ATKI	306	2
KOLYE	549	2
OTOMOBİL	4277	2
GAZ	6773	2
METAL	2619	2
BAHÇE	12,957	2
ÇİÇEK	11,940	2
NEHİR	3328	2
NANE	561	2
PASTA	1506	2
YÜZÜK	1382	2
PANTOLON	2086	2
OTOYOL	515	2
TAKSİ	3228	2
BAKIR	1259	2
PLASTİK	2250	2

Word	Frequency	List
PİJAMA	490	2
GEMİ	7982	2
ÇİMEN	643	2
ÖRDEK	550	2
KURBAĞA	879	2
YENGEÇ	1074	2
BOZA	86	2
KÜREK	1040	2
ÇANAK	930	2
VALİZ	592	2
KOLTUK	6348	2
HALI	2810	2
BATTANİYE	751	2
İPEK	1762	2
TRAMVAY	584	2
SANDIK	3361	2
İPLİK	1221	2
LAMBA	1951	2
TEPSİ	1529	2
DERGİ	10,512	2
ÇİMENTO	1435	2
ÇEKMECE	705	2
KEMAN	1258	2
EVRAK	1302	2
ANIT	1201	2
RAF	1720	2
KASET	1904	2

Appendix C

Word	Frequency
LEYLEK	992
GEYİK	949
KARGA	848
UN	1805
BAL	2438
DOMATES	2375
MANTAR	1822
ELMA	2281
SİRKE	561
YAĞ	8003
BARDAK	5999
SU	54,954
ELBİSE	1447
GÖMLEK	2509
HIRKA	486
HARİTA	4035
LİMAN	2744
ARABA	14,845
YAKIT	2496
KARTON	871

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Author contributions DÇ conceived the initial idea and the experiment first. TE and ÇA helped with the development of the idea and the experimental procedure. DÇ and AY collected the data and led data analysis under the supervision of TE and ÇA. The first version of the manuscript was written by DÇ and all the authors provided feedback and edited the manuscript.

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Data availability Data is available in the supplementary materials.

Declarations

Conflict of interests There is no competing interest to disclose.

Ethics approval This study was conducted in line with the principles of the Declaration of Helsinki. Ethics approval was obtained from the Ethics Committee of Koç University (Ethics approval number: 2019.058. IRB3.033).

Consent to Participate Written informed consent was obtained from each participant. All participants were either 18 years of age or older.

References

Aksan, Y., Aksan, M., Mersinli, Ü., & Demirhan, U. U. (2016). A frequency dictionary of Turkish: Core vocabulary for learners. *Routledge*. https://doi.org/10.4324/9781315733302

Anastasi, J., Rhodes, M., Marquez, S., & Velino, V. (2005). The incidence of false memories in native and non-native speakers. *Memory, 13*(8), 815–828. https://doi.org/10.1080/09658210444000421

Arbuckle, T. Y., & Cuddy, L. L. (1969). Discrimination of item strength at time of presentation. *Journal of Experimental Psychology*. https://doi.org/10.1037/h0027455

Baird, B., Mrazek, M. D., Phillips, D. T., & Schooler, J. W. (2014). Domain-specific enhancement of metacognitive ability following meditation training. *Journal of Experimental Psychology: General, 143*(5), 1972–1979. https://doi.org/10.1037/a0036882

Bugaiska, A., Mermillod, M., & Bonin, P. (2015). Does the thought of death contribute to the memory benefit of encoding with a survival scenario? *Memory, 23*(2), 213–232. https://doi.org/10.1080/09658211.2014.881881

Burns, D. J., Hart, J., & Kramer, M. E. (2014). Dying scenarios improve recall as much as survival scenarios. *Memory, 22*(1), 51–64. https://doi.org/10.1080/09658211.2013.795973

Carpenter, J., Sherman, M. T., Kievit, R. A., Seth, A. K., Lau, H., & Fleming, S. M. (2019). Domain-general enhancements of metacognitive ability through adaptive training. *Journal of*

Experimental Psychology: General, 148(1), 51–64. https://doi.org/10.1037/xge0000505

Chatburn, A., Kohler, M. J., Payne, J. D., & Drummond, S. P. (2017). The effects of sleep restriction and sleep deprivation in producing false memories. *Neurobiology of Learning and Memory, 137*, 107–113. https://doi.org/10.1016/j.nlm.2016.11.017

Coane, J. H., McBride, D. M., Huff, M. J., Chang, K., Marsh, E. M., & Smith, K. A. (2021). Manipulations of list type in the DRM paradigm: A review of how structural and conceptual similarity affect false memory. *Frontiers in Psychology, 12*, 668550. https://doi.org/10.3389/fpsyg.2021.668550

Dodson, C. S., Bawa, S., & Krueger, L. E. (2007). Aging, metamemory, and high-confidence errors: A misrecollection account. *Psychology and Aging, 22*(1), 122–133. https://doi.org/10.1037/0882-7974.22.1.122

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fleming, S. M., & Dolan, R. J. (2012). The neural basis of metacognitive ability. *Philosophical Transactions of the Royal Society B: Biological Sciences, 367*, 1338–1349. https://doi.org/10.1098/rstb.2011.0417

Fleming, S. M., Huijgen, J., & Dolan, R. J. (2012). Prefrontal contributions to metacognition in perceptual decision making. *Journal of Neuroscience, 32*(18), 6117–6125. https://doi.org/10.1523/JNEUROSCI.6489-11.2012

Fleming, S. M., & Lau, H. C. (2014). How to measure metacognition. *Frontiers in Human Neuroscience, 8*, 443. https://doi.org/10.3389/fnhum.2014.00443

Fleming, S. M., Ryu, J., Golfinos, J. G., & Blackmon, K. E. (2014). Domain-specific impairment in metacognitive accuracy following anterior prefrontal lesions. *Brain, 137*(10), 2811–2822. https://doi.org/10.1093/brain/awu221

Goff, L. M., & Roediger, H. L. (1998). Imagination inflation for action events: Repeated imaginings lead to illusory recollections. *Memory & Cognition, 26*(1), 20–33.

Hart, J. T. (1965). Memory and the feeling-of-knowing experience. *Journal of Educational Psychology, 56*(4), 208–216. https://doi.org/10.1037/h0022263

Haselton, M. G., & Buss, D. M. (2000). Error management theory: A new perspective on biases in cross-sex mind reading. *Journal of Personality and Social Psychology, 78*(1), 81–91. https://doi.org/10.1037/0022-3514.78.1.81

Howe, M. L., & Derbish, M. H. (2010). On the susceptibility of adaptive memory to false memory illusions. *Cognition, 115*(2), 252–267. https://doi.org/10.1016/j.cognition.2009.12.016

Howe, M. L., Garner, S. R., Charlesworth, M., & Knott, L. (2011). A brighter side to memory illusions: False memories prime children's and adults' insight-based problem solving. *Journal of Experimental Child Psychology, 108*(2), 383–393. https://doi.org/10.1016/j.jecp.2010.08.012

JASP Team (2022). JASP (Version 0.16.1)[Computer software].

Johnson, D. D., Blumstein, D. T., Fowler, J. H., & Haselton, M. G. (2013). The evolution of error: Error management, cognitive constraints, and adaptive decision-making biases. *Trends in Ecology & Evolution, 28*(8), 474–481. https://doi.org/10.1016/j.tree.2013.05.014

Kazanas, S. A., & Altarriba, J. (2015). The survival advantage: Underlying mechanisms and extant limitations. *Evolutionary Psychology*. https://doi.org/10.1177/147470491501300204

Kazanas, S. A., & Altarriba, J. (2017). Did our ancestors fear the unknown? The role of predation in the survival advantage. *Evolutionary Behavioral Sciences*, *11*(1), 83

Kepecs, A., & Mainen, Z. F. (2012). A computational framework for the study of confidence in humans and animals. *Philosophical Transactions of the Royal Society B: Biological Sciences, 367*, 1322–1337. https://doi.org/10.1098/rstb.2012.0037

Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning and Memory, 4*(1), 19–31. https://doi.org/10.1037/0278-7393.4.1.19

Maniscalco, B., & Lau, H. (2014). Signal Detection Theory Analysis of Type 1 and Type 2 Data: Meta-*d′*, Response-Specific Meta-*d′*, and the Unequal Variance SDT Model. In S. Fleming & C. Frith (Eds.), *The Cognitive Neuroscience of Metacognition.* Heidelberg: Springer, Berlin.

Mazzoni, G. A. L., Kirsch, I. A., & memories and beliefs: A preliminary metacognitive model,. (2002). *Applied metacognition* (pp. 121–145). Cambridge University Press.

McCurdy, L. Y., Maniscalco, B., Metcalfe, J., Liu, K. Y., De Lange, F. P., & Lau, H. (2013). Anatomical coupling between distinct metacognitive systems for memory and visual perception. *Journal of Neuroscience, 33*(5), 1897–1906. https://doi.org/10.1523/JNEUROSCI.1890-12.2013

Misirlisoy, M., Tanyas, H., & Atalay, N. B. (2019). Does survival context enhance memory for source? *A within-Subjects Comparison. Memory, 27*(6), 780–791. https://doi.org/10.1080/09658211.2019.1566928

Nairne, J. S., & Pandeirada, J. N. (2010). Adaptive memory: Ancestral priorities and the mnemonic value of survival processing. *Cognitive Psychology, 61*(1), 1–22. https://doi.org/10.1016/j.cogpsych.2010.01.005

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

Nairne, J. S., Thompson, S. R., & Pandeirada, J. N. S. (2007). Adaptive memory: Survival processing enhances retention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(2), 263–273. https://doi.org/10.1037/0278-7393.33.2.263

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

Otgaar, H., Howe, M. L., van Beers, J., van Hoof, R., Bronzwaer, N., & Smeets, T. (2015a). The positive ramifications of false memories using a perceptual closure task. *Journal of Applied Research in Memory and Cognition, 4*(1), 43–50. https://doi.org/10.1016/j.jarmac.2014.12.001

Otgaar, H., Jelicic, M., & Smeets, T. (2015b). Adaptive memory: Identifying the proximate roots of the survival processing advantage. *The Journal of Psychology, 149*(4), 339–355. https://doi.org/10.1080/00223980.2013.879848

Otgaar, H., & Smeets, T. (2010). Adaptive memory: Survival processing increases both true and false memory in adults and children. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*(4), 1010–1016. https://doi.org/10.1037/a0019402

Palmore, C. C., Garcia, A. D., Bacon, L. P., Johnson, C. A., & Kelemen, W. L. (2012). Congruity influences memory and judgments of learning during survival processing. *Psychonomic Bulletin & Review, 19*(1), 119–125. https://doi.org/10.3758/s13423-011-0186-6

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods*. https://doi.org/10.3758/s13428-018-01193-y

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology, 21*(4), 803–814.

Rouault, M., McWilliams, A., Allen, M., & Fleming, S. (2018). Human metacognition across domains: insights from individual differences and neuroimaging. *Personality Neuroscience, 1*, E17. https://doi.org/10.1017/pen.2018.16

Schooler, J. W., & Engstler-Schooler, T. Y. (1990). Verbal overshadowing of visual memories: Some things are better left unsaid. *Cognitive Psychology, 22*(1), 36–71. https://doi.org/10.1016/0010-0285(90)90003-M

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26*, 113–125. https://doi.org/10.1023/A:1003044231033

Soderstrom, N. C., & McCabe, D. P. (2011). Are survival processing memory advantages based on ancestral priorities? *Psychonomic Bulletin & Review, 18*, 564–569. https://doi.org/10.3758/s13423-011-0060-6

Song, C., Kanai, R., Fleming, S. M., Weil, R. S., Schwarzkopf, D. S., & Rees, G. (2011). Relating inter-individual differences in metacognitive performance on different perceptual tasks. *Consciousness and Cognition, 20*(4), 1787–1792. https://doi.org/10.1016/j.concog.2010.12.011

Tay, P. K. C., Jonason, P. K., Li, N. P., & Cheng, G.H.-L. (2019). Is memory enhanced by the context or survival threats? A quantitative and qualitative review on the survival processing paradigm. *Evolutionary Behavioral Sciences, 13*(1), 31–54. https://doi.org/10.1037/ebs0000138

Tolin, D. F., Abramowitz, J. S., Brigidi, B. D., Amir, N., Street, G. P., & Foa, E. B. (2001). Memory and memory confidence in obsessive–compulsive disorder. *Behaviour Research and Therapy, 39*(8), 913–927. https://doi.org/10.1016/S0005-7967(00)00064-4

Tversky, B., & Marsh, E. J. (2000). Biased retellings of events yield biased memories. *Cognitive Psychology, 40*(1), 1–38. https://doi.org/10.1006/cogp.1999.0720

Underwood, B. J. (1965). False recognition produced by implicit verbal responses. *Journal of Experimental Psychology, 70*(1), 122–129. https://doi.org/10.1037/h0022014

Veenman, M. V., Elshout, J. J., & Meijer, J. (1997). The generality vs domain-specificity of metacognitive skills in novice learning across domains. *Learning and Instruction, 7*(2), 187–209. https://doi.org/10.1016/S0959-4752(96)00025-4

Yang, L., Truong, L., & Li, L. (2021). Survival processing effect in memory under semantic divided attention. *Canadian Journal of Experimental Psychology/revue Canadienne De Psychologie Expérimentale, 75*(3), 299–306. https://doi.org/10.1037/cep0000210