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ORIGINAL RESEARCH REPORT

Does the Survival Processing Memory Advantage Translate to Serial Recall?

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The survival processing effect describes the phenomenon that memory for items is better after they have been processed in the context of a fitness-related survival scenario as compared to alternative processing contexts. In the present study, we examined whether the survival processing memory advantage translates to memory for the order of processed items. Across two serial-recall experiments, we replicated the survival processing effect for free recall but did not find an additional survival processing advantage for serial recall when we controlled serial recall performance for the total number of words recalled per person. Adjusted serial recall performance was not better in the survival processing condition when compared to a moving and a relational pleasantness processing condition (Experiment 1), even when processing of the relational order of stimuli was explicitly endorsed in the survival processing task (Experiment 2). This finding is in line with the idea that enhanced item-specific rather than enhanced relational processing of items underlies the survival processing effect. Moreover, our findings indicate that survival processing does not increase memory efficiency for temporal context information.

Keywords: survival processing memory advantage; serial recall; relational versus item specific processing; boundary conditions

Which functions do our memory systems serve in life? A popular approach to study adaptive memory is to consider how evolution might have shaped the development of human mnemonic faculties (Sherry & Schacter, 1987). Nairne and Pandeirada (2008a) argue that our mnemonic abilities evolved to efficiently process and retain information that is relevant for our reproductive fitness. An evolutionary memory bias towards survival-related information could have helped our ancestors to remember the location of food or to recognise the appearance of predators, thereby elevating survival chances and increasing reproductive fitness as a consequence. Nairne and Pandeirada (2008a) supported this hypothesis by showing enhanced memory for information gathered while a survival motive was activated. In their studies, participants remembered words better in free recall as well as recognition tests when they had been processed in the context of an imaginary survival scenario during encoding than when they engaged in alternative mnemonic procedures. This memory enhancement by survival processing has been shown for various retention measures, different populations and when compared to other encoding tasks or schematically similar scenarios (Burns, Hart, Griffith, & Burns, 2013; Kang, McDermott, & Cohen, 2008; Nairne & Pandeirada, 2008b; Nairne, Pandeirada, & Thompson, 2008; Nairne, Thompson, & Pandeirada, 2007; Otgaar & Smeets, 2010; Weinstein, Bugg, & Roediger, 2008).

In a seminal study in this field, Nairne and colleagues (2007) asked participants to imagine a situation in which they have stranded in the grasslands of a foreign land without any survival materials. For the next months, they would have to find steady supplies and to protect themselves from predators. Participants then received a list of words to be rated with regard to their relevance in this survival scenario. In the control conditions, words were rated for personal preference, perceived pleasantness or their relevance to an imagined situation in which participants had to plan to move to another city, respectively. In surprise free-recall as well as recognition tests, more words were recalled when they had been processed within the survival scenario than in all other conditions.

By employing variations of this survival processing paradigm, it has been shown that the relative advantage of processing information in a survival context to induce long-term retention is a robust effect. It has been replicated in within- and between-subject designs (Burns et al., 2013; Nairne et al., 2007), different age

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groups (Otgaar & Smeets, 2010), using alternative control scenarios as well as encoding procedures known to foster retention, like pleasantness ratings, imagery processing or announcement of the retention tests (Kang et al., 2008; Nairne & Pandeirada, 2008b; Nairne et al., 2008). The survival processing effect was observed for different word and visual material (Nairne, VanArsdall, Pandeirada, & Blunt, 2012; Otgaar, Smeets, & van Bergen, 2010; Weinstein et al., 2008). It furthermore generalised to the memory of the location of items when the incidental learning phase was framed as a food collection or animal capturing task that is critical for the survival of the group (Nairne et al., 2012; but see, Bröder, Krüger, & Schütte, 2011, for a null effect). The retention advantage for the survival scenario was found in both free-recall and recognition tests (Burns et al., 2013; Kang et al., 2008; Nairne et al., 2007).

With the body of survival processing research growing, efforts were intensified to outline the mnemonic processes that underlie the survival processing effect. Some researchers argued that this effect can be explained by the efficient combination of basic memory principles such as relational, elaborative, distinctive, self-referential and/or functional processing. According to this view, several of these processes may be jointly activated by the survival scenario, producing the observed memory advantage (Howe & Otgaar, 2013; Kroneisen & Erdfelder, 2011). Supporting this view, Kroneisen and Erdfelder (2011) found the survival processing effect disappearing when they reduced the survival scenario to the imaginative search for survival relevant water only. They assumed that, in doing so, options for elaboration and distinct processing were reduced, which could be driving factors of high word retention rates under survival conditions (Kroneisen & Erdfelder, 2011). In a recent study, Bell, Röer and Buchner (2015) showed that the survival processing effect occurs when people think about survival-related functioning of the presented items but not when they think about survival-related concerns during encoding, further bolstering the elaborative-encoding explanation for this effect. The controversy about the incremental explanatory value of a bias towards survival relevant material has been redirected by introducing the conceptual distinction between ultimate and proximate explanations of the survival processing effect (Nairne, 2014). Ultimate explanations aim to account for why a trait or cognitive function emerged during evolution whereas proximate explanations account for how a trait or function operates on a cognitive level; that is, which specific mechanisms and conditions underlie its expression (Mayr, 1963). Nairne (2014; 2008a) argued that the ultimate explanation of a mnemonic predisposition towards survival is indeed compatible with different proximate explanations like elaborative encoding or functional processing since it only focuses on the adaptive end of the effect and leaves open how it is realised on a mechanistic level. In this view, the fact that the survival processing effect disappears under certain conditions, e.g. when reducing options for elaboration during encoding, does not disqualify the functional evolutionary explanation of the memory benefit. Instead, Nairne and Pandeirada (2016) propose survival processing to be an evolutionary adaption that co-opts existing mnemonic mechanisms to generate advantages for survival and reproduction.

Nevertheless, in order to better understand the survival processing memory advantage, it seems fruitful to examine how it is implemented on a proximal mechanistic level and to investigate boundary conditions under which the effect occurs (Erdfelder & Kroneisen, 2014; Howe & Otgaar, 2013; Nairne, 2014). Especially, the study of the boundary conditions proved helpful to assess the generality of this phenomenon. So far, the relative survival advantage could not be found in memory of faces (Savine, Scullin, & Roediger, 2011), in implicit memory (Tse & Altarriba, 2010) or in paired-associate learning (Schwartz & Brothers, 2014). A domain for which evidence for the generality of the survival processing advantage is mixed is memory of source information. Nairne, Pandeirada, Smith, Grimaldi and Bauernschmidt (2010), as well as Bröder et al. (2011), could not find a survival processing advantage for source memory using a free recall and a recognition test, respectively. On the other hand, Nairne et al. (2012) found increased memory for the source of pictures when they designed a rating task that motivated participants to consider the source of information when giving rating decisions within the respective scenarios. Moreover, better memory for the source of words was observed for the survival context when participants indicated in within-subjects free recall and recognition tests whether they had processed the remembered words in the survival or the control scenario (Kroneisen & Bell, 2018; Misirlisoy, Tanyas, & Atalay, 2019). Another line of research has investigated the boundary conditions of survival processing by examining if its mnemonic benefit translates to alternative evolutionary scenarios that should possess fitness relevance, too. In these studies, rating scenarios involving fitness-relevant cheater detection, fear or phobia contexts, mate selection, incest avoidance, infidelity, jealousy and status did not significantly benefit memory performance. They were outperformed by the standard survival processing condition (Sandry, Trafimow, Marks, & Rice, 2013). Likewise, reformulated survival scenarios that included different degrees of involvement of kin selection processes did not significantly impact memory performance (Krause et al., 2019). As said, such null results are informative, because they ask for refinement of the theoretic framework that explains the adaptive role that survival processing plays in our life (Nairne, 2014).

With regard to the proximate mnemonic mechanisms of survival processing, an important question is whether the processes fostering the memory advantage work primarily on an item-specific level, whether they are of a more relational nature or a combination of the two. Burns, Burns and Hwang (2011) observed the survival advantage to disappear when the control condition encouraged participants to engage in both item-specific and relational processing. They suggested that survival processing is boosting recall because it recruits both deep processing of the single items and processing of the relational structure between items. Both mechanisms are known to foster word retention and have been shown to work less cooperatively in other encoding procedures (Burns et al., 2011). However, one concern of these studies was the lack of an appropriate control condition (e.g., moving, vacation, etc.). For this reason, Burns, Hart, Griffith, and Burns (2013) also compared cumulative-recall curves between the standard survival and moving scenarios. Results of these analyses indicated that survival processing improves especially item-specific processing. That survival processing might not be driven by increased relational processing of input information was also suggested by Nairne, Cogdill and Lehman (2017) who tested whether the survival processing effect occurs for temporal, semantic or rating-related clustering of the remembered words. They found no evidence for above chance temporal clustering of output words for both the survival and the control conditions (Experiments 1 and 2). Moreover, in their Experiment 3, they did not find a survival processing advantage for memory performance in a surprise test that required participants to reconstruct the initial word order from a provided list of all presented word stimuli.

In the present experiments, we examined whether the survival processing effect generalises to the retention of the serial order of information in a free recall paradigm. In doing so, we intended to test for another boundary condition of the survival processing effect that should also be informative with regard to the role relational processing plays for the survival processing effect, as serial order information is often interpreted as a particular kind of relational information (Jonker & MacLeod, 2015; McDaniel & Bugg, 2008). Tasks asking for recalling sequentially presented items in a specific order (usually in the serial order in which they occurred) place a special burden on the human memory because they require not only to remember the items themselves but also their temporal order (e.g., Haberlandt, 2011). The temporal order in which items were experienced, however, can be crucial from an adaptive memory perspective. For example, when one has to hide from a predatory animal it would be good to remember not only whether one had passed a tree that would serve this purpose but also whether one had passed this particular tree before or after one crossed the river, at least when the predator is a particularly good swimmer (cf. Nairne et al., 2012, who made similar arguments for the memory for spatial order).

Experiment 1

In Experiment 1, we aimed to test whether serial order memory profits from survival processing over and above item memory benefits. To this end, we compared item memory and serial-order memory of a standard survival scenario to a schematically comparable moving scenario and a relational pleasantness processing condition. In the latter condition, we asked participants to rate the perceived pleasantness of a word as compared to the previous word that has been presented to them. In doing so we established a control condition that is known to foster item-specific processing and modified it to additionally emphasise processing of the relational order between the word items. With this condition, we intended to test whether the relative retention advantage of survival processing over pleasantness processing (Nairne et al., 2008; Nairne et al., 2007) can be reproduced for serial recall when the pleasantness rating task emphasises processing of the order in which stimuli appear.

Method

Both experiments reported in this article were conducted in accordance with the Declaration of Helsinki and the national ethical guidelines of the authors' university, where the data was collected.

Participants and design

The sample size was determined based on simulation studies suggesting that 20–50 units of observation on level 2 are required for achieving reliable estimates within a hierarchical regression model of two levels (cf. McNeish & Stapleton, 2016). Accordingly, we collected n = 36 participants per condition, resulting in a total of N = 108 participants (80% female). One participant did not indicate her age. The age of the remaining 107 participants ranged from 18 to 31 years (M = 22.54, SD = 2.72). All participants gave informed consent before participation and were compensated with either monetary incentives or course credit. In sessions lasting approximately 30 minutes, up to six participants simultaneously absolved the computer-based experiment at visually separated workspaces.

A between-subjects design was employed: Participants were randomly allocated to one of three conditions (Condition 1: Survival scenario; Condition 2: Moving scenario; Condition 3: Relational pleasantness processing).

Material and procedure

A list of 26 words was randomly drawn from a pool of two to three-syllable German nouns with five to nine letters downloaded from the dlex database (Heister et al., 2011). Word frequencies of the pool ranged from 0.7 to 2.5 log10 normalised frequency per million words. All words were nouns of medium to high frequency stemming from the first three of the five logarithmic frequency classes described by Engbert, Nuthmann, Richter, and Kliegl (2005). The instructions for the imaginary survival and moving scenarios were adapted from Nairne and colleagues (2007) and translated to German. Exact wording of the task instructions is provided in the appendix.

Stimulus presentation for the experiment was controlled by computers running Eprime (Version 2.0). After entering the laboratory and being seated, participants of the survival and moving conditions first read the instructions familiarising themselves with the respective scenario context in which the words had to be assessed. Participants in the survival condition were asked to imagine a scenario in which they are stranded in the grasslands of a foreign country, need to organise water and food supplies as well as defend themselves against predators for the following months. The instruction for the moving scenario was to imagine a situation in which participants plan to move to another country and have to organise a new flat and transport of their belongings. Participants were asked to rate the relevance of word items in the context of the respective scenario using a 5-point scale ranging from –2, indicating "absolutely not relevant" to +2, indicating "very relevant". Participants in the relational pleasantness condition were asked to assess if a word was subjectively more or less pleasant than the previously presented word of the list on a 5-point-rating scale ranging from –2, indicating "much more unpleasant" to +2, indicating "much more pleasant".[1] The first word on the list was rated for its general pleasantness marking the reference point for the first comparison.

Participants first performed four practise trials to familiarise themselves with the task. All participants then rated the same 26 words. The words were presented individually one after another for a fixed duration of five seconds. The order of words was randomised, except for the first three and the last three buffer words, whose order was held constant. Rating options were presented below the stimulus words and could be selected via mouse click. If participants did not rate a word within the 5-second presentation window the respective word disappeared and participants were warned to respond quicker. After the rating task, participants worked on a distractor task (finding mistakes in visually similar images) for three minutes. Afterwards, they had to freely recall as many of the previously rated words as possible in the correct order. Participants were asked to write down the words on a sheet of paper in the exact same order in which they had been presented. They were encouraged to correct potential position errors by drawing arrows. The time limit for this serial recall test was ten minutes for all conditions.

Data analysis

As dependent variables, free-recall performance, serial-recall performance, serial-recall performance adjusted for free-recall performance, intrusions and response latencies were measured. To analyse group differences, we conducted model comparisons between hierarchical Bayesian regression models which allow to account for dependencies in the data. In our case, recall performance data was nested in presented words and participants. Therefore, we first specified a null model that included subject identification number and word identity as crossed-random effects, allowing intercepts of recall performance to vary between word items and participants. To test for group differences, we then compared the null model with a model that additionally featured instruction-condition membership as a population-level effect. Significant model comparisons were followed up by testing whether Bayesian credible intervals (95% *BCIs*) of contrast coefficients juxtaposing the survival condition against the respective baseline condition overlapped with zero. All Bayesian models were calculated within the Stan computational framework (Stan Development Team, 2018) and assessed with the *brms* package (Bürkner, 2017) using R. Model parameters were estimated using the *brms* default settings for the number of Markov Chain Monte Carlo (MCMC) chains, burn-in samples, additional samples and thinning parameter. For regression weights, we used default priors which are non-informative for population-level effects and weakly informative for the group-level effects (Bürkner, 2017). Although we expected a survival processing advantage in item recall, we used uninformed priors for all analyses for consistency reasons. That is because we did not have a priori knowledge about the existence of a survival processing memory advantage for serial recall which was of central interest. To assess convergence of the MCMC algorithm we visually inspected time series plots of estimated parameter values and report their Gelman-Rubin Potential Scale Reduction Factors (PSRFs) $\hat{R}$, with $\hat{R}$ values close to 1 indicating no significant differences in variance of a parameter estimation within and between the chains (Brooks & Gelman, 1998). Throughout our analyses PSRFs of all model parameters were $\hat{R} \leq 1.01$, indicating no signs for lack of convergence (Sinharay, 2004). Visual inspection of time series plots supported that sampling of MCMC algorithms terminated normally.

Results

Free recall performance

Free recall performance was calculated using the item score procedure (Drewnowski & Murdock, 1980). Every word that was output on the recall sheet was scored as a correct recall when it appeared on the word input list presented during the rating task. The first row of **Table 1** displays means and standard deviations of the proportions of recalled items by condition. Given the present data, the model including group membership as predictor showed a better fit than the null model, with a Bayes factor (BF) of $BF_{10} = 6.44 \times 10^4$. According to the conventions of Kass and Raftery (1995), this ratio provides very strong evidence for the existence of condition differences in recall performance. For item recall, credible intervals (95% *BCIs*) around contrast coefficients revealed that participants who were introduced to the survival scenario remembered more words from the input list than participants who were introduced to the moving scenario, *BCI* [–0.60; –0.11]. Moreover, participants in the survival condition remembered more words than participants who rated words by comparing their pleasantness, *BCI* [–0.95; –0.45].[2]

We also tested for condition differences in recall of the first and last three words (primacy and recency effect) to rule out that the present results are convoluted with condition differences in the size of primacy or recency effects. The null model including subject identification number as crossed-random effect and word type (primacy or recency) as fixed effect showed a better fit than a model additionally including instruction condition as fixed effect, $BF_{01} = 2.78$, as well as a model furthermore including the interaction between word type and condition as fixed effect, $BF_{02} = 1.08$.

Absolute serial recall performance

Serial recall performance was measured using relative order scoring. This method quantifies the relative order of words given that they have been correctly recalled (Drewnowski & Murdock, 1980). As recommended by Addis and Kahana (2004) a recalled word was scored as being in the correct relative order if it was from a later serial position on the word input list than the previously

Table 1: Means and standard deviations (in parentheses) of proportions of participants' item scores, relative order scores, adjusted order scores, intrusions and response times.

Measure	Survival	Moving	Relational Pleasantness	BF_{10}	*BCI*	
					Moving – Survival	Relational Pleasantness – Survival
Item Memory	.53 (.13)	.45 (.12)	.38 (.10)	6.44×10^4	[–0.60; –0.11]	[–0.95; –0.45]
Relative Order Memory	.31 (.09)	.27 (.08)	.25 (.07)	8.07	[–0.39; 0.04]	[–0.54; –0.11]
Adjusted Order Memory	.58 (.10)	.61 (.10)	.66 (.10)	0.53 (BF_{01} = 1.89)	[–0.21; 0.37]	[–0.03; 0.58]
Intrusions	2.17 (1.38)	2.39 (1.23)	2.36 (1.33)	0.21 (BF_{01} = 4.87)		
Response Time	2334 (370)	2173 (390)	2292 (454)	7.69×10^{-4} ($BF_{01} = 1.3 \times 10^3$)		

Note: Bayes factors in favour of the alternative hypothesis (BF_{10}) of hierarchical model comparisons between models including group as fixed effect and null models. Bayesian credible intervals (*BCI*) of contrast coefficients (treatment contrast-coded with survival condition as baseline) of models including condition membership as fixed effect.

recalled word. The first word on the output sheet was always scored as correct marking the reference point for the scoring of the following recalled words. Relative order scoring was chosen over strict positional scoring because of the length of the employed word list and the surprise nature of recall instructions. This method has been shown to be less affected by such task characteristics than exact positional scoring (Addis & Kahana, 2004).

Means and standard deviations of relative order score proportions of participants are displayed in the second row of **Table 1**. Given the present data, the model including instruction condition as a fixed effect showed a better fit than the null model, BF_{10} = 8.07. For relative order scores, credible intervals around contrast coefficients indicated no reliable difference between participants in the moving condition and participants in the survival condition although scores in the survival condition were numerically higher, *BCI* [–0.39; 0.04]. Participants who compared words with regard to their pleasantness, however, had lower relative order scores than participants in the survival condition, *BCI* [–0.54; –0.11].[3]

Adjusted serial recall performance

The relative order score measures the amount of words recalled in the correct order without considering the total amount of words that have been recalled correctly by an individual. As a measure that takes into account individual differences in item recall, we calculated adjusted relative order scores (Francis & Baca, 2014). To this end, the sum of correctly recalled words remembered in the right relative order was divided by the total amount of correctly recalled words for each participant.

Row three of **Table 1** shows the average adjusted order scores for the three experimental conditions. This time, the data favoured the null model over the model including instruction condition as a fixed effect, BF_{01} = 1.89. This small Bayes factor in favour of the null hypothesis cannot be considered strong evidence against condition differences. However, a closer inspection of the means provided in **Table 1** shows that, if anything, there was a slight numerical adjusted serial recall advantage for the pleasantness condition that was especially designed to foster relational processing. Credible intervals around contrast coefficients underline this trend for higher adjusted relative order scores in the relational pleasantness condition as compared to the survival condition, *BCI* [–0.03; 0.58], but still include the possibility that the contrast attains values close to zero. Likewise, there was no evidence for a reliable difference in adjusted serial recall performance between the moving and the survival condition, *BCI* [–0.21; 0.37].[4]

Intrusions

We defined intrusions as words recalled on the output sheet that were not part of the input list. This included words that appeared during practise trials. The overall average sum of falsely recalled words was M = 2.31, SD = 1.31. Mean intrusion rates for all conditions are displayed in **Table 1**. The null model showed a better fit than the model additionally including condition as a fixed effect, BF_{01} = 4.87, suggesting that there is moderate evidence that the experimental manipulation did not affect intrusion rates.

Response times

Mean rating response times and their standard deviations are shown in row 5 of **Table 1**. To achieve a normally distributed dependent variable, we log-transformed response times using a natural logarithm (Baayen & Milin, 2010). When predicting log-transformed response times, the null model was more likely to fit the present data than the model including group as a fixed effect, $BF_{01} = 1.3 \times 10^3$. This is very strong evidence that scenario instructions did not influence the time participants needed to rate the words (Kass & Raftery, 1995).

Discussion

In Experiment 1, we found good evidence for the presence of a survival processing benefit in free recall. There was some evidence that serial recall, as indexed by relative order scores, was better in the survival condition than in the relational pleasantness condition but no evidence for such a difference between the survival and the moving condition. Importantly, there was no evidence that adjusted serial recall, which is reflective of serial recall differences over-and-above item recall differences, differed between conditions. The numerical pattern of results was in the opposite direction than one would expect if a survival-processing benefit for adjusted serial recall existed.

One potential limitation to these findings might be, however, that the survival condition we used in Experiment 1 was not optimal for fostering a survival benefit in serial recall. With regard to the question of whether and under which circumstances the survival advantage shall translate to source memory it has been argued that the source has to be made explicit as a relevant factor during the survival rating task in order to boost participants' source memory in a later surprise source memory test (Nairne et al., 2012). Analogously one could argue that in our study the survival processing advantage for temporal context information could not be found because the temporal order in which the words have been presented was not a relevant factor during the survival rating task (cf. Nairne et al., 2012). For this reason, we conducted a second experiment in which we intended to replicate the findings from Experiment 1 but to also extend them by realising an additional survival processing condition in which the relational processing in the context of the rating task was encouraged in a similar way as in the pleasantness condition of Experiment 1.

Experiment 2

In Experiment 2, we aimed to replicate findings from Experiment 1 and to test whether a survival processing effect for item-recall-adjusted serial recall will occur when serial position processing is made more likely in the context of the survival processing scenario.

Method

Participants and design

114 Students (77% female) participated in exchange for course credit or monetary compensation. The age of participants ranged from 19 to 31 years (M = 22.86, SD = 2.70). Informed consent was obtained from all participants.

In a between-subjects design participants were randomly assigned to three conditions while ensuring equal cell numbers for all conditions (Condition 1: Survival scenario, n = 38; Condition 2: Relational survival processing, n = 38; Condition 3: Relational pleasantness processing, n = 38).

Material and procedure

Procedure and stimulus materials were identical to the ones used in Experiment 1 with the following exceptions. We did not realise a moving control condition but a second survival condition for Experiment 2. Participants of the new relational survival condition received the same survival scenario instructions as used for the standard survival condition. However, borrowing from the relational pleasantness condition of Experiment 1, they were asked to evaluate each word's survival relevance in comparison to the survival relevance of the previously presented word. Rating options were again presented on a 5-point rating scale ranging from –2, indicating "much less relevant" to +2, indicating "much more relevant". The first word on the list was rated for its general survival relevance and served as the reference point for the first comparison.

Data analysis

Scoring procedures and data analysis were similar to Experiment 1. All employed regression models showed good convergence as indicated by visual assessment of parameters' times series plots and PSRFs, $\hat{R} \leq 1.01$. In Experiment 2, for the analysis of group differences, we used the relational pleasantness condition as reference condition and interpreted the 95% *BCI*s of contrast coefficients that compare the relational pleasantness condition to the survival condition and the relational survival condition, respectively. Experiment 2 was preregistered prior to its conduction on June 10th, 2019, at https://osf.io/u5mk3/ (doi: 10.17605/OSF.IO/U5MK3).

Results

Table 2 displays means and standard deviations of proportions of free recall, absolute serial recall and adjusted serial recall as well as intrusions and rating response time in the survival, relational survival and relational pleasantness condition.

Table 2: Means and standard deviations (in parentheses) of proportions of participants' item scores, relative order scores, adjusted order scores, intrusions and rating response times.

Measure	Survival	Relational Survival	Relational Pleasantness	BF_{10}	*BCI*	
					Survival – Relational Pleasantness	Relational Survival – Relational Pleasantness
Item Memory	.61 (.12)	.47 (.13)	.36 (.11)	3.52 × 10^{11}	[0.87; 1.41]	[0.22; 0.75]
Relative Order Memory	.36 (.10)	.29 (.09)	.24 (.07)	5.45 × 10^{5}	[0.41; 0.82]	[0.07; 0.49]
Adjusted Order Memory	.59 (.49)	.62 (.49)	.65 (.48)	1.24	[–0.56; 0.02]	[–0.42; 0.20]
Intrusions	2.66 (1.49)	3.13 (1.61)	2.71 (1.27)	0.40 (BF_{01} = 2.47)		
Response Time	2228 (483)	2592 (492)	2417 (491)	0.04 (BF_{01} = 25.06)		

Note: Bayes factors in favour of the alternative hypothesis (BF_{10}) and credible intervals (*BCI*) of contrast coefficients (treatment-coded with relational pleasantness condition as baseline) of models including group as fixed effect.

Free recall performance

The model including instruction condition as a fixed effect for recall performance showed a better fit for the present data than the null model, BF_{10} = 3.52 × 10^{11}. This is very strong evidence that free recall performance differed between experimental conditions (Kass & Raftery, 1995). For item recall, credible intervals (95% *BCIs*) of contrast coefficients indicate that participants in the standard survival condition recalled more words than in the relational pleasantness condition, *BCI* [0.87; 1.41]. Participants in the relational survival condition, too, had significantly higher item scores than participants in the relational pleasantness condition, *BCI* [0.22; 0.75].[5]

We again tested for condition differences in recall of the first and last three items (primacy and recency effect). The model additionally including condition as a fixed effect showed a better fit than the null model including word type as fixed effect and subject identification number as crossed-random effect only, BF_{10} = 182.03. Likewise, a model that furthermore included the interaction between word type and condition as fixed effect fitted the data better than the null model, BF_{20} = 147.44, too. But the latter models did not differ reliably, BF_{12} = 1.36. Thus, there was evidence for condition differences in primacy and recency effects but no indication that these effects differed. However, when conducting the analyses of group differences for absolute and adjusted serial recall performance excluding the first and last three respective words from the list, the pattern of results remained the same. Therefore, we only report results using the complete data set in the following sections.

Absolute serial recall performance

Given the present data, the model including instruction condition as a fixed effect showed a better fit than the null model assuming no condition-level effects, BF_{10} = 5.45 × 10^5. This is very strong evidence that serial recall performance as measured with the serial order score differed between experimental conditions (Kass & Raftery, 1995). For absolute serial recall, credible intervals (95% *BCIs*) of contrast coefficients suggest that the standard survival condition had higher relative order scores than the relational pleasantness condition, *BCI* [0.41; 0.82]. Likewise, there is evidence that participants in the relational survival condition had significantly higher relative order scores than in the relational pleasantness condition, *BCI* [0.07; 0.49].[6]

Adjusted serial recall performance

The model including condition membership as a predictor for adjusted serial recall performance fitted the present data better than the null model, BF_{10} = 1.24. This is only very weak evidence in favour of the alternative hypothesis (Kass & Raftery, 1995). For adjusted serial recall, credible intervals of contrast coefficients point towards higher values in the relational pleasantness condition than in the survival condition but do not rule out that both groups did not differ in adjusted order scores, *BCI* [–0.56; 0.02]. Moreover, credible intervals show no reliable difference in adjusted serial recall performance between the relational survival condition and the relational pleasantness condition, *BCI* [–0.42; 0.20].[7]

Intrusions

Mean intrusion rates for each condition are depicted in row 4 of **Table 2**. Across all conditions, the mean amount of falsely remembered words was M = 2.83, SD = 1.47. The null model fitted the data better than the model including condition membership as a predictor, BF_{01} = 2.47. However, this Bayes factor cannot be considered substantial evidence for the absence of group differences (Kass & Raftery, 1995).

Response time

Mean response times and standard deviations are shown in row 5 of **Table 2**. Again, the null model fitted the data better to predict log-transformed response times than the model including group as a fixed effect, BF_{01} = 25.06, indicating strong evidence that there were no condition differences in response time.

Discussion

In Experiment 2, we replicated the findings of Experiment 1, including a survival condition that endorsed processing of the serial order of words. For free item recall, participants receiving standard survival as well as relational survival instructions remembered more words than participants in the relational pleasantness processing condition. For unadjusted serial recall participants in the two survival conditions, too, outperformed the relational pleasantness processing condition. For adjusted serial recall performance, however, we found no evidence in favour of group differences. As in Experiment 1, numerically the relational pleasantness condition achieved a higher adjusted relative order score than both survival conditions. Given that the relational survival processing condition was designed to explicitly foster survival processing of the relational structure of items, these results support the conclusion that the mnemonic survival processing advantage does not translate to enhanced memory of serial order of presented words, even when processing of their temporal structure is emphasised within the survival scenario.

General Discussion

Across two experiments, we examined the effect of survival processing on memory for the serial order of presented words. For free item recall, we replicated the mnemonic advantage of survival processing in both experiments. We did not observe a survival processing advantage for serial recall when it was measured as the proportion of words recalled in the correct serial order relative to the total amount of words recalled per person. In Experiment 1, the absence of a survival advantage for adjusted serial recall was observed when comparing the survival scenario to a moving scenario and a relational pleasantness processing scenario (i.e., words were rated in their pleasantness relative to the preceding word). This finding was extended in Experiment 2 in which the standard survival scenario, as well as a relational survival processing scenario, did not outperform the relational pleasantness control condition in adjusted serial recall. These results lead us to interpret that, in the present study, survival processing did not improve memory for serial order of words over-and-above its effect on item memory.

Notably, when considering the absolute amount of words remembered in the correct serial order, survival processing indeed increased serial order memory in the present study. According to the results of the absolute relative order scores, in Experiment 1, the survival condition outperformed the relational pleasantness condition and showed a non-significant numerical trend towards higher serial recall performance than the moving condition. Likewise, in Experiment 2, both survival conditions outperformed the relational pleasantness condition in the relative order scoring measure. Thus, when focusing on the serial recall behaviour as the unit of analysis one could argue that survival processing increases the overall quantity of words that are recalled in the correct serial order. However, when aiming to explain how the survival processing memory advantage works on a mechanistic level, one has to consider whether survival processing, independent of its effect on item memory, leads to better memory for the serial order of items. Only the adjusted relative recall scores, which take differences in item recall into account, are informative for this question (cf. Francis & Baca, 2014). Adjusted relative order-scoring results of both experiments indicated that survival processing is unlikely to enhance the efficiency of memory for the temporal structure of items apart from its effect on item memory.

The absence of a survival-processing effect in (adjusted) serial recall is well in line with research by Burns et al. who found survival processing to foster both item-specific and relational processing in an early study (Burns et al., 2011), but later showed that the effect on relational memory was no longer present when using an adequate control condition (Burns et al., 2013). Using a serial recall paradigm we add further evidence to the idea that survival processing does not increase memory of the relational structure between items in general (Burns et al., 2013) and memory of temporal context of presented words in particular (Nairne et al., 2017). Our findings bolster the view that the survival processing advantage primarily operates on an item-specific level (and even so, when relational processing during survival processing is encouraged).

On a more global level, our results point to a boundary of the beneficial impact of survival processing on memory which has been suggested to be a domain-specific memory process (Nairne & Pandeirada, 2008a). In light of the present study, it is unlikely that if our memory is prioritising survival-related information, this effect translates automatically to more efficient retention of the temporal structure of encountered items.

Conclusion

In this study, we found that the survival processing advantage does not spread to memory for the serial order of word items. This finding demonstrates that survival processing does not, above its effect on item memory, improve retention of the temporal order of stimuli relative to other encoding techniques. It adds to the body of research highlighting that the mnemonic boost of survival processing does not rely on relational processing and does not necessarily generalise to retention of information related to situational context. This finding also suggests another boundary condition for the survival processing effect, which needs to be further investigated in future research.

Data Accessibility Statement

The data and analyses code underlying all reported results can be downloaded here: https://osf.io/u5mk3/ with the doi: 10.17605/OSF.IO/U5MK3.

Appendix

Survival Instructions.

Für diese Aufgabe bitten wir dich, dir vorzustellen, dass du in der Steppe eines fremden Landes ausgesetzt wurdest. Du hast keinerlei Dinge bei dir, die dir beim Überleben behilflich sein könnten. Während der nächsten Monate musst du für einen ständigen Nachschub an Nahrung und Wasser sorgen und dich vor Raubtieren schützen.

Im Folgenden werden wir dir eine Liste von Begriffen präsentieren. Wir bitten dich zu bewerten, wie relevant jeder dieser Begriffe für dich in dieser Überlebenssituation wäre. Einige der Wörter mögen relevant sein und andere nicht. Es ist deine Entscheidung.

[For this task, we kindly ask you to imagine yourself being stranded in the grassland of a foreign country. You have no items with you that could help you to survive. During the following months, you need to take care of steady supplies with food and water as well as to protect yourself against predators.

In the following we will present you with a list of words with different meanings. Please indicate for every word, how relevant you consider it in this survival situation. Some words will be more relevant and others will be less relevant. This is your decision.]

Moving Instructions.

Für diese Aufgabe bitten wir dich, dir vorzustellen, dass du gerade dabei bist, deinen Umzug in ein anderes Land zu planen. Innerhalb der nächsten Monate musst du sowohl eine neue Wohnung finden und kaufen als auch den Transport deines Eigentums organisieren.

Im Folgenden werden wir dir eine Liste von Begriffen präsentieren. Wir bitten dich zu bewerten, wie relevant jeder dieser Begriffe für dich wäre, um diese Aufgabe zu erledigen.

Einige der Wörter mögen relevant sein und andere nicht. Es ist deine Entscheidung.

[For this task, we kindly ask you to imagine yourself being about to plan moving to another country. During the following months, you need to find a flat and buy it as well as organise the shipping of your belongings.

In the following we will present you with a list of words with different meanings. Please indicate for every word, how relevant you consider it to fulfil this task. Some words will be more relevant and others will be less relevant. This is your decision.]

Relational Pleasantness Instructions.
Im Folgenden werden wir dir verschiedene Begriffe präsentieren. Bitte gib für jeden Begriff an, wie angenehm du ihn im Vergleich zu dem vorherigen Begriff empfindest.

Einige der Begriffe mögen angenehmer sein als das davor präsentierte Wort und andere unangenehmer. Es ist deine Entscheidung.

[In the following we will present you with words with different meanings. Please indicate for every word, how pleasant you consider it relative to the preceding word. Some words will be more pleasant than the previous ones and others will be less pleasant. This is your decision.]

Relational Survival Instructions.
Für diese Aufgabe bitten wir dich, dir vorzustellen, dass du in der Steppe eines fremden Landes ausgesetzt wurdest. Du hast keinerlei Dinge bei dir, die dir beim Überleben behilflich sein könnten. Während der nächsten Monate musst du für einen ständigen Nachschub an Nahrung und Wasser sorgen und dich vor Raubtieren schützen.

Im Folgenden werden wir dir eine Liste von Begriffen präsentieren. Bitte gib für jeden Begriff an, wie relevant dieser Begriff im Vergleich zu dem vorherigen Begriff in dieser Überlebenssituation für dich wäre.

Einige der Wörter mögen relevanter sein als das davor präsentierte Wort und andere weniger relevant als das davor präsentierte Wort. Es ist deine Entscheidung.

[For this task, we kindly ask you to imagine yourself being stranded in the grassland of a foreign country. You have no items with you that could help you to survive. During the following months, you need to take care of steady supplies with food and water as well as to protect yourself against predators.

In the following we will present you with a list of words with different meanings. Please indicate for every word, how relevant you consider it in this survival situation relative to the preceding word. Some words may be more relevant than the previously presented word and others may be less relevant than the previously presented word. This is your decision.]

Notes

1. We used a rating scale ranging from –2 to +2 because it better reflects the comparative nature of the pleasantness rating task (more or less pleasant) than a rating scale ranging from 1 to 5, for instance. For consistency reasons, the same scale was employed in all conditions.
2. When analysing item score data with a one-way ANOVA the same pattern of condition differences was found: Instruction condition had a significant effect on free recall performance, $F(2,105) = 15.08$, $p < .001$, $\eta_p^2 = .223$. Follow up treatment contrast-coded planned comparisons revealed that the baseline survival condition had higher item scores than the moving condition, $t(106) = -2.90$, $p = .005$, and the relational pleasantness condition, $t(106) = -5.49$, $p < .001$.
3. Analysing relative order scores using a one-way ANOVA revealed significant group differences, $F(2,105) = 5.02$, $p = .008$, $\eta_p^2 = .087$. Planned contrast analyses revealed that the relative order score in the survival condition was higher than in the relational pleasantness condition, $t(106) = -3.16$, $p = .002$, but did not significantly differ from the moving condition, $t(106) = -1.83$, $p = .070$.
4. Analysing adjusted relative order scores using a one-way ANOVA revealed significant group differences, $F(2,105) = 5.62$, $p = .005$, $\eta_p^2 = .097$. Planned contrast analyses showed that the mean adjusted relative order score was significantly higher in the relational pleasantness condition than in the survival condition, $t(106) = 3.34$, $p = .001$, but did not significantly differ between the moving and the survival condition, $t(106) = 1.41$, $p = .160$. Notably, this indication in favour of condition differences deviates from the hierarchical model comparison results. This is most likely due to the skewed nature of the dependent variable that is better accounted for by the hierarchical approach.
5. A one-way ANOVA revealed a significant effect of experimental condition on item scores, $F(2,111) = 37.91$, $p < .001$, $\eta_p^2 = .41$. Treatment-coded contrast analyses using the relational pleasantness condition as baseline showed that participants in the standard survival condition remembered more words than participants in the relational pleasantness condition, $t(112) = 8.67$, $p < .001$. Furthermore, participants in the relational survival condition remembered more words than in the relational pleasantness condition, $t(112) = 3.64$, $p < .001$.
6. A one-way ANOVA revealed that relative order scores differed significantly between groups, $F(2,111) = 18.37$, $p < .001$, $\eta_p^2 = .25$. Planned contrast analyses showed that relative order scores were higher for the standard survival condition than for the relational pleasantness condition, $t(112) = 6.04$, $p < .001$, and higher for the relational survival condition than for the relational pleasantness condition, $t(112) = 2.61$, $p = .01$.
7. A one-way ANOVA revealed a significant difference of adjusted relative order scores between groups, $F(2,111) = 5.79$, $p = .004$, $\eta_p^2 = .09$. Planned contrasts showed that the survival condition had lower adjusted relative order scores than the relational pleasantness condition, $t(112) = -3.40$, $p < .001$. The relational survival condition and the relational pleasantness condition did not significantly differ in adjusted serial recall performance, $t(112) = -1.72$, $p = 0.09$.

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Competing Interest
The authors have no competing interests to declare.

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