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The survival processing effect in episodic memory in older adults and stroke patients

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ABSTRACT

In the present study, we tested whether processing information in the context of an ancestral survival scenario enhances episodic memory performance in older adults and in stroke patients. In an online study (Experiment 1), healthy young and older adults rated words according to their relevance to an ancestral survival scenario, and subsequent free recall performance was compared to a pleasantness judgment task and a moving scenario task in a within-subject design. The typical survival processing effect was replicated: Recall rates were highest in the survival task, followed by the moving and the pleasantness judgment task. Although older adults showed overall lower recall rates, there was no evidence for differences between the age groups in the condition effects. Experiment 2 was conducted in a neurological rehabilitation clinic with a sample of patients who had suffered from a stroke within the past 5 months. On the group level, Experiment 2 revealed no significant difference in recall rates between the three conditions. However, when accounting for overall memory abilities and executive function, independently measured in standardized neuropsychological tests, patients showed a significant survival processing effect. Furthermore, only patients with high executive function scores benefitted from the scenario tasks, suggesting that intact executive function may be necessary for a mnemonic benefit. Taken together, our results support the idea that the survival processing task – a well-studied task in the field of experimental psychology – may be incorporated into a strategy to compensate for memory dysfunction.

1. Introduction

Memory difficulties are among the most common cognitive complaints both in healthy older adults (Langlois & Belleville, 2014) and in stroke survivors (van Rijsbergen et al., 2014). Snaphaan and de Leeuw (2007) estimated that in neuropsychological tests, 23 % to 55 % of stroke patients show memory dysfunction three months after the incident, with a prevalence of 11 % to 31 % one year post-stroke. For some patients, deficits persist over many years (Schaapsmeerders et al., 2013).

Besides training the usage of external memory aids, neuropsychological rehabilitation programs addressing persisting mild to moderate memory impairment often involve acquisition of effective memory strategies, such as interactive imagery (das Nair & Lincoln, 2007). Similar strategy training programs have also been developed for healthy older adults (Hudes et al., 2019). In the present study, we examined whether a task known as "survival processing" in the experimental psychology literature leads to a memory enhancement in older adults and in stroke patients and hence may be a potential strategy to compensate for memory impairment or decline.

1.1. Survival processing effect in episodic memory

The "survival processing effect" denotes the memory advantage observed when information is processed in the context of an ancestral survival scenario (Nairne et al., 2007). In the typical version of the task, participants are instructed to imagine that they are stranded in the grasslands of a foreign land and must scavenge for food and water as well as protect themselves from predators. Subsequently presented

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words are to be rated according to their relevance to this survival scenario. After a distractor activity, an unexpected memory test (typically free recall) follows. A memory advantage for words rated in this scenario emerges compared to various control scenarios, such as a move to a foreign country (Nairne et al., 2007), a vacation at a fancy resort (Nairne & Pandeirada, 2008a), a bank heist (Kang et al., 2008), or a city survival scenario (Nairne & Pandeirada, 2010; Weinstein et al., 2008). Rating words for survival relevance has further been compared to other effective encoding tasks that induce deep semantic processing, such as pleasantness, imagery, and self-reference ratings, generating words from scrambled letters combined with subsequent pleasantness ratings, and intentional learning (Nairne et al., 2008). Survival processing resulted in better memory performance compared to all of these control conditions, making it, according to Nairne et al. (2008), one of the most effective encoding tasks known so far. Kroneisen and Makerud (2017) demonstrated that for words that were high in imageability, survival processing led to comparable memory advantage as the method of loci, which is a well-known, highly effective strategy to improve memory performance. Overall, the survival processing effect has been shown to be very robust across studies involving healthy young adults (e. g. Kang et al., 2008; Nairne et al., 2008; Tse & Altarriba, 2010; for a review, see Scofield et al., 2018).

Nairne et al. (2007) suggest a functional, evolutionary-adaptive “ultimate” explanation of the survival processing effect. Evolutionary psychologists take the perspective that human memory was shaped to effectively react to adaptive challenges in the daily life of our ancestors (e.g., Klein et al., 2010; Kroneisen & Erdfelder, 2011; Nairne & Pandeirada, 2008b; Tooby & Cosmides, 1992, 2015). From an evolutionary perspective, it is indispensable to consider the individual selection pressures that shaped the development of our memory systems when examining reasons of their evolution (Nairne et al., 2008; Nairne & Pandeirada, 2008a). Considering the environment of our early ancestors, one can assume that organisms which could effectively find necessary resources to provide a steady supply of food and water and protect or defend themselves from predators were more likely to survive and reproduce. Hence, processing systems which prioritized survival-related and fitness-relevant information successfully contributed to environmental adaptation as well as survival and reproductive success and were therefore naturally selected (Nairne et al., 2008; Nairne & Pandeirada, 2016).

While ultimate explanations address traits or behaviors that were naturally selected during evolution to support fitness, “proximate” explanations are concerned with the mechanisms underlying these effects (Scott-Phillips et al., 2011). Several proximate mechanisms of the survival processing effect have been proposed (for a review, see Erdfelder & Kroneisen, 2014). A promising hypothesis regarding potential proximate mechanisms that underlie the effect is the richness-of-encoding hypothesis, which postulates that processing items with respect to their relevance for a survival scenario leads to the generation of a variety of creative and novel uses of these items. Hence, each item is associated with numerous self-generated cues, which promotes rich and distinct encoding and enhances the likelihood of successful retrieval (Kroneisen et al., 2013; Kroneisen & Erdfelder, 2011). Indeed, the number of ideas generated during the survival processing task is a good predictor of subsequent recall (Röer et al., 2013). The richness-of-encoding hypothesis has been supported by a number of studies (Kroneisen & Erdfelder, 2022). This includes neuropsychological studies (for a review, see Kroneisen et al., in press), demonstrating that survival processing is associated with higher-level elaborative processes rooted in prefrontal activity and a reduction of lower-level encoding processes (Forester et al., 2020a, 2020b), leading to the activation of larger and more interconnected neural areas during recollection (Fellner et al., 2013; Forester et al., 2019).

The richness-of-encoding hypothesis of the survival processing effect implies that cognitive control and executive functions like cognitive flexibility, planning and semantic fluency are necessary to observe the effect (Kroneisen et al., 2014, 2016, 2024). Furthermore, and in line with the fact that elaboration is a cognitively costly process (e.g., Eysenck & Eysenck, 1979), the survival processing effect emerges only when sufficient attentional resources are devoted to the task. Indeed, Kroneisen et al. (2014, 2016) reported that the survival processing effect was abolished when a secondary task placed a high load on working memory, leaving reduced resources for the survival task itself. More recent evidence based on the psychological refractory period paradigm also shows that survival processing requires central cognitive resources exclusively (Kroneisen et al., 2024).

1.2. *Survival processing in older adults and patient groups*

Some executive functions decline throughout the process of aging (Kray & Lindenberger, 2000; Zuber et al., 2019). Furthermore, general cognitive capacities tend to decline in older adults (Salthouse, 1996). Likewise, a large percentage of stroke patients show some form of executive dysfunction (Povroznik et al., 2018) and attentional deficits (Loetscher et al., 2019), compared to healthy controls. This raises the question of whether older adults and stroke patients show an intact survival processing effect in episodic memory. The majority of studies on the survival processing effect have been conducted with healthy young adults; studies with developmental or clinical samples are rare. Regarding age comparisons, Otgaar and Smeets (2010) as well as Aslan and Bäuml (2012) reported a survival processing effect in children between the ages of four and eleven years, suggesting that the survival processing effect may be independent of memory development. Nouchi (2012) reported a survival processing effect in both young and older adults. Nevertheless, the magnitude of the effect was reduced in older adults. Pandeirada et al. (2014) tested survival processing in healthy older adults vs. a group of older adults with moderate memory deficits, but without a dementia diagnosis. A survival processing effect was found in both groups. Likewise, Yang et al. (2014) reported a survival processing effect in both young and older adults, which in this study also extended to a more modern survival scenario. By sharp contrast, Stillman et al. (2014) and Otgaar et al. (2015) reported no mnemonic benefit of survival processing in older adults. Taken together, although some evidence suggests that survival processing is intact in older adults and hence may be a beneficial strategy to compensate for age-related memory decline, prior evidence has been mixed and additional data are needed.

Regarding clinical samples, the study by Pandeirada et al. (2014) mentioned above reported that community-dwelling older adults who received outpatient treatment “for a memory problem” showed an intact survival processing effect. The medical causes underlying the memory problem were unspecified, and hence the sample was potentially heterogeneous. Nevertheless, these results are encouraging regarding a potential benefit of populations with memory deficits from survival processing. Nouchi and Kawashima (2012) investigated survival processing in sub-clinically depressed, compared to non-depressed participants. There was a survival processing effect for both groups, but the magnitude of the effect was reduced in the former group. Thus far, no prior evidence exists regarding the effectiveness of survival processing specifically in stroke patients.

1.3. *The present study*

To examine whether survival processing may be a potential strategy to be applied in cognitive rehabilitation programs to compensate for memory decline or impairment, and in order to gain novel insights into potential boundary conditions of the survival processing effect, the present study tested whether the survival processing effect differs between a group of healthy older versus young adults (Experiment 1) and is observable in a sample of stroke patients (Experiment 2).

Data collection for both experiments was conducted in parallel. Both experiments were designed such that important aspects of the procedure, like the number of stimuli and the presentation rates, were held constant, for the purpose of comparability. In both experiments, we manipulated survival processing within subjects and compared free recall in the survival processing task to two control conditions: a moving scenario task and a pleasantness rating task. The three conditions were investigated in three subsequent sessions with a delay of at least one day between each set of two sessions. In the sample of stroke patients (Experiment 2) we also collected a set of neuropsychological tests. In additional analyses, these were entered as covariates to examine a potential role of cognitive deficits in the domains of episodic memory and executive function in the emergence of a typical survival processing effect.

2. Experiment 1

Regarding the overarching research question of the present study, Experiment 1 served two purposes. First, we aimed to replicate the survival processing effect and tested whether older adults differ from young adults in the presence and magnitude of the effect. Thereby, we attempted to provide further evidence regarding potential adult age differences in the effect, since evidence from prior studies was inconsistent. Second, Experiment 1 served to provide a basis for the interpretation of Experiment 2, in which stroke survivors participated in an on-site experiment in which crucial aspects of the study design were held constant to Experiment 1.

In an online setting, survival processing was manipulated within-subjects: Free recall for words encoded with a relevance rating in the context of a survival scenario was compared to two control conditions with different encoding tasks: (1) relevance rating in the context of a moving scenario and (2) a deep encoding task (pleasantness judgment). The three conditions (survival, pleasantness and moving) were completed in three separate sessions on three different days. The pleasantness task was always completed first, while the order of survival and moving was counterbalanced.

2.1. Methods

All methods of Experiments 1 and 2 were reviewed and approved by the ethics committee at Trier University before data collection started. All participants provided their informed consent, in Experiment 1 by pressing the enter-key after reading an informed consent form and in Experiment 2 by signing an informed consent form.

2.1.1. Participants

Participants were recruited through an existing data base, flyers, advertisements through the university mailing list, and a newspaper announcement. Inclusion criteria were an age between 18 and 30 (young adults) or above the age of 50 (older adults) years and German as a native language. Exclusion criteria were a current or prior neurological condition (such as a stroke or traumatic brain injury), a diagnosed affective disorder (such as an anxiety disorder or depression), and prior participation in a survival processing experiment at Trier University. Information regarding the exclusion criteria were provided in the study invitation and were queried within the first experimental session (see Task). They were not checked formally in a clinical examination. For each older adult who completed the study, 5 Euros were donated to a charitable cause by private funds of the first author. The young adults had the option of either earning partial course credit or yielding the same donation.

A total of 86 adults completed all three sessions. Of these, 10 participants either did not complete the three sessions with the instructed time interval in between (for example, more than one session was completed on the same day) or exhibited a prior neurological or psychological condition that composed an exclusion criterion for participation. An additional 2 older adults were excluded because in both the survival and the moving condition, they pressed the enter-key during the relevance-rating phase rather than providing numeric ratings and we had no way of ensuring that these participants actually engaged in the scenarios. It is, however, worth noting that inclusion of these two participants did not change the overall result pattern regarding recall performance. The final sample hence consisted of $n = 37$ older (age range: 50–82 years) and $n = 37$ young (20–30 years) adults (see Table 1 for demographic information).

2.1.2. Design and procedure

Each participant completed all three conditions (pleasantness, survival, moving), resulting in a 2 (age groups) by 2 (session order) by 3 (conditions) mixed factors design. Given $N = 74$, with a desired power of $1\text{-}\beta = 0.9$ and $\alpha = 0.05$, this design can detect a main effect of conditions of a small to medium effect size ($f = 0.17$), as revealed by a sensitivity analysis using G*Power (Faul et al., 2007). Note that in the current paper, all power analyses assume a correlation of $\rho = 0.5$ between repeated measurements within groups and refer to the between-subjects error variance metric Cohen (1988) used to define effect size conventions.

The experiment was programmed in *E*-prime 3.0 and administered through E-prime Go 1.0 (Psychology Software Tools). Participants were sent links for each of the three sessions in a single email. They were instructed to complete the tasks associated with the three links on three separate days. If the timing of the three sessions was not as instructed, as revealed by the time stamp in the data file, the dataset from the participant was excluded. There were an average of 1.5 (older adults) and 1.8 (young adults) days in between the first two sessions; and an average of 2.7 (older adults) and 3.7 (young adults) days in between the second and third session.

2.1.3. Stimuli

A subset of 90 German words were taken from Forester et al. (2019), which were originally extracted from the Berlin Affective Word List Reloaded (BAWL-R; Võ et al., 2009). Imageability was high for all words ($M = 6.01$, $SD = 0.33$, on a scale from 1 [hardly imageable] to 7 [very imageable]). Further, words were moderate in valence ($M = 0.34$, $SD = 0.84$, on a scale from −3 [very negative] to 3 [very positive]), arousal ($M = 2.6$, $SD = 0.52$, on a scale from 1 [low-arousing] to 5 [high-arousing]), and frequency ($M = 28.29$ per million, $SD = 43.19$). Word length varied between 4 and 8 letters ($M = 6.14$, $SD = 1.15$).

Words were randomly assigned to one of six lists (A-F) of 15 words each (supplementary material A; https://osf.io/nkb2q/?view_only=77d

Table 1

Means (+/− SD) of demographics, recall performance (number of words recalled), and study ratings for Experiments 1 and 2.

	Experiment 1		Experiment 2
	Young (n = 37)	Old (n = 37)	Patients (n = 37)
Demographic information			
Age	27.32 (2.65)	62.62 (8.12)	54.24 (8.27)
Sex	19 F, 18 M	18 F, 19 M	10 F, 27 M
Education	17.41 (2.52)	14.85 (3.18)	14.09 (1.83)

	Experiment 1		Experiment 2	
	Young (n = 37)	Old (n = 37)	Patients (n = 37)	
Recall (proportion of words recalled)			Trial 1	Trial 2
Pleasantness	0.66 (0.14)	0.59 (0.18)	0.55 (0.18)	0.51 (0.18)
Survival	0.78 (0.12)	0.66 (0.15)	0.60 (0.15)	0.56 (0.16)
Moving	0.73 (0.14)	0.64 (0.16)	0.59 (0.16)	0.52 (0.20)
Study rating				
Pleasantness	2.57 (0.37)	2.73 (0.45)	2.86 (0.45)	2.91 (0.50)
Survival	2.28 (0.70)	2.50 (0.73)	2.22 (0.54)	2.75 (0.63)
Moving	2.24 (0.76)	2.40 (0.79)	2.41 (0.69)	2.61 (0.73)

93dd0c54449f9916ba5c0ea163ab6). The words were then shuffled to ensure that the lists were comparable in all of the above-mentioned word characteristics (all *p*-values > .65). Word order within a given list was randomized, but constant for all participants. Three of the word lists (A-C) were used for Experiment 1; the entire set of 6 lists was used for Experiment 2. The assignment of word lists to sessions and conditions was fully rotated across participants.

2.1.4. *Task*

Each session began with some general instructions, for example, to make sure that participants completed the task in a quiet environment. In the first session, the encoding task included a pleasantness judgment for each of 15 words. In the second and third sessions a relevance rating task was conducted in the context of a survival and a moving scenario, respectively, whereas the order of the scenarios was counterbalanced between subjects. Other than the encoding task instructions, all aspects of the design, including stimulus timing and list length, were held constant across sessions.

2.1.4.1. First session: pleasantness rating task. In the first session, demographic information and a potential history of neurological conditions were queried. Furthermore, participants were instructed to calculate their years of education (Memory Clinic, Basel, Switzerland, 2005). Next, the participants were informed that a list of 15 words would be presented, and their task was to judge each word's pleasantness on a scale of 0 (not at all) to 5 (very). Participants were explicitly informed of the subsequent recall test.

2.1.4.2. Second and third session: survival processing and moving tasks. Participants were explicitly informed of the later recall test. We adapted the survival and moving scenarios introduced by Nairne et al. (2007) and translated into German by Forester et al. (2020a, 2020b). We made some minor changes to the original wording of the scenarios because in Experiment 2, the scenarios were read to the participants as a thought journey, and for this purpose we planned to match the text describing the scenarios as best as possible in factors such as presentation length. The scenarios were worded as follows and each scenario was displayed all at once on the screen:

> ***Survival scenario.*** Please imagine that you are waking up in the morning and are stranded at a foreign shore. You have no memory of how you got there. Besides your clothes, you are not carrying any items with you. There are no other people in this place. You are far away from civilization and on your own. Over the next few months, you'll need to find steady supplies of food and water. You will also have to protect yourself from predators. Unfortunately, you do not own any items that could be helpful for your survival. Please try to visualize your situation as precisely as possible.
>
> ***Moving scenario.*** Please imagine that you are planning to move to a new home in a foreign land. Over the next few months, you'll need to find and purchase a new home. The apartment should be of a sufficient size so that you have enough space for your belongings. However, the apartment should also be located in a nice residential area, have good transport connections, and shops for daily needs should be quickly reached. You must also take care of packing your belongings into boxes and organize the transport of the boxes and furniture. Please try to visualize your situation as precisely as possible.

Participants had unlimited time to read the scenario and could continue with the task at their own pace.

Next, participants were instructed to rate how relevant each of the words presented next would be in this situation. A list of 15 words was then presented on a computer screen. Each word was shown individually for 10 s in black letters on a white background, followed by a display of the rating scale. This scale prompted participants to rate the word's relevance to the scenario on a scale of 0 (not at all) to 5 (very). The participant's response was provided through their computer keyboard without any time limit and terminated the rating screen. A blank screen was shown for 1000 ms between each rating screen and the onset of the next word.

2.1.4.3. Memory task procedure. After the rating of the last word, a blank screen was shown for 3 s and the free recall phase began. Participants typed as many words as they could from the preceding word list in any order. Participants had unlimited time to complete the recall phase.

2.1.5. *Statistical analysis*

Study ratings were compared between the two scenario conditions in a Condition (Survival versus Moving; within subjects) x Age Group (Young versus Old; between subjects) x Session Order (1. Pleasantness, 2. Survival, 3. Moving, versus 1. Pleasantness, 2. Moving, 3. Survival; between subjects) mixed factors ANOVA. Since the pleasantness ratings were not directly comparable to the ratings of the scenario tasks, they were analyzed in a separate Age Group x Session Order ANOVA.

Recall rates were analyzed with a mixed factors ANOVA including the within subject factor Condition (Pleasantness versus Survival versus Moving) as well as the between-subject factors Age Group and Session Order. For follow-up analyses of main and interaction effects of condition, we report two simple contrasts, first comparing the moving against the pleasantness condition, and second, comparing the survival to the moving condition to examine the classical survival processing effect.

2.2. *Results*

Data sheets and supplementary materials for both experiments are available at https://osf.io/nkb2q/?view_only=77d93dd0c54449f9916ba5c0ea163ab6.

2.2.1. *Study ratings*

The overall average relevance rating for the survival ($M = 2.39$, $SD = 0.72$) and the moving ($M = 2.32$, $SD = 0.77$) conditions were similar (Table 1). A 2 (condition) x 2 (age group) x 2 (session order) mixed factors ANOVA did not reveal any main or interaction effects (all *p*-values > .16). Likewise, for the ratings in the pleasantness task, in an age group x session order ANOVA there was no difference between age groups, $F(1, 70) = 3.27$, $p = .09$ (Table 1) and no other significant effect (both *p*-values > .29).

2.2.2. *Recall performance*

Recall rates are presented in Table 1 and Fig. 1. A 3 (condition) x 2

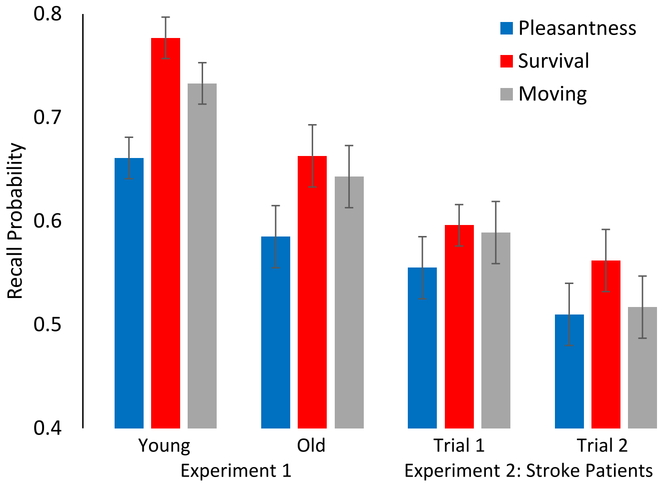

Fig. 1. Mean number of words recalled by condition for Experiments 1 and 2. Error bars denote the standard error of the mean.

(age group) x 2 (session order) mixed factors ANOVA revealed a main effect of condition, $F(2, 140) = 14.41, p < .001, \eta_p^2 = 0.17$. Overall, recall rates were highest for the survival condition, followed by the moving and the pleasantness condition. Planned comparisons revealed that both the difference between the moving and the pleasantness condition, $F(1, 70) = 12.41, p < .001, \eta_p^2 = 0.15$, and the difference between the survival and the moving condition, $F(1, 70) = 4.23$, $p = .04$, $\eta_p^2 = 0.06$, were statistically significant. In addition, there was a significant main effect of age group, $F(1, 70) = 10.79$, $p = .002$, $\eta_p^2 = 0.13$: Young adults showed higher recall rates than older adults. There was no significant two-way or three-way interaction involving the factors age group and condition (both p-values $> .31$), suggesting that the magnitude of the condition effect did not differ between the age groups. However, there was unexpectedly a significant condition x session order interaction, $F(2, 140) = 3.25$, $p = .042$. This interaction was significant in both the moving versus pleasantness, $F(1, 70) = 4.65, p = .04, \eta_p^2 = 0.06$, and the survival versus moving contrast, $F(1, 70) = 6.39$, $p = .01$, $\eta_p^2 = 0.08$, and was driven by the fact that session order affected recall specifically in the moving condition (cf. Table 2). Indeed, separate lower-level ANOVAs for each condition revealed a main effect of session order only for the moving condition ($p = .015$), with better performance when the survival condition preceded the moving condition, but no main effects of order for the survival or the pleasantness condition (both p-values $> .86$) (cf. Table 2).

To ensure comparability with many other studies that tested the survival processing effect for the survival vs. moving contrast only (ignoring the pleasantness rating condition), we additionally compared recall performances following survival vs. moving rating tasks both within and between subjects. First, we conducted 2 (condition: survival vs. moving) by 2 (age group: young vs. old) mixed ANOVAs separately for participants who completed the moving task first and for participants who completed the survival task first. A significant survival processing effect was obtained in the former, $F(1,32) = 9.74$, $p = .004$, $\eta_p^2 = 0.23$, but not in the latter subgroup, $F(1, 38) = 0.12$, $p = .73$. Second, we focused only on the second experimental session, in which some participants completed the survival task and some completed the moving task, but no participants had completed another scenario task previously. Although this between-subjects analysis is underpowered due to the sample size being determined based on a within-subjects manipulation, a 2 (condition: survival vs. moving) x 2 (age group: young vs. old) ANOVA revealed a significant main effect for condition, $F(1, 70) = 5.21$, $p = .026$, $\eta_p^2 = 0.069$, with better recall in the survival than in the moving condition. In all of the latter three ANOVAs, main effects for age group (all p-values $< .082$), but no interactions (all p-values $> .45$) were observed. Hence, the results from this analysis demonstrate a typical survival processing effect with no evidence for significant age differences in the effect.

2.3. Discussion

Experiment 1 replicates the survival processing effect and aligns with prior findings that the effect can be observed in both young and older adults (e.g., Nouchi, 2012; Pandeirada et al., 2014; Yang et al., 2014). In fact, while older adults generally recalled fewer words than young adults, the age group factor did not interact with condition in any of the analyses. Hence, we found no evidence for a significant attenuation or modulation of the survival processing effect in older, compared to young adults. Notably, the older adults recruited in our Experiment 1 were relatively young (at least 50 years old, $M = 62.62$) compared to typical samples in the aging literature, which often include participants older than 60 or even 65 years, and also compared to other studies on age effects of the survival processing effect (with mean ages of older adults ranging between $M = 61.56$ in Pandeirada et al., 2014 to $M = 74.84$ in Otgaar et al., 2015). The main reason for including 50–60 year old participants was that Experiment 1 served in part as a basis for interpreting the results from the stroke patients in Experiment 2, who were expected to have somewhat lower average ages than the typical samples in the aging literature due to the recruitment in a rehabilitation clinic. Thus, 12 participants in Experiment 1 were under the age of 60. In an exploratory analysis (comparable to a similar control analysis reported by Pandeirada et al., 2014, who also included participants above the age of 50 in their older adult sample), we excluded these participants from the 3 (condition) x 2 (age group) x 2 (session order) ANOVA. The results were comparable: The main effects for condition and age were significant, but there were no interactions involving the factors age group and condition. Although these exploratory analyses were underpowered, they revealed no indication that the specific age range of our sample was responsible for the fact that we found no age differences in the survival processing effect while other studies did.

Table 2
Mean proportion of words recalled (+/− SD) for each condition by session order in Experiment 1.

Condition	Session order	
	Pleasantness-survival-moving	Pleasantness-moving-survival
Pleasantness	0.63 (0.16)	0.62 (0.17)
Survival	0.73 (0.15)	0.71 (0.15)
Moving	0.73 (0.15)	0.64 (0.15)

Our results contradict others that have suggested that the survival processing effect is absent in older adults with between- (Otgaar et al., 2015; Stillman et al., 2014, Exp. 1 and 2) and within-subject (Stillman et al., 2014, Exp. 3) manipulations of survival processing. Descriptively, the moving condition even led to higher recall rates than the survival condition in older adults in some cases (Stillman et al., 2014). Several differences between the designs of these prior studies and ours are notable, which may have contributed to this different result pattern. For example, apart from differences in sample sizes, in both of these studies, words were presented for a duration of 5 s, and participants provided their rating while the word was presented. An analysis of response times suggested that both young and older adults succeeded in doing so (Stillman et al., 2014). However, aging is known to be associated with a reduced speed of processing, and some processes, especially effortful ones like elaboration, may require significantly more time in older than young adults (Salthouse, 1996). Moreover, a response deadline can be used as a manipulation to push participants to provide a speeded response, which can thus change which mechanisms participants rely on to complete a task (for example, see Scheuplein et al., 2014). In our task, only 15 words were presented for 10 s each, and the rating was provided after the end of each word presentation without any response deadline. This non-speeded design may have allowed older adults to successfully elaborate on the stimuli in the context of the survival scenario and hence benefit from the strategy. This idea is generally supported by Pandeirada et al. (2014), who did report a survival processing advantage for older adults in a task in which 16 words were presented for 10 s each (although in their study, the response was provided during word presentation rather than subsequently).

Furthermore, the overall memory task difficulty appeared to be relatively low in our study, due to a shorter list length (15 words in our study, compared to 32 and 60 in Stillman et al., 2014 and Otgaar et al., 2015, respectively) and due to recall starting immediately following the last word, rather than using a distractor task. Although from a theoretical point of view it is unclear why this would be the case, it is possible that the discrepancy between previous results and ours is due to a higher overall task difficulty counteracting the survival processing effect in older adults. Future studies are needed to test more directly, and within experiments, under what conditions older adults show a survival processing effect. Taken together, Experiment 1 demonstrated that under the conditions of the present experiment, older adults do not differ significantly from young adults in the magnitude of the survival processing effect.

Our result patterns unexpectedly suggested that, in a within-subject design, the order of conditions can affect the magnitude of the survival processing effect. In particular, when the survival processing condition was completed first, performance in the moving condition tended to be higher than when the moving condition was completed first, leading to an absent survival processing effect in the former case (Table 2). One possible explanation is that encoding processes engaged during survival processing may carry over to the moving condition, thus supporting memory performance in this condition as well. However, as we did not capture which strategies participants actually applied in each session, this explanation is somewhat speculative. Another possibility is that the effect of session order is actually a side effect of the within-subject design, which may allow participants to learn from the prior sessions and consequently improve their performance across sessions, independently of the specific encoding task. Due to the fact that performance in the survival condition was already very high when it was completed in the second session, there was potentially not as much room for further improvement, resulting in a further increase in recall performance from session 2 to session 3 only when the moving task was completed first.

3. Experiment 2

Experiment 2 tested whether stroke patients show a survival processing effect in episodic memory. Furthermore, we explored whether the magnitude of the survival processing effect depends on an individual patient's memory abilities and on intact executive functions.

We implemented two rounds (“trials”) of the same task within each session, allowing for a short practice phase in between. Prior research has shown that healthy, young adults tend to generate more ideas for different possibilities of usage in the survival compared to the moving scenario (Röer et al., 2013), which in turn enhances the survival processing memory benefit. In line with this, the survival processing effect is reduced for objects with fewer potential usages (Kroneisen et al., 2021) and for words that have been independently rated as relatively irrelevant to the scenario (Bonin et al., 2024). Due to potentially reduced abilities in executive function or other cognitive deficits, we speculated that stroke patients may be less likely to spontaneously generate ideas for alternative usage. However, they may be able to generate alternative usages after being introduced to this way of thinking about the objects in the task and practicing alternative usages. In other words, patients may benefit from such a practice phase. Hence, in Experiment 2, we also tested whether the survival processing effect might emerge in stroke patients in a second round of the task (“trial”) after a short practice phase.

3.1. Methods

3.1.1. Participants

Data collection took place within a neurological rehabilitation clinic (Median Clinic Burg Landshut, Bernkastel-Kues, Germany). Inpatients who had suffered an ischemic or hemorrhagic stroke in the past 5 months and who spoke German as their primary language were invited for study participation. All participants were treated in rehabilitation Phase D, meaning that they had largely reached independence in everyday life activities. Exclusion criteria included aphasias that would prevent the completion of the (verbal) experimental tasks, affective disorders, severe amnesia, as well as an existing history of stroke before the prior acute event.

The target sample size was determined in advance using G*Power 3.1.9.4 (Faul et al., 2007). To detect a medium-sized ($f = 0.25$) within-subjects effect of condition on recall performance using an ANOVA with three within-subject levels, given an α of 0.05 and a desired power of 0.9, a sample of $N = 36$ participants was necessary. This result holds irrespective of whether an additional between-subjects factor is included in the design.

Forty-one patients participated in the experiment between May 2022 and December 2022. Four patients did not complete all three sessions due to early termination of their rehabilitation (in 3 cases due to a SARS-Cov-2 infection). Therefore, the final sample consisted of 37 participants between the ages of 26 and 70. Demographic information is provided in Table 1; neuropsychological tests are shown in the appendix, and stroke localizations are included in supplementary material B (https://osf.io/nkb2q/?view_only=77d93dd0c54449f9916ba5c0ea163ab6).

3.1.2. Design and procedure

The task design was largely held constant to Experiment 1, the major changes being that data collection took place in-person rather than online, and that two rounds (“trials”) of each task were implemented within a session, with a short practice phase in between. Other changes are specified below. As in Experiment 1, all conditions were completed by all subjects in separate sessions on three separate days. There was an average of 2.6 days in between the first two sessions and an average of 3.6 days in between the second and third session. Each session lasted maximally 30 min.

All instructions were given verbally by the experimenter. For the presentation of the word lists within the memory tasks E Prime 3.0 was used. Stimuli were presented on a computer screen; the computer keyboard was controlled by the experimenter.

3.1.3. Stimuli

Stimulus selection followed the same principles already described in detail for Experiment 1.

3.1.4. Task

Analogously to Experiment 1, in the first session, the encoding task included a pleasantness judgment. In the second and third session, a relevance rating task was conducted in context of a survival and a moving scenario, respectively, with the order of the scenarios being counterbalanced between subjects.

3.1.4.1. First session: pleasantness rating task. In the first session, the task was to judge each word's pleasantness on a scale of 0 (not at all) to 5 (very). The instructions were identical to Experiment 1.

3.1.4.2. Second and third session: survival processing and moving tasks. The same scenarios used in Experiment 1 were slowly read by the experimenter to the patient, and the patient was instructed to try as best as possible to imagine the scenario. If they considered it helpful, they could close their eyes while doing so.

Subsequently to being read the scenario, the participants were asked four questions regarding the mental scenario (Question 1: “In your mind, where are you (according to the scenario)?”, Question 2: “How have you pictured the situation? Please describe it in one or two sentences.”, Question 3: “How do you feel?”, Question 4: “How well could you imagine this situation on a scale from 0 = “not at all” to 5 = “very well”). Participants' responses were documented by the experimenter on a separate recording sheet.[1]

Subsequently, participants were instructed to rate each word regarding its relevance to the respective scenario on a scale of 0 (not at all) to 5 (very).

At the beginning of the second trial within a session, participants were briefly reminded of the contents of the respective scenario and instructed to again visualize the scenario as well as possible.

3.1.4.3. Rating and memory task procedure. All aspects of the stimulus/word list presentation were analogous to Experiment 1. Rather than using the keyboard to provide the encoding ratings, the patients named their ratings out loud, the experimenter noted the rating and started the

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[1] Note that the last question was also asked in Experiment 1, but due to a technical error, responses to this question were not recorded.

presentation of the next word. In the free recall phase, rather than typing the words, participants named the words they recalled out loud and the experimenter documented these responses.

Each task was completed twice (i.e., in two study-test cycles or “trials”) within a session, using different lists of 15 words. In the first session (pleasantness task), in between both trials, demographic data were queried, and years of education were calculated following a guideline from the CERAD-PLUS test battery (Memory Clinic, Basel, Switzerland, 2005). In the second and third session, in between both trials, generating alternative uses of an item in the context of the respective scenario was practiced for a duration of five minutes. The idea behind this practice phase was that potentially, patients would be able to use the survival scenario to their advantage only after they had been guided to generate atypical usages for objects in this scenario (the training was, however, done for both scenario tasks). For the purpose of the practice phase, participants were asked to think of atypical and unique ideas of how they could use objects from the previous study list in the context of the scenario. The experimenter assisted the participants and provided specific ideas if the patient had difficulties generating their own idea. Prior to the second trial, the participants were instructed to consider alternative, atypical, possible uses when rating the following words.

3.1.5. *Neuropsychological testing*

A battery of standardized neuropsychological tests was conducted by a certified clinical neuropsychologist. This included the German version of the auditory verbal learning test (VLMT; Helmstaedter & Durwen, 1990),[2] four subtests of verbal fluency of the “Regensburger Wortflüssigkeitstest” (RWT, including the semantic fluency/animals subtest, lexical fluency/P-words, semantic switching/fruits and sports, and lexical switching/G- and R-words; Aschenbrenner et al., 2000), four subtests of the TAP (Zimmermann & Fimm, 2004; testing alertness, divided attention, selective attention and cognitive flexibility), as well as the digit span task forward and backward (measuring verbal short-term and working memory; Wechsler, 2008). Neuropsychological test scores were converted into percentile ranks using age-group-specific norms. Descriptive statistics are summarized in the appendix.

3.1.6. *Statistical analysis*

Study ratings were analyzed in a Condition (Survival versus Moving) x Session Order x Trial (1,2) mixed ANOVA, and with a 2 (trial) x 2 (session order) ANOVA for the pleasantness ratings.

We conducted mixed factors ANOVAs with the within-subject factors condition (pleasantness rating, survival, moving) and trial (1,2), and the between-subjects factor session order. In addition, we examined whether recall performance in the experimental task, and more importantly, the condition effect on recall rates, was moderated by general memory abilities and executive dysfunction, captured in separate neuropsychological tests. To test this, we included the delayed recall scores from the VLMT and scores on the RWT (summed across subtests) as covariates into an ANCOVA.

3.2. *Results*

3.2.1. *Analysis of study ratings*

A 2 (condition) × 2 (session order) ANOVA on the ratings of how well patients were able to place themselves within both scenarios, which were recorded after the first time of being exposed to the scenario, revealed no reliable difference between the survival ($M = 3.70$, $SD = 0.20$) and the moving ($M = 3.91$, $SD = 0.16$) condition and no main or interaction effect of session order (all p-values $> .34$).

Regarding relevance ratings for the survival and moving conditions, a 2 (condition) × 2 (trial) × 2 (session order) ANOVA revealed a main effect of trial, $F(1, 35) = 28.73$, $p < .001$, $\eta_p^2 = 0.45$, with higher ratings in the second than in the first trial. A significant condition × trial interaction, $F(1, 35) = 5.59$, $p = .024$, $\eta_p^2 = 0.14$, suggested that the increase in relevance ratings from the first to the second trial was higher in the survival than in the moving condition. Furthermore, a condition x session order interaction, $F(1, 35) = 15.68$, $p < .001$, $\eta_p^2 = 0.31$, reflected that the ratings were consistently higher in the last session. These effects were superseded by a significant three-way interaction, $F(1, 35) = 5.59$, $p < .024$, $\eta_p^2 = 0.14$. Descriptive statistics illustrating this three-way interaction are shown in Table 3.

Following up on the three-way interaction, separate ANOVAs for each condition revealed main effects of trial in both cases (both p-values $< .05$). A main effect for session order was significant in the survival condition, $F(1, 35) = 7.52$, $p = .01$, $\eta_p^2 = 0.18$, and a similar trend emerged in the moving condition, $F(1, 35) = 7.52$, $p = .08$, $\eta_p^2 = 0.086$. These effects again reflected that the ratings for the survival condition were highest when the survival condition was completed last and the ratings in the moving conditions were highest when the moving condition was completed last. In both conditions, there was also a non-significant trend for an interaction (both p-values $< .10$), suggesting that the increase in relevance ratings from trial 1 to trial 2 tended to be higher when the condition was completed in the second session (Table 3).

For the pleasantness ratings, a 2 (trial) × 2 (session order) ANOVA revealed no significant main or interaction effects (all p-values $> .75$).

3.2.2. *Recall rates*

Table 1 and Fig. 1 show free recall performance. Descriptively, and in line with the expected pattern, in both trials recall performance was higher in both scenario conditions compared to the pleasantness condition, and more words were recalled in the survival compared to the moving condition. However, a 3 (condition) x 2 (trial) x 2 (session order) ANOVA revealed no significant main effect of condition, $F(2, 70) = 2.75$, $p = .07$, $\eta_p^2 = 0.07$. The main effect of trial was significant, indicating that more words were recalled in trial 1 compared to trial 2, $F(1, 35) = 11.47$, $p = .002$, $\eta_p^2 = 0.25$. No other effects were significant.[3]

3.2.3. *Recall performance and neuropsychological test scores*

To examine the potential role of memory function and executive function, in an ANCOVA we included both delayed recall performance in the VLMT and the sum of percentile ranks in the subtests of the RWT as continuous covariates.[4] Results are shown in Table 4. The 3 (condition) x 2 (trial) x 2 (session order) ANCOVA revealed a significant main effect of condition, $F(2, 60) = 3.52$, $p = .036$, $\eta_p^2 = 0.11$. Estimated marginal mean recall rates adjusted for covariate effects were pleasantness: $M =$

Table 3
Means (+/− SD) of relevance ratings in the survival and the moving condition for both trials by session order in Experiment 2.

	Pleasantness-survival-moving		Pleasantness-moving-survival	
	Survival	Moving	Survival	Moving
Trial 1	1.93 (0.51)	2.67 (0.70)	2.54 (0.41)	2.14 (0.59)
Trial 2	2.68 (0.75)	2.69 (0.80)	2.88 (0.53)	2.47 (0.59)

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[2] Two patients completed the German version of the California Verbal Learning Test (CVLT; Niemann et al., 2008) instead of the VLMT.

[3] Inclusion of age as a covariate did not change the general result pattern. Specifically, when including age as a covariate, the main effect of condition was still non-significant.

[4] For one patient, no RWT scores were available. Two patients completed the CVLT instead of the VLMT and are not included in these analyses. However, when including these two participants and using percentile-ranks on delayed recall in the CVLT as measures of delayed recall, equivalent results were obtained.

Table 4
Results of the 3 (condition) x 2 (trial) x 2 (session order) ANCOVA including delayed recall in the VLMT and summed RWT scores as continuous covariates.

	F	df1	df2	p	η_p^2
Condition	3.52	1	30	0.036	0.105
Condition x VLMT delayed recall	1.12	1	30	0.332	0.036
Condition x RWT score	**5.242**	**1**	**30**	**0.008**	**0.149**
Condition x session order	0.226	1	30	0.798	0.007
Trial	**11.10**	**1**	**30**	**0.002**	**0.270**
Trial x VLMT delayed recall	3.764	1	30	0.062	0.111
Trial x RWT score	0.731	1	30	0.399	0.024
Trial x session order	2.179	1	30	0.151	0.067
Condition x trial	0.238	2	60	0.789	0.008
Condition x trial x delayed recall	0.065	2	60	0.938	0.002
Condition x trial x RWT score	0.446	2	60	0.642	0.015
Condition x trial x session order	0.115	2	60	0.115	0.004
VLMT delayed recall	**20.066**	**1**	**30**	**<0.001**	**0.401**
RWT score	0.836	1	30	0.368	0.027
Session order	**5.757**	**1**	**30**	**0.023**	**0.161**

Note. Significant effects are printed in bold font.

0.54 (*SD* = 0.13), survival: *M* = 0.59 (*SD* = 0.14), moving: 0.56 (*SD* = 0.14). The difference between conditions, *F*(1,30) = 3.56, *p* = .069, η_p^2 = 0.11, was significant in the directed (i.e., one-tailed) contrast of survival vs. moving, and was also significant for the contrast between pleasantness and moving, *F*(1, 30) = 7.08, *p* = .012, η_p^2 = 0.19.

The main effect of condition was qualified by a condition x RWT score interaction, *F*(2, 60) = 5.24, *p* = .008, η_p^2 = 0.15 (Tables 4 & 5). This interaction was significant in the pleasantness versus moving, *F*(1, 30) = 11.13, *p* = .002, η_p^2 = 0.27, but not in the survival versus moving contrast (*F* = 0.62, *p* = .44). The nature of this interaction is illustrated in Table 5. Only patients with relatively high scores on the RWT (based on a median split) improved their recall performance in the two scenario conditions compared to the pleasantness condition. A similar effect was not seen for patients with relatively low scores on the RWT. It is worth noting that patients who scored below the median on the RWT did not differ in age from patients who scored above the median, mean ages *M* = 55.17 and *M* = 52.33, respectively; *t*(34) = 0.99, *p* = .33. Therefore, age differences cannot explain the association of RWT scores with the condition differences in recall rates.

The ANCOVA also revealed a main effect of memory function, *F*(1, 30) = 20.07, *p* < .001, η_p^2 = 0.40: Patients with better age-adjusted delayed recall scores in the VLMT recalled more words in the experiment. The main effect of trial was again significant, *F*(1, 30) = 11.10, *p* = .002, η_p^2 = 0.27. Finally, a main effect of session order, *F*(1, 30) = 5.76, *p* = .023, η_p^2 = 0.16, suggested that recall performance across conditions was higher for participants with the session order pleasantness-moving-survival. Session order did not interact with any other factors (Table 4).

3.3. Discussion

In an initial ANOVA, no condition effect was found in Experiment 2, although there was a tendency for a condition effect favoring survival processing with an effect size of η_p^2 = 0.07, which was somewhat smaller than in Experiment 1 (η_p^2 = 0.17).

Importantly, when delayed recall and executive functions, independently measured in neuropsychological tests, were accounted for, a significant survival processing effect was found. Furthermore, executive function, quantified by verbal fluency scores on the RWT, significantly modulated the magnitude of condition differences, as evidenced by a condition x RWT score interaction in the ANCOVA. Thus, only patients with comparably high RWT scores showed enhanced recall rates in the survival and moving conditions, compared to pleasantness rating, while patients with low RWT scores did not. Notably, this effect was not due to differences in memory abilities between the high vs. low RWT groups, because in the pleasantness condition (session 1), the high RWT group tended to show even lower recall rates than the low RWT group (Table 5). Furthermore, age differences could also not explain the effect, because the high and low RWT groups did not differ in age. Taken together, in line with suggestions by theoretical models of the survival processing effect (Kroneisen et al., 2014, 2016, 2024), the mnemonic benefit of such scenario tasks compared to other deep encoding tasks appears to depend on executive functions. Practically, this may tentatively suggest that only patients with intact executive function may be able to use scenario tasks like the survival and moving tasks to their advantage.

Table 5
Means (+/− SD) for the number of words recalled in the three conditions depending on RWT score (median split).

	Low RWT score	High RWT score
Pleasantness	8.34 (2.41)	7.89 (2.09)
Survival	8.22 (2.35)	9.39 (2.17)
Moving	7.92 (2.07)	8.94 (2.32)

We did not find any evidence for a modulation of the condition difference (or the survival processing effect more specifically) in stroke patients due to general memory abilities, as quantified as delayed word recall in the VLMT, although the latter was a significant covariate in the ANCOVA, thus predicting overall recall in the experimental task. This finding thus aligns with Pandeirada et al. (2014), who reported that the survival processing effect was intact in older adults being treated for memory problems. It suggests that the survival processing effect in stroke patients may be independent of overall memory performance and may hence be of practical benefit to those patients who are actually in need of compensatory strategies (i.e. those with low overall memory abilities).

One of the hypotheses of Experiment 2 was that the survival processing effect would increase after a short training phase of generating alternative uses of the object within the scenarios. Although there were clear descriptive tendencies (1) for the relevance ratings to increase more strongly for survival processing (difference from trial 2 to trial 1 = 0.53) than for moving (difference = 0.20; see Tables 1 & 3), and (2) for recall to be less strongly attenuated from trial 1 to trial 2 in the survival task (difference from trial 2 to trial 1 = −0.49 words) than in the moving task (difference = −1.11 words; see Table 1, Fig. 1), these differences were not statistically significant. Given the descriptive patterns, however, it would be worth it for further research to examine whether patients may benefit from a training to enhance the effect of survival processing on recall performance. We only implemented a very short practice phase, which the patients had to immediately apply in the following trial. More intensive, and perhaps repeated, training may thus lead to a stronger training effect (which in a design like the present one may be overshadowed by proactive interference or fatigue effects from trial 1 to trial 2) and thus enhance the potential benefit of survival processing as a mnemonic strategy to improve memory in patients.

4. General discussion

The richness-of-encoding hypothesis of the survival processing effect postulates that the effect is due to richer, more elaborate encoding in the survival task, thus relying on cognitively demanding executive functions, raising the question of whether individuals with deficits in these domains show the same effect. In the present study, we hence examined whether older adults (Experiment 1) and stroke patients (Experiment 2) – two groups known to exhibit deficits in (some) executive functions and in general processing capacities – exhibit a survival processing effect in episodic memory. Our first motivation was to replicate the survival processing effect in different age and patient groups, thereby contributing to a better understanding of the boundary conditions of the effect. Our second motivation was to test whether survival processing could be the basis for a potential mnemonic strategy to enhance memory performance in these groups.

Experiment 1 demonstrated that older adults above the age of 50 did not differ in the survival processing effect from younger adults. Although prior results have been inconsistent with regards to adult age differences in the survival processing effect, it appears that in some circumstances – specifically, when there is sufficient time per item to allow elaborative processes in older adults – their memory can benefit from survival processing. Although aging is associated with a decline in some potentially relevant aspects of executive function (Kray & Lindenberger, 2000; Zuber et al., 2019) and in attentional capacity (Salthouse, 1996), it appears that the reduced level of function in these domains is nevertheless sufficient for a survival processing effect to occur in principle in older adults. Notably, this interpretation is limited by the fact that in Experiment 1 we did not capture any neuropsychological tests to examine whether in our specific sample, age-related deficits in memory, executive function, processing capacity, or other cognitive domains were actually present, and whether these were associated with the magnitude of the survival processing effect.

Experiment 2 revealed that, on a group level, stroke patients did not show a survival processing effect. A comparison between experiments thus suggests that the neural and/or cognitive consequences of stroke may abolish the memory-enhancing effect of survival processing. This cannot be solely because of natural aging, because the older adult sample in Experiment 1 was on average over 8 years older than the patient sample in Experiment 2 (Table 1), and a survival processing effect was still observed in Experiment 1 across age groups. Hence, while age-related cognitive changes may not be sufficient to abolish the survival processing advantage (Experiment 1), neural insult due to stroke may cause more severe changes in neurocognitive function, perhaps prohibiting sufficient levels of elaboration required for the survival processing effect to occur on a group level. It is worth noting that we cannot draw conclusions about the permanence of the absence of a survival processing advantage after stroke, because we included only patients who experienced a stroke within the past 5 months and who did not experience any strokes previously. Furthermore, we did not follow up on these patients to examine the plasticity of the survival processing effect over time. Future studies should address whether in the chronic phase after a stroke, patients show an intact (or recovered) survival processing effect.

Although we attempted to hold constant the central aspects of the task design between Experiments 1 and 2, including the specific stimulus material, the list length and the presentation rate, some potentially important aspects differed between the experiments. Perhaps most importantly, the task was completed in interaction with an experimenter in Experiment 2, while in Experiment 1, participants completed the task independently at home. In Experiment 2, patients were read the scenarios in the form of a thought journey and could chose to close their eyes, which could influence the depth of immersion into the two scenarios. Furthermore, in the recall phase, patients named the recalled words out loud rather than typing them on the keyboard, which could have non-trivial effects on retrieval-related aspects like output interference. Therefore, it is possible that differences in task design could have contributed to the different result patterns between the experiments.

Strikingly, when controlling for verbal memory abilities and executive functions (measured in a verbal fluency task) in an ANCOVA, a significant survival processing effect emerged in the stroke patients, suggesting that the survival processing task has the potential to enhance recall in some stroke patients. Specifically, the encoding condition (pleasantness vs. survival vs. moving) affected recall rates only in patients with high scores on verbal fluency tasks, suggesting that only patients with intact executive function may show a mnemonic benefit from survival processing. From a theoretical viewpoint, this result is important in that it is in line with executive function (and more specifically those aspects of executive function measured in verbal fluency tasks) playing a crucial role in the survival processing effect. Thus, if executive functions are reduced beyond a certain critical point after neural insult, this may prohibit elaboration and hence prohibit the effect to occur. A cautionary note is in order, however: Although it is tempting to draw causal inferences, the present evidence is purely correlational. Other aspects than executive functions likely differed between those patients with high vs. low RWT scores.

From an applied viewpoint, these results encourage more research on the potential of developing compensatory memory strategies to improve encoding in older adults and some stroke patients (i.e., those with memory difficulties, but who show relatively intact executive function) based on the survival processing task.

4.1. Limitations, methodological considerations and conclusions

Some methodological considerations are warranted. Due to the concern that the experimental sessions may overall become too long for patients due to the implementation of two task rounds (trials) in Experiment 2, we did not include a distractor task in between encoding and free recall. Rather, only a delay of 3 s but no distractor task was implemented between study and test phases. This aspect of our design deviates from most survival processing studies in the literature. We would like to note, however, that we conducted separate control analyses on the recall rates for the words from the primacy (1–5), middle (6–10) and recency (11–15) positions of the study lists and found that the result patterns were not specific to any part of the serial position curve. We hence consider it unlikely that the lack of a distractor task had a major influence on our main result patterns.

Further, our patient sample was relatively high-functioning (see appendix for a summary of the neuropsychological test results), and it is unclear whether the present results would generalize to patients with more pronounced cognitive deficits, and deficits in other domains such as reasoning, language or spatial attention.

In conclusion, we found that older adults (Experiment 1) and stroke patients with intact executive function (Experiment 2) showed a mnemonic advantage from processing information in the context of an ancestral survival scenario. These results suggest that subtle declines in cognitive capacities and executive function like those observed in older adults are not sufficient to prohibit a survival processing effect in principle, but neural insult can result in a reduction of the effect. It will be important for future studies to replicate these results and to examine whether the survival processing task can form the basis for novel cognitive rehabilitation strategies.

CRediT authorship contribution statement

Siri-Maria Kamp: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lisa Henrich:** Writing – original draft, Project administration, Formal analysis, Data curation, Conceptualization. **Ronja Walleitner:** Project administration, Investigation, Formal analysis, Data curation. **Meike Kroneisen:** Methodology, Funding acquisition, Conceptualization. **Julia Balles:** Project administration, Conceptualization. **Inga Dzionsko-Becker:** Project administration, Conceptualization. **Heike Hoffmann:** Project administration, Conceptualization. **Sara Königs:** Project administration, Conceptualization. **Selina Schneiders:** Project administration, Conceptualization. **Markus Leisse:** Conceptualization. **Edgar Erdfelder:** Writing – review & editing, Validation, Methodology, Funding acquisition, Formal analysis, Conceptualization.

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Declaration of competing interest

None.

Data availability statement

The data that support the findings of this study are openly available at https://osf.io/nkb2q/.

Appendix A

Summary of neuropsychological test scores (Experiment 2).

	n	Percent PR < 16	Percent PR < 50	Min	Max
Attention					
Alertness (TAP A)					
RT without tone	36	36.1	47.2	1.00	86.00
RT with tone	36	28.6	57.1	1.00	84.00
Phasic alertness index	36	19.4	52.8	4.00	98.00
Divided attention (TAP G)					
RT auditory	37	59.5	89.2	1.00	88.00
RT visual	37	16.2	48.6	1.00	97.00
Errors	37	5.6	47.2	1.00	90.00
Omissions	37	16.2	54.1	1.00	88.00
Selective attention (TAP S 2/5)					
RT	37	10.8	43.2	1.00	99.00
Errors	37	2.7	78.4	4.00	42.00
Omissions	36	16.7	100	2.00	05.00
Memory					
Digit Span					
Forward	35	8.6	51.4	5.00	99.00
Backward	33	6.1	33.3	5.00	94.00
VLMT					
Trial 1 Recall	35	8.6	40.0	7.50	95.00
Trial 5 Recall	35	17.1	51.1	5.00	90.00
Trials 1–5 (sum) Recall	35	14.3	45.7	5.00	95.00
Trial 6 Recall	35	25.7	45.7	5.00	95.00
Trial 7 Recall	35	17.1	54.3	5.00	95.00
Difference Trial 6–5	35	20.0	60.1	5.00	92.50
Difference Trial 7–5	35	20.0	77.1	5.00	95.00
Interference Trial Recall	35	14.3	42.9	5.00	95.00
Recognition: Hit Rate	35	17.1	45.7	5.00	85.00
Corrected Recognition	31	16.1	64.5	5.00	87.50

Note. n = number of patients with valid data. "*Percent PR < 16" = Percentage of scores below PR = 16; "Percent PR < 50" = Percentage of scores below PR = 50. MIN =* Minimum. *MAX* = Maximum. TAP = Testbatterie zur Aufmerksamkeitsprüfung (Zimmermann & Fimm, 2004). VLMT = „Verbaler Lern- und Merkfähigkeitstest"(Auditory Verbal Learning Test) (Helmstaedter & Durwen, 1990). RWT = Regensburger Wortflüssigkeitstest (Verbal fluency test) (Aschenbrenner et al., 2000). RT = reaction time. Presented are age-normed percentile ranks.

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