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The effects of healthy aging on the mnemonic benefit of survival processing

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Abstract A number of studies have shown that information is remembered better when it is processed for its survival relevance than when it is processed for relevance to other, non-survival-related contexts. Here we conducted three experiments to investigate whether the survival advantage also occurs for healthy older adults. In Experiment 1, older and younger adults rated words for their relevance to a grassland survival or moving scenario and then completed an unexpected free recall test on the words. We replicated the survival advantage in two separate groups of younger adults, one of which was placed under divided-attention conditions, but we did not find a survival advantage in the older adults. We then tested two additional samples of older adults using a between- (Exp. 2) or within- (Exp. 3) subjects design, but still found no evidence of the survival advantage in this age group. These results suggest that, although survival processing is an effective encoding strategy for younger adults, it does not provide the same mnemonic benefit to healthy elders.

Keywords Adaptive cognition · Aging · Evolutionary psychology · Memory · Survival processing

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The idea that organisms adapt over time to meet the demands of their environment better is a widely accepted concept in biology, but it has only recently been extended to the empirical study of memory. Much like physiological systems for respiration, circulation, and vision, memory also likely evolved to enhance an organism's survival. For example, the abilities to learn and remember where to locate food and resources, how to recognize kinfolk, and how to avoid predators were likely fitness-enhancing for our ancestors who possessed these skills (e.g., Todd, Hertwig, & Hoffrage, 2005), ultimately shaping the memory capabilities of modern humans. Such adaptive/functional accounts of memory are difficult to test empirically, but they provide an interesting perspective by which to interpret and conceptualize memory phenomena, spurring research on the proximate mechanisms underlying such phenomena and promoting understanding of how human memory functions.

The survival-processing paradigm, developed by Nairne, Thompson, and Pandeirada (2007), demonstrates how an adaptive perspective can be applied to memory research. In this paradigm, participants rate unrelated words for their relevance to a grassland survival scenario or to a control scenario (e.g., moving to a foreign land or planning a bank heist). After a brief delay, participants are given a surprise memory test for the rated words. Nairne and colleagues, as well as others (e.g., Kang, McDermott, & Cohen, 2008; Otgaar & Smeets, 2010; Weinstein, Bugg, & Roediger, 2008), have found that retention is higher in the survival condition than in control conditions, suggesting that processing information in terms of its survival value enhances subsequent retention. The mnemonic benefit of survival processing is exceptionally strong, even when compared with other effective deep-processing conditions (e.g., pleasantness or self-reference ratings; Nairne, Pandeirada, & Thompson, 2008), across experimental designs (e.g., between and within subjects; Nairne et al., 2007), across explicit memory tests (e.g., recall and recognition; Nairne et al., 2007; but see Tse & Altarriba, 2010), and using different task stimuli (Otgaar, Smeets, & Van Bergen, 2010; but see

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Savine, Scullin, & Roediger, 2011). The survival-processing advantage, or simply the *survival advantage*, thus refers to the robust mnemonic benefit for information processed for its survival relevance, as compared to when the same information is processed for relevance to other, non-survival-related contexts.

Nairne and colleagues posited that the survival advantage is so robust because rating words for their survival relevance, in a sense, reinstates the ancestral priorities present at the time of selection, perhaps by activating proximate cognitive mechanisms that promote exceptional retention, such as enhanced gist-level processing (Otgaar & Smeets, 2010; Savine et al., 2011), richer elaborative encoding schemes (Kroneisen & Erdfelder, 2011; Röer, Bell, & Buchner, 2013), or the engagement of multiple, complementary types of processing (Burns, Burns, & Hwang, 2011). However, it is important to note that the underlying mechanisms for the effect are still not clear. For example, explanations that rely heavily on the reinstatement of ancestral priorities (i.e., the fact that the grasslands scenario is critical because of the evolutionary importance; e.g., Weinstein et al., 2008) were recently challenged by studies demonstrating the survival advantage persisted in scenarios set in outer space (Kostic, McFarlan, & Cleary, 2012) or when avoiding zombie attacks (Soderstrom & McCabe, 2011). Distinctiveness or emotional salience, thus, might also play a role, although prior studies that did match scenarios on these dimensions (e.g., Kang et al., 2008) still obtained a survival advantage. In sum, although the effect is robust, exactly why it promotes such strong retention is not clear, and in the present research we attempted to refine the critical elements of this survival advantage. For example, Bell, Röer, and Buchner (2013) recently demonstrated that mortality salience and negativity are not critical factors. Regardless of the proximate mechanism(s) underlying the survival advantage, however, one limitation of the survival-processing research program is that the majority of replications of the effect have been in college-aged adults. This limitation is particularly problematic when considering the survival advantage from an adaptive perspective.

Replicating the survival advantage in different participant populations is critical for adaptive accounts of the advantage, as doing so supports that the effect is developmentally invariant and not due to experience-induced cognitive tuning or learning. Following this logic, two recent studies (Aslan & Bäuml, 2012; Otgaar & Smeets, 2010) have extended the survival advantage to young (4–11 years old) children, bolstering the idea that the memorial effect may indeed be universal across age groups. From an adaptive perspective, it makes sense that children's memory should benefit from fitness-relevant processing, as ancestral selection pressures would also have acted on organisms that were of a pre-reproductive age (e.g., Bjorklund & Pellegrini, 2000). One open question, however, is whether the effect persists at later points in the lifespan (i.e., when individuals are *past* reproductive age). An adaptive perspective would predict that groups that are past reproductive prime might show a diminished survival advantage, as evolution does not select for postreproductive characteristics (Williams, 1957), and survival at the level of the postreproductive organism might be a less pressing concern. This adaptive perspective forms the basis of the hypothesis in the present series of experiments, in which we extended the original survival-processing paradigm (Nairne et al., 2007) to healthy older adults (60+ years old). Because some evidence has indicated that the survival advantage is developmentally invariant (i.e., it has been demonstrated in children), it seems plausible to expect that older adults might also show the effect. However, we hypothesized that there would be an interaction between age and processing condition, such that healthy elders would show a reduced survival advantage in comparison to younger adults, due to adaptive changes that occur as a function of aging (i.e., changes reflecting a shift away from the needs of reproduction and genetic transmission).

If our predicted age group difference in the survival advantage were to be obtained, however, it might be argued that older adults show a reduced survival advantage not because of the adaptive reasons mentioned above, but because they differ from younger adults in basic episodic memory performance. For example, relative to younger adults, older adults typically show deficits in tasks that rely on episodic memory (Balota, Dolan, & Duchek, 2000), while showing preserved gist-based processing and semantic memory (Salthouse, 2004; Tun, Wingfield, Rosen, & Blanchard, 1998). Age-related cognitive changes that mediate declines in episodic memory include a reduction in the speeds of all cognitive processes (Salthouse, 1996), declines in basic processing resources such as attentional capacity (Rabinowitz, Craik, & Ackerman, 1982), and reduced ability to inhibit distracting information (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991). These changes may limit older adults' ability to spontaneously generate elaborations during episodic encoding tasks or to apply effective strategies (Craik & Simon, 1980; Dunlosky & Hertzog, 1998; Naveh-Benjamin, Brav, & Levy, 2007; Rankin & Collins, 1985), even though their memory does benefit from deep-processing strategies when they are explicitly instructed to use them (Burke & Light, 1981). Importantly, however, orienting tasks such as self-reference can enhance older adults' recall and recognition performance relative to standard encoding instructions (e.g., Gutchess, Kensinger, Yoon, & Schacter, 2007), indicating that, although older adults may not spontaneously engage in elaborative processing, they are clearly able to do so when appropriate instructional manipulations are provided. Thus, although the present study was motivated from an adaptive perspective, proximate cognitive changes between young and older adults are important to consider, because the effectiveness of survival processing in late life may be moderated by such changes. The specific question addressed here, therefore, was whether older adults, like younger adults, show a selective survival-processing advantage, above and beyond that afforded by deep-orienting tasks.

Because a leading proximate explanation for the survival advantage is that it hinges on individuals' ability to deeply encode the words (i.e., to generate multiple ideas and memory traces; Kroneisen & Erdfelder, 2011; Röer et al., 2013), we also investigated the effect of survival processing in an additional group of younger adults whom we prevented from engaging in their usual level of elaborative processing by having them encode the words under divided-attention conditions. Performing a secondary task during encoding, by requiring the allocation of finite attentional resources, effectively reduces the resources available to engage in effective and elaborative encoding (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005). This manipulation was chosen because it often leads younger adults to mimic the memory performance patterns of older adults (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Troyer, Winocur, Craik, & Moscovitch, 1999), as age-group differences in memory performance are thought to stem, at least in part, from age-related declines in attentional capacity (Craik, 1982; McDowd & Craik, 1988; Rabinowitz et al., 1982). We therefore reasoned that including a divided-attention condition would allow us to examine the survival advantage under conditions in which the two age groups' processing capacities would be made more similar. Furthermore, the divided-attention group could be considered an indirect test of the richness-of-encoding hypothesis of the survival advantage (Kroneisen & Erdfelder, 2011; Röer et al., 2013), as it presumably decreases young adults' capacity to elaborate on the words during the rating task. Thus, if the survival advantage is related entirely or in part to participants' capacity to form rich elaborations on the words, the effect should be reduced or eliminated in the younger adult group whose attentional resources were taxed. However, if reducing the attentional resources of younger adults does not eliminate or reduce the survival advantage, this would suggest that other proximate mechanisms must be considered.

Experiment 1

In Experiment 1, we tested younger adults and healthy older adults using the traditional survival-processing task described in the second experiment of Nairne et al. (2007). In addition to extending the survival-processing paradigm to older adults, we included a group of younger adults under divided attention.

Method

Participants A group of 52 younger (*n* = 24 in the full-attention and *n* = 28 in the divided-attention group) and 26 older adults participated in this study. Older adults had a mean age of 69.56 years (*SEM* = 0.87) and a mean education of 16.40 years (*SEM* = 0.62). Young adults in the full- and divided-attention groups had mean ages of 19.30 (*SEM* = 0.24) and 20.25 (*SEM* = 0.38) years, and mean education of 13.48 (*SEM* = 0.24) and 14.18 (*SEM* = 0.30) years, respectively. Participants were recruited through either the Georgetown University research participant pool or from the surrounding community. Younger adults were compensated for their time with course credit or $25. All older adults were compensated with $25.

Materials The participants rated a single list of 32 target words using either a survival or a moving scenario identical to those used by Nairne et al. (2007, Exp. 2). Participants rated each word using a Likert scale, which ranged from 1 (*not at all relevant*) to 5 (*extremely relevant*). After the rating task, participants worked on a distractor task (a Sudoku puzzle), and were then given a surprise free recall test. All participants completed a cognitive battery consisting of the digit–symbol substitution test (DSST; Salthouse, 1996) to assess processing speed, the National Adult Reading Test (NART; Nelson, 1982) to assess verbal intelligence, and backward digit span (BDS; Wechsler, 1997) to assess working memory. Older adults also completed the Mini Mental State Examination to screen for signs of dementia (MMSE; Stern, Sano, Paulson, & Mayeux, 1987).

General procedure Upon arriving at the laboratory, participants in each of the three groups (young full attention, young divided attention, and old full attention) were randomly assigned to one of two processing conditions, survival or moving, with the following instructions, as they appeared in Nairne et al. (2007):

> *Survival.* In this task, we would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival materials. Over the next few months, you'll need to find steady supplies of food and water and protect yourself from predators. We are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in this survival situation. Some of the words may be relevant and others may not—it's up to you to decide.
> *Moving.* In this task, we would like you to imagine that you are planning to move to a new home in a foreign land. Over the next few months, you'll need to locate and purchase a new home and transport your belongings. We

> are going to show you a list of words, and we would like you to rate how relevant each of these words would be for you in accomplishing this task. Some of the words may be relevant and others may not—it's up to you to decide.

The experimenter verbally instructed participants to make a response to each word within a 5-s presentation window using the corresponding number keys on the keyboard and informed them that, regardless of when they made their response, the word would remain on the screen for the entire time. Participants then rated three practice words before beginning the experimental phase.

The presentation of the 32 target words was randomized anew for each participant. After rating all 32 words in the experimental list, participants worked on a Sudoku puzzle for 3 min. They were then handed a blank sheet of paper and instructed to write down all of the words that they remembered rating earlier. When participants could no longer remember any words (or after 10 min had passed), the experimenter collected the response sheet. Participants then completed the cognitive tests and were debriefed.

Procedure for the divided-attention group The experimental procedure for the younger adults in the divided-attention group differed slightly from that of the full-attention group. After reading either the survival or the moving scenario, participants in the divided-attention group were told that they would be hearing either a high- (2000 Hz) or a low- (1000 Hz) pitched tone at a comfortable listening level following each word, and that they should keep track of the number of high-pitched tones they heard in addition to rating the words for their relevance to the scenario. Participants then heard an example of each tone and, as in the full-attention group, practiced rating three practice words to be sure that they understood the instructions and were able to distinguish between the tones (all participants indicated that they were able to do so). One high- or low-pitched tone was presented immediately following the presentation of each word; thus, 32 tones were presented in total. Unbeknownst to participants, there were always 16 high-pitched tones. The experimenter asked participants to report the number of high-pitched tones that they had counted prior to the Sudoku distractor task. Overall, the responses were quite accurate; all but two participants were within three of the correct number of high-pitched tones, suggesting that they had engaged in the dual task.

Results

Half of the participants in each group (n = 14 in divided attention, n = 12 in full attention, and n = 14 older adults) were assigned to each encoding condition. Due to computer malfunctions, however, data from one young adult in the full-attention group and one older adult were lost, both from the survival condition. The following analyses are based on data from the remaining 23 full-attention younger adults, 28 divided-attention younger adults, and 25 older adults. The results of the cognitive battery are presented in Table 1. As is typical, younger adults scored significantly higher than older adults on the DSST, $t(74) = 8.80$, $p < .001$. However, the two age groups did not differ in their NART or BDS scores (ps > .28). All older adults scored a 27 or higher on the MMSE (younger adults did not complete this test), suggesting that this was a cognitively healthy sample of older individuals.

Younger participants in the divided-attention and full-attention groups rated 98.6 % and 98.4 % of the words, respectively, whereas older adults provided ratings for 95.7 % of the words. A one-way analysis of variance (ANOVA) showed that this difference was significant, $F(2, 73) = 5.90$, $p = .004$, $\eta_p^2 = .14$; older adults rated fewer words than both the divided-attention, $t(51) = 2.6$, $p = .01$, and full-attention, $t(46) = 2.6$, $p = .01$, groups of younger adults, whereas the younger adult groups did not differ from each other ($p = .71$). Importantly, however, all participants rated the vast majority of the words, suggesting that the 5-s presentation rate was sufficient to allow older adults to complete the task.

Recall data The free recall data were submitted to a between-subjects ANOVA in which group (young full attention, young

Table 1 Cognitive battery scores for younger adults under full attention (FA) and divided attention (DA) and for older adults in Experiment 1

Task	FA Younger Adults		DA Younger Adults		Older Adults	
	Mean (*SEM*)	Range	Mean (*SEM*)	Range	Mean (*SEM*)	Range
DSST	95.22 (2.68)$_A$	74–127	90.96 (2.65)$_A$	57–111	65.92 (2.10)$_B$	43–85
NART	20.19 (1.69)$_A$	9–30	21.81 (1.12)$_A$	10–29	23.20 (1.64)$_A$	3–35
BDS	8.61 (0.66)$_A$	4–17	—	—	7.40 (0.57)$_A$	4–17
MMSE	—	—	—	—	28.68 (0.21)	27–30

Means in each row that are statistically different from one another are denoted with different subscripts. DSST, digit–symbol substitution test; NART, National Adult Reading Test; BDS, backward digit span; MMSE, Mini Mental State Examination

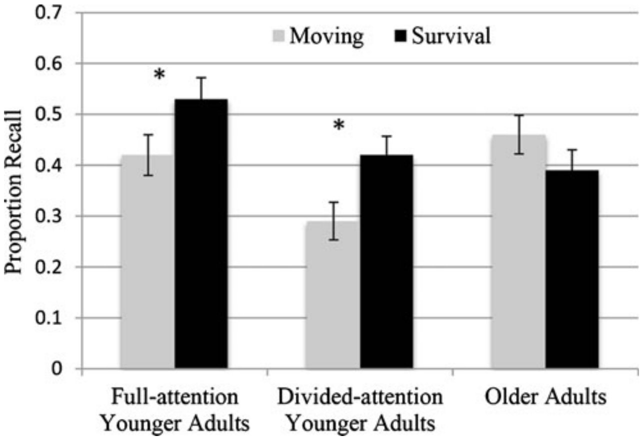

Fig. 1 Mean proportions of words recalled in Experiment 1, separated by group and processing condition. Asterisks indicate a significant difference between groups. Error bars represent the standard errors of the means

divided attention, or old) and condition (survival or moving) served as independent variables (Fig. 1, Table 2). We found a main effect of group, $F(2, 70) = 5.20$, $p = .008$, $\eta_p^2 = .13$. Full-attention younger adults recalled significantly more words ($M = .47$, $SEM = .03$) than divided-attention younger adults ($M = .35$, $SEM = .03$), $t(49) = 2.95$, $p = .005$. Older adults also recalled a marginally greater proportion of words ($M = .43$, $SEM = .03$), $t(51) = 1.76$, $p = .08$, than did the divided-attention younger adults, suggesting that the tone-counting task was effective in reducing the performance of the younger adults. Overall, recall did not differ for the full-attention younger and older adult groups ($t = 1.2$), another indication that the older adults in this study were cognitively healthy and had no signs of memory impairment. The effect of condition approached significance, $F(1, 70) = 2.83$, $p = .097$, $\eta_p^2 = .04$, with slightly more words being recalled in the survival ($M = .44$, $SEM = .02$) than in the moving condition ($M = .39$, $SEM = .02$). Crucially, a significant Group × Condition interaction emerged, $F(2, 70) = 4.39$, $p = .02$, $\eta_p^2 = .11$. Younger adults in both the divided-attention and full-attention groups showed a robust survival advantage, recalling more words in the survival than in the moving condition, $t(26) = 2.33$, $p = .03$, and $t(21) = 2.17$, $p = .04$, respectively. Older adults' recall performance, however, did not differ as a function of condition, $t(23) = 1.38$, $p = .18$. In fact, older adults in the moving condition recalled slightly more words than did those in the survival condition (albeit not significantly). Thus, although the dual task reduced overall recall performance, we still observed a significant survival advantage in the divided-attention young group. Importantly, the Group × Condition interaction was also evident at the individual level. Figure 2 depicts individuals' recall performance, separated by condition and arranged in order from lowest to highest proportional recall. In both groups of younger adults (divided and full attention), the top performers were in the survival-processing condition, whereas the best performers in the older adult group were in the moving condition.

Response time and rating data Analyses on response times (RTs) to rate the words revealed only a main effect of group, $F(2, 70) = 4.45$, $p = .02$, $\eta_p^2 = .11$. As is typical in research on cognitive aging, older adults took significantly longer ($M = 2{,}563.96$, $SEM = 85.37$) than both the full-attention ($M = 2{,}243.67$, $SEM = 82.64$), $t(46) = 2.69$, $p = .01$, and divided-attention ($M = 2{,}339.06$, $SEM = 71.99$), $t(51) = 2.02$, $p = .05$, younger adults to rate the words (the young groups did not differ from each other: $p = .39$). However, the mean RTs of all three groups fell well within the 5-s presentation window for each word, suggesting that all groups had ample time in which to complete the rating task. The Condition × Group interaction approached significance, $F(2, 70) = 2.45$, $p = .09$, $\eta_p^2 = .07$. Post hoc t tests revealed that this marginal interaction was driven by the fact that both full- and divided-attention younger adults in the survival condition were significantly faster than older adults in this condition: $t(21) = 3.28$, $p = .004$, and $t(24) = 2.52$, $p = .02$, respectively. The groups in the moving condition, however, did not differ in their average RTs (ts < 0.62, ps > .54).

We observed no significant main effects or interactions in an ANOVA using mean rating as the dependent variable, all Fs < 0.63, ps > .53, suggesting that participants' ratings

Table 2 Mean proportions recalled, response times in milliseconds, and relevance ratings for younger adults under full attention (FA) and divided attention (DA), and for older adults in Experiment 1, separated by condition

	Mean Proportion Recalled (*SEM*)		Mean Response Time (*SEM*)		Mean Rating (*SEM*)	
	Survival	Moving	Survival	Moving	Survival	Moving
FA Young	.53 (.04)$_A$	.42 (.03)$_B$	2,134.75 (92)$_F$	2,343.53 (131)$_F$	2.83 (0.14)$_H$	2.73 (0.13)$_H$
DA Young	.42 (.04)$_C$	.29 (.03)$_D$	2,270.15 (100)$_F$	2,407.97 (103)$_F$	2.68 (0.14)$_I$	2.87 (0.14)$_I$
Older Adults	.39 (.03)$_E$	.46 (.05)$_E$	2,696.05 (140)$_G$	2,442.04 (94)$_G$	2.72 (0.17)$_J$	2.67 (0.14)$_J$

Within each row, means that are statistically different from one another are denoted with different subscripts.

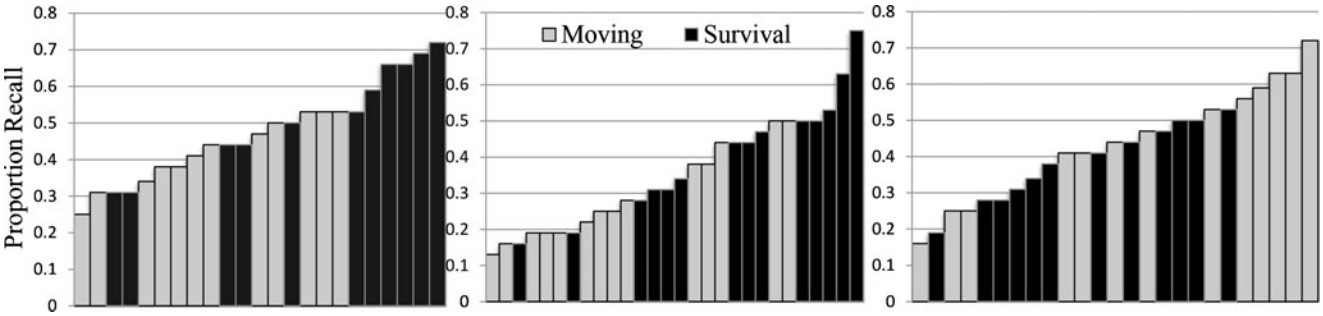

Fig. 2 Individual recall data for the three experimental groups in Experiment 1. From the left, the recall data from individuals in the full-attention young, divided-attention young, and older adult groups are arranged in ascending order and separated by processing conditions

did not differ by experimental group or processing condition (Table 2).

Discussion

In Experiment 1, we found no evidence of a survival advantage in healthy older adults, despite the fact that we replicated the advantage in two separate groups of younger adults, one of which completed the rating task under divided-attention conditions designed to mimic age-related reductions in processing capacity. Younger adults in the divided-attention group recalled fewer words than both younger adults in the full-attention group and older adults, whereas the latter groups' recall did not differ from each other. The comparable overall levels of recall in the young full-attention and older adult groups supports that the older adults that we tested were cognitively healthy. This finding is also consistent with literature showing that deep-processing strategies, although not spontaneously initiated by old adults, can overcome age differences in recall (Craik & Rabinowitz, 1985). The divided-attention young adults' poor recall performance is intriguing, as it indicates that the tone-counting task did affect this group's ability to encode the words, yet it still did not eliminate the mnemonic benefit of survival processing. Together, these results suggest that age-related differences in processing resources cannot completely account for the absence of a survival advantage in older adults, and they add to the wealth of evidence speaking to the robustness of this effect in younger adults. The effects are also not likely due to older adults having found the words to be less relevant to the survival scenario, because we found no evidence that participants' mean ratings differed as a function of processing condition. Furthermore, older adults were slower in the survival condition than in the moving condition, suggesting that they were engaged in processing the items. However, this still did not translate into better recall.

Not finding a survival advantage in one sample of older adults is clearly not enough to claim that the effect is absent in this age group. We also acknowledge the relatively small sample size in Experiment 1 (although we did detect an interaction). In the following experiments, we tested new samples of older adults using identical testing procedures (Exp. 2) and using a within-subjects experimental design (Exp. 3).

Experiment 2

A second sample of older adults was recruited from a different population, again testing for the survival advantage that we observed in both groups of younger adults in Experiment 1.

Method

Participants A group of 31 healthy older adults were recruited from the Waterville, Maine, community. The data from two participants were omitted from the analyses because of concerns about their cognitive status (MMSE scores below 27). The mean age was 67.77 years (*SEM* = 1.04), and their mean education was 15.1 years (*SEM* = .50). Participants were compensated at a rate of $10/h.

Materials and procedure The experimental design was the same as in Experiment 1 (full-attention condition).

Results

BDS and MMSE scores for one participant were missing due to experimenter error. See Table 3 for the cognitive battery scores of the other participants.

Overall, participants rated almost all (94.7 %) of the words within the 5-s deadline. Participants in the moving condition (n = 13) recalled an average of .33 (*SEM* = .03) items and participants in the survival condition (n = 16) recalled an average of .31 (*SEM* = .03) items. This difference was not significant, $t < 1$. However, relevance ratings in the survival condition (M = 3.04, *SEM* = 0.09) were significantly higher

Table 3 Cognitive battery scores in Experiment 2

Task	Mean	*SEM*	Range
DSST	49.86	2.32	29–82
NART	23.83	1.55	5–35
BDS	7.31	0.43	2–12
MMSE	29.1	0.18	27–30

The battery tests are as in Table 1.

than ratings in the moving condition ($M = 2.41$, $SEM = 0.18$), $t(27) = 3.21$, $p = .003$, whereas RTs were slower in the survival condition (M = 2,617.29, SEM = 87.84) than in the moving condition (M = 2,148.54, SEM = 108.12), $t(27) = 3.40$, p = .002. Thus, older adults rated the words in the survival scenario as more relevant and took longer to make the ratings; this did not, however, result in enhanced retention. The fact that ratings in the survival condition were higher than those in the moving condition is inconsistent with the results of Experiment 1, in which no difference in ratings was observed. If anything, however, this might be expected to increase the likelihood of observing a survival advantage, due to the benefits of congruity (e.g., Butler, Kang, & Roediger, 2009), yet such an advantage did not appear.

Because the experimental design and procedure of Experiment 2 were identical to those of Experiment 1, we conducted analyses on the pooled sample (n = 57) of older adults and found the same pattern of results. Older adults in the moving condition (n = 28) recalled more words (M = .39, SEM = .03) than did those in the survival condition (n = 29; M = .34, SEM = .02), although, even with this larger sample size, the difference was not significant (p = .25). One concern could be that we did not have the statistical power in this study to observe the effect in older adults. However, we were able to detect a strong survival advantage with a sample of 23 younger adults (Cohen's d = 0.93); this effect size was consistent with previous studies using a similar design (e.g., Butler et al., 2009; Kang et al., 2008; Nairne et al., 2007). Using this estimated size of the effect (i.e., d = 0.93), we then conducted a power analysis using the G*Power package (Faul, Erdfelder, Lang, & Buchner, 2007). This analysis indicated that we had a power of .93 (two-tailed) to detect the presence of a survival advantage in this pooled sample of healthy older adults.

For the pooled sample, relevance ratings in the survival condition (M = 2.89, SEM = 0.09) were significantly higher than ratings in the moving condition (M = 2.54, SEM = 0.11), $t(55) = 2.50$, p = .02, whereas RTs were slower in the survival condition (M = 2,664.74, SEM = 75.64) than in the moving condition (M = 2,312.82, SEM = 71.53), $t(55) = 3.38$, p = .001. The results of Experiment 2 are thus consistent with those of Experiment 1, again demonstrating the lack of a survival advantage in older adults, even though the higher ratings and longer processing times observed in the survival condition, overall, would be expected to result in improved memory.

Experiment 3

Prior studies (e.g., Kang et al., 2008; Nairne et al., 2008; Nairne et al., 2007) have demonstrated that the survival-processing advantage in younger adults is robust in both within- and between-subjects designs. In addition to showing that our effects were replicable beyond a between-subjects design, within-subjects designs would help to minimize the probability that any effects of condition (or lack thereof) that we detected were due to an unequal distribution of participant characteristics during random assignment. In addition, the effect sizes of some mnemonic phenomena, including the survival advantage, have been found to be larger in within-subjects than in between-subjects designs (e.g., Nairne, Riegler, & Serra, 1991; Nairne et al., 2007). For these reasons, we tested an additional group of older adults using a within-subjects design.

Method

Participants A group of 56 healthy older adults were recruited from the Waterville, Maine, community. Participants' average age was 68.04 years (SEM = .90), and their average education was 16.33 years (SEM = .40). Participants were compensated at a rate of $10/h.

Materials The same stimuli and experimental instructions were used as in the previous experiments. Participants read both the moving (M) and survival (S) scenarios and were given three practice words for each scenario. The rating task was administered in four blocks consisting of eight words each. Participants were instructed before the start of each block which scenario they should use to rate the words in that block. The order of the instructions was counterbalanced across participants (i.e., SMSM or MSMS). Processing speed and executive functioning were assessed using the DSST and the Trail Making Test, Part B, respectively. Working memory was measured using the automated version of the operation span task (O-span; Unsworth, Heitz, Schrock, & Engle, 2005), and vocabulary knowledge was measured using the Shipley synonym task (Shipley, 1940).

Procedure Participants were tested individually and were given the same general instructions as in the previous experiments. The experimenter read the instructions aloud for the first practice block (survival or moving, depending on the counterbalancing) and the three practice items were presented. After the second scenario had been read and the second practice block completed, the experiment began. Prior to each experimental block of eight words, participants were reminded of which scenario to use (i.e., the instructions appeared). All other aspects of the task were the same as in the earlier experiments. The cognitive battery was administered after the surprise recall task.

Results

Due to experimenter error, vocabulary scores were missing for six participants, and O-span scores for one participant. See Table 4 for performance on the cognitive battery. In the results reported below, rating and RT data are missing for another participant due to computer error.

As in the prior experiments, participants rated the majority of words (95.5 %). Rating RTs did not differ as a function of processing condition (M = 2,729.57 in the moving scenario and M = 2,734.34 in the survival scenario). Most importantly, we found no survival advantage; mean recall was .34 (SEM = .02) in the moving condition and .37 (SEM = .02) in the survival condition, $t(55) = 1.51$, $p = .14$. Again using the estimate of the effect size from Experiment 1 (Cohen's d = 0.93), a power calculation using the G*Power package indicated that we achieved power (two-tailed) of .99 to detect the presence of a survival advantage in Experiment 3. Once again, RTs were well within the 5-s time limit, suggesting that participants had ample time to make their ratings. However, mean relevance ratings in the survival scenario (M = 3.08, SEM = 0.08) were significantly higher than ratings in the moving scenario (M = 2.79, SEM = 0.08), $t(54) = 2.76$, p = .008, supporting that older adults were indeed making different kinds of judgments in the two conditions. In sum, older adults, once again, did not show a survival advantage, in this case using a within-subjects variation.

General discussion

To our knowledge, the present study is the first to examine whether the mnemonic benefit of survival processing, recently demonstrated to be a robust effect in both children and young adults (Kang et al., 2008; Otgaar & Smeets, 2010; Otgaar et al., 2010; Röer et al., 2013; Weinstein et al., 2008), persists in older adults. Even though we replicated the survival advantage in two samples of younger adults (one of which encoded the words under divided-attention conditions), we did not find evidence for a survival advantage in three separate samples of older adults and with both within- and between-subjects manipulations. These results suggest that, although survival processing is an effective encoding strategy for younger adults, it does not provide the same mnemonic benefit in healthy elders. In line with adaptive accounts of the advantage, it is possible that the survival advantage was absent in older adults due to the fact that this age group was past reproductive age, a factor that should decrease the benefit of fitness-related processing.

According to adaptive accounts of the effect, the survival advantage reflects evolutionary traits that would have enhanced the survival and reproduction of our ancestors. Whereas retaining a greater proportion of information processed for fitness relevance may have been adaptive for prehistoric children and younger adults who had (or would eventually have) the capacity to reproduce (Aslan & Bäuml, 2012; Nairne et al., 2007), it may not have been as functional for older adults who were past their reproductive prime. Instead, this group would have likely served different societal roles (e.g., preserving and transmitting knowledge or preserving social connections; Mergler & Goldstein, 1983), perhaps shifting their priorities away from fitness goals and toward a more reflective/evaluative approach (Mather, 2010). Because the scenario used in the present studies makes explicit reference to food gathering, locating shelter and other resources, and predator avoidance, it is possible that such actions are less relevant to older adults because of differences in their evolutionary roles within social groups. The absence of a survival advantage in older adults therefore may be consistent with adaptive/functional perspectives of the phenomenon, because what is most functional for a given group should vary according the group's role in a social setting.

Although the present experiment was motivated from an adaptive perspective, extending the survival-processing research program to older adults has also provided clues as to the proximate mechanism(s) that may mediate the effect. For example, despite the fact that we reduced their attentional capacity during the encoding task, younger adults in the divided-attention condition of Experiment 1 still showed a survival advantage. This result challenges proximate accounts of the survival advantage based on richness of encoding (Kroneisen & Erdfelder, 2011; Röer et al., 2013). That is, by these accounts, reducing younger adults' processing capacity (by having them complete a concurrent tone-counting task) should have reduced their ability to elaborate on the words and form multiple rich associations to act as retrieval cues during the recall test. It might be argued that the tone-counting task

Table 4 Cognitive battery scores in Experiment 3

Task	Mean	*SEM*	Range
DSST	48.45	1.51	23–73
Trails B	87.46	5.06	44–240
Shipley	34.24	0.53	22–40
O-Span	18.60	1.06	6–37

DSST, digit–symbol substitution test; Trails B, Trail Making Test, Part B; Shipley, Shipley synonym task; O-span, operation span task did not require enough attention to disrupt the younger adults' elaboration processes during the encoding task. However, the fact that the divided-attention group recalled fewer words overall than both the full-attention young adult group *and* the older adult group suggests that the dual task was effective at disrupting the encoding of the words. The mechanism underlying this disruption is unclear, but it is possible that the tone-counting task disrupted encoding and overall recall by reducing the degree to which the divided-attention group could make associations amongst the words (i.e., relational processing). That is, expecting and concentrating on a tone presented after each word may have encouraged this group to focus more on each word as an individual element (i.e., item-specific processing). It seems unlikely that this explanation could completely account for the pattern of results that we observed in Experiment 1, however, because the survival advantage is thought to elicit its unique mnemonic benefits by inducing *both* item-specific and relational processing (Burns et al., 2011). Thus, if the tone-counting task severely restricted relational processing, the survival advantage should have been diminished in the divided-attention group, and this was not the case. Therefore, age-related differences in attentional resources, which we presume limited the extent of elaborative processing possible in the 5-s rating window provided for each word, cannot completely explain the lack of a survival advantage in older adults. Because the survival advantage persists in children, who also have fewer attentional resources than do college-aged individuals (Casey, Giedd, & Thomas, 2000), but does not persist in older adults, a direction for future work could be to examine cognitive processes (besides attention) that are known to differ between older adults and these other groups. In this way, demonstrating that the survival advantage does not persist in older adults helps to narrow down the list of candidate proximate mechanisms mediating the effect in other age groups.

By including a divided-attention group of young adults, we examined one potential proximate explanation for the age difference that we detected in the survival advantage, but other potential alternative explanations could be considered in future work. For example, one might argue that older adults could have a general deficit in using elaborative encoding strategies that is not specific to survival processing alone. Two pieces of evidence, however, suggest that this particular alternative explanation for our results is unlikely. First, as we mentioned above, older adults in Experiment 1 recalled a number of words equivalent to those remembered by the full-attention young adults, suggesting that they were indeed able to benefit from elaborative encoding strategies. Second, evidence from the levels-of-processing literature indicates that healthy older adults benefit just as much (and, in some circumstances, more) from the use of other commonly studied encoding strategies (e.g., self-reference, pleasantness) as do younger adults (Bäckman, 1986; Craik & Rabinowitz, 1985; Gutchess, Kensinger, & Schacter, 2007; Gutchess et al., 2007; Verhaeghen, Marcoen, & Goossens, 1993; Yang, Truong, Fuss, & Bislimovic, 2012). Therefore, the fact that older adults apparently do not enjoy the same mnemonic "boost" as young adults from survival processing is not easily explained by a generalized deficit in using encoding strategies, and supports the idea that the effect may indeed have adaptive underpinnings. Future work can investigate other proximate explanations for our results.

One such alternative proximate explanation for our finding that older adults do not show the survival advantage relates to this age group's priorities and life goals, which may differ from those of younger adults and children. For example, in her socio-emotional selectivity theory, Carstensen (1992, 2006) has argued that older adults shift their priorities toward emotion regulation to enhance psychological well-being, and they deprioritize knowledge acquisition. In the present study, older adults' shift in priorities toward emotion regulation and away from information acquisition might explain their failure to take full advantage of the rich encoding implied by the survival scenario, rendering it no more effective than the moving scenario at aiding free recall performance. Future studies might also investigate whether scenarios that focus on the types of information that older adults are more likely to prioritize, such as social or emotional material, would reinstate the survival advantage in this age group. For example, there is evidence that older individuals have a bias toward remembering social information because of the critical role that complex social interactions can have with regard to an individual's survival. Moreover, evidence has also indicated that individual or normative goals can moderate age-related memory deficits, such that age-related deficits are reduced or eliminated when the task or material promotes the type of processing that older adults are more likely to find relevant (Hess, 2005).

In summary, only limited work has applied an adaptive perspective to study developmental (i.e., non-college-aged) samples, and even less work has applied such a perspective to the study of cognitive aging. Our results demonstrate that the same survival-processing task that has consistently been shown to yield a mnemonic advantage in children and young adults does not do so in older adults. Thus, a focus on the goals of survival, as presented in the original scenario used here, does not appear to be effective at enhancing older adults' memory, above and beyond instructing them how to engage in elaborative processing. In addition, our finding that the survival advantage persists in a group of younger adults who were prevented (via a dual task) from engaging in their usual degree of elaborative encoding argues against the proximate explanation that older adults' lack of a survival advantage is due to a failure to engage in rich and elaborative encoding strategies. Instead, we pose another possible proximate explanation for our results, which warrants future research: Older adults have shifted their priorities away from the acquisition of new information, in order to apply their reduced cognitive resources to other, more satisfying and socially useful goals. Examining the functional purpose of age-related cognitive changes in memory is beyond the scope of a single study and requires a concerted effort in multiple areas, but the present work is one step in this direction.

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