How can survival processing improve memory encoding?

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We investigated the psychological mechanism of survival processing advantage from the perspective of false memory in two experiments. Using a DRM paradigm in combination with analysis based on signal detection theory, we were able to separately examine participants' utilization of verbatim representation and gist representation. Specifically, in Experiment 1, participants rated semantically related words in a survival scenario for a survival condition but rated pleasantness of words in the same DRM lists for a non-survival control condition. The results showed that participants demonstrated more gist processing in the survival condition than in the pleasantness condition; however, the degree of item-specific processing in the two encoding conditions did not significantly differ. In Experiment 2, the control task was changed to a category rating task, in which participants were asked to make category ratings of words in the category lists. We found that the survival condition involved more item-specific processing than did the category condition, but we found no significant difference between the two encoding conditions at the level of gist processing. Overall, our study demonstrates that survival processing can simultaneously promote gist and item-specific representations. When the control tasks only promoted either item-specific representation or gist representation, memory advantages of survival processing occurred.

adaptive memory, false memory, survival processing advantage, DRM paradigm, signal detection theory

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Traditional research on memory has focused on memory structure; however, structures are linked with specific functions, meaning that the important principle of natural selection connects structure with function. In recent years, researchers have begun to use functional analysis methods to examine memory [1,2]. American psychologist James S. Nairne, who studies the function of memory, is a pioneer in this field [2]. Like other human capabilities, memory is shaped by the process of natural selection. The unique sets of adaptive problems faced by our hunter-gatherer ancestors involved solving hunter-gatherer problems; thus, we can speculate that survival-related information and reproduction-related information will be accorded preferential cognitive processing [3–5].

In Nairne et al.'s initial study investigating the adaptability of memory, each participant was asked to imagine that he/she was stranded in the grasslands of a foreign land without any basic survival materials; to survive, the participants needed to find stable supplies of food and water and protect themselves from predators. Participants were then asked to make judgments on the relevance of words to this survival scenario and were given a surprise retention test for the rated words following a filler task [1,2]. For comparison purposes, Nairne also set up control tasks that induced similar depth of meaning processing to the survival task, such as a moving rating task and a pleasantness rating task. The results show that retention of words rated for their relevance to the survival scenario is superior to that of words encoded under other deep processing tasks. This special memory phenomenon was called the survival processing advantage

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[2]. According to Nairne, human memory has an adaptive characteristic, as humans can remember survival-related information more easily than other information; hence, this memory characteristic is termed adaptive memory [1,2,4]. Abundant follow-up studies have evidenced this survival processing advantage as a robust and universal psychological phenomenon, with picture or word stimuli in within- or between-subject designs for free recall or recognition tests among elderly, young adult, or child participants [3,6,7].

Using the correct recall/recognition rate as an indicator of memory accuracy, Nairne suggested that survival processing promoted memory accuracy by elevating recall/recognition rate [2]. Fuzzy trace theory proposed that individuals can simultaneously process two types of information at the memory encoding stage: gist processing and item-specific processing. Item-specific processing encodes an item's surface features (verbatim representations), such as physical characteristics (e.g., color, size), background, and sources of information. Memory traces of this processing type may support correct recall/recognition of studied items and reduce false memory of semantically related lures through a process known as recollection rejection. Gist processing refers to the processing of general senses of an item and their meaning (gist traces). Retrieval of gist traces can result in the correct recognition of studied items but can also lead to false recognition of semantically related lures [8]. The specific encoding processes that are actually altered by survival processing are unclear and are pending further investigation. Therefore, from the perspective of fuzzy trace theory, correct recall/recognition of a word is likely based on gist representation or successful retrieval of verbatim representation. Meanwhile, judgment criteria can also affect the correct recall/recognition rate. Therefore, it is necessary to further investigate the mechanism of how survival processing improves memory, whether due to the promotion of gist processing or item-specific processing (or both) or due to the more relaxed response criteria.

Based on Nairne's research, Howe and Derbish employed the Deese-Roediger-McDermott (DRM) paradigm to study the impact of survival processing on correct memory and false memory [6]. Associative memory illusion is a common type of false memory that refers to the phenomenon of treating non-experienced events that are closely related to the experienced as having actually occurred [9,10]. As the most widely used method for studying associative memory illusion, the DRM paradigm presents participants with lists of words, with all words in each list (e.g., "bed", "rest", "wake up") being semantically related to a thematic word that is not presented during the studying stage (critical lure or CL, such as "sleep"). Subsequent memory tests showed that the non-presented CLs are falsely remembered/recognized at relatively high rates [9,10]. Howe and Derbish included the DRM paradigm in the research on adaptive memory and found that survival processing amplified not only true recognition but also false recognition of

the critical lures. The memory accuracy index used by Howe and Derbish was the correct recognition rate of old items/(correct recognition rate of old items+false recognition rate of lures), based on which method of accuracy of memory under the survival condition was lower than the non-survival conditions (the moving rating and pleasantness rating tasks) [6]. Therefore, Howe and Nairne hold different views on whether survival processing can result in more accurate memory.

These differences are likely produced by the different indexes of memory accuracy. According to signal detection theory, response bias can affect both the correct recognition rate and false recognition rate to a certain extent. The more lenient one's response bias is, the higher correct and false recognition rates are [8]. The data processing methods used in Howe's study partialled out the impact of response bias on the memory results but did not differentiate the effect of gist processing from item-specific processing, whereas Nairne's study did not exclude the impact of response bias on judgment.

The psychological mechanism of adaptive memory remains controversial. The evolution-functional hypothesis was proposed by Nairne from a functional perspective to explain the survival processing advantage, which takes the standpoint that our memory systems have evolved to solve survival-related and reproduction-related problems [2]. The richness-of-encoding hypothesis implies that rating words in a survival scenario leads to the generation of a large number of association ideas that may be used as retrieval cues on memory tests to boost recall/recognition [11]. Similarly, the elaboration hypothesis attributes the survival processing advantage to more elaboration at the encoding phase under the survival rating task, such as thinking of visual images of presented words or associating words with something [12]. The above viewpoints are similar in viewing survival processing as promoting memory by changing the encoding process. However, it is unknown which encoding process is altered by survival processing.

To explore the inner psychological mechanism of the survival processing advantage, Burns et al. [13] compared survival processing with non-survival processing in free recall and recognition tests with category lists. Burns used the pleasantness rating task and the category sorting task as control conditions. The pleasantness rating task is a typical task that requires item-specific processing, and the category sorting task requires gist processing [13,14]. The survival processing advantage was thought to result from the simultaneous processing of item-specific and relational information, whereas the control tasks only promoted either item-specific processing or relational processing [13]. Burns's conclusion is based on the assumption that recognition tests mainly rely on item-specific processing and free recall tests based on both item-specific and gist processing. However, this logic is erroneous, as recognition tests not only depend on the retrieval of item-specific information

but also depend on the retrieval of gist information [15]. The current research adopts a different line of reasoning and combines the DRM paradigm with signal detection theory to directly examine the influence of survival processing on the formation of gist representation, the encoding and retrieval of item-specific information, and the response bias [16].

The present research explored the effect of survival processing on memory encoding through two experiments. Experiment 1 employed the pleasantness rating task as the control task because it is considered to mainly involve item-specific processing [13], and Experiment 2 utilized the category rating task as the control task because it mainly involves gist processing [14]. In the recognition test, the “old” responses to studied items could be based on gist representation, verbatim representation, or both, but the “old” responses to critical lures are primarily based on gist representation and occasionally on guessing, while the “old” response to unrelated new items are generally based on guessing. Therefore, the distinction between old items and critical lures (A_v) reflects the ability to utilize item-specific information. Similarly, the distinction between critical lures and unrelated new items (A_g) can be interpreted as the degree to which participants use gist information [17–19]. If the survival rating task results in a higher A_g than the pleasantness rating task but no difference in A_v in Experiment 1, this finding would suggest that the survival rating task triggered an encoding level of item-specific information comparable to that in the pleasantness rating task but that the survival rating task induced more gist processing. Similarly, if Experiment 2 found a larger A_v in the survival rating condition than the category rating condition but no difference in A_g , this finding would suggest that gist processing in memory encoding induced by the survival rating task is comparable to that in the category rating task but that the survival rating involved a higher level of item-specific processing. The results of the current study confirmed the above expectations and supported the idea that survival processing promoted both gist processing and item-specific processing at the memory encoding phase.

1 Experiment 1

In Experiment 1, we contrasted two different within-subject encoding conditions: survival condition (survival rating task) and pleasantness condition (pleasantness rating task). The survival rating task required participants to rate words on a seven-point scale according to how relevant the words would be to survival if they were stranded in a survival scenario. The pleasantness rating task required the rating of words based on their pleasantness on a seven-point scale. Following the rating tasks, participants completed a filler task for 5 min, followed by a recognition test. With the DRM paradigm, we can observe participants’ discrimina-

tion between three types of items (studied items, critical lures and unrelated new items) and their response bias under the survival condition and the pleasantness condition.

1.1 Methods

(i) Participants. A total of 30 undergraduate or graduate students with normal or corrected-to-normal vision at the Capital Normal University participated in the experiment and received monetary compensation for their time. Data from two participants were excluded because their memory scores were beyond two standard deviations of the mean. Therefore, 28 participants remained (19 women, 9 men; $M=20.5$ years, ranging from 18 to 26 years). Informed consent was obtained from each participant prior to the study. The study was approved by the ethics review committee of the Department of Psychology, Peking University.

(ii) Material. Materials included 32 word lists selected from a pool of Chinese associative word lists [20]. Unlike the original word lists that were composed of a lure word and 15 associates, we only kept the lure and 11 strongest associates for each word list. In addition to the original critical lure, the most associated item in each word list was selected as the second lure in the test. Therefore, each adapted list was composed of two lure words and 10 associates, arranged in order of decreasing relatedness to the corresponding lure word. Half of the lists were presented during the encoding phase, while the others were used for new items in the recognition test.

(iii) Design. The experiment was a within-subject design with the different encoding conditions (survival vs. pleasantness) as the independent variable. All participants completed an encoding phase (including a survival rating task and a pleasantness rating task), a filler task, and a recognition test. The order of the rating tasks and the use of word lists were counterbalanced across participants. Associates in each word list were presented in order of decreasing relatedness to the corresponding lure word.

Dependent variables included the mean probability of saying “old” to studied items, lures, and new items, namely, the correct recognition rate, related false alarm, and novel false alarm, respectively. Dependent variables also included the accuracy of memory [correct recognition rate/(correct recognition rate+related false alarm)] and the four indicators (A_v , A_g , BD_v , and BD_g) based on signal detection theory [16,18].

(iv) Procedure. The encoding phase was divided into two blocks, with one rating task (survival or pleasantness) in each block. First, participants were randomly presented either of the instructions below:

The survival rating task: “We would like you to imagine this scenario. Your life is in danger. You have no basic survival materials and are threatened by earthquakes and other natural disasters; you may also be attacked by dangerous predators and diseases. To live, you will need food and veg-

etables, and you may need sticks and shovels to protect yourself from predators; you also need antibiotics to treat inflammation. To survive you will need many items, but they may each be related to your survival needs to differing degrees. We will show you lists of words, and then we would like you to rate how relevant each word would be for you in this survival situation on a rating scale of 1 (least relevant) to 7 (most relevant) by pressing the 1–7 number keys on the keyboard.”

The pleasantness rating task: “Words can be categorized as pleasurable according to different strengths. We will show you lists of words, and would like you to rate each word for how pleasant you find it to be on a rating scale of 1 (least pleasant) to 7 (most pleasant) by pressing the 1–7 number keys on the keyboard.”

After reading the instructions, participants completed 80 trials to rate 8 word lists (10 words in each list) for each rating task. The eight word lists were presented in a random order in each task. Each trial began with a blank screen for 500 ms, followed by an associate word for 2000 ms. A seven-point rating scale then replaced the associate word and was presented for 3000 ms for participants to formulate a judgment.

After the rating tasks, participants completed a 5-min filler task by completing a demographic information scale and the Beck Depression Inventory (BDI). Participants were also asked to evaluate how interesting and easy the rating task was under each scenario.

Subsequently, participants received a recognition test consisting of a list of 192 items (arranged randomly) and were asked to indicate whether an item had been displayed in the rating phase (old response) or not (new response). The list was composed of 80 studied items from the 1, 3, 5, 7, 9 positions of each of the 16 study lists, 32 critical lures from 16 study lists, and 80 new items from the same positions of 16 new lists. After each “yes or no” judgment, participants were instructed to assess their confidence of judgment based on four levels: no confidence (0.50), little confidence (0.65), some confidence (0.85) and high confidence (1.00). The experiment took approximately 40 min to complete.

1.2 Results

Participants’ data were eliminated if they did not complete the rating response within the designated 3 s. Therefore, valid data for the survival condition and the pleasantness

condition were 99.33% and 99.38%, respectively. Analyses were conducted on participants’ rating scores and reaction times, mean probability and confidence levels of saying “old” to studied words, lures, and new words, as well as the results of Av , Ag , BDv , and BDg calculated based on the signal detection theory methods under each of the two encoding conditions. The degree of difficulty and interest level of the two rating tasks were analyzed. The correlation analysis showed that the BDI score had no impact on any other dependent variables. Therefore, the data for BDI were omitted in the below analysis.

(i) Rating score and reaction time. Participants’ mean rating scores did not differ between the survival rating task ($M=3.66$, $SE=0.18$) and the pleasantness rating task ($M=3.82$, $SE=0.14$), $t(27)=1.910$, $P=0.067$. Response times for the survival rating task ($M=1093.51$ ms, $SE=53.32$) and the pleasantness rating task ($M=1017.64$ ms, $SE=53.23$) did not significantly differ from one other, $t(27)=-0.784$, $P=0.44$ (“ M ” is the abbreviation of “mean”; SE is the abbreviation of standard error).

(ii) Overall recognition scores. The mean rates of correct recognition rate, related false alarm, novel false alarm, and memory accuracy (accuracy=correct recognition rate/(correct recognition rate+related false alarm)) as a function of encoding condition are presented in Table 1.

Paired t -tests revealed that the survival condition produced significantly higher rates of correct recognition rates and related false alarms than did the pleasantness condition, $t(27)=2.801$, 3.087 and $P=0.009$, 0.005 , respectively. However, memory accuracy was lower in the survival condition than in the pleasantness condition, $t(27)=-2.026$, $P=0.053$.

(iii) The analysis of discrimination ability (A') and response bias ($B''D$). Although discrimination ability is reflected by the d' in the traditional signal detection theory, in the non-parametric model, A' , which is calculated by area, is considered to be a precise indicator of discrimination. A' ranges from 0.5 to 1, while 0.5 represents completely guessing and 1 represents complete discrimination between new and old items. $B''D$ reflects participants’ response bias in the non-parameter model, ranging from -1 to $+1$, with 0 indicating completely impartial judgment, the positive value reflecting a more stringent criteria, and the negative value reflecting a relaxed criteria [16]. Curran et al. introduced Donaldson’s method into the DRM paradigm: A' computed by the rates of correct recognition and related false alarm represents the discriminability between old items and critical lures (Av , v means Verbatim representation); A' calcu-

Table 1 The rates of correct recognition rates, related false alarms, novel false alarms, and memory accuracy under the two encoding conditions^{a)}

	Correct recognition rate	Related false alarm	Novel false alarm	Accuracy
Survival condition	0.93 (0.01)	0.50 (0.03)	0.13 (0.02)	0.66 (0.02)
Pleasantness condition	0.87 (0.03)	0.41 (0.04)	0.13 (0.02)	0.69 (0.02)
D -value	0.06**	0.09**		-0.03

a) Standard error is in brackets. D -value is the difference between survival condition and pleasantness condition in different indexes. The new items were identical in the two encoding conditions; thus, the novel false alarm rate was the same in the two encoding conditions. ** Represents $P<0.01$.

lated based on the rates of related false alarm and novel false alarm expresses the discriminability between lures and new items (Ag , g means gist representation). Similarly, $B''D$ calculated by the rates of correct recognition and related false alarm represents participants' response bias when distinguishing old items from critical lures (BDv), and $B''D$ calculated based on the rates of related false alarm and novel false alarm expresses the response bias when discriminating lures from unrelated new items (BDg) [18,19]. The "old" responses to studied items may be based on gist representation, verbatim representation, or both, and the "old" responses to critical lures are primarily based on gist representation or guessing, while the "old" response to unrelated new items are based completely on guessing. Therefore, Av reflects the extent of utilizing verbatim representation, and Ag reflects the extent of using gist representation [17].

Paired t -test analysis on Av and Ag revealed that the survival rating produced better performance in Ag ($M=0.79$, $SE=0.01$) than did the pleasantness rating ($M=0.75$, $SE=0.02$), $t(27)=3.165$, $P=0.004$, but the two encoding conditions had no significant differences in Av (survival condition: $M=0.82$, $SE=0.02$; pleasantness condition: $M=0.82$, $SE=0.02$), $t(27)=-0.075$, $P=0.941$ (Figure 1).

Paired t -test analysis on BDv revealed that the survival condition ($M=-0.61$, $SE=0.06$) applied a looser criterion than did the pleasantness condition ($M=-0.44$, $SE=0.07$), $t(27)=-2.376$, $P=0.025$. The analysis of BDg found no significant difference between the two encoding conditions (survival condition: $M=0.38$, $SE=0.05$; pleasantness condition: $M=0.37$, $SE=0.04$), $t(27)=0.864$, $P=0.395$ (Figure 2).

(iv) Analysis of confidence level. We conducted a 2 (encoding conditions: survival vs. pleasantness) $\times$ 3 (item types: old words vs. lures vs. new words) $\times$ 2 (response type: "old" vs. "new") repeated-measures analysis of variance (ANOVA) on participants' confidence level. This analysis revealed significant main effects of encoding conditions,

Figure 1 The contrasts of discrimination under the survival and pleasantness conditions. ** Represents $P<0.01$ and error bars represent standard error.

Figure 2 The contrasts of response bias under the survival and pleasantness conditions. * Represents $P<0.05$ and error bars represent standard error.

item types and response types, $F(1,27)=6.037$, $F(2,26)=3.680$, $F(1,27)=11.676$, $P=0.021$, 0.039 , 0.002 , respectively. Post-hoc comparison showed that the confidence level in the survival condition ($M=0.87$) was less than that in the pleasantness condition ($M=0.89$), the confidence level of old words ($M=0.89$) was significantly higher than that of new words ($M=0.87$), and the confidence level of "old" responses ($M=0.90$) was higher than that of "new" responses ($M=0.86$). A marginally significant interaction was found between encoding conditions and item types, $F(2,26)=3.326$, $P=0.052$. The interaction between encoding conditions and response types was significant, $F(1,17)=7.650$, $P=0.010$. The interaction between item types and response types was significant, $F(2,26)=63.563$, $P<0.001$. The interaction of encoding conditions $\times$ item types $\times$ response types was also significant, $F(2,26)=3.707$, $P=0.038$. A simple effect test showed that the confidence level when new words were false alarmed ($M=0.84$, $SE=0.02$) was significantly lower than when new words were correctly refused ($M=0.91$, $SE=0.01$), $P<0.001$; the confidence level when lures were false alarmed ($M=0.89$, $SE=0.01$) was significantly higher than when lures were correctly refused ($M=0.85$, $SE=0.02$) in the survival condition, $P=0.039$, but this difference was not found in the pleasantness condition; the confidence level when old items had a correct recognition rate (survival: $M=0.98$, $SE=0.01$; pleasantness: $M=0.98$, $SE=0.01$) was significantly higher than when old items were omitted (survival: $M=0.78$, $SE=0.03$; pleasantness: $M=0.83$, $SE=0.02$), $P<0.001$; the confidence level when old words were omitted was significantly lower under the survival condition than under the pleasantness condition, $P=0.036$.

(v) Difficulty and interest of rating. A paired t -test revealed that the difficulty of rating did not differ between the survival condition ($M=4.68$, $SE=0.35$) and the pleasantness condition ($M=4.89$, $SE=0.40$), $t(27)=-0.640$, $P=0.527$. However, participants were more interested in the survival rating task ($M=6.61$, $SE=0.25$) than in the pleasantness rating task ($M=5.71$, $SE=0.36$), $t(27)=2.471$, $P=0.020$. To examine the effects of rating interest on other dependent vari-

ables (correct recognition rate, related false alarm, memory accuracy, Av , Ag , BDv , BDg), we performed regression analyses of interest on each of the other dependent variables. The analysis showed a significant regression of interest level on Ag under the survival condition, $R^2=0.216$, $P=0.013$. In the pleasantness condition, the regressions of interest level on memory accuracy and Av were significant, $R^2=0.177$, 0.183 , $P=0.026$, 0.023 , respectively. No other significant effect was found ($P>0.05$).

2 Experiment 2

Experiment 2 included two encoding conditions as did Experiment 1, but the control task was a category rating task. Instead of the DRM lists, the materials used were category lists, each containing a category name (e.g., fruit) and 12 words that belonged to the category (e.g., apple, banana). The category rating task instructed participants to rate on a seven-point scale the extent to which each presented word belonged to a category. The survival rating task was the same as that in Experiment 1.

2.1 Methods

(i) Participants. A total of 20 undergraduate or graduate students (14 women, 6 men; $M=21.0$ years, ranging from 18 to 27 years) with normal or corrected-to-normal vision at the Capital Normal University participated in the experiment. They received monetary compensation for their time.

(ii) Material. A total of 48 category lists with 24 lists were used for the rating tasks in the encoding phase, and 24 lists were used as new materials in the recognition test, all from a Chinese category word-list pool built in our laboratory. Each category list was composed of a category name (e.g., reading material) and 12 sample words (e.g., newspaper) that belonged to the category. The 12 sample words were arranged in order of decreasing typicality in the category, and we selected the first five items of each category list as the critical lures and the remaining seven sample words as to-be rated items in the encoding phase. Therefore, each category list was composed of a category name, five lure words, and seven sample words.

(iii) Design. The design was similar to Experiment 1, except that the control condition was the category condition.

(iv) Procedure. The procedure was the same as Experiment 1, except the presenting time of each item was reduced from 2 to 1 s and the words in each list were presented in a random rather than fixed order. Every subject completed 24 lists (a total of 168 words). The order of the rating tasks and the materials were balanced among participants. In each trial of the category rating task, a category name was presented on the left of screen and a sample word was presented on the right, with a dash linking the two words. Participants were asked to rate on a seven-point

scale the degree to which the sample word belonged to the left category. Instructions for the survival rating task were similar to Experiment 1. The instructions for the category rating task were as follows.

Some words can refer to the “category name” of a certain category, such as “drug”. At the same time, words that belong to a category can be referred as “sample words”, such as “penicillin”, “Banlangen” and “yunnan Baiyao”, because they belong to the drug category. We will show you a list of paired words and would like you to rate the “typicality” that a sample word on the right part of the screen belongs to the category on the left part of the screen. Please rate the degree to which you find this sample word as belonging to the left word category on a 1 (least belonging) to 7 (most belonging) scale by pressing the 1–7 number keys on the keyboard.

After the study, there was a 10-min distraction task, during which participants completed a demographic information scale, the BDI and the Self-Rating Anxiety Scale (SAS). Participants were also asked to evaluate how interesting and easy the two rating tasks (survival and category rating tasks) were on a nine-point scale.

Subsequently, participants received a recognition test consisting of 456 randomly arranged items, including 168 studied words, 120 critical lures, and 168 new unrelated words. Participants were asked to indicate whether an item had been presented in the rating phase (“old” response) or not (“new” response). The entire experiment took approximately 40 min to complete.

2.2 Results

Participants’ data were eliminated if they did not complete the rating response within the designated 3 s; thus, valid data for the survival condition and pleasantness condition were 99.88% and 98.99%, respectively. Analyses were conducted on participants’ rating scores and reaction times, mean probabilities of saying “old” to studied words, lures, and new words, as well as the results of Av , Ag , BDv , BDg calculated by the signal detection theory method. The degree of difficulty and interest level were also analyzed under the two encoding conditions. In addition, correlation analysis showed that BDI scores and SAS scores had no impact on any other dependent variables. Therefore, the data on BDI and SAS were omitted in the below analysis.

(i) Rating score and reaction time. The analysis revealed that response times did not differ between the survival condition ($M=916.89$ ms, $SE=41.04$) and the category condition ($M=924.99$ ms, $SE=46.27$), $t(19)=-0.309$, $P=0.761$. However, the mean rating score in the survival condition ($M=3.87$, $SE=0.18$) was significantly lower than that of the category condition ($M=5.84$, $SE=0.13$), $t(19)=7.933$, $P<0.001$. To examine the impact of rating scores on other dependent variables, we conducted a regression analysis, which proved that the rating score had no significant influence on correct recognition rate, related false alarm, memory accuracy, and Av , Ag , BDv , BDg under the survival

Table 2 The rates of correct recognition rates, related false alarms, novel false alarms, and memory accuracy under the survival and category conditions^{a)}

	Correct recognition rate	Related false alarm	Novel false alarm	Accuracy
Survival condition	0.84 (0.02)	0.23 (0.03)	0.06 (0.01)	0.80 (0.02)
Category condition	0.79 (0.03)	0.23 (0.03)	0.06 (0.01)	0.79 (0.02)
<i>D</i> -value	0.05*	-0.00		0.01

a) Standard error is in brackets. *D*-value is the difference between survival condition and category condition in different indexes. The new items were identical in the two encoding conditions; thus, the novel false alarm rate was the same in the two encoding conditions. * Represents $P < 0.05$.

and category conditions ($P > 0.05$).

(ii) Overall recognition scores. The mean rates of correct recognition rate, related false alarm, novel false alarm, and memory accuracy (accuracy=correct recognition rate/(correct recognition rate+related false alarm)) as a function of encoding condition are presented in Table 2.

A paired *t*-test on correct recognition rate, related false alarm, and memory accuracy revealed that the survival condition produced significantly higher correct recognition rates than did the category condition, $t(19)=2.258$, $P=0.036$. However, related false alarm and memory accuracy did not differ in the two encoding conditions, $t(19)=-0.236$, 1.282 , $P=0.816$, 0.215 , respectively.

(iii) Analysis of discrimination ability (*A'*) and response bias (*B''D*). Based on the rates of correct recognition rate, related false alarm and novel false alarm, we calculated the index of discrimination ability (*Av*) and response bias (*BDv*) when distinguishing between old items and critical lures as well as those indexes (*Ag* and *BDg*) when distinguishing between critical lures and unrelated new items under the two encoding conditions.

A paired *t*-test on *Av* and *Ag* revealed that the survival condition ($M=0.88$, $SE=0.01$) produced better performance in *Av* than in the category condition ($M=0.86$, $SE=0.01$), $t(19)=2.390$, $P=0.027$ but that the two encoding conditions had no significant difference in *Ag* (survival condition: $M=0.72$, $SE=0.02$; category condition: $M=0.70$, $SE=0.03$), $t(19)=0.626$, $P=0.539$. These results were entirely opposite to those of Experiment 1 (Figure 3).

The paired *t*-test analyses of *BDv* (survival condition: $M=-0.04$, $SE=0.10$; category condition: $M=0.00$, $SE=0.10$)

and *BDg* (survival condition: $M=0.51$, $SE=0.05$; category condition: $M=0.56$, $SE=0.06$) did not find any significant difference between the survival and category conditions, $t(19)=-0.692$, -1.571 , $P=0.497$, 0.133 , respectively.

(iv) Difficulty and interest of rating. Paired *t*-tests revealed that the difficulty of rating did not differ between the survival condition ($M=4.70$, $SE=0.37$) and the category condition ($M=4.00$, $SE=0.50$), $t(19)=1.224$, $P=0.236$. However, similar to the results of Experiment 1, participants were more interested in the survival rating task ($M=6.85$, $SE=0.38$) than the control task (category task: $M=5.35$, $SE=0.49$), $t(14)=3.099$, $P=0.006$. To examine the effects of rating interest on other dependent variables (correct recognition rate, related false alarm, memory accuracy, *Av*, *Ag*, *BDv*, *BDg*), regression analyses of interest on each of the other dependent variables were conducted in the two encoding conditions, and no significant effect was found ($P > 0.05$).

3 Discussion

We verified the typical memory advantages of survival processing with the results that correct recognition rate in the survival condition was higher than in the control condition, regardless of whether the control scenarios were the pleasantness rating task or the category rating task. More importantly, we discovered that survival processing can promote not only gist information processing but also item-specific information processing, while the latter processing type is an important foundation of memory source monitoring. These findings support the idea that the memory advantages of survival processing result from its eliciting both item-specific processing and gist processing.

Consistent with Nairne's results, we found that relative to the pleasantness condition, the survival condition induced a higher correct recognition rate. However, given that the survival condition also resulted in a higher false recognition rate of critical lures, we cannot conclude that survival processing improves memory accuracy because there are two alternative explanations. First, the survival rating task causes participants to rely more heavily on gist processing, which results in more "old" responses toward old words and lures with strong semantic associations. Second, participants adopted a more relaxed response bias in the recognition test, which led to increases in both the correct recognition rate of old words and the false alarm rate of critical lures. When the

Figure 3 The contrasts of discrimination under the survival and category conditions. * Represents $P < 0.05$ and error bars represent standard error.

same memory accuracy indicators (correct recognition rate/(correct recognition rate+false recognition rate)) were used [6], we found the same result as Howe and Derbish: that the survival condition had a lower accuracy of memory than the pleasantness condition. However, Otgaar found that memory accuracy was not different between the survival condition and the pleasantness condition with the same indicator [21]. As Otgaar employed a free recall test, while Howe et al. and the current study used a recognition test, the different results of memory accuracy may be related to the different tests. A number of studies have failed to find higher accuracy of memory under the survival condition [6,21,22], suggesting that accuracy of memory may not be the critical nature of adaptive memory. Just as the suggestion that false memory is a manifestation of memory being adaptive [23], survival processing adaptability may not lead to more accurate memory.

Based on Donaldson's data analysis method of the non-parametric model, we analyzed the discrimination and response bias between various types of test items with independent indicators. We found that survival processing only promotes the distinction between critical lures and new items but not the distinction between old items and critical lures when compared with the pleasantness condition. One reason for associative memory illusion is that gist processing can lead to related false alarms. In contrast, the encoding and use of item-specific information will lead to better monitoring of a memory source, which can assist participants in better distinguishing critical lures from old items, thereby inhibiting the occurrence of association memory illusion [17]. Consequently, discrimination between old items and critical lures reflects the utilization of item-specific representation, and discrimination between critical lures and unrelated new items may be interpreted based on the extent of using gist representation. The results of Experiment 1 demonstrated that although the extent of encoding and using item-specific information did not differ between the survival condition and the pleasantness condition, the survival condition produced gist processing superior to that of the pleasantness condition. Consistently, the response bias between lures and new items was equivalent in the two encoding conditions (survival vs. pleasantness), but the survival processing produced a more relaxed response criterion when distinguishing critical lures from old items, which resulted in higher related false alarms. The more liberal criteria under the survival condition have an adaptive value and can explain increases in correct recognition rates and related false alarm rates. In addition, the data on confidence level also support the above results to some extent. First, participants' confidence levels were higher when the lures were false alarmed than when the lures were correctly rejected under the survival condition, but this difference was not found in the pleasantness condition. These results also reflected the fact that survival processing could produce more false recognitions of lures than that in the pleas-

antness condition. In addition, the confidence level when old words were omitted was lower under the survival condition than under the pleasantness condition, which suggested that participants had a better memory of old items under the survival condition than the pleasantness condition.

Because the rating score and response time did not differ between the survival condition and the pleasantness condition, these factors cannot account for the survival processing advantage. Moreover, the difficulties of the two rating tasks were equivalent to one another, but participants were more interested in the survival rating task than in the control task, which is consistent with the idea that survival processing is adaptive and can stimulate people's interest.

Experiment 2 also confirmed the memorial advantages of survival processing by demonstrating that the correct recognition rate of old words was improved by survival processing. Unlike Experiment 1, Experiment 2 did not find differences in related false alarm and memory accuracy between the survival condition and the category condition. As mentioned above, the related false alarm of lures is based on gist processing. The related false alarm rate being equivalent between the survival and category conditions reflected similar levels of gist representation under these two conditions. Therefore, the higher correct recognition rate under the survival condition may reflect better utilization of item-specific information. Although the above discussion based on recognition rates was speculative to some extent, the analyses of discrimination and response bias based on signal detection theory between various types of items provided clearer evidence. Specifically, compared with the category condition, the survival condition promoted discriminability between old items and critical lures but not between lures and new items. These results attested that the level of item-specific processing and memory source monitoring under the survival condition was higher than in the category condition, while no difference was observed in establishing and using gist representation. For the response bias, participants held the same criteria in the survival and category conditions when distinguishing between the lures and old items and between the lures and new items.

The rating score analysis showed that the category condition induced higher rating scores than did the survival condition. To examine whether this difference is related to the survival processing advantage, we conducted a series of regression analyses to explore the relationship between rating score and each dependent variable (correct recognition rate, related false alarm, accuracy, A_v , A_g , BD_v , and BD_g). None of the regression analyses was significant, which excluded the influence of rating score on the other dependent variables' results. Just as in Experiment 1, participants' reaction time and difficulty rating did not differ between the two encoding conditions, and only a higher rating of interest was found in the survival condition.

Altogether, the results of Experiment 1 and Experiment 2 clearly indicate that survival processing promoted memory

encoding in both gist processing and item-specific processing. The pleasantness rating is normally considered to be a typical task that primarily triggers item-specific processing [13]. The results of Experiment 1 showed that the survival rating could trigger the same level of item-specific processing as could the pleasantness rating, but the survival rating task led to better performance in gist processing than did the pleasantness rating task. The category rating is normally considered to be a typical task that mainly elicits gist processing [13,14]. The results of Experiment 2 showed that the survival rating could induce equal levels of gist processing as the category rating, and at the same time, the survival rating resulted in better performance in item-specific processing than did the category rating. Thus, survival processing's advantage lies in its effects on both item-specific and gist processing. Future research should test this idea by designing a control task that promotes both types of processing, such as self-referential coding [24], to further clarify the mechanism of survival processing advantage.

Currently, three hypotheses explain the survival processing advantage: the richness-of-encoding hypothesis, the elaboration hypothesis and the evolution-function hypothesis. These hypotheses hold the same view that the survival processing advantage is achieved by changing the memory encoding process [2,8,9]. In particular, the richness-of-encoding hypothesis and elaboration hypothesis attribute the memory effect of survival processing to the more elaborate processes in the memory encoding phase. Compared to the Fuzzy Trace theory, these two hypotheses seemingly argue that the mechanism of the survival processing advantage is due to the more item-specific processing (such as physical details of items) under the survival condition. However, the present study found that the survival processing advantage was not only due to the promotion of item-specific processing but also due to the promotion of gist processing. Thus, our study suggests a new interpretation, i.e., "the dual-process promotion hypothesis", of the survival processing advantage. Like the above hypotheses, we also believe that the presence of adaptive memory is due to the richer information encoding under the survival condition, which includes both item-specific information encoding and gist information encoding. When the survival rating task was compared to tasks in which participants presumably processed mainly gist information or item-specific information, the typical memory advantages of survival processing were obtained. Although gist processing can result in associate memory illusion and reduced memory accuracy, this processing mode possesses an adaptive value, as gist processing can effectively avoid overload of the human memory system and save cognitive resources [25]. Sufficient item-specific processing can inhibit memory illusion and improve memory accuracy to a certain extent by promoting source monitoring in the retrieval phase, which comes at the cost of cognitive resources. Therefore, both item-specific processing and gist processing have important im-

plications for human memory.

We found a higher level of interest among participants toward the survival rating task relative to the control tasks in both experiments. Although there were some significant regression results between interest level and other dependent variables (Ag in survival task, memory accuracy and Av in category task) in Experiment 1, the remaining regression analyses in Experiment 1 and all regression analyses in Experiment 2 were not significant; thus, the interest level toward the task may affect memory results to a certain extent, but it cannot be the major mechanism of the survival processing advantage. At the same time, the higher interest level may embody adaptive memory because when the human brain is more interested in survival-related information, the individual will be willing to invest more energy to focusing on survival information and, thus, be more likely to survive. Future research must also explore other differences between survival processing and non-survival processing, such as arousal levels and degree of attention [2,6], and must further examine the brain mechanisms of the survival processing advantage to learn more about adaptive memory.

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