Adaptive Memory: Temporal, Semantic, and Rating-based Clustering Following Survival Processing

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Abstract

Processing items for their survival relevance often produces a robust memory advantage. The current experiments assessed possible proximate mechanisms responsible for this advantage by assessing output strategies during free recall. Previous research has shown that item clustering during recall can provide diagnostic information about the structure of representations in episodic memory, particularly the encoding of temporal, semantic, and source information. Following survival processing and moving or pleasantness controls, measures of temporal and semantic clustering were generated. A robust recall advantage was found for survival processing, but no evidence for temporal clustering was detected. Above-chance levels of semantic clustering were obtained, but there were no differences between the survival and control conditions. An additional clustering measure based on scenario-based relevance ratings also failed to explain recall differences, as did absolute and relative measures of remembered temporal position. Our results indicate that neither enhanced temporal coding nor increased semantic processing among the items on the study list can easily explain the oft-replicated survival processing advantage. Our results also suggest that the ubiquitous temporal clustering patterns seen in free recall studies may be a product, in part, of using intentional learning and multiple study trials.

The thesis that human memory evolved, subject to the constraints of natural selection, is noncontroversial. Just as the organs of the body were sculpted over generations to solve specific problems (such as pumping or filtering blood), human memory almost certainly evolved because it helped solve adaptive problems, ones that were highly relevant in ancestral environments (Klein, Cosmides, Tooby, & Chance, 2002; Nairne & Pandeirada, 2008). The ability of an organism to remember the location of food and to recognize potential predators and prey, as well as to recognize and remember possible mating partners, likely enhanced our ancestors' survival chances. Such reasoning led Nairne, Thompson, & Pandeirada (2007; see Nairne, 2010, for a review) to propose that memory may be biased or "tuned" to the processing and retention of information relevant to survival and reproductive fitness. In support, Nairne et al. (2007) found that items processed with respect to an imagined survival scenario produced particularly good long-term retention.

In the original survival processing paradigm, participants were asked to imagine themselves stranded in the grasslands of a foreign land without any basic survival materials. People were told that over the next few months they would need to find food and water and protect themselves from predators. The task was to rate the relevance of a list of unrelated words (that is, the concepts represented by the words) to this imagined survival scenario. A surprise free recall test followed, and processing words for survival-relevance led to better memory than processing words for a control scenario (moving to a new home in a foreign land), self-reference (personal experience), or a standard deep processing control (pleasantness ratings; Nairne et al., 2007).

Since its original demonstration, the survival processing advantage has been widely replicated, using a variety of control procedures and survival scenarios (see Erdfelder & Kroneisen, 2014; Kazanas & Altarriba, 2015; Nairne, 2010, for reviews). Nairne, Pandeirada, Gregory, & VanArsdall (2009) used a matched design in which participants generated relevance ratings about activities related to hunting or gathering food, but based in either a survival or a game-based context (e.g., gathering food for survival or to win a scavenger hunt). Ratings were made about the same activities in both groups, and the observed ratings did not differ, but the survival framing led to significantly better recall. Thus, it is something about the survival context, rather than the rating task itself (e.g., its difficulty or familiarity), that produces the memory advantage. Some boundary conditions have since been identified—for example, survival processing advantages may not extend to the processing of stories (Seamon et al., 2012) or faces (Savine, Scullin, & Roediger, 2011) or indirect tests of retention (Tse & Altarriba, 2010)—but the effect has proven robust across various age groups, stimuli, and experimental designs.

Not surprisingly, investigators have been keenly interested in discovering the proximate mechanisms that drive the advantage. Selection pressures over generations may have tuned our memory systems to work efficiently in survival situations, but the memory mechanisms involved may be familiar (Nairne et al., 2007; Nairne & Pandeirada, 2016). In fact, Nairne and Pandeirada (2016) recently suggested that survival processing may constitute a “front-end” adaptation, meaning a natural tuning that relies on the recruitment of otherwise general processes. Adaptations of this kind are common in the body. For example, the fight-or-flight response “works” via activation of the sympathetic nervous system which, in turn, recruits and coordinates changes in blood pressure, heart rate, blood sugar levels, respiration rates, and so on. As part of a more general survival optimization system, processing information in a survival context might naturally recruit mechanisms that promote good episodic retention. For example, survival processing could induce elaborative processing which, in turn, aids recovery because additional retrieval routes are available (Kroneisen & Erfelder, 2011; Roer, Bell, & Buchner, 2012). Importantly, however, considerable evidence now suggests that the recruitment of such memory-enhancing mechanisms is driven by the survival mode rather than by some general feature or artifact of the relevance rating task (see Nairne & Pandeirada, 2016, for a detailed account).

In the present case, we were interested in the involvement of a mechanism that has been used to account for a number of phenomena associated with free recall—associations between items and slowly updating contextual information. Kahana (1996) and colleagues (Howard & Kahana, 2002a) have shown that output clustering during recall can provide diagnostic information about the structure of representations in episodic memory, particularly the encoding of temporal, semantic, and source information. Temporal clustering is a common property of free recall: Items studied in neighboring serial positions in a list tend to be reported together during the recall output sequence (known as the temporal contiguity effect). The extent of temporal clustering, in turn, has been used to draw inferences about the formation of associations between studied items and/or with an evolving temporal context (e.g., Howard & Kahana, 2002a; Polyn, Norman, & Kahana, 2009). One can also find semantic clustering—that is, participants may be more likely to transition to a word that is similar in meaning than to one that is less similar. Semantic clustering indexes the role that longstanding semantic associations are playing in recall (Howard & Kahana, 2002b) and the degree to which meaningful relationships among items have been accessed during the retrieval process. Finally, source characteristics can influence clustering patterns as well; people tend to recall items presented in the same modality together (Murdock & Walker, 1969), as they do items of similar emotional valence (Long, Danoff, & Kahana, 2015) and items processed via the same orienting task (e.g., size versus pleasantness judgments; cf. Polyn et al, 2009). Source clustering can indicate the extent to which people have encoded source characteristics and, perhaps, are using source as a retrieval cue during recall.

In short, clustering patterns can serve as “toolkits” for uncovering the dimensions that control performance across various kinds of manipulations. As a case in point, recent research indicates that practicing retrieval of presented information, as opposed to additional study periods, leads to increased temporal-based clustering during later free recall that is representative of a more diagnostic encoding of temporal context (Lehman, Smith, & Karpicke, 2014). More distinctive temporal coding, in turn, enables people to restrict their search during the test period, reducing interference from prior encodings and increasing list discrimination performance (see Chan & McDermott, 2007; Karpicke, Lehman, & Aue, 2014). Thus, variations in contextual encoding, as measured through temporal clustering, present a proximate mechanism through which a well-known empirical phenomenon such as the testing effect can be explained.

In the present case, we were interested in whether an analysis of clustering patterns in free recall might provide useful information about the proximate mechanisms that underlie survival processing advantages. For example, it is conceivable that survival processing leads to more robust encoding of temporal context, as revealed through greater relative amounts of temporal clustering during output. Given that episodic retention relies on the recovery of temporal and spatial occurrence information (see Nairne, 2015), fitness-based "tunings" might well operate through the recruitment of contextual encoding mechanisms. Alternatively, survival processing could lead to enhanced relational processing (Burns, Burns, & Hwang, 2011)—defined as an increase in meaningful connections among items within the study list—or increased elaboration in general (Kroneisen & Erdfelder, 2011). If so, then we might expect to see greater evidence of semantic clustering during recall output after survival processing. The fact that survival processing sometimes leads to an increase in false memories, or extra-list intrusions in general, is consistent with this expectation (e.g., Howe & Derbish, 2010; Otgaar & Smeets, 2010).

We were also interested in whether people might cluster based on scenario ratings—that is, do items that have been given high relevance ratings for a particular scenario cluster together during output, presumably because of an excellent "fit" between the item and the scenario (Butler, Kang, & Roediger, 2009). If people are using the assigned scenario as a retrieval cue to aid recall, and scenario-item congruity matters, then evidence for rating-based clustering should be observed. Once again, the output strategies employed by the participant during recall potentially provide insight into the proximate mechanisms that underlie survival processing advantages.

Three experiments are reported. In Experiment 1, we compared survival processing to a standard control scenario (moving to a foreign land), one likely to induce relational or schematic processing. In Experiment 2, we compared survival processing to pleasantness processing, a task that is typically thought to enhance individual-item processing. In both experiments, measures of temporal, semantic, and rating-based clustering were assessed across conditions. Finally, in order to provide a more direct measure of temporal order retention, Experiment 3 used a surprise reconstruction of order test; again, of main interest were potential temporal or position memory differences between survival processing and a moving control.

Experiment 1

In Experiment 1, separate groups of participants were asked to make relevance decisions, based on one of two scenarios, for a common set of unrelated items. Participants in one condition were asked to make survival ratings; participants in the control condition were asked to make ratings based on a moving scenario. Following the ratings, everyone was given a surprise free recall task and clustering patterns were assessed.

Method

Participants and apparatus. Eighty undergraduates (39 men and 41 women) participated in exchange for partial credit in an introductory psychology course. Participants were brought into the lab in groups of up to four for sessions lasting approximately 30 minutes. Stimuli were presented and responses collected by computer.

Materials and design. Stimulus materials were selected from the extended Paivio, Yuille, and Madigan norms (Clark & Paivio, 2004). Following earlier work, the word pool consisted of familiar (at least 5.5 on a 7-point scale) concrete nouns (at least 5.28 on a 7-point scale). A total of thirty-two words was selected for the study list. Four additional items meeting the same criteria were chosen as practice items. The set of 32 words was randomly re-ordered to create five different study lists. The four practice words were also randomly re-ordered five separate times. A given participant saw only one of these lists; the five unique versions were created simply to reduce the chances that any single presentation order might explain the recall or clustering results.

The experiment used a simple between-subjects design: Participants in each condition (N = 40 in each group) were asked to rate a single list of words according to one of the assigned scenarios. The rating task was followed by a two-minute addition task prior to an unexpected free recall task. Importantly, all aspects of the design were held constant except for the rating scenario.

Procedure. On arrival, participants were randomly assigned to one of two rating conditions with the following instructions:

> *Survival scenario*. 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 scenario.* 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 purchase a new house and find help transporting 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 this moving situation. Some of the words may be relevant and others may not – it’s up to you to decide.

Each word was presented for five seconds and participants were asked to rate the word on a five-point scale, with one indicating totally irrelevant and five indicating extremely relevant. Reminder instructions were presented near the top of the screen explaining that participants should rate the word for its relevance to the given scenario. The labeled rating scale (one through five) was displayed below each word and participants provided their response by entering the number corresponding to their chosen rating. All participants were given a short practice session to familiarize them with the task.

Immediately following the rating task, participants were instructed to complete an addition distractor task. For this task, participants were asked to add together two-digit numbers in their head and enter their responses as quickly as possible. The addition problem was presented on the center of the screen and their responses were displayed directly under the problem. Participants pressed the spacebar to enter their responses. The distractor task lasted approximately two minutes.

Next, instructions appeared for the recall task. Participants were instructed to remember the rated words and enter them via the keyboard one at a time into a text box. They were told they would have ten minutes to recall as many words as possible and could enter them in any order they desired. After a word was submitted, it appeared in a list of already recalled items to the right of the text box. Participants were fully debriefed at the end of the experiment.

Results and Discussion

Proportion correct recall for the survival and moving conditions is shown in Figure 1. A one-way analysis of variance (ANOVA) revealed that participants in the survival condition (M_{Surv} = .50, *SD* = .12) recalled more words than those who rated words in the moving control (M_{Mov} = .40, *SD* = .11), $F(1, 78) = 13.86$, $MSE = .014$, $\eta_p^2 = .15$, $p < .001$, thus replicating the typical survival-processing advantage. There were no significant differences in mean relevance ratings between the survival (2.56) and moving (2.72) conditions, $F(1, 78) = 2.44$, $MSE = .229$, $\eta_p^2 = .03$. Response times (in milliseconds) also did not differ between the survival (2,261) and moving (2,131) conditions, $F(1, 78) = 1.68$, $MSE = 201{,}785$, $\eta_p^2 = .02$. In addition, there was no significant correlation between response time and recall performance ($r = .07$).

Temporal Clustering. Of main interest were the clustering patterns observed during recall output. To begin, we calculated the degree of temporal clustering for each participant, using the method developed by Polyn et al. (2009). In the Polyn et al. method, for each recall transition a relative temporal distribution is generated from the just-recalled word to every other word in the study list that has yet to be recalled. A percentile score is then generated by comparing the temporal distance value corresponding to the next item in the recall sequence with the rest of the distribution. This calculation is done for every transition from a word presented in the original study list to another word presented in the original study list; all transitions to and from practice words, intrusions, and repeats are ignored. Finally, the values are averaged for each participant providing an overall temporal clustering score known as a “temporal factor” (for details see Polyn et al., 2009; Sederberg, Miller, Howard, & Kahana, 2010). A temporal factor value of .50 represents chance temporal clustering—that is, no evidence of temporal organization during the entire recall output period. Values greater than .50 indicate a tendency to recall words that appeared in nearby serial positions during initial presentation in adjacent positions during output.

The mean temporal factor across all participants in the survival condition was .502, which was not significantly different from the chance value of .50, $t(39) < 1$, and .506 in the control condition, also not significantly different from chance, $t(39) < 1$. Neither condition showed any evidence of temporal clustering during output, as shown in Figure 2 (left panel), nor did the temporal factor differ between conditions, $t(78) < 1$. There was also no correlation between the temporal factor and overall recall (r = -.009). The absence of any temporal clustering in the recall output is somewhat surprising given the ubiquitous nature of temporal clustering in free recall (see Healey & Kahana, 2014). It is important to note, though, that most observations of temporal clustering have occurred under intentional learning conditions, and performance is usually averaged across multiple lists or trials (see Sederberg et al., 2010). This suggests that robust temporal clustering patterns may depend, in part, on intentional strategies employed by participants over multiple trials (see Hintzman, 2016, for a similar conclusion). In the present case we used incidental learning and only a single trial. Temporal clustering patterns have rarely been examined in such a context, although differences in one's ability to reconstruct the order of list items have been observed after incidental learning of a single list (e.g., Burns, 1996; Serra & Nairne, 1993; see the current Experiment 3 as well).

As an additional check, we used a measure developed by Asch and Ebenholtz (1962) that provides a relative index of correct input-output correspondence. Asch-Ebenholtz considers adjacent recalls as pairs and then calculates the proportion of those pairs, relative to the total number of pairs recalled, that preserve the relative order of input. Asch-Ebenholtz does not factor in the temporal distance between adjacent recalls, as does the temporal factor, only the relative order. Chance performance is again .50, meaning that half of adjacent recalls are in the same order as originally presented and half are not. Replicating the temporal factor data, there were no differences between the survival (M_{Surv} = .48) and moving (M_{Mov} = .48) conditions and overall performance hovered around chance. Thus, no differential use of temporal information was apparent during recall output for either the temporal factor or the Asch-Ebenholtz index even though a robust survival processing advantage was obtained in recall.

Semantic Clustering. As with the temporal factor, we computed the semantic factor for each participant. Here, for each recall transition a relative distribution is generated like that of the temporal distribution, except that the ranking is based on the relative strength of the preexisting semantic associations between the just-recalled word and the remaining unrecalled words. Semantic relatedness was determined using latent semantic analysis (Landauer, Foltz, & Laham, 1998). Calculations were performed for every valid transition (transitions to and from practice words, intrusions, and repeats were ignored) and then averaged across all transitions for each participant. Like the temporal factor, a semantic factor greater than .50 indicates some use of clustering based on meaning, and a value of .50 indicates no overall tendency for semantic clustering (see Polyn et al., 2009; Sederberg et al., 2010).

As shown in Figure 2 (right panel), the mean semantic factor for the survival condition was .554, significantly larger than the chance value of .50, $t(39) = 4.21$, $p < .001$, and .555 for the moving control, also significantly larger than chance, $t(39) = 3.02$, $p < .01$. Thus, unlike the findings for temporal clustering, participants were more likely to transition to semantically similar items during recall output than would be expected by chance. However, importantly, there was no difference in semantic clustering between the survival and control conditions, $t(78) < 1$. Thus, the current data provide no indication that the survival processing advantage is due to enhanced use of semantic information (at least as measured through intralist semantic clustering).

Because there was significant semantic clustering, we also examined the relationship between the semantic factor and proportion correct recall. There was a significant correlation between proportion recalled and the semantic factor for those in the survival condition, $r = -.375$, $p < .05$, but not in the moving control, $r = .065$, $p = .69$. The correlation in the survival condition was negative, however, suggesting that an increased reliance on semantic associations in recall was associated with poorer free recall performance (for a similar trend, see Sederberg et al., 2010). The reason for this negative relationship is not entirely clear, but it is inconsistent with any account proposing that the survival processing advantage is due to increased relational processing among the items in the list (e.g., Burns et al., 2011).

Rating-based Clustering. Lastly, we were interested in measuring the tendency to cluster recall output by relevance rating. For this analysis, we calculated the likelihood of transitioning between similarly-rated items during recall—that is, given that a recalled item was rated a 5, what proportion of the time was the next recalled item also given a rating of 5, or 4, and so on. Because we were interested in the use of the scenario as a retrieval cue, we restricted our analysis to words that were rated “relevant” (a rating of 4 or 5 on the scale). Again, the point was to investigate whether people tend to recall scenario-relevant items together during output, and whether such a tendency might differ between the survival and control conditions. If people are using the scenario as a retrieval cue, then items that “fit” the scenario well are likely to be recalled together. The fact that people might have recalled items together that were given low relevance ratings seemed less germane to the question of interest.

Table 1 shows the transition probabilities for the survival and moving conditions. As the table shows, there was little evidence for clustering based on rating, especially in the survival condition. Participants were just as likely to transition from an item rated as highly relevant to the survival scenario to another highly relevant item (e.g., .22 for the 5-to-5 transitions) as to an item deemed irrelevant to the scenario (e.g., .27 for the 5-to-1 transitions). Moreover, there was no evidence for enhanced clustering in the survival condition relative to the moving condition. In fact, those in the moving condition showed a somewhat greater likelihood of making within-relevant rating transitions.

Overall, then, the three main clustering measures used in Experiment 1—temporal, semantic, and rating-based—revealed no significant differences between the survival and moving conditions. In fact, there was little evidence for organizational output strategies in this experiment, which contrasts with the strong evidence for temporal clustering that has been seen in other work (Sederberg et al., 2010). As noted, however, most earlier reports of clustering used intentional learning, along with multiple trials, so temporally-based output strategies might be a consequence of intentional instructions. At the same time, participants were clearly able to recall many of the items; moreover, despite no differences in temporal, semantic, or rating-based transitions, we observed a recall advantage for the survival condition. Our data suggest therefore that the typical survival processing advantage cannot easily be attributed to differential temporal, semantic, or rating-based output strategies during recall.

Experiment 2

Experiment 2 was designed to replicate the results of Experiment 1 using a different control condition. Participants in the survival processing condition were again asked to make relevance decisions based on the survival scenario; participants in the control condition were asked to make pleasantness ratings. Following the ratings, both groups were given a free recall test and clustering tendencies were assessed. As noted earlier, pleasantness judgments are widely believed to encourage individual-item processing (Hunt & Einstein, 1981). It is conceivable, then, that relatively more semantic clustering will be found in the survival condition because survival processing is sometimes thought to induce both individual-item and relational processing (Burns et al., 2011). Our main goal, however, was simply to see if the clustering patterns found in Experiment 1 will replicate when a different control procedure is used.

Method

Participants and apparatus. Eighty undergraduates (43 men and 37 women) participated in exchange for partial credit in an introductory psychology course. Participants were brought into the lab in groups up to four in sessions lasting approximately 30 minutes. Stimuli were presented and responses were collected by computer. One participant in the pleasantness condition was later eliminated due to not following the instructions during the experiment.

Materials and design. The 32 target words and four practice words from Experiment 1 were used for Experiment 2. The experiment was a simple between-subjects design: Participants in each condition (N = 40 in each group) were asked to rate and later recall the words. The rating task was followed by a two-minute distractor task prior to the unexpected free recall task. Importantly, all aspects of the design were held constant except for the two different rating conditions.

Procedure. On arrival, participants were randomly assigned to one of the rating conditions. The same survival instructions were used for Experiment 2, but the following instructions were provided for the pleasantness control:

> *Pleasantness.* In this task, we are going to show you a list of words, and we would like you to rate the pleasantness of each word. Some of the words may be pleasant, others may not – it's up to you to decide.

Each word was presented individually in the center of the computer screen for five seconds and participants were asked to rate the word on a five-point scale, with one indicating totally irrelevant/unpleasant and five indicating extremely relevant/pleasant. Reminder instructions were presented directly above each word appropriate for each condition: "How relevant is this word to the survival situation?" or "How pleasant is this word?" The rating scale was presented below each word and participants had five seconds to enter their responses using the keyboard. A practice session preceded the actual rating task. The distractor and free recall task were as described in Experiment 1.

Results and Discussion

Figure 3 shows the recall data, broken down by condition, and once again there was a robust survival processing advantage (M_{Surv} = .46, *SD* = .10; M_{Pleas} = .35, *SD* = .12), $F(1, 78) = 18.19$, $MSE = .013$, $\eta_p^2 = .19$, $p < .001$. The mean ratings and response times were also analyzed. Unlike in Experiment 1, there was a significant difference in mean ratings between survival (2.58) and pleasantness (3.24), $F(1, 78) = 81.28$, $MSE = .111$, $\eta_p^2 = .51$, $p < .001$, but the higher ratings occurred in the pleasantness control. The mean response times (in milliseconds) did not differ significantly between the survival (2,228) and pleasantness groups (2,117), $F(1, 78) = 1.61$, $MSE = 152{,}939$, $\eta_p^2 = .02$. However, unlike in Experiment 1, there was a significant correlation between response time and recall ($r = .31$), suggesting that some of the survival advantage might be attributable to a more effortful (or at least time-consuming) decision.

Temporal Clustering. As in Experiment 1, we calculated the temporal factor for each participant. Replicating Experiment 1, independent *t*-tests revealed no evidence of temporal clustering in the recall output for the survival condition (mean temporal factor = .498), $t(39) < 1$, or for the control condition, (mean temporal factor = .501), $t(38) < 1$. Not surprisingly, a *t*-test comparing the two conditions failed to reach significance, $t(77) < 1$. The overall correlation between the temporal factor and recall was, once again, near zero (r = -.003). We also calculated the Asch-Ebenholtz index and, again, there was no difference between conditions (M_{Surv} = .48; M_{Pleas} = .48); performance on this index was also around chance. As in Experiment 1, none of these analyses provides support for the hypothesis that temporal information is the driving factor underlying the strong survival effect obtained in recall.

Semantic Clustering. Next, we measured the semantic factor to assess the extent of semantic clustering in the recall output. The results for both the temporal (left panel) and semantic factor (right panel) are displayed in Figure 4. Replicating the pattern from Experiment 1, the semantic factors for both the survival and pleasantness control were above .50 (.545 for survival and .562 for pleasantness). Similarly, one-sample *t*-tests revealed reliable semantic clustering in both the survival condition, $t(39) = 3.81$, $p < .001$, and in the and pleasantness condition, $t(38) = 3.29$, $p < .01$. However, as in Experiment 1, there was no difference in semantic factor across conditions, $t(77) < 1$. Although participants made use of semantic information during recall, there was no evidence of greater reliance on semantic information in the survival condition. We also examined the relationship between clustering and recall. No significant correlations between recall and the semantic factor were detected for either the survival condition, $r = -.137$, $p = .40$, or the pleasantness control, $r = .196$, $p = .23$.

Rating-based Clustering. Finally, following the procedure used in Experiment 1, we calculated the likelihood of transitioning between similarly-rated items during recall. Those data are shown in Table 2. As in Experiment 1, there was little evidence for rating-based clustering overall, nor for enhanced clustering in the survival condition. In fact, as the table shows, those who processed words for pleasantness actually had a slightly higher probability of clustering by relevance. It seems unlikely, then, that the survival advantage in recall is due to differential “fit” between rated items and their respective processing dimensions.

Experiment 3

Although the preceding two experiments provided no evidence for differential encoding of temporal information, clustering analyses are inherently limited because they rely exclusively on successfully recalled items[1]. Experiment 3 was designed to provide a more direct test of temporal order and/or position memory. Instead of having participants freely recall after processing, participants were given back all the studied words (in alphabetical order) and were asked to reconstruct the original presentation order. In principle, a reconstruction of order test enables one to assess the retention of temporal information for each serial position in a way that is unconfounded by differential recall output (although see Neath, 1997). Again, we were mainly interested in whether survival processing would produce better reconstruction of order than a moving control condition.

Method

Participants and apparatus. Participants were eighty undergraduates (29 men and 51 women) who volunteered in exchange for partial course credit. The experiment sessions lasted no longer than 30 minutes, and participants were brought into the testing room in groups of up to four.

Materials and design. To form the study list, twelve target words were randomly chosen from the set of 32 words used in the previous experiments. The reduction in list length was necessary to ensure reasonable levels of reconstruction performance. Two versions of the 12-item list were created, using the same words but in a different random order, to enhance generality; participants were randomly assigned to one of the two versions of the list. A between-subjects design was used with type of processing manipulated between-subjects. Each group (N = 40) was asked to rate each of the 12 words based on the presented scenario and participants were not informed of the purpose of the study. A two-min distractor task followed the rating task, after which participants completed a surprise order reconstruction task. All aspects of the design were held constant except for the rating scenario.

Procedure. Participants were randomly assigned to one of two rating conditions (survival or moving). For the rating task, the scenarios, rating instructions, and procedural characteristics matched those used in Experiment 1. Immediately following the two-min distractor task, participants were handed a single sheet of paper containing the reconstruction of order test. Each of the previously-rated words was printed along the left-hand side of the paper in alphabetical order. On the right-hand side of the paper were a series of 12 horizontal lines. Participants were given five minutes to write down the original order in which the words were presented to them. After five minutes, the recall sheet was collected from each participant.

Results and Discussion

Mean relevance ratings were not significantly different between the survival (2.45) and moving conditions (2.64), $F(1, 78) = 3.21$, $MSE = .22$ $\eta_p^2 = .04$. Mean rating response times in the survival condition (2,254 ms) also did not differ from the moving condition (2,202 ms), $F(1, 78) < 1$. No significant correlation was found between response time and reconstruction performance ($r = .03$).

The proportion of words correctly placed in their original serial positions is shown in Figure 5. A mixed ANOVA was conducted to evaluate reconstruction performance by serial position and processing condition. Overall, there was a significant main effect of serial position, $F(11, 858) = 27.03$, $MSE = 0.12$, $\eta_p^2 = .26$, $p < .0001$, but no main effect of condition $F(1, 78) < 1$. The interaction between serial position and condition also failed to reach significance, $F(11, 858) < 1$.

Given that reconstruction performance was relatively poor overall, we also calculated the mean distance that an item was placed from its correct absolute position. This measure is potentially more sensitive to condition differences because it does not rely on correct performance—e.g., an item might, on average, be placed nearer to its correct position in the survival condition than in the moving condition. Those data are plotted in Figure 6, broken down by serial position and condition; the mean distances that would be expected by chance have been included as well. Except for the middle serial positions, participants were clearly performing above chance levels, but no differences were found between the survival and moving conditions. An overall ANOVA revealed a main effect of serial position, $F(11,858) = 6.89$, $MSE = 4.34$, $\eta_p^2 = .081$, $p < .001$, no main effect of condition, $F(1, 78) < 1$, and no significant interaction between serial position and condition, $F(11,858) < 1$.

Temporal Clustering. It is also possible to use reconstruction of order performance to calculate a temporal factor for each participant—that is, one can use final reconstruction performance as stand-in for recall output. Measured in this way, there was significant use of temporal information for both the survival (.571, $t(39) = 3.70$, $p = .001$) and moving conditions (.565, $t(39) = 3.86$, $p < .001$); there was a significant correlation between the temporal factor and overall reconstruction performance as well ($r = .414$, $p < .001$). However, the temporal factors for the survival and moving conditions did not differ, $t(78) < 1$. The Asch-Ebenholtz index revealed a somewhat different pattern. For this measure, more input-output correspondence was detected for the survival condition

(M_{Surv} = .62, SD = .10) than for the moving condition (M_{Mov} = .56, SD = .11), $t(39)$ = 2.27, p = .03; these data suggest that when participants are explicitly attempting to use temporal order, which a reconstruction of order test requires them to do, prior survival processing may produce a benefit. It is unclear why these results differ from those of the temporal factor, although the temporal factor relies primarily on the temporal distance, defined in terms of the original input order, and distance is essentially ignored in the Asch-Ebenholtz index.[2]

General Discussion

The purpose of the present research was to explore how survival processing affects output strategies during recall as well as general temporal coding. More specifically, we were interested in whether clustering patterns might provide some insight into the proximate mechanisms underlying survival processing advantages. Kahana (1996) and colleagues (e.g., Howard & Kahana, 2002a) have shown that free recall performance is often influenced by temporal, semantic, and source information, as evidenced by clustering of items during recall output. However, in the current experiments we found little evidence for organizational strategies during recall output. For example, no evidence for temporal clustering was found in free recall in either Experiment 1 or 2. Some significant semantic clustering was obtained, but semantic clustering patterns could not account for the survival processing advantages seen in free recall.

We also examined the influence of rating-based clustering in recall to determine whether people tended to recall items together that were rated similarly with respect to the survival or control scenario. Some have argued that survival processing advantages might be due to an inherently greater "fit" (or congruity) between to-be remembered items and survival scenarios (relative to control scenarios; e.g., Butler et al., 2009). If so, then one might anticipate more clustering by rating in the survival condition. As with the temporal and semantic factors, however, we found little evidence for rating-based clustering during recall output and, consequently, no evidence for enhanced rating-based clustering after survival processing.

Overall, the present data provide no direct support for elaboration or "richness of encoding" accounts of survival processing (see Erdfelder & Kroneisen, 2014, for a review). If survival processing induces people to form rich connections among the rated items or other information in memory, then we might have expected to see survival and control differences emerge in the semantic factor analysis. However, there were no semantic clustering differences between survival and controls in either Experiment 1 or 2. Of course, our analysis only considered semantic clustering among list items, so it is possible that recall was driven by rich or elaborative connections between list items and other (non-list) semantic information in memory. We also failed to obtain any evidence of rating-based clustering; presumably if people were forming rich connections between list items and information related to the survival scenario we would have seen some evidence of a rating-based clustering advantage in the survival condition.

One could argue that the present results lack diagnostic value because we are relying primarily on null results. Statistical power might be an issue. However, most studies of temporal contiguity effects report strong effect sizes. Sederberg et al. (2010) did an analysis of temporal and semantic clustering collapsing across nine experiments, including data from 510 participants. They calculated a temporal factor of .614. The effect size was not reported, but it can be calculated using the *t*-test [$t(509) = 31.20$ against .50 chance]: Cohen's $d = 1.38$. Thus, if the effect size for temporal clustering is 1.38 in free recall, then the probability of detecting the effect (power: $1 - \beta$) in our Experiments 1 and 2 with 40 participants in a group was effectively 1.0. With respect to condition differences (survival versus control), the true effect size is unknown. However, if we use the effect sizes in Experiments 1 and 2 for survival versus controls in free recall, which averaged $d = .893$, then our power is once again close to 1.0. We also examined survival versus control after collapsing across our first two experiments—no differences were found for either the temporal factor or the semantic factor (both t-tests were less than 1). Again, it is crucial to note that strong survival processing advantages were present in both Experiments 1 and 2; people recalled more words processed for survival than for moving or pleasantness. While it is not entirely clear what factors produce these differences in recall, the current set of experiments establish that the effect is not driven by differences in temporal or semantic organization strategies during recall output or by the absolute amount of temporal order information that is encoded.

One might argue that the locus of the survival advantage lies in a form of individual-item processing, albeit one that is not tied to the encoding of temporal context. Following Hunt and McDaniel (1993), Nairne (2006) argued that relational processing helps one limit the size of the episodic search set—restricting the search to items that fit a certain criterion—and individual-item processing helps one discriminate items within that established set. Thus, survival processing might lead to the encoding of distinctive trace features that are diagnostic within the search set, but remain insensitive to organizational measures in recall output. Based on an analysis of cumulative recall curves, Burns, Hart, Griffith, & Burns (2013) argued that survival processing does indeed lead to enhanced individual-item processing. However, the nature of the encoded features, and the mechanisms through which those features are accessed during recall, remains unknown.

The fact that significant survival advantages were found in the absence of any obvious temporal clustering has additional implications for models of free recall. As noted previously, temporal clustering is a ubiquitous finding in most free recall experiments. In fact, Healey and Kahana (2014) proposed that a temporally-based organizational strategy is a universal property of memory search, present in all published work on the topic. This conclusion, in turn, has been used to bolster support for models of recall that rely heavily on the establishment of inter-item associations and/or associations with an evolving temporal context (e.g., Polyn et al., 2009). However, again, virtually all existing support for temporal strategies has come from intentional learning experiments employing multiple lists or trials (see Hintzman, 2016). The present experiments found no evidence for temporal clustering, except when people were explicitly instructed to reproduce the original order of presentation (Experiment 3). But we used incidental learning, and retention was assessed after a single list. In some computational models, such as Lehman & Malmberg's (2013) buffer model, temporal clustering is partially driven by buffer operations, as inter-item associations are created when items are simultaneously rehearsed, and those associations produce temporal clustering during recall. These operations would presumably not be active during incidental learning, reducing the likelihood of temporal clustering. It remains to be seen, then, how current temporal context models can explain robust findings such as the survival processing effect that occur in incidental learning environments. One possibility is that the locus of the advantage lies in a recovery stage, after a trace complex has been successfully identified as having occurred in the experimental context (but see Sederberg et al., 2010).

Finally, although the current experiments do not provide definitive evidence in favor of any known proximate mechanism, both experiments produced strong survival processing benefits. From an adaptive perspective, it is sensible to propose that nature evolved memory systems that are selectively "tuned" to the enhancement of fitness, regardless of the proximate mechanisms that underlie those tunings. In this vein, it is important to separate the ultimate evolutionary hypothesis—that memory should show sensitivity to fitness—from the particular proximate mechanisms that may have evolved (see Scott-Phillips, Dickens, & West, 2011). As we have argued in detail elsewhere (Nairne & Pandeirada, 2016), it is quite possible that selective adaptive "tunings" tap familiar mnemonic machinery, such as enhanced encoding of contextual information, to achieve their fitness benefits. Many evolved adaptations work this way, through the co-opting of other domain-general mechanisms (see Burke, 2014). In the present case, it is clear that survival processing advantages cannot be easily attributed to enhanced temporal coding or a better "fit" between the item and a salient survival scenario. Exactly where the locus of the advantage lies—e.g., in some kind of vertical elaboration between the target and other information in memory or in some kind of special processing machinery—remains a topic for future research.

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Footnote

[1]Condition differences can be masked when one looks only at items that have exceeded a recall threshold. To clarify, suppose you own a factory and Employee A produces twice as many finished products as Employee B. You hypothesize that B makes more errors than A which slows him or her down. To test your hypothesis, you analyze their finished products but find no differences in product defects (or the same proportion of errors). Would you be able to reject your original hypothesis? No, because you are only looking at the finished products, which would not be "finished" if they had errors. You need to look at the entire output, which includes the products that never made it to the finished state. Hence, looking only at recalled items, or finished products, suffers from an item selection problem that clouds interpretation.

[2]The Asch-Ebenholtz measure produced a significant survival processing advantage on only one of the two versions of the target list. For List A, no differences were found between the two conditions (M_{Surv} = .60, *SD* = .11, M_{Mov}= .60, *SD* = .09). For List B, the index for survival processing remained the same (M_{Surv} = .60, *SD* = .10), but dropped for the moving condition (M_{Mov}= .53, *SD* = .12). An ANOVA revealed a marginally-significant interaction between list and condition, $F(1, 76) = 3.69$, $\eta_p^2 = .046$, $p = .059$. Thus, the effect of condition is driven primarily by the poor performance in the moving condition with List B.

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Table 1

Probability of Relevant-Rating Transitions Based on Scenario for Experiment 1 (Standard Deviations in Parentheses)

Condition	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5
Moving					
Rating 5	.19 (.28)	.12 (.22)	.16 (.29)	.21 (.30)	.31 (.30)
Rating 4	.17 (.31)	.16 (.30)	.21 (.30)	.23 (.27)	.23 (.33)
Survival					
Rating 5	.27 (.28)	.15 (.27)	.19 (.24)	.16 (.23)	.22 (.25)
Rating 4	.33 (.36)	.15 (.24)	.20 (.28)	.12 (.18)	.20 (.28)

Table 2

Probability for Relevant-Rating Transitions Based on Scenario for Experiment 2 (Standard Deviations in Parentheses)

Condition	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5
Pleasant					
Rating 5	.14 (.25)	.20 (.32)	.18 (.26)	.19 (.27)	.30 (.27)
Rating 4	.13 (.30)	.12 (.23)	.33 (.39)	.21 (.29)	.22 (.29)
Survival					
Rating 5	.22 (.29)	.27 (.33)	.17 (.24)	.17 (.21)	.18 (.21)
Rating 4	.27 (.31)	.23 (.33)	.14 (.30)	.19 (.25)	.18 (.31)

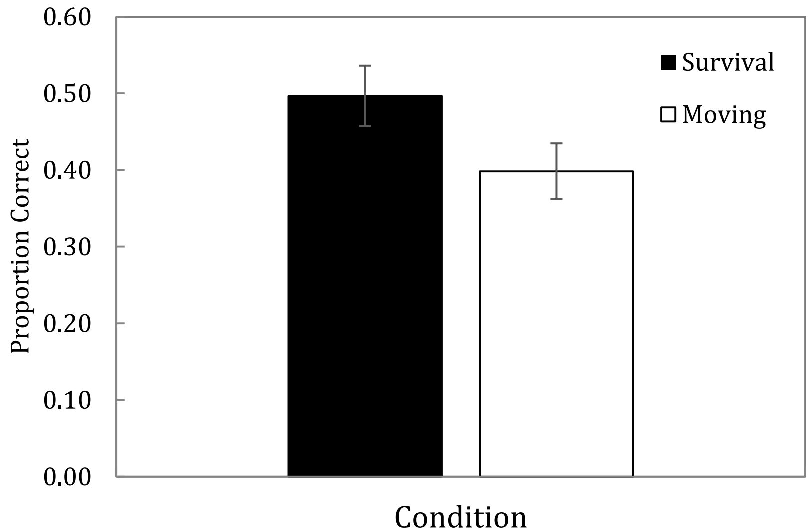

*Figure 1.*Mean proportion of correct recall for each condition in Experiment 1. Error bars represent 95% confidence intervals.

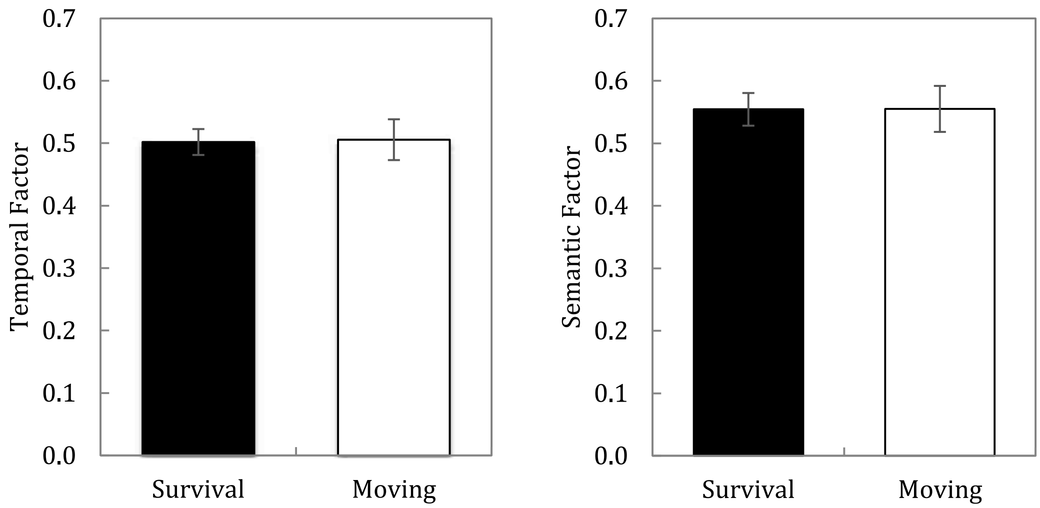

Figure 2. Temporal (left panel) and semantic (right panel) factors for each condition in Experiment 1. Errors bars represent 95% confidence intervals.

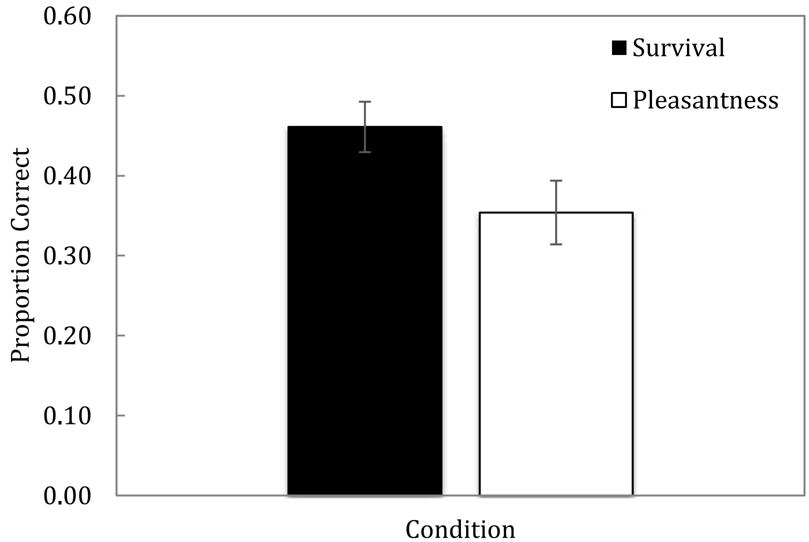

Figure 3. Mean proportion of correct recall for each condition in Experiment 2. Error bars represent 95% confidence intervals.

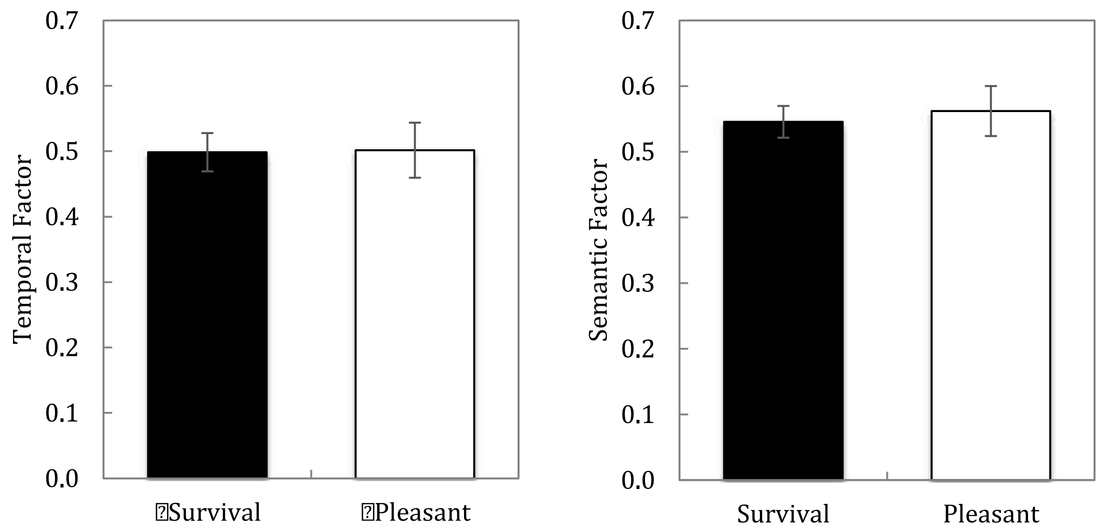

*Figure 4.*Temporal (left panel) and semantic (right panel) factors for Experiment 2. Error bars represent 95% confidence intervals.

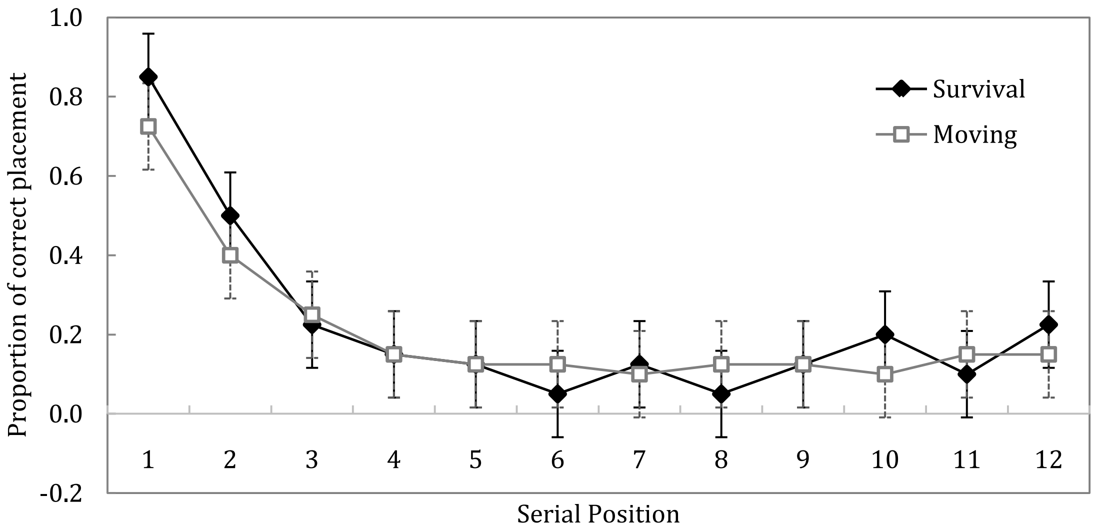

Figure 5. Mean performance for reconstruction performance in Experiment 3, shown as a function of serial position and condition. Error bars represent 95% confidence intervals as per Masson & Loftus (2003).

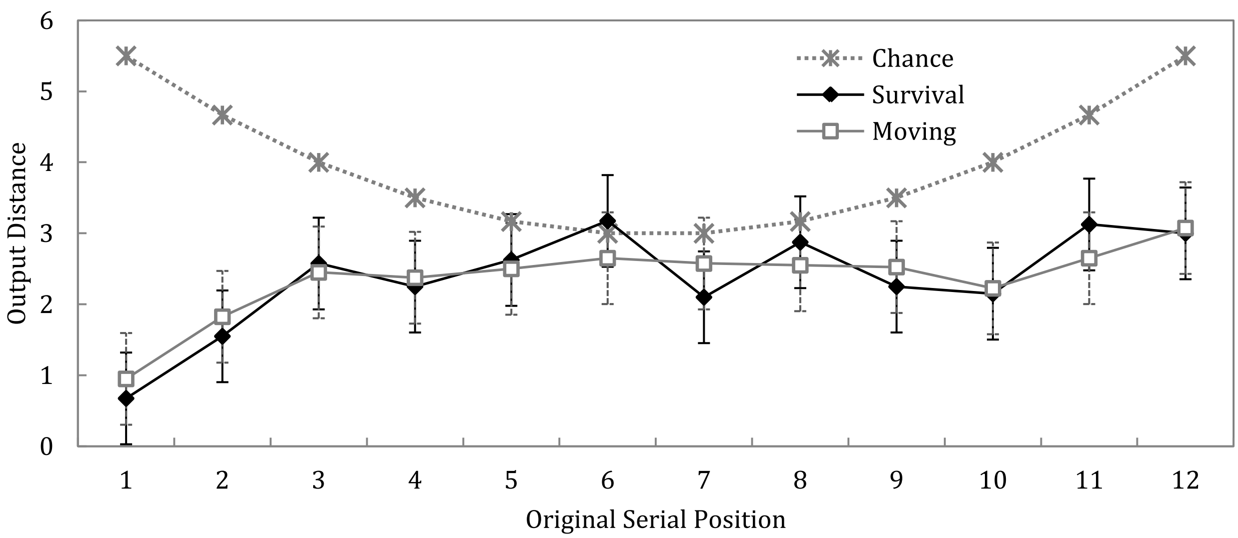

Figure 6. Mean distance from correct position in final reconstruction performance, plotted as a function of serial position and condition. Error bars represent 95% confidence intervals as per Masson & Loftus (2003).