Spatial and Temporal Uncertainty in Long-Term Memory

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Two experiments examined the long-term retention of spatial order information. Both experiments produced substantial evidence of spatial memory, even though the retention test was unexpected, and the patterns of performance mimicked those found in the delayed retention of temporal order. The reconstruction of spatial and temporal position produced bow-shaped serial position curves and error generalization gradients that were roughly symmetrical around the true serial positions. These results, among others, seem to identify general characteristics of the mnemonic processing of dimensions, regardless of the time scales involved (e.g., immediate versus delayed). © 1992 Academic Press, Inc.

Much of the skill in remembering lies in pinpointing the position of items in space and time. Remembering where we parked our car, or whether a particular word was part of a presentation episode, are two concrete examples. For items positioned in time, memory is marked by a lack of precision that can be characterized systematically by the nature of the errors that occur. In immediate memory, for example, when subjects are required to recall items in their correct temporal sequence, response distributions resemble generalization gradients anchored around true serial positions. Response probability peaks at the correct position and declines gradually as distance from the true position increases. These response position functions, known as positional uncertainty gradients, are among the more stable characteristics of immediate memory (e.g., Bjork & Healy, 1974; Estes, 1972; Jahnke, Davis, & Bower, 1989; Lee & Estes, 1977, 1981).

Comparable patterns are obtained in the delayed retention of temporal order. In experiments by Nairne (1990a, 1991), subjects were asked to make pleasantness ratings about five words in each of five lists. After a period of distraction (ranging from 2 to 10 min) a surprise reconstruction test was administered in which list items were presented again, in scrambled fashion, for the reconstruction of temporal order. In each of these experiments, bow-shaped serial position curves were produced—better performance for the first and last items in a list—and the positional uncertainty gradients mimicked the patterns found in immediate serial recall. In fact, it was possible to fit these data quite well with an immediate memory model, the perturbation model of Estes (Estes, 1972; Lee & Estes, 1977, 1981), without any changes in its basic assumptions (see Nairne, 1991, for a detailed description).

The mnemonic characteristics of the spatial case are less well established. In delayed retention, a number of researchers have demonstrated memory for spatial position, ranging from the location of an item on a printed page (Lovelace & Southall, 1983; Rothkopf, 1971; Zechmeister, McKillip, Pasko, & Bespalec, 1975), to the reconstruction of elements of a visual matrix (Mandler, Seegmiller, & Day, 1977; Naveh-Benjamin, 1987), to the relocation of items in a map or naturalistic scene (McNamara, Hardy, & Hirtle, 1989; Pezdek & Evans, 1979). However, none of these reports has attempted direct comparisons with temporal data, nor has any provided systematic analyses of response position gradients.
Only in immediate retention, particularly in work by Healy and her colleagues (e.g., Healy, 1975, 1977; Healy, Cunningham, Gesi, Till, & Bourne, 1991), have direct comparisons of spatial and temporal order recall been attempted (also see Anderson, 1976; Murdock, 1969).

In most of Healy's experiments, subjects have been presented with four list items (usually letters), consecutively, in one of four spatial locations in a display. Depending on the condition, an immediate memory test is given for either the particular items that were presented, the temporal order of occurrence, or the spatial positions in which given items appeared. One important feature of these designs is the control that is administered over the different kinds of mnemonic information at test. If recall of spatial position is required, both the temporal order of occurrence and the identity of the presented items are held constant from trial to trial (e.g., the letter B is always first, K second, etc.), only the spatial location of occurrence is varied. For the recall of temporal order, both the item information and the spatial order of presentation are held constant.

The various conditions have shown markedly different patterns of results. For temporal order recall, as noted above, subjects produce bow-shaped serial position curves and errors that are symmetric around the true serial positions. For instance, if an item was presented in the second serial position but positioned incorrectly at test, subjects are most likely to place it in the first or third serial position. For the recall of spatial position, however, the serial position curves are relatively flat, with little primacy and recency. The response distribution gradients are also flat, at least when measured as variation along a true spatial dimension. Rather than placing items incorrectly in adjacent spatial positions, subjects are likely to place items in the spatial locations of items that occurred adjacent to the presented item in time. These results, among others, led to the conclusion that subjects encode temporal-spatial patterns—where the spatial code is extracted from a primarily temporal representation—as the basis for spatial order recall.

A different pattern of results was obtained in work by Anderson (1976). In her experiments, list items were presented in one of eight spatial locations followed immediately by a reconstruction test for temporal or spatial order. In contrast to Healy's results, subjects produced bow-shaped serial position curves in the spatial as well as the temporal condition; moreover, errors in the spatial condition, as in the temporal condition, tended to cluster around the correct position and regular distance gradients were obtained. Subjects in the Anderson experiments apparently encoded (and used) spatial information in a fashion that was independent of the corresponding temporal code. Although the discrepancies between these results and the work of Healy have been the subject of speculations (see Anderson, 1976; Healy, 1982), no clearcut resolution has emerged.

The present experiments extend the logic of the immediate memory designs to the study of delayed reconstruction of spatial information. The main intent was to provide data on the long-term retention of spatial order and to provide a systematic analysis of the response distribution gradients. Subjects were asked to make pleasantness ratings about words presented in one of several spatial locations on a slide. After a period of distraction, a surprise reconstruction test was given that required subjects to place items in their original spatial positions. Following Healy (1975, 1977), both item and temporal order information were controlled by providing the rated items and information about their temporal order of occurrence at the point of test. Experiment 1 demonstrates that subjects tend to produce a pure form of spatial memory in delayed retention, characterized by bow-shaped serial position curves and symmetrical error generalization gradients.
**Experiment I**

The first experiment explored the retention of spatial position after a delay of approximately 10 min. Subjects were asked to make pleasantness ratings about five words in each of seven lists. Each word was presented visually on a slide in one of five possible spatial locations (each word replaced one of five blank lines). After rating the words in all seven of the lists, subjects engaged in a hidden-figures distractor task for 10 min. They were then handed a response sheet containing seven groups of five response blanks. Above each group of response blanks the rated words were presented again, in a single line, in their original temporal order of presentation. Subjects were told that each group of words was from a single rated list and that the words within the groups were typed in a correct temporal order. The task was to place each word in the spatial position (i.e., blank line) in which it originally had occurred.

**Method**

**Subjects.** Fifty-four undergraduate students participated in partial fulfillment of an introductory psychology requirement. The sessions were conducted with groups of three to 15 subjects.

**Materials and design.** Thirty-five high-frequency (A or AA), high imagery (I > 5.90) nouns, drawn from Paivio, Yuille, and Madigan (1968), were used as stimuli. Each word was printed on a standard slide replacing one of five clearly visible blank lines. The blanks, which formed evenly spaced lines in the center of each slide, served as the spatial position markers. For a given five-word list there were five slides, one word per slide, and each of the five spatial positions was used exactly once per list. The particular combinations of spatial and temporal position (e.g., first item in the fourth blank, second item in the first blank, etc.) were determined randomly for each list. Some care was taken, however, to ensure that a variety of temporal–spatial combinations was used across the lists. Each subject received a total of seven 5-word lists; across subjects, two different temporal–spatial patterns of presentation were used ($N = 27$ for each presentation order). A Kodak Ectographic slide projector with an external timer was used to present the slides. The temporal–spatial patterns, for both presentation conditions, are presented in the Appendix.

**Procedure.** The stimuli were projected onto a white screen with 5 s separating the onset of each slide. After each list of five words, the screen was darkened for an additional 5 s. The experimenter said the word “ready” when the presentation of a new list was about to begin. All subjects were told that they would be making rapid judgments about words by rating each word for pleasantness on a scale from one (Unpleasant) to three (Pleasant). No mention was made about a subsequent memory test or about why the words were grouped in any particular manner. Additionally, it was explained to subjects that in order to facilitate record keeping, they should put their rating in the blank on the answer sheet that corresponded to the word’s spatial position on a particular slide. Rating sheets were provided and explained. Each sheet contained seven rows of five blanks; one row was used for each list.

Following the seventh list, a distractor task was distributed that required finding concealed figures in line drawings; subjects worked on the task for 10 min. When the distractor interval had elapsed, new response sheets were distributed that again contained seven rows of five blanks each. Above each row of blanks, however, the previously rated words were typed in the temporal order in which they had appeared. Subjects were informed fully about the structure of the response sheet and about how the words were organized. Their task was to write the words in the spatial positions (i.e., response lines) that they had originally occupied. Everyone was given as much time as needed.
Results and Discussion

The fact that subjects can retain information about spatial position under truly incidental learning conditions is well established (e.g., Naveh-Benjamin, 1987) and is not of main interest here. Of more direct concern are the reconstruction results when considered as a function of the position of the item along the five-point spatial dimension. From this perspective, the items that appeared in the first (far left) and last (far right) spatial positions, regardless of their temporal orders of occurrence, are considered to be the primary and recency items, respectively. If information about the item’s location along a primarily spatial dimension is encoded, then one would expect better retention of items anchored at the end points of the dimension.

Performance as a function of spatial serial position is shown in the top row of Table 1. The data are reported as mean proportion correct for each of the five spatial positions, collapsed across the seven lists. The results are also collapsed across the two presentation sequences (see Appendix) because this variable produced no significant effects in any of the analyses. The first serial position refers to the spatial location located at the far left side of the slide, and the fifth position signifies the other end point of the display. The overall performance levels establish quite clearly that subjects were capable of retaining information about spatial order of occurrence. Even though the retention test was unexpected, performance averaged nearly 68% correct for the 35 presented items. More importantly, the serial position curve is bow-shaped. There is a small primary effect and a clear recency effect extending over the last two serial positions. An analysis of variance (ANOVA) on the data, performed on the number correct, produced a significant effect of the spatial position variable, \( F(4,212) = 4.97; MSe = 1.13; p < .01 \); a subsequent analysis of trend showed significant linear \( F(1,53) = 5.60; MSe = 1.36 \) and quadratic \( F(1,53) = 9.61; MSe = 1.38 \) components.

Because of the immediate memory results, we also examined how performance varied as a function of the temporal position of the items in the lists. If spatial memory is mediated, in part, by the retention of temporal information (e.g., subjects might remember that the first list item occurred in the third spatial position), then it is reasonable to expect better performance for the items occurring first and last in the list because the first and last temporal positions are known to be retained well. These data are displayed in the bottom row of Table 1. In this case, the data points represent how well subjects were able to retain the spatial positions of items presented first through last in the list, collapsed across list and the various possible spatial positions. Unlike the data in the top row, there was no evidence of primacy and recency. An overall ANOVA on these data produced a significant effect of position \( F(4,212) = 2.71; MSe = 0.92; p < 0.04 \), but no significant quadratic trend \( F(1,53) < 1 \).

The uncertainty gradients. The shapes of the serial position curves suggest that performance in this paradigm probably reflects the encoding of values along a primarily spatial dimension rather than the encoding of temporal–spatial patterns. The uncertainty gradients, which are displayed in Figs. 1 and 2, further support this hypothesis. Figure 1 shows, for each of the five spatial positions, how responses were distributed across spatial position. More concretely, when subjects responded to an item presented originally in a particular spatial position, the gradient shows the proportion of instances in which responses

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<th>TABLE 1</th>
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were placed in each of the possible dimension values. If subjects encoded position values primarily along the spatial dimension, then one would expect errors to cluster in adjacent spatial positions rather than in positions more removed along the dimension. In contrast, Fig. 2 presents the temporally based gradients, which reveal how responses were distributed across items presented sequentially in time. In this case, the far left gradient displays the proportion of instances in which subjects placed the first item in the list in the spatial position of the first item, second item, and so on. In her studies of immediate retention, Healy (e.g., 1982) found orderly temporal gradients in which subjects were likely to place items incorrectly in the spatial positions of items that were closely adjacent in time.

The uncertainty gradients reinforce the idea that subjects responded primarily on the basis of a spatial rather than temporally mediated code. When an error was made, subjects were likely to respond with an adjacent value along the pure spatial dimension rather than with the spatial position of an item close in time. The gradients in Fig. 1 show regular distance effects, whereas the gradients in Fig. 2 are irregular in form. Figure 3 displays these results in another way, by plotting the distance gradients, collapsed across serial position, for both conditions compared to the gradient expected by chance. It is clear that subjects in the spatial condition produced many more adjacent errors than would be expected by chance ($t(53) = 5.00; p < .01$) and fewer responses were placed incorrectly in positions farther removed from the true presented position. When analyzed from the temporal–spatial perspective, adjacent errors were actually less likely to occur than expected by chance.

The two main empirical results—a bow-shaped serial position curve and spatially anchored uncertainty gradients—mirror the patterns found in earlier work on the delayed reconstruction of temporal order (Nairne, 1990a, 1991). In both cases, items at the end points of the encoding dimension

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**Fig. 1.** The response distribution gradients across the spatial dimension. The first through fifth panels refer to items presented originally in the first through fifth spatial positions.

**Fig. 2.** The response distribution gradients for items presented first through last temporally in the lists. For example, the first panel shows the likelihoods that subjects placed the first list item in the spatial positions of the first through last items in the lists.
Fig. 3. Error distance gradients, collapsed across serial position, for the data of Experiment 1. The solid line shows the error gradient expected by chance.

show a relative retention advantage and errors cluster around the true dimensional value. One way to interpret these results is to assume that subjects encode position information that diffuses, in accordance with a perturbation process, with the passage of time. Estes (1972) has argued that such a diffusion process creates uncertainty about the originally encoded value; further, this uncertainty can be reduced, at least initially, for items at the end points of the dimension. More precision is maintained about the end values because the diffusion process at this point can operate only in one direction, inward toward intermediate values. Boundaries at the end points of the dimension cause inertia in the diffusion process and a relative retention advantage. The details of the diffusion process are beyond the scope of the present work, but detailed descriptions can be found elsewhere (e.g., Estes, 1972; Healy, Fendrich, Cunningham, & Till, 1987; Lee & Estes, 1977; Nairne, 1991).

**Experiment 2**

The primary function of our second experiment was to provide a more direct comparison of spatial and temporal order retention. One of the advantages of our procedure is that it allows one to choose, based on the construction of the test sheet, which kind of mnemonic information to assess at test. After giving pleasantness ratings for five words in each of seven lists, subjects in Experiment 2 were required to reconstruct either the spatial or the temporal order in which items had appeared. The spatial case was a direct replication of Experiment 1; subjects were provided with the rated words at test, in their temporal order of appearance, with the requirement of placing them in their proper spatial positions. In the temporal condition, the rated words were presented in their correct spatial positions, and subjects were required to reconstruct the original temporal sequence. Based on previous findings, we expected to find bow-shaped serial position functions and the appropriate uncertainty gradients in each case.

In addition to manipulating the task requirements at test, Experiment 2 was also designed to explore the effects of presentation modality on the long-term reconstruction of order information. For both the temporal and spatial conditions, the stimulus items were presented visually on slides, in one of the various spatial positions. For half of the subjects, however, in addition to the visual presentation, the stimulus words were also spoken aloud by the experimenter. There is a great deal of evidence in the immediate memory literature (see Nairne, 1990b; Penney, 1989, for reviews) indicating that modality plays an important role in retention. Specifically, auditory input especially helps the retention of temporal order information, perhaps because temporal information is more precisely encoded for auditory events (e.g., Gathercole & Conway, 1988; Glenberg & Swanson, 1986; Metcalfe, Glavanov, & Murdock, 1981).

**Method**

**Subjects.** The subjects were 160 undergraduates who participated in partial fulfillment of an introductory psychology requirement. The sessions were once again conducted in groups.
Materials and Design. In nearly all respects, Experiment 2 was a direct replication of the first experiment. Exactly the same stimulus materials were used and the lists were composed of the same temporal–spatial patterns. During presentation, however, half of the subjects \(N = 80\) received additional auditory input. The experimenter spoke each of the words aloud, in as clear a voice as possible, concurrent with the appearance of each slide. The remaining 80 subjects received only visual input, as in the previous experiment. The other important manipulation involved the construction of the reconstruction test sheet. For each presentation condition, half of the subjects received the words at test, grouped as lists, in their appropriate temporal positions. For the remaining subjects, the words were typed above the response blanks in their appropriate spatial positions. Once again, following the seventh list, a hidden-figures distractor task was administered for 10 min prior to presentation of the surprise retention test.

Procedure. Subjects once again made pleasantness ratings about five words in each of seven lists. No information was given about the reasons for the ratings or about why the words were presented in this fashion. Moreover, all subjects were instructed, as in Experiment 1, to write their rating response in the blank on their answer sheet that corresponded to the spatial position of the presented item. At test, the structure of the response sheet was fully explained. Subjects in the spatial conditions (aloud and silent) were told that the rated words were presented grouped by list, and in their original temporal order of appearance; their task was to place the items in their proper spatial positions. Subjects in the temporal conditions (aloud and silent) were told that the grouped words were typed in their proper lists and in the spatial positions occupied at presentation; their task was to write the words in their original temporal sequence. All subjects were given as much time as needed to complete the tasks.

Results and Discussion

For several of the comparisons that motivated the present experiment, it was not possible to make any clearcut predictions. For example, although Healy (1977) found that spatial order recall was superior to temporal order recall in many conditions, no comparable data are available when the retention test is delayed. Moreover, whereas the effects of modality are robust and well replicated in immediate recall, the effects of modality on the long-term retention of order information are not well established. The only firm prediction deals with the nature of the serial position curves for the spatial and temporal groups. Based on the results of Experiment 1 and previous work on long-term temporal memory by Nairne (1990a, 1991), bow-shaped serial position curves were the anticipated result.

The results from the four conditions of interest are displayed in Fig. 4. The data are shown as a function of serial position, but this variable carries different meanings for the two retention conditions. For the spatial data, serial position refers to the spatial dimension (position one is the far left spa-
tial position); for the temporal condition, the data point above the first serial position refers to how well subjects were able to reconstitute the temporal position of the first item in the list. An overall ANOVA on these data, performed on the number correct, revealed reliable effects of retention condition \(F(1,156) = 109.39; MS_e = 9.03; p < .01\) and serial position \(F(4,624) = 19.39; MS_e = 1.02; p < .01\). The only other reliable effect in the analysis was an interaction of retention condition by serial position \(F(4,624) = 8.38; MS_e = 1.02; p < .01\). The other F ratios were all less than one.

Of immediate concern are the results of the spatial order condition, considered irrespective of the modality of presentation. Clearly, these results replicate the pattern found in Experiment 1. The serial position curve is not flat, but rather is bow-shaped with pronounced primacy and recency effects. The pattern is quite robust in Experiment 2 and, as in Experiment 1, the recency effect appears to extend across the last several serial positions. A similar replication is apparent for the spatial uncertainty gradients, which are shown in Fig. 5. Once again, these gradients, which are collapsed across modality, show orderly distance effects along the spatial dimension. When an error occurred, subjects were likely to position the incorrect response in a spatial location near the correct position. At least for the long-term reconstruction of spatial order, subjects appear to rely primarily on the encoding of position along a purely spatial dimension. It is also quite clear that the modality of presentation had no effect on reconstruction performance.

Performance in the temporal groups was quite a bit lower and differs in some respects from earlier work (Nairne, 1990a, 1991). There are pronounced primacy effects, but these conditions failed to show robust recency effects of the type documented in the earlier work. It is possible that requiring subjects to place their original rating responses in the corresponding spatial positions may have contributed to the pattern. The task demands required subjects to attend to spatial position, and this procedure may have led to an overshadowing of the temporal dimension. However, subjects were performing at levels well above chance, and the serial position functions are by no means flat. Figure 6 shows the uncertainty gradients for the temporal condition; each curve represents how responses were distributed for an item presented in a particular temporal position, across the five possible temporal positions. The temporal uncertainty gradients are flatter than the spatial gradients, due to the lower performance levels, but they still show a characteristic form. Figure 7 shows the distance gradients collapsed across position, for both the spatial and temporal conditions, compared to chance. For both the spatial \(t(79) = 10.34; p < .01\) and the temporal \(t(79) = 4.55; p < .01\) groups, more adjacent errors were recorded than were expected by chance.

There was no evidence in Experiment 2

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**Fig. 5.** The response distribution gradients across the spatial dimension in Experiment 2. The first through fifth panels refer to items presented originally in the first through fifth spatial positions.
to support a role for presentation modality in the long-term reconstruction of temporal order. In immediate memory, visual presentation with concurrent auditory input produces enhanced recency relative to visual alone (i.e., the modality effect) and, in some cases, better overall ordering performance (Metcalf et al., 1981); no similar trends were evident here. It is of interest to note that Gathercole and Conway (1988) found persistent auditory advantages in long-term recognition memory, but these effects presumably reflect differences in item availability rather than in the kind of pure position memory tested here (also see Geiselman & Bjork, 1980). Although firm conclusions are hard to draw from a single experiment, these data suggest that modality of presentation may play a limited role when the retention test is delayed.

**General Discussion**

The primary intent of these experiments was to investigate the long-term reconstruction of spatial order and, in particular, to note how responses were distributed across the values of the spatial dimension at test. The logic of the designs followed Healy (1975, 1977), in that an effort was made to control for the various kinds of mnemonic information that are available to guide performance. In the spatial conditions, subjects were provided with both the rated items and their temporal sequence of occurrence at test, thereby allowing for a relatively unconfounded examination of spatial order recall. In most retrieval contexts, where subjects are simply asked to recall presented items, it can be difficult to disentangle the relative contributions of item and order information to overall performance (see Nairne, Riegler, & Serra, 1991, for a further discussion of this point).

Both experiments produced strong evidence of spatial memory, and the response distributions resembled generalization gradients anchored around positions on the spatial dimension. The serial position curves were bow-shaped, with pronounced primacy and recency effects. Given that subjects encoded and accessed values along a spatial dimension, then it is reasonable to anticipate better retention of items at the end points of the encoding dimension. Items at the end points can produce more stable representations because precision can be lost in only one direction, in-

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**Fig. 6.** The response distribution gradients across the temporal dimension in Experiment 2. The first through fifth panels refer to items presented originally in the first through fifth temporal positions.

**Fig. 7.** Error distance gradients, collapsed across serial position, for the conditions of Experiment 2. The solid line shows the error gradient expected by chance.
ward toward intermediate values. A quite different pattern of results is often obtained in the immediate retention of spatial order, presumably because subjects sometimes encode and utilize more complex temporal-spatial patterns. Analysis of the response position gradients in Experiment 1 provided no support for such a strategy under the present conditions.

Although subjects did not seem to use a temporally mediated code during spatial retention in our experiments, such a strategy may be viable under different circumstances. The temporal and spatial dimensions were uncorrelated in our lists, which may be one determining factor. Across the different presentation orders, the correlation of the temporal and spatial values defined by each presentation combination was only $-0.04$; therefore, knowledge about a particular temporal or spatial position provided little, if any, information about the position on the corresponding dimension. Moreover, the retention test was unexpected in our experiments, which may have reduced the likelihood of strategic encoding. In immediate memory experiments, subjects are expecting the test and, consequently, may seek to sample a broader range of coding configurations. Finally, because short-term memory plays an important role in the retention of temporal sequences (e.g., the interpretation of spoken language), the temporal aspects of experience may often play an obligatory role when this system is tapped (see Healy, 1982).

It is our belief that the spatial memory results of the present experiments reflect the more general case. As just noted, the short-term memory system is designed to solve a particular class of problems, especially the production and interpretation of spoken language, and therefore is likely to reflect somewhat idiosyncratic strategies. Under incidental learning situations of the type tested here, subjects’ retention performance is clearly tied closely to the particulars of the encoding dimension. The shapes of the serial position curves and uncertainty gradients indicate that subjects can potentially encode values along a variety of dimensions at input—in the present case space and time—and each can be characterized systematically by the errors that occur. Depending on the requirements of the test, these encoded values are accessed and combined, where necessary, during retrieval.

The present results seem to suggest that long-term retention of position information will exhibit comparable performance patterns across a wide range of dimensions. Although features of the temporal versus spatial comparison of Experiment 2 remain unexplained (e.g., the relative amounts of primacy and recency), the presence of bow-shaped curves and symmetrical generalization gradients appear to be general mnemonic features of processing values along dimensions, irrespective of the particular dimensions involved. In this vein, Estes (1987) showed that immediate retention of the heights of bars produced patterns similar to those obtained in the present experiments. Subjects, irrespective of the temporal order of presentation, were likely to produce errors corresponding to adjacent bar heights and showed better retention of values that marked the end points of the bar height dimension. In addition, Nairne (1991) demonstrated the same trends for multiple temporal dimensions. Long-term memories for list and with-list position both showed bow-shaped serial position curves and error generalization gradients that were roughly symmetrical around the true serial positions.

Understanding the functional rules governing the retention of temporal and spatial position (and other dimensions as well) is clearly one of the more important tasks facing the memory researcher. Forgetting an item from a memory list, regardless of the retention test employed, involves not the loss of the item itself, but rather its position in some temporal–spatial context. (You do not forget the word “elephant,” only that it
occurred on the memory list.) The fact that the retention of spatial and temporal position seem to show many of the same characteristics is encouraging to those seeking to understand and predict the dynamics of forgetting.

APPENDIX: THE TEMPORAL–SPATIAL PATTERNS FOR THE TWO PRESENTATION CONDITIONS

The spatial positions are shown horizontally and the temporal positions are shown vertically. For example, in the first pattern of Group A, the subject would see the first list item in the fourth spatial position, the second list item in the first spatial position, etc.

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