Temporal–spatial memory: retrieval of spatial information does not reduce recency

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Abstract

Factors influencing the shape of serial position curves in non-verbal serial short-term memory were examined, using a task testing memory for the position of dots. Similar recency slopes were found when both position and order were recalled (Experiment 1A) and when order only was required (Experiment 1B). This observation was confirmed and tested further in conditions requiring the same encoding but different amounts of spatial information at retrieval (Experiment 2). However, Experiment 2 also revealed an effect of spatial information retrieval on the overall level of memory for recency items. Overall, the results indicate that spatial items produce bow-shaped serial positions curves in tasks requiring the maintenance of order information and that recency is affected by the demand on spatial information retrieval in terms of the overall level of performance but not in terms of the recency slope. These findings are contrary to what is found in the literature on serial verbal recall when both item and order information are required. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Curves depicting the pattern of error in a test of memory for serial order tend to be bowed, exhibiting performance that is markedly better over the first few items (the primacy effect), and modestly better over the last few items (the recency effect), than for the intervening items (for an overview see, Crowder, 1976; Greene, 1992). Classically, this pattern of results was established using relatively short lists of verbal items. Recently, emerging evidence has suggested that this pattern extends beyond verbal tasks to spatial tasks also (Avons, 1998; Jones, Farrand, Stuart, & Morris, 1995; Parmentier & Jones, 2000). However, by comparison with verbal tasks, our understanding of spatial short-term memory is impoverished. The current paper is concerned with exploring the role that memory for item information, as opposed to memory for order, plays in shaping serial position effects in visuo-spatial short-term memory. We exclude from our analysis changes in the visual identity of the to-be-remembered material in contrast to other studies (e.g. Avons, 1998).

Diverging evidence has been reported with regard to the shape of serial position curves for verbal and non-verbal stimuli. Generally, bow-shaped serial position curves have been observed in verbal studies (e.g. Bjork & Healy, 1974; Caplan, Rochon, & Waters, 1992; Conrad, 1965; Healy, 1974; Henson, Norris, Page, & Baddleley, 1996), but recency without primacy was found for non-verbal stimuli. This led some authors to propose a functional distinction between verbal and visuo-spatial mental representations (e.g. Broadbent & Broadbent, 1981). As Jones et al. (1995) pointed out however, studies showing only recency are tests of recognition memory and do not require participants to maintain any order information, only item information (Broadbent & Broadbent, 1981; Korsnes, 1995; Neath, 1993; Phillips & Christie, 1977; Walker, Hitch, & Duroe, 1993; Wright, Santiago, Sands, Kendrick, & Cook, 1985). Tests of recall of order, without recognition, using the position of visual items in space, showed marked bowing of the serial position curve (Jones et al., 1995; Smyth & Scholey, 1996). This conclusion was recently reinforced in tests of recall of novel visual patterns (Avons, 1998; Avons & Mason, 1999). When verbal and non-verbal tasks are equated in terms of task demand characteristics, verbal and non-verbal serial curves were of similar shape. Moreover, interference in serial memory occurs irrespective of the type of stimuli used in the primary and secondary tasks (verbal or non-verbal, see Jones et al., 1995). These results certainly call into question the assumption of separate memory representations for verbal and non-verbal stimuli based on the shape of serial position curves, and further, the validity of such a distinction in models of memory (Jones, 1993; Jones et al., 1995; Avons & Mason, 1999).

Studies involving memory for sequences of verbal material suggest that the balance of emphasis on order as against item information has important consequences for serial recall performance. Re-presenting test items simultaneously at recall so that only order information has to be retrieved (e.g. Battacchi, Pelamatti, & Umiltà, 1990), results in verbal serial position curves which exhibit both marked primacy and recency. However, requiring participants to recall both item and order information results in a serial position curve lacking serial position effects compared to when order only has to be recalled (Bjork & Healy, 1974; Fuchs, 1969; Healy, 1974). These differences in
overall shape are interpreted conventionally as arising as a result of differences in the encoding of item and order information (Healy, 1974). Further, it has been suggested that item and order information can be encoded and stored independently of each other, and that item and order errors are dependent upon different processes (for example see, Bjork & Healy, 1974; Detterman & Brown, 1974; Devine, Burke, & Rohack, 1979; Donaldson & Glathe, 1969; Estes, 1972; Healy, 1974, 1982; Rohrman & Jahnke, 1965; Zimmerman & Underwood, 1968).

Within this paper, the distinction between item and order information is applied to the recall of spatial material. In verbal serial memory tasks, item information corresponds to the identity of the to-be-remembered stimuli. In non-verbal serial recall tasks however, item information can take one of several forms. Sequences of events may change both in visual identity and spatial location, in visual identity alone, or in spatial location alone. One of the key issues is whether spatial location acts similarly to what is described in verbal studies as item information. Serial position curves have been reported in tasks involving memory for items’ visual identity, as well as in tasks focusing on items’ spatial location. That is, serial position curves for abstract visual stimuli were shown to exhibit primacy and recency effects in an order reconstruction task requiring the maintenance of both visual identity and order information, but not in a recognition task involving visual identity information only (Avons, 1998; Avons & Mason, 1999). In other settings, primacy and recency effects were observed for items presented sequentially that were visually identical and differed only in their spatial locations (Farrand & Jones, 1996; Jones et al., 1995; Smyth & Scholey, 1996; see also Parmentier & Jones, 2000, for corresponding discussion of the auditory modality).

The distinction between visual and spatial information in non-verbal serial recall is not well established. A key question addressed in this study is whether spatial information per se, independent of visual information, can be considered as equivalent to what is described as item information in verbal studies. If it is equivalent, then serial position curves for spatial stimuli would exhibit primacy and recency when mostly order information was to be recalled. Whereas reduced recency would result with an increased emphasis on the recall of spatial information. This pattern of results would resemble the effects found for order versus item information in verbal studies (Healy, 1974, 1975, 1977; Healy, Cunningham, Gesi, Till, & Bourne, 1991). When tested using stimuli differing from each other both in terms of their visual features and their spatial locations, recency was not suppressed when spatial rather than order information was required. Indeed, Anderson (1976) found bow-shaped serial position curves for words, pictures and line drawings, both when participants were required to recall items on the basis of their order of presentation and on the basis of their spatial location. As pointed out earlier however, no direct test has examined reductions in recency that arise when an increased emphasis is placed on the recall of spatial information when the stimuli differ only in spatial location, but share the same visual features.

In the present study, we investigated the role of spatial and order information in a task requiring the reconstruction of order using a method similar to that of Jones et al. (1995). Items differed only by their order and spatial location; they were identical visually. It was hypothesized that if spatial location is functionally equivalent to
what is referred to as item information in verbal tasks, then testing for retrieval of order information only on a temporal–spatial task should lead to serial position curves like those for verbal material (Battacchi et al., 1990; Bjork & Healy, 1974; Healy, 1974, 1982). Specifically, spatial serial position curves that exhibit marked primacy and recency should arise when only order information is recalled. However, recency should be somewhat reduced when both spatial location and order information are required. Serial position curves are described in conditions in which order and spatial information are required (Experiment 1A), and in circumstances in which order only has to be remembered (Experiment 1B). The effect of increasing the demand on spatial information at retrieval is then evaluated (Experiment 2). Two main predictions were made. First, bow-shaped curves should be observed for spatial location information, providing additional evidence to the conclusions of Jones et al. (1995). Second, if spatial location can be considered as item information in tasks in which visual identity is identical for all items, the recency slope should become flatter as the task requires more spatial information to be retrieved, following the observations reported in verbal studies with regards to the item-order dissociation (Bjork & Healy, 1974; Estes, 1972; Fuchs, 1969; Healy, 1974, 1982).

2. Experiment 1A

The spatial task adopted for this experimental series was similar to the one previously used by Jones et al. (1995), and involved testing the recall of seven dots presented one at a time in different spatial locations upon a two-dimensional display. After the presentation of the last dot of the to-be-remembered sequence, participants were expected to hold the sequence in memory until prompted to retrieve the sequence. A distinctive feature of the present version of Jones et al.’s (1995) task was that at retrieval participants were required to mark the spatial position on the screen where each item was presented, and in the order of presentation. The task therefore was one that obliged participants to recall the spatial location of the item as well as its order in the sequence. It was hypothesized that this requirement to recall both spatial and order information would result in serial position curves that exhibit marked primacy and some recency, similar in shape to those typically reported for visually presented verbal material (e.g. Bjork & Healy, 1974; Healy, 1974). In designing the task several precautions were taken to minimize the likelihood that the spatial information could be verbally recoded. The spatial locations of the dots varied across trials and the positional uncertainty of the presented stimuli was high so that items could not be recoded using a simple set of verbal labels. Furthermore, other visual cues that might lead to verbal recoding, such as grid lines, were excluded.

2.1. Method

2.1.1. Subjects

Eighteen male and female undergraduates, reporting normal or corrected-to-normal vision, volunteered to participate in this experiment, and were paid an honorarium.
2.1.2. Materials and procedure

All materials were presented by an Apple Macintosh LC II computer using SuperCard programs. The participant interacted with the computer using a mouse as a pointing device. Written instructions were presented explaining the nature of the task and emphasizing the need for recall in the correct serial order. The experimental procedure was self-paced; participants used the mouse to click on the image of a green ‘button’ to begin each trial.

A sequence of seven black dots 0.5 cm in diameter was presented randomly within a 350×350 matrix (taking up a 16.5×16.5 cm² area of the screen). During presentation of the stimulus sequence only one dot was present on the screen at any time. The dots were presented for one second with an inter-stimulus-interval of a second, prior to the presentation of the next dot, during which the screen was blank. The position of each dot was constrained by the rule that if any randomly generated dot was to appear closer than 60 units (2 cm) in either axis of the matrix to another dot, a different set of dot co-ordinates would be generated automatically by the software. After presentation of the seventh dot, the screen went completely blank for ten seconds during which the participant was expected to retain the sequence. After this interval a vertical display consisting of seven panels was presented to the right of the matrix. This prompted the participant to begin retrieval. Responses were recorded by using the mouse to point and mark the position on the screen in which the participant judged that each item was presented in the order in which they were presented. Marking was achieved by moving the cursor on the screen with the mouse and pressing the button on the mouse, upon which the computer returned a dot of the same dimensions as an item in the stimulus set. As the position of each dot was marked by the participant in this way, a sector on the seven-panel vertical display was blanked in order to provide the participant with an indication of how many dots were left. This was done to avoid omissions, and so to make the present task more comparable to the task used in later experiments, the nature of which made participants aware of the number of items selected as they responded. Participants were instructed to recall as quickly and accurately as possible and informed that once an item had been reported it could not be altered. Prior to the beginning of the experiment proper, participants had been practiced (for six trials) in the use of the mouse to mark the location of their responses. Participants undertook 16 trials which resulted in an experimental session lasting approximately 20 min. The experimenter remained present throughout to ensure compliance with the instructions.

2.2. Results

Scoring was carried out in terms of the ‘city block’ distance of the center of the response from the center of the corresponding target item (see Farrand & Jones, 1996). For example, the first response was measured in relation to the position of presentation of the first item in the stimulus sequence, and so on. Scores were based upon the sum of the deviation based on units of azimuth and elevation within the 350×350 matrix of the screen.
Analysis of variance performed on the city block error data revealed a highly significant effect of serial position, $F(6, 102) = 18.99$, MSE = 666.36, $P < 0.0001$ (see Fig. 1). Primacy and recency were observed, as revealed by a trend analysis showing significant linear, $F(6, 102) = 61.51$, $P < 0.0001$, and quadratic components, $F(6, 102) = 50.33$, $P < 0.0001$.

2.3. Discussion

Requiring the recall of both spatial and temporal information results in a serial position curve for this temporal–spatial task presenting marked primacy coupled with relatively little recency. In this respect, this serial position curve resembles those previously obtained when recalling verbal item and order information for lists presented visually (e.g. Healy, 1974). The pattern of results obtained in Experiment 1A therefore suggests that when demands are made upon spatial location and order information, the shape of the serial position curve is similar to that found in verbal studies when item and order information are required. As a corollary to this finding one might suggest that if participants are given a task in which they are required to recall the order of items in a temporal–spatial task without additionally having to recall spatial information, then serial position curves will resemble those obtained in conditions under which only the order of items in verbal sequences is required, that is

Fig. 1. Experiment 1A. City block error with sequences of seven items (nominal units).
have the characteristics of marked recency (Battacchi et al., 1990; Healy, 1974). This possibility is examined in Experiment 1B.

3. Experiment 1B

The main feature of Experiment 1B is that the task requires the retrieval of order information without item information. This was achieved by re-presenting simultaneously, at the end of the retention interval, the to-be-remembered items in their original spatial locations and asking the participant to mark them in the order in which they were presented. This method is sometimes described as order reconstruction and presented as a good selective measure of order memory (Nairne, 1990; Nairne, Whiteman, & Kelley, 1999). Unlike Experiment 1A, therefore, the participant was required to recall the order of presentation of the items without additionally recalling their spatial locations. In this respect, the present experiment mimics the task used by Jones et al. (1995), and Farrand and Jones (1996), and it is therefore expected that serial position effects such as those observed in these studies should be replicated.

A direct comparison of the data in the Experiment reported below with that of Experiment 1A should provide useful information regarding the role of the item-order balance in shaping serial position curves for visuo-spatial material. If spatial information acts as item information in the verbal domain, one would predict that the recency slope would be steeper when mostly order is to be recalled. On the contrary, if similar recency slopes were found, one would conclude that spatial information in a visuo-spatial serial memory task is not equivalent to item information in a verbal serial memory task.

3.1. Method

3.1.1. Subjects

Eighteen male and female undergraduates, reporting normal or corrected-to-normal vision, volunteered to participate in this experiment, and were paid an honorarium.

3.1.2. Materials and procedure

Materials were as for Experiment 1A. The procedure was generally similar to Experiment 1A, however participants were required to adopt a different method of retrieval. At retrieval, the to-be-remembered items were re-presented simultaneously in their original spatial locations as dots. Retrieval was achieved by using a mouse to locate and click on each of the dots in the order in which they were presented. When each dot was selected, the shading within the circle lightened appreciably, so that the participant was aware that the response had been registered by the computer and could discern those locations already selected. The seven-panel vertical display used in Experiment 1A was therefore not used in the
present experiment. Participants were instructed to respond as quickly and accurately as possible, without prevarication, and were informed that once a response had been made it could not be altered. The responses were scored automatically with respect to serial position: Only a correct response in the appropriate serial order was regarded as correct. Prior to the beginning of the experiment proper, participants had been practiced (for six trials) in the use of the mouse to locate and click on each of the dots in the order in which they were presented. Participants undertook 16 trials which resulted in an experimental session lasting approximately 20 min. The experimenter remained present throughout to ensure compliance to the instructions.

3.2. Results

An ANOVA performed on the serial order error revealed a highly significant effect of serial position, $F(6, 102) = 10.18$, MSE = 2.57, $P < 0.0001$. As can be seen in Fig. 2, the serial position curve exhibits primacy and recency. This observation was confirmed by a trend analysis, revealing significant linear, $F(1, 102) = 7.12$, $P < 0.01$, and quadratic components, $F(1, 102) = 49.82$, $P < 0.0001$.

To allow a comparison between the different measures of performance used in Experiments 1A and 1B, the raw data were converted into a standardized z score

![Fig. 2. Experiment 1B. Serial order error with sequences of seven items. Maximum error = 16.](image-url)
(calculated on performance across all subjects and serial positions for each experiment separately) and a one-between (recall method: item-and-order versus order) and one-within (serial position) participants ANOVA was performed. The mean and standard deviation used in the computation of the \( z \) score were 146.34 and 41.17, respectively, for Experiment 1A, and 5.8 and 2.58 for Experiment 1B. The main effect of recall method failed to reach significance, \( F(1, 34) = 0.07, \) MSE = 2.86, \( P > 0.05 \). However both the effect of serial position, \( F(6, 204) = 26.36, \) MSE = 0.37, \( P < 0.0001 \), and the interaction between serial position and recall method, \( F(6, 204) = 2.33, \) MSE = 0.37, \( P < 0.05 \), were significant. As can been seen from Fig. 3, the serial position curves seem to differ in terms of their overall shape. However, trend analysis revealed that they did not differ in terms of their quadratic component, \( F(1, 34) < 1, \) MSE = 0.6, \( P > 0.85 \). To analyze the effect of the task on recency, performance on positions 6 and 7 was analyzed using a 2 (recall method) × 2 (positions 6 & 7) ANOVA. The effect of recall method appeared marginally significant, \( F(1, 34) = 3.7, \) MSE = 0.92, \( P = 0.06 \), whereas the effect of serial position clearly was, \( F(1, 34) = 17.49, \) MSE = 0.42, \( P < 0.0005 \). Most importantly, however, no interaction between condition and serial position was observed, \( F(1, 34) < 1, \) MSE = 0.42, \( P > 0.1 \), indicating that the recency slopes were similar for both recall method conditions.

Fig. 3. Experiments 1A and 1B. Standardized \( z \) scores for the data obtained in Experiments 1A and 1B.
3.3. Discussion

The results obtained in Experiment 1B echo those previously obtained by Jones et al. (1995): Recalling the order in which items appear but not their specific spatial location results in serial position curves that exhibit marked primacy and recency. This serial position curve bears a strong resemblance to those obtained on tasks that require the recall of only order information, whether these tasks presented verbal stimuli (Battacchi et al., 1990; Healy, 1974, 1982) or visual abstract patterns (Avons, 1998; Avons & Mason, 1999). Generally the pattern of results obtained in Experiments 1A and 1B differ from verbal studies (e.g. Bjork & Healy, 1974; Healy, 1974) as the recency slope did not become flatter when spatial information was required.

The conclusion is perhaps not so clear-cut, however, since Experiments 1A and 1B imposed different constrains on retrieval mechanisms. In Experiment 1A, participants must retrieve both the order and the location of each item, whereas in Experiment 1B, locations are re-presented to them and only order must be retrieved. Furthermore, the two tasks might differ in terms of output interference. In Experiment 1A, recency items are recalled after all preceding items have been recalled, subjecting the memory representation for the last items to some output interference. In Experiment 1B, the re-presentation of the items at recall might allow participants to spot the last items and reinforce their memory representations for these items before they start retrieving the preceding items. Such potential retrieval factors should be neutralized before any conclusion regarding the effect of the location-order balance on recency could be reached. It seems necessary to use a task allowing us to vary the location-order information ratio while keeping encoding and retrieval requirements similar (locations and order). Experiment 2 meets this requirement.

Additionally, one possible shortcoming of Experiments 1A and 1B is the use of different scoring techniques. The city block error measured in Experiment 1A possibly confounds spatial and order errors. That is, error can arise either because the participant is recalling the correct item in the sequence but with some error in its spatial location, recalling an incorrect item, or a combination of these two. Ideally, temporal and spatial errors should be unraveled and analyzed separately. This was not possible in the present setting however, since it was not possible to identify items unambiguously. Since all dots were visually identical, it was not possible to measure the distance error and temporal error for each item. However, it is reasonable to argue that a confusion of temporal and spatial errors is unlikely to have affected the degree of recency reported in Experiments 1A and 1B. Indeed, if differences in the scoring procedure had affected the serial position curves, it would be plausible to expect differences in levels of performance to be evident throughout the serial position curve, not only in recency. Nevertheless, empirical evidence confirming the role of spatial location in decreasing the level of recall of recency items should clarify this issue.

Finally, although this is unlikely, one may wonder whether the use of the seven-panel vertical display in Experiment 1A and not in Experiment 1B could have produced some visual interference at recall. This methodological discrepancy was eliminated in the next experiment.
In Experiment 2, the effect of varying the demand on spatial location information at retrieval was investigated using a task keeping encoding requirements constant.

4. Experiment 2

In Experiment 2 either 7, 9 or 12 dots were presented simultaneously prior to recall. In all conditions, participants were required to recall the seven to-be-remembered items and on those trials in which more than seven items were presented, ignore the redundant items. It was predicted that if the differences found between Experiments 1A and 1B were not due to factors affecting retrieval mechanisms, such as distinct output interference, but due to the balance between the amounts of spatial and order information to retrieve, then similar results to those of Experiments 1A and 1B should be observed in a task requiring participants to retrieve mostly order information in all conditions. That is, although overall levels of recall in recency might be higher when no or little spatial information must be retrieved compared to when more spatial information is required, recency slopes should not differ between those conditions.

4.1. Method

4.1.1. Subjects

Eighteen male and female undergraduates reporting normal or corrected-to-normal vision, volunteered to participate in this experiment as part requirement for course credit. None of the participants had participated in the previous experiments.

4.1.2. Materials and procedure

Materials were as for Experiment 1B. Participants were required to retrieve, after a ten second retention interval, the order of presentation of the seven spatial stimuli. Whilst the stimuli were presented in the same way as in Experiment 1B, at retrieval either seven, nine, or 12 dots were presented. In one third of the trials, the seven to-be-remembered items were re-presented at recall time (7-dots condition). However in another third of the trials the seven dots were accompanied, at recall time, by an additional two dots that had not been in the presentation sequence (9-dots condition). In remainder of the trials, five additional dots were presented at recall time (12-dots condition). In these two last conditions in which nine dots or twelve dots were presented, participants were instructed to recall the order of presentation of the seven items that they saw in the stimulus sequence, but not to mark the two or five redundant items. In every condition, the screen cleared upon selection of the seventh stimulus, in preparation for the next trial. Each participant received 48 trials, 16 in each condition and the experiment lasted 45–50 min. Conditions were randomized from trial to trial. No indication was given to the participant in advance of how many items would be presented at retrieval. Other aspects of the procedure were the same as for Experiment 1B.
4.2. Results

A three (number of dots presented at retrieval: seven, nine or twelve) by seven (serial positions) ANOVA was performed on the serial order error data. There was a main effect of the number of dots presented, $F(2, 34) = 8.61$, MSE $= 6.93$, $P < 0.001$, and serial position, $F(6, 102) = 36.02$, MSE $= 3.67$, $P < 0.0001$. The interaction between the number of dots presented and serial position was however non-significant, $F(12, 204) = 1.57$, MSE $= 2.52$, $P > 0.05$. Performance was lower in the 12-dots condition than in both the 9 and 7 dots conditions, $F(1, 34) = 16.92$, $p < 0.0005$, $F(1, 34) = 6.43$, $P < 0.05$, respectively. No difference was observed between these two later conditions however, $F(1, 34) = 2.49$, $P > 0.1$.

Primacy and recency effects were found in each condition and confirmed by trend analysis. Linear components were found in the 7-dots condition, $F(6, 102) = 25.4$, $P < 0.0001$, the 9-dots condition, $F(6, 102) = 35.31$, $P < 0.0001$, and the 12-dots condition, $F(6, 102) = 88.1$, $P < 0.0001$. Quadratic components were also found in the 7-dots condition, $F(6, 102) = 29.42$, $P < 0.0001$, the 9-dots condition, $F(6, 102) = 66.42$, $P < 0.0001$, and the 12-dots condition, $F(6, 102) = 29.37$, $P < 0.0001$. It appears from Fig. 4 that recency items were overall better recalled in the 7-dots and 9-dots conditions than in the 12-dots conditions.

![Fig. 4. Experiment 2. Effects on serial order error of re-presenting the to-be-remembered items with an additional two, or an additional five items not presented at test. Maximum error = 16, in each case.](image-url)
A 3 (condition) × 2 (position 6 and 7) ANOVA for repeated measures was carried out to investigate further the effect of condition in recency. Significant effects of condition, $F(2, 34) = 11.18$, MSE = 4.87, $P < 0.0005$, and serial position, $F(1, 17) = 22.03$, MSE = 4.37, $P < 0.0005$, were found. Planned comparisons revealed that performance was significantly lower in the 12-dots conditions than in the 7-dots condition, $F(1, 34) = 13.96$, $P < 0.001$, the 9-dots condition, $F(1, 34) = 19.16$, $P < 0.0001$, whereas no difference was found between these two last conditions, $F(1, 34) < 1$, $P > 0.1$. However, more importantly in the context of the present study, no interaction condition × serial position was found, $F(2, 34) < 1$, MSE = 2.78, $P > 0.1$, indicating that the recency slopes were comparable in all conditions.

4.3. Discussion

The results of Experiment 2 indicate that the overall level of recall is reduced when an additional five items, not previously presented, are displayed along with the seven to-be-remembered items, whereas an additional two items did not produce any effect. However, and most importantly in the context of the present article, recency slopes were similar regardless of the amount of spatial location information to be retrieved along serial order.

5. General discussion

The present series of experiments showed that bow-shaped serial position curves were found when using a task requiring order information to be maintained in memory. Moreover, it was found that increasing the task demand on spatial location information retrieval affected levels of recall for the last items without affecting the recency slope.

The finding of bow-shaped serial position curves for non-verbal items differing by their location only and not their visual identity parallels the findings of Jones et al. (1995) and Smyth and Scholey (1996). Generally, the present results point to the generality of the serial position effects. The dependence of the serial position curve on the seriation process rather than on the type of stimuli is now well established (Avons, 1998; Avons & Mason, 1999; Jones et al., 1995; Nairne & Dutta, 1992; Parmentier & Jones, 2000; Smyth & Scholey, 1996). The J-shaped curves found for non-verbal stimuli in other studies appear clearly as a result of procedures testing visual identity rather than order information (Broadbent & Broadbent, 1981; Korsnes, 1995; Neath, 1993; Phillips & Christie, 1977; Walker et al., 1993; Wright et al., 1985).

The major finding of the present study is that spatial and order information appear to differ from what is usually called item and order information in verbal studies. In verbal studies, stronger recency was found when the task required order information only, compared to when it necessitated both order and item information.
In our study however, whilst overall levels of recall decreased in recency when large amounts of spatial information retrieval were required, the recency slope did not flatten. This was found when comparing conditions in which participants were required to recall either spatial and order information (Experiment 1A), or only order information (Experiment 1B), and when the amount of spatial information was increased in steps (Experiment 2).

The present results contradict the claim that recency is an attribute of verbal memory. In particular, the idea that phonetic representation underpins recency was flatly contradicted by the results of the foregoing experiments. Simply, it is difficult to envisage how dots would be converted into a phonetic code. Even if we accept the frankly improbable argument that the phenomena that have been observed within the current series are a result of verbal re-coding, the difficulty is not circumvented. Such a transformation of verbal material is most closely analogous to that deployed for the encoding of graphic verbal material and presumably shares with it the fate of not having phonetic representation, that is, the absence of recency.

Finally, the results reported in this article also question the assumption that recency is a product of the richness of the stimulus domain (Nairne, 1988, 1990). This conception suggests that richly encoded stimuli, such as continuously varying and multi-dimensional stimuli, are relatively more discriminable and in turn enhance recency. The view has much to recommend it, including the fact that it can serve as a plausible account of the various suffix effects in a range of stimulus modalities (for a discussion see, deGelder & Vroomen, 1994). However, the current results do not harmonize with such a model as they apply to phenomena of recency. There is unambiguous evidence of recency with stimuli that are discrete, static and steady state, that vary only their spatial location, conditions that should according to the model propagate curves exhibiting poor recency.

That serial position curves exhibiting both primacy and recency can be obtained for spatial as for verbal material questions the assumption that spatial and verbal information are functionally distinct within memory, as is proposed in the working memory model (Baddeley, 1992; Baddeley & Hitch, 1974). A more parsimonious account advanced by the object-oriented episodic record model (O-OER) (Jones, 1993; Jones, Madden, & Miles, 1992; Jones, Beaman, & Macken, 1996) is that verbal and spatial information share a common level of representation in short-term memory and are serviced by the same order maintenance mechanism. Evidence in favor of this approach includes the observation of similar list length limitations, effects of a retention interval and cross-modal interference (Jones et al., 1995), similar effects of direction of report (Farrand & Jones, 1996), similar shape of the serial position curve, sensitivity to the similarity of items, and distinction between item and order errors (Avons & Mason, 1999).

However, the results of the present article point perhaps to a difference between verbal and spatial memory. Indeed, recency in spatial serial memory, defined in terms of its slope, was not affected by an increase of the demand on spatial information retrieval, contrary to what is reported in verbal studies when both item and
order information are required. This finding suggests that in tasks where items differ only in terms of their spatial location and not their visual identity, spatial information does not exhibit the same functional characteristics as those of what is referred to as item information in verbal serial recall tasks.

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