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RUNNING HEAD: Visual similarity and immediate verbal memory

Visual Similarity Effects on Short-term Memory for Order:

The case of verbally labeled pictorial stimuli

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Abstract

Four experiments examined the effect of visual similarity on immediate memory for order. Experiments 1 and 2 used easily nameable line drawings. Following a sequential presentation in either silent or suppression conditions, participants were presented with the drawings in a new random order and required to remember their original serial position. In Experiment 3, participants first learned to associate a verbal label with an abstract matrix pattern. Then they completed an immediate memory task where they had to name the matrices out loud during presentation. At recall, the task required remembering either the order of the matrices or the order of their names. In Experiment 4, participants learned to associate non-word labels with less abstract schematic line drawings of faces; phonemic similarity of the verbal labels was also manipulated. All four experiments indicate that the representations supporting performance comprise both verbal and visual features. The results are consistent with a multi-attribute encoding view.

Visual Similarity Effects on Short-term Memory for Order:

The case of verbally labeled pictorial stimuli

In his seminal paper, Crowder (1979) argued that similarity was an “all-purpose memory tool” and went on to discuss how similarity manipulations had a long and rich history in memory research. More recent examples of the importance of similarity—and of its counterpart distinctiveness—in memory research abound (see for example Hunt & Worthen, in press, for a review, as well as Avons & Mason, 1999 and Jones, Farrand, Stuart, & Morris, 1995 for relevant examples). Similarity and distinctiveness have been central to memory research and theorizing mainly because similarity manipulations provide a window into the nature of the representations that are the stuff of memory. Simply put, if similarity along a given dimension has an effect on memory performance, information about this dimension must somehow be represented in the memory system.

This paper is concerned with the nature of the representations that support immediate memory. More specifically, the objective of the reported experiments was to investigate the role of visual characteristics in the processing of stimuli that can be verbally labeled. Hence, we set out to determine if a reliable visual similarity effect could be obtained in an immediate memory task when the to-be-remembered visual items were also verbally encoded.

One of the benchmark effects in this area is that memory over the short-term is influenced by phonemic similarity (Baddeley, 1966; Coltheart, 1993; Conrad & Hull, 1964; Crowder, 1979; Poirier & Saint-Aubin, 1996). For example, recall of a list of rhyming words is poorer than the recall of a list containing words that do not rhyme. The classic interpretation of this finding is that in order for similarity along the phonemic dimension to have an effect, the

representations called upon must maintain some of the phonemic characteristics of the to-be-recalled items.

Importantly, based on this effect, many of the better established models of short-term memory assume that phonemic information dominates verbal representations in short-term memory tasks (Baddeley & Hitch, 1974; Baddeley, 1986; Nairne, 1988, 1990; Neath & Nairne, 1995). Whether or not parallel visual similarity effects can be demonstrated is important because such effects would indicate that the nature of the representations supporting verbal short-term memory are more complex or general than previously thought (Frick, 1985).

From a theoretical viewpoint, a number of proposals predict that visual similarity should have an effect on the immediate recall of verbal material presented in the visual modality. In the typical immediate memory task, participants are asked to recall verbatim a short list of words, immediately after their presentation. More elaborate or richer encoding is usually considered a predictor of enhanced memory performance. Schiano & Watkins (1981) reported evidence that is coherent with this suggestion in an experiment where they compared immediate serial recall performance for printed words and nameable pictures in a number of conditions. For both types of materials, the results showed a phonemic similarity effect, a word-length effect, as well as an articulatory suppression effect, all of which are compatible with the assumption that phonemic coding is supporting performance. However, they also reported an advantage for the recall of the nameable pictures, a fact that suggests that visual information has been encoded and is playing a role in performance.

According to Hitch, Woodin, and Baker (1989), the Working Memory model (Baddeley & Hitch, 1974; Baddeley, 1986) is another prominent proposal that suggests that visual similarity effects should be observed in standard serial recall settings. Because visually presented items are

thought to be encoded in a short-term visuospatial store before an articulatory control process translates them into a phonemic code, Hitch et al. argued that evidence of visual coding should be observed under the right circumstances. This would occur, for instance, when phonological codes cannot play their usual role; in the context of the working memory model this is assumed to be the case when to-be-remembered words are presented under an articulatory suppression requirement [the latter involves the continuous repetition of an irrelevant word or syllable and is usually considered to hamper phonemic coding (Murray, 1967)]. Moreover, discussing the same model, Logie, Della Sala, Wynn, and Baddeley (2000) note that performance in immediate serial recall does not fall to zero under conditions of articulatory suppression; they suggest the possibility that visual codes might be supporting performance.

Finally, there are a number of proposals that suggest that multiple features are encoded into the memory representations that support immediate memory for verbal materials, including semantic, contextual, phonemic and visual features (Avons, 1998; Avons & Mason, 1999; Haarmann & Usher, 2001; Lewandowsky & Murdock, 1989, Nairne, 1990; Neath, Brown, McCormack, Chater, & Freeman, in press; Neath & Nairne, 1995; Parmentier, Tremblay & Jones, 2004; Tremblay, Macken, & Jones, 2001;). How much influence the latter are thought to exert on performance depends on the specifics of the model considered. However, generally speaking, based on this multi-attribute view, the prediction is that there should be a number of circumstances where the influence of visual similarity on memory for verbally encoded materials can be observed.

Although there appears to be some agreement with respect to the expectation of visual similarity effects in the immediate recall of verbal materials, clear supportive evidence is sparse (see, Logie et al., 2000 and Logie, 1995 for reviews). For example, Baddeley (1966) conducted

one of the early studies investigating similarity effects in immediate serial recall did not find reliable effects. However, as Logie et al. point out, he used auditory presentation. Frick (1985) examined immediate serial recall of letters with sequential and simultaneous visual presentation, while requiring articulatory suppression. Visual confusion errors were found to be significantly above chance for simultaneous presentation only.

A few recent studies have also found evidence of visual similarity effects in verbal short-term serial recall. These include studies with children (Hitch et al., 1989; Hitch, Halliday, Schaafstal, and Schraagen, 1988) and a study with adults published by Logie et al. (2000).

In the Hitch et al. (1988) study, 5 year old and 11 year old children completed an immediate serial recall task involving visually similar or distinct line drawings not unlike the ones used in the first two studies reported here (see Appendix A). Their results showed a visual similarity effect in the case of the young children but not in the case of the older group. Hitch et al. (1989) confirmed these results. They also reported evidence interpreted as indicating that older children relied on both visual and phonemic coding: When the older children were required to perform articulatory suppression, presumably interfering with phonemic coding, a visual similarity effect was found. As was the case in the Frick (1985) paper, this made it difficult to firmly conclude that visual characteristics of stimuli were encoded in silent conditions.

Nevertheless, the pattern of results of these studies was consistent with the idea of multi-code representations. However, as Avons & Mason (1999) have noted, interpretation of the Hitch et al. (1988; 1989) studies is complicated by the fact that spatio-temporal cues were available at recall, i.e. the spatial position of items varied systematically with their temporal order.

Experimenters pointed to the spatial position to elicit responses, implying cues were spatial.

Hence, in both the Frick (1985) and the Hitch et al. (1988, 1989) studies there was possibly some form of spatial information that could mediate the reported visual similarity effect.

Logie et al. (2000) argued that there was little evidence to suggest that the type of visual coding used by children recalling picture names might also be involved in verbal recall in adults. These authors hence set out to re-examine the question of visual similarity effects in the serial recall of verbal sequences and attempted to maximize the chances of observing the said visual similarity effects. In their first two experiments, the to-be-recalled items were words. Visual similarity was manipulated by varying the number of letters the words had in common while phonemic similarity was held constant. For example, the visually similar set for their Experiment 1 comprised the words *FLY PLY CRY DRY THY SHY* while the visually distinct set comprise the words *GUY, THAI, SIGH, LIE, PI, RYE*. Hence, all the words were phonemically similar, but the first set was more visually similar. Logie et al. also manipulated articulatory suppression; when required, suppression was carried out throughout presentation and recall. The results of both studies showed a clear visual similarity effect in that visually similar lists were more difficult to recall. Moreover, there were no interactions with articulatory suppression suggesting that the visual similarity effect is not the result of a shift in strategies, i.e. the results of participants using phonemic coding in silent condition and more visually based representations under suppression. However, it could be argued that phonological coding was already disrupted by the use of a high degree of phonemic similarity (rhyming one syllable words). As a consequence, articulatory suppression would not have produced a shift from a reliance on phonemic to visual coding. It remains to be seen if the same results could be observed when relying on phonemic coding is likely to be an efficient strategy.

In the last two experiments, Logie et al. (2000) called upon letters to test for visual similarity. They presented lists of 4 letters that could vary in identity or case (for example: KzQm). Participants were required to recall the items as well as their case, i.e. they wrote down the letters as they appeared, including case. Visual similarity was manipulated by using set of letters with different visual characteristics. Visually similar sets consisted of letters whose upper- and lower-case were similar (e.g. *Kk*, *Cc*, *Zz*, *Ww*), while visually distinct sets consisted of letters with visually dissimilar case information (e.g. *Tt*, *Gg*, *Hh*, *Qq*). Articulatory suppression was also manipulated in these experiments. In both cases, there were significant effects of visual similarity. Interactions with suppression were significant but visual similarity effects were obtained in silent conditions.

Given the importance of these effects, it seemed appropriate to attempt to replicate and extend the finding of a visual similarity effect in the ordered recall of a sequence of verbally encoded items. The series of experiments reported by Logie et al. (2000) manipulated visual similarity under silent or articulatory suppression conditions. Moreover, in all cases there was a high degree of phonemic similarity between the stimuli to be distinguished. In the first experiment reported here we manipulated visual similarity without calling upon items that were phonemically similar. In effect, we borrowed from Hitch et al. (1989) and examined the serial recall of easily nameable line drawings. However, in the study reported below all items were presented in the same spatial location and there were no spatial cues to support recall. We called upon an immediate reconstruction of order task where following presentation, participants are provided with the to-be-recalled items in a new random order. Their task is to indicate the original order in which the stimuli appeared. Using a reconstruction of order task makes sense as it has often been demonstrated that factors such as phonemic similarity have their effect on order

memory (Saint-Aubin & Poirier, 1999). Because there is the possibility that visual similarity effects will only appear when phonemic coding is made less useful, we also manipulated articulatory suppression.

EXPERIMENT 1

Method

Participants. Thirty-two participants volunteered to take part in the experiment; they were either 1st year psychology undergraduates or working within the university. They were awarded course credits or five pounds for their time.

Materials. The experimental materials comprised six sets of six line drawings of everyday objects (36 drawings in total; see Appendix A for the complete list of items). Among these, there were three sets of visually similar pictures and three sets of visually distinct pictures. As shown in Appendix A, one visually similar set contained items that had similar round outlines. The items in the second similar set all had an elongated shape and they were presented in the same oblique orientation. The third set of visually similar items contained square line drawings with similar outlines. Each of these similar sets had a control counterpart consisting of visually distinct pictures. All the drawings were easily nameable. Moreover, pairs of similar and control item-sets were selected so that their names were matched for Thorndike-Lorge written word frequency, concreteness and imageability using the MRC Psycholinguistic Database (Coltheart, 1981). Due to the constraints associated with manipulating visual similarity and controlling for word frequency, the words in the visually distinct sets are either equal to or

slightly less frequent than those in the similar set (note that this favored results in the opposite direction to our main prediction which was *better* recall of visually distinct items).

In this experiment, there were two blocks of 24 trials – one presented in silent conditions and one under suppression. Similar and distinct lists were mixed within these blocks. With respect to the presentation order of the trials, for each block of 24 trials, two separate orderings were generated as follows. We randomly selected without replacement one of the six item-sets [three similar and three distinct] and repeated the procedure until we obtained 6 trials. We repeated this procedure 4 times to produce the 24 trials of a block. With this procedure, within a block of 24 trials, all item-sets had to appear once before they could be presented a second time and so on until each set had been used four times. We then repeated the whole procedure to generate a further block of 24 trials. In all cases, the order of items within lists was randomly determined with the constraint that an item could not appear twice in the same serial position within a block of 24 trials. The two versions of the trial-order were counterbalanced across participants. The same was true of the order of the suppression and silence conditions.

The stimuli were presented in the center of a standard 28-cm monitor. Timing and presentation was computer controlled except for the initiation of each trial sequence where the participant had to press the enter key (details in procedure section).

In order to collect participant responses, response sheets reproduced the presented stimuli, in a horizontal line and in a new random order relative to the presentation order (one 8.5 x 5.5 sheet per response – See the example in Appendix A). To avoid the possibility that participants would encode items in terms of their positions on the response sheets, a different random order was used for each response sheet with two constraints: 1) The position of items on the answer sheet was never the same as their presentation position and 2) within a block of 24

lists an item never appeared in the same serial position on the answer sheet twice. Hence, there was a separate answer sheet for each trial, each reproducing the to-be-ordered items. Because there were two separate orders for item presentation, there were also two sets of response sheets – both constructed according to the rules just described.

Procedure. Testing began by presenting participants with all 36 line drawings to be used in the experiment. The drawings appeared individually in the centre of the screen within an 11 cm square area. Each stimulus appeared with its verbal label (set in Times New Roman font, size 36) directly below it and participants were required to read this out loud. Once the label was read out, participants could view the next picture by pressing the space bar. This procedure was used to familiarize participants with the labels associated with the line drawings and to encourage all participants to use the same labels.

Familiarization with the picture labels was followed by four practice trials. Participants first had two trials in the silent condition and two in the suppression condition. Stimulus presentation began once the participant pressed the spacebar. A visual warning signal (XXXXXX) was given 1 second before the start of each sequence of pictures. Six images then appeared one at a time in the centre of the screen. Each picture was presented for one second with a blank inter-stimulus interval of 250 msec. At the end of each sequence a visual recall cue (*****) appeared on the screen. Participants were then required to turn over their response sheet and indicate the serial order of the reproduced pictures by numbering each item on the sheet: They had to first write “1” under the first stimuli presented, “2” under the item presented second, etc. Strict serial order recall was called upon. If participants were unable to recall a picture in a particular position, they were asked to write the position number on the side of the response sheet (in a box provided on the left – see Appendix A). Once the response sheet

had been completed, the participant turned it over and put it to one side; the next answer sheet was then available, but face down so that the presented items could not be encoded in terms of the positions of the pictures on the answer sheet. Participant hit the space bar to proceed to the next trial.

In the silent condition participants performed the task as described above. In the suppression condition, participants were asked to repeat aloud the word 'tea-time' at a rate of 2 repetitions per second, starting when they pressed the spacebar to commence presentation of a sequence, and continuing until the visual recall cue had appeared. They then recalled in silence. As mentioned above, the experimental trials were divided into two blocks of 24 trials corresponding to the suppression conditions. Because similar and distinct lists were mixed within each block of 24 trials, each of the four experimental conditions (two similarity x two suppression) was associated with 12 trials. The entire session lasted approximately 50 minutes.

Results & Discussion

Performance was scored according to the usual strict serial recall criterion. Experiment 1 used a reconstruction task where the participant had to number the stimuli on a response sheet. Hence, to be considered correct, each item had to be attributed the number corresponding to its presentation position. For every participant and condition, the probability of correct recall was computed for each serial position. One participant was omitted prior to analysis, as his performance was unacceptably poor.

The results are presented in the left panel of Figure 1. The figure shows the typical suppression effect and there appears to be a visual similarity effect under suppression conditions. Results for the silent condition appear less clear. A three-way, repeated measures analysis of variance (ANOVA) was carried out on recall scores with similar/dissimilar, suppression/no

suppression and serial position (1-6) as the within-subject factors. For all analyses in this paper, the .05 level of significance was adopted, except for simple main effect tests in which Dunn's correction was used (Kirk, 1982).

The ANOVA revealed a significant disruptive effect of articulatory suppression on performance, $F(1,30) = 190.45$, $MSE = .0892$, a significant effect of visual similarity, $F(1,30) = 10.96$, $MSE = .0217$, and a significant main effect of serial position, $F(5,150) = 41.94$, $MSE = .0236$. There was an interaction between suppression and serial position, $F(5,150) = 10.91$, $MSE = .0165$. This interaction is attributable to the fact that the serial position curve is flatter under silent than under suppression conditions. This is likely to be due to a ceiling effect in the silent condition. A second interaction just missed the statistical significance criterion and involved similarity and suppression, $F(1,30) = 4.00$, $MSE = .0287$, $p = .055$. Simple main effect tests revealed that visually dissimilar items were better recalled than visually similar items under suppression, $F(1,60) = 13.55$, $MSE = .0042$, but not in the silent recall condition, $F < 1$.

Insert Figure 1 about here.

Concerning these results, perhaps the first point to note is that there is a sizeable effect of suppression on recall performance. Although a number of proposals have been put forward to explain how articulatory suppression hinders performance, the modal view is that it disrupts phonemic coding (but see Jones, Farrand, Stuart, & Morris, [1995] and Neath & Nairne, [1995]). According to this view then, the task called upon requires verbal or at least phonemic coding. On the other hand, the observed results partly support the notion that visual coding is called upon in

the immediate serial recall of nameable pictures by demonstrating an effect of visual similarity under conditions of articulatory suppression; fewer visually similar than dissimilar items were recalled under suppression. However, in this experiment there was no convincing evidence of a visual similarity effect in the absence of suppression.

These results are in line with those of Hitch et al. (1989): No visual similarity effect under silent condition and a significant effect of visual similarity under suppression. However, there is the possibility that the absence of a visual similarity effect is attributable to a ceiling effect in the silent condition. Another possibility is that there was a mainly phonemically based encoding strategy in the silent condition and a more visually based strategy in the suppression condition as phonemic coding is less useful in these circumstances. It remains however that performance in the silent condition was high and could have hindered the observation of an effect. Experiment 2 addressed this issue by reproducing experiment 1 with longer lists.

Experiment 2

Method

Participants. Sixteen participants volunteered to take part in Experiment 2. They were all college students and were paid \$7 (CAN) for their trouble.

Materials. The experimental materials were slightly different for this experiment. There were four sets of 7 items (28 items total), with 2 sets comprising visually similar items and two sets comprising visually distinct items. Because of the constraints imposed by the various controls in terms of stimuli characteristics, only two of the similar and control sets from Experiment 1 were extended to include an extra item. As in Experiment 1, picture names were equated for word-length, frequency, concreteness and imageability. Similar items were either

elongated shapes (for example ruler, pencil, or flute) or round shapes (for example ball, button, or apple). The complete set of stimuli can be found in Appendix A.

In Experiment 2, trials were blocked according to similarity and suppression conditions (2 x 2) and each condition held 14 trials (for a total of 56 trials). Half of the participants were tested with one similar and one distinct subset of items while the other half was tested with the other. Hence, in this experiment, similar and distinct conditions were tested with a closed set of items – i.e. the same items were presented on every trial. This more clearly emulates the conditions employed in classic studies of phonemic similarity where closed sets of consonants were called upon (e.g. Conrad, 1964; Baddeley, 1966). The order of the four conditions produced by the combination of the similarity and suppression factors was counterbalanced across participants by calling upon a Latin square. The order of presentation of the items within each trial was randomized for each group of 14 trials with two seven-item Latin squares. The same procedure was used to prepare the answer sheets. As before, care was taken to ensure that items were not in the same position on the answer sheet as they were during presentation.

Procedure. The procedure here was identical to the one used in Experiment 1, with a few exceptions. During familiarization, participants were presented with three repetitions of the 14 stimuli (7 similar and 7 distinct) that would be used in the course of the experiment for them, in a random order, and had to read the accompanying verbal labels aloud. This was followed by a reading test where all the stimuli were presented twice, once again in random order, but without their verbal labels. Participants had to name the presented line drawing to ensure they were familiar with the proper labels. All participants completed this task without any difficulty. The order reconstruction task began once familiarization was completed.

Results & Discussion

As in the previous experiment, performance was scored according to a strict serial recall criterion. The results are presented in the right panel of Figure 1. An examination of the figure shows the usual serial position curve along with the expected decrease in performance under suppression. Also, all conditions show a lower recall level than in Experiment 1. Most importantly, the figure reveals a lower recall performance for similar items under both quiet and articulatory suppression conditions. A 2 X 2 X 7 repeated measures ANOVA confirmed these trends with a main effect of visual similarity, $F(1,15) = 8.19$, $MSE = .0361$, of articulatory suppression, $F(1,15) = 21.40$, $MSE = .1257$, and of serial position, $F(6,90) = 32.65$, $MSE = .0484$. Neither the interaction between similarity and suppression, $F < 1$, nor any of the other interactions reached significance. This experiment provides evidence of visual coding in both the silent and suppression conditions.

However, one potential criticism of the two previous experiments is that it is not clear the degree to which phonemic coding is involved in performance. After all, line drawings are presented and the ordering of the same line drawings is required at recall. The fact that articulatory suppression has its typical effect on performance has very often been considered as an indication that verbal encoding is relied upon. Nonetheless, this is not the only interpretation of the effect of articulatory suppression (e.g. Neath & Nairne, 1995) and hence perhaps not as convincing as one would hope. In experiment 3, we adopted a different procedure in order to address this issue as well as a few others.

Experiment 3

Experiment 3 used stimuli for which a more precise measure of similarity could be computed. Abstract block matrix patterns were adapted from stimuli used by previous investigators (Avons, & Mason, 1999; see Appendix A). Moreover, participants were taught to

associate each abstract block matrix pattern with a non-word. Hence we avoided the constraints associated with using natural language through the selection of a pool of statistically equated non-words. Also, to encourage phonemic encoding, participants were required to say the name of each to-be-recalled stimulus out loud during the presentation of each memory list. A further feature of this study was the manipulation of response modality. This was achieved as follows. At the point of recall, reconstruction was attempted based on either a sequence of visual images or their learned verbal labels. These different response modalities were introduced as a further means of ensuring that the representations on which performance was based involved phonemic components. If visual similarity effects can be demonstrated under these conditions, then an interpretation suggesting that these items are not verbally or phonemically encoded appears more difficult to maintain.

Method

Participants. A total of 24 participants volunteered to participate in the experiment. All were undergraduate students; they were awarded course credits or freely volunteered their time.

Materials. The experimental stimuli comprised two sets of six computer generated graphics depicting abstract block matrix patterns (12 patterns in total). The patterns used were 6 x 6 cell matrix patterns with 50% of the cells filled (see Appendix A). They were displayed as black patterns on a white background, and the size of each cell was 6mm x 6mm. One set comprised block matrix patterns that were visually similar. This was achieved by using a prototype pattern (previously used by Avons, & Mason, 1999; exp 1, see their Figure 1.) and changing the position of one cell for each image, with the constraints that no two patterns had the same cell changed and the number of filled cells remained constant. This created six visually similar block matrix patterns that had 16 out of 36 cells in common. The second set of stimuli

comprised six visually distinct block matrix patterns. These were created by changing the position of an average of 6.67 cells of the prototype pattern to create each pattern of the series. The six visually distinct patterns shared an average of 9.49 cells (range: 7 to 12).

The non-words (one for each block matrix pattern) comprised two sets of six one-syllable non-words selected from a low-frequency item pool used by Roodenrys and Hinton (2002). Non-Words in each list were equated by number of letters, number of phonemes, neighborhood frequency, and biphone frequency¹. Low-frequency items were selected, as they appeared less word-like than high-frequency items, and thus benefited from having fewer phonologically similar characteristics in common with real words. To ensure that the non-words within one visually similar list were not inadvertently more or less easy to learn/recall than the non-words in the corresponding control list, half the participants (12) learnt to associate List 1 with the visually similar patterns and List 2 with the visually distinct patterns. For the remaining 12 participants the pattern/non-word combination was reversed.

This experiment called upon 18 different six-item sequences for the visually similar block matrix patterns and 18 different sequences of the six visually distinct patterns. The order of stimuli within each sequence was determined using Latin squares, with the constraint that no two sequences corresponding to each visual category had the same order of patterns. Both groups of lists were then combined such that the order of trials was alternated and predictable: No two consecutive trials held items from the same similarity category (i.e. a visually similar sequence was followed by a visually distinct sequence). This created a series of 36 six-item sequences, starting with a sequence of visually similar images, followed by a sequence of visually dissimilar

¹ Roodenrys and Hinton (2002) determined the frequency of three phoneme words in the CELEX psycholinguistic database (Baayen et al., 1993) in which a given VC (vowel, consonant) or CV (consonant, vowel) phoneme pairing occurs.

images, etc. The first four six-item sequences (two visually similar sequences, two visually distinct sequences) were used in a practice block. To manipulate response modality, the first block of eight trials for half of the participants was followed by the ordered reconstruction of non-word (verbal) labels. The second block of eight trials was followed by the ordered reconstruction of the visually presented images. This order was repeated for the remaining 16 sequences. For the remaining participants, the first block of eight trials was followed by the ordered reconstruction of the visual presented images, and the second block of eight trials was followed by the ordered reconstruction of the verbal labels. Again this order was repeated for the remaining 16 sequences.

Participants used response sheets that reproduced the presented items (either in their visual or verbal form). The order of the stimuli on the response sheets was determined using Latin squares taking care to avoid reproducing the presentation order of the items. The stimuli were presented on a standard 28 cm PC monitor; presentation of the items and their timing were computer controlled.

Procedure. Participants were tested individually in a quiet room. Testing began with a procedure designed to familiarize the participants with the 12 images and to teach them the verbal label associated with each matrix pattern. Each image was presented in the centre of a white screen within a square of 3.6 x 3.6cm. Images were accompanied by their non-word label, positioned directly below (Arial, bold, 44pt), and participants were required to read the labels out loud. The first learning trial began by presenting visually similar image numbers 1-3 individually with their corresponding verbal labels. Once the image had been studied and the label had been repeated, the participants could proceed to the next image by pressing the spacebar. The images were then presented individually, and without their verbal label, in a new random order, and the

participant was required to provide its verbal label. Upon pressing the spacebar the participant was provided with the image's verbal label. Images 1-3, with and without their verbal labels, were presented in this manner for a total of six presentations each before the practice moved to visually distinct images 1-3. This procedure was continued until all images/labels had been presented on six occasions. The whole process was again repeated but was expanded to include all six images corresponding to each visual category (e.g. images 1-6, and 7-12 were presented together). During the learning phase, a complete cycle involved presenting each image/label a total of 144 times. This cycle was repeated until the experimenter was satisfied that the correct verbal label was consistently and easily associated with its corresponding visual image. An average of 3.58 complete practice cycles (ranging from two to six cycles) were needed for the participants to learn to associate each visual image with its verbal label. Pilot testing showed that this procedure resulted in very few naming errors during the actual memory test; with participants making two or three naming mistakes during the memory test that involved naming 216 items (36 lists x six items).

Once the participants had learnt to associate each image with its verbal label, four practice memory trials were given. Participants were given two trials in the visually distinct condition and two trials in the visually similar condition. Presentation began after the participant pressed the spacebar. A '***' visual warning cue was then given one second before the onset of each sequence of images. Each image was presented at the centre of the screen for a duration of one second with the time lag between each image of 250 msec. Participants were required to name the image out loud as it appeared on screen. At the end of each sequence a visual cue '*****' appeared in the centre of the screen. This was the participant's cue to turn to the response sheet and number the images or verbal labels from one to six, in accordance with the

order in which they had been presented on screen. Strict serial order recall instructions were followed, i.e. the first item presented had to be the first item numbered etc. Participants hit the space bar to initiate the next trial. Eight trials were associated with each condition (two visual similarity x two response modality), for a total of 32 trials. The entire session lasted between 60 and 90 minutes.

Results and Discussion

Responses were scored according to the usual serial recall criterion. Each item had to be ordered / numbered adequately to be considered correct. The probability of correct recall as a function of serial position, similarity, and response modality (ordering verbal labels or matrix patterns at the point of recall) is presented in Figure 2. An examination of this figure shows a disruptive effect of visual similarity, with poorer primacy performance for visually similar items than for visually distinct items. The graph displayed also appears to indicate that reconstruction performance was somewhat superior with verbal labels compared to visual images. A 3-way repeated measures analysis of variance (ANOVA) was carried out on the recall scores with similarity (similar/distinct), response type (images/words), and serial position as factors.

Insert Figure 2 about here

Results of the ANOVA revealed a significant main effect of visual similarity, $F(1,23) = 44.00$, $MSE = 0.030$, a significant effect of response modality $F(1,23) = 12.41$, $MSE = 0.024$, and a significant effect of serial position $F(5,115) = 30.85$, $MSE = 0.039$. The analysis revealed one

significant interaction between similarity and serial position $F(5,115) = 3.42$, $MSE = 0.022$. No other interaction reached significance. Simple main effect tests indicated that the effect of similarity was significant for the first three serial positions.

The observed results provide evidence that visual coding is called upon during the immediate serial ordered recall of nameable block matrix patterns demonstrating an effect of visual similarity; fewer visually similar items were recalled regardless of response modality. Additionally the results are compatible with the notion that phonemic encoding was used, by demonstrating the presence of a response modality effect; recall was superior when verbal labels were presented at test rather than visual images.

Experiment 4

The results of Experiment 3 extend the findings of the first two experiments to a situation where the to-be-recalled items were named aloud and where either visual or verbal identifiers were called upon at recall. The most important result of the previous experiment is arguably that a visual similarity effect was obtained even when stimuli were named aloud during presentation and verbal labels were used for the reconstruction response. However, given that previous research has not easily demonstrated visual similarity effects with verbally encoded items, a further demonstration with a different type of stimuli and manipulation would help to establish the reliability of the findings. This was the objective of Experiment 4. We called upon an alternative, more direct and explicit way of demonstrating that verbal encoding was involved through a manipulation of phonemic similarity. We reasoned that if a phonemic similarity effect could be obtained for stimuli also showing a visual similarity effect this would provide further and stronger evidence supporting the idea that both visual and verbal features were playing a role in recall.

In Experiment 4, instead of using block matrix patterns we called upon simple line drawings depicting schematic faces (a less abstract set of stimuli). Non-word verbal labels or "names" were again used as well as a learning procedure.

Method

Participants. Thirty-two participants took part in this experiment. All were undergraduate students; they were awarded course credits or a small reward for volunteering to participate.

Materials. The experimental materials comprised two sets of line drawings depicting schematic faces (see Appendix A). One set contained seven visually similar line drawings while the other set held seven visually distinct line drawings. The visually distinct set consisted of "faces" that differed in head shapes (triangle, heart, square, oval, hexagon, diamond and star). For the visually similar set the shape of the head was always round, the eyes and nose remained the same throughout all the seven stimuli while the eyebrows and mouth differed. Hence all the drawings in the similar set had three features in common. For the visually distinct set, the eyes remained the same throughout all seven stimuli while the eyebrows, nose and mouth varied from one drawing to the next. The head sizes and the number of features were kept constant across all stimuli; no color was added to the drawings.

The experimental materials also included four sets of seven non-words. Two sets were phonemically similar non-words and two sets were phonemically distinct non-word list. The non-words were obtained from the ARC Non-word Database (Rastle, Harrington, & Coltheart, 2002). Items in each list were equated in terms of number of letters, neighborhood frequency, summed frequency of neighbors, size of phonological neighborhoods, and number of phonemes. Low-frequency items were selected to avoid any strong word-likeness effects. The combination of visually similar and distinct stimuli with the phonemically similar and distinct non-words

created four sets of stimuli. The order of stimuli within trials was determined with the use of Latin squares, so that each stimulus appeared equally as often in each serial position.

Stimuli presentation was computer controlled and images of the drawings were presented on a standard 28-cm monitor.

In order to collect participant responses, response sheets reproduced the presented stimuli, in a row and in a new random order as in the previous experiments. The order of stimuli within a response set was determined using Latin squares, again so each stimulus appeared equally often in each position. However, care was taken to ensure the order of presentation was not reproduced in the stimuli order on the response sheet.

Procedure. Phonemic similarity was manipulated between participants, while visual similarity was manipulated within participants. The experiment consisted of four phases. Phases one, two and three involved learning the names associated with each visual stimulus, while the fourth phase involved the immediate reconstruction of order test. In Phase 1 the stimuli appeared individually in the center of the screen. Each drawing appeared with its non-word label (set in Times New Roman font, size 72) directly above it and participants were required to read this out loud. In Phase two of this experiment, the stimuli again appeared individually in the center of the screen. Participants tried to say the name of the schematic face out loud; after two seconds, the label associated with the face appeared. If the participant had not done so already, she/he was to name the drawing out loud. This phase consisted of 4 repetitions of the two sets of seven stimuli. A Latin square was used to vary the order of presentation of the items. Phase three was like phase two in that participants had to name each drawing aloud; however, there was only a one second delay before the label appeared. This phase consisted of three repetitions of the stimulus set. Pre-testing had established that this learning sequence was sufficient to virtually eliminate

naming errors. The final phase involved the reconstruction of order test. Participants were presented with the face characters without the label and had to name each stimulus out loud. Stimulus presentation began once the participant pressed the spacebar. A visual warning signal (XXXXX) was displayed for one second followed by a sequence of seven schematic face drawings. The seven images appeared one at a time in the center of the screen, at a rhythm of one item every two seconds. At the end of each sequence of seven stimuli a visual recall signal (*****) indicated the start of the response phase for that trial. Participants were then required to turn to their response sheet (as before, a different one for every trial) and indicate the serial order of the reproduced face characters by numbering each item in the order in which it appeared during presentation. Once the response sheet had been completed, the participants hit a key to proceed to the next trial. There were two blocks of 14 trials, one per visual similarity condition. The order of conditions as well as the association of label set to stimulus set was counterbalanced across participants. The entire session lasted approximately 50 minutes.

Results & Discussion

Performance was scored according to the usual strict serial criterion. As an order reconstruction task was used, each item had to be correctly numbered to be considered correct. Mean performance in each condition is presented in Table 1 while performance in each condition as a function of serial position is presented in Figure 3. Both visual similarity and phonemic similarity appear to have a detrimental effect on performance.

Insert Table 1 & Figure 3 about here.

The data were analyzed using a mixed three-way analysis of variance (ANOVA), with two within-subject factors, visual similarity and serial position and one between-subjects factor phonemic similarity.

The ANOVA revealed a significant main effect of visual similarity $F(1,30) = 22.91$, $MSE = 1.75$, a significant main effect of group or phonemic similarity $F(1,30) = 9.33$, $MSE = 0.25$, and a significant effect of serial position, $F(6,180) = 20.03$, $MSE = 0.46$. The analysis revealed one interaction which nearly reached significance, between phonemic similarity and serial position $F(6,180) = 3.46$, $MSE = 0.08$, $p = .051$. This appears attributable to a larger phonemic similarity effect for positions 3 and 4. No other interaction approached significance (All F s < 1).

The present experiment has shown a clear effect of visual and phonemic similarity on short-term serial memory for nameable drawings. The effect of phonemic similarity indicates that subjects relied on a representation that maintained some of the phonemic information in the stimuli names. The observed results also provide further evidence that visual coding was called upon in this experiment.

General Discussion

The aim of the experiments reported here was to determine if evidence of visual coding could be provided when the task required the short-term maintenance of a sequence of items that could be encoded verbally. In Experiment 1, the order reconstruction of nameable pictures was disrupted by visual similarity when concurrent suppression was required but not in silent conditions; it was thought that the latter effect was attributable to a ceiling effect in the silent condition. In Experiment 2, longer lists of items were called upon; as expected, a visual similarity effect was obtained in both silent and suppression conditions. In Experiment 3, abstract matrix patterns were named aloud during presentation. This was followed by a

reconstruction task where either the patterns or their labels had to be re-ordered. A visual similarity effect was again observed in both cases, i.e. whether the patterns or their labels had to be re-ordered. Taken together the results of Experiments 1 and 2 indicate that visual similarity effects can be obtained with items that are nameable under both quiet and suppression conditions even when list items do not share a high degree of phonemic similarity. Moreover, Experiment 3 demonstrated that the visual similarity effect occurs when the participant is required to name the stimuli out loud at study and is presented with either the verbal label or the visual image at test. Finally, Experiment 4 replicated the visual similarity effect for stimuli that were named out loud. Experiment 4 also showed that a visual similarity effect could be observed for stimuli that simultaneously produced a phonemic similarity effect. Taken together, the results of these experiments serve to establish that, even under conditions where verbal coding was clearly involved, a reliable visual similarity effect was observed.

The results build upon the findings of Avons and Mason (1999), those of Hitch et al. (1989), as well as those of Logie et al. (2000). Avons and Mason reported visual similarity effects for sequence of non-verbal stimuli. The results reported here extend these finding to sequences of verbally encoded items. Hitch et al. examined the performance of children and reported pattern of results similar to the one of Experiment 1 - however, they called upon a presentation method that involved spatial as well as temporal elements. Our results show a visual similarity effect is also found with adult participants, in silent conditions as well as in suppression conditions. Finally, our results extend those of Logie et al. by providing evidence of visual similarity effects without high levels of phonemic similarity -- that is when phonemic information is still a useful basis for a distinctive encoding of to-be-recalled items.

Before discussing this visual similarity effect, we wish to comment on the response modality effect observed in Experiment 3. The results showed that immediate serial reconstruction performance was superior when responding involved verbal labels rather than line drawings – an effect perhaps indicating the greater familiarity with verbal processing of sequences. The important fact here is that the response modality effect was independent of visual similarity. This is important because it provides evidence that the visual similarity effect was not dependent upon participants abandoning a phonemic encoding strategy. The suggestion is that the visual properties of the stimuli were encoded in tandem with the phonemic properties, in order to produce independent effects of similarity and response modality. This interpretation is reinforced by the results of Experiment 4, where a phonemic similarity effect was observed for the same stimuli that produced a visual similarity effect.

Why was evidence of visual similarity found here while it proved elusive in a number of other studies (Baddeley, 1966; Frick, 1985, 1988)? Procedural differences between studies could be involved. However, a few aspects of the present study are perhaps more likely to be of importance. First of all, we borrowed from Hitch et al. (1988, 1989) in using line drawings. Because this type of stimuli allow relatively good control over the number of distinctive features associated with each item, they may well have been important in obtaining visual similarity effects, especially when compared to visually presented letters or words. For printed letters and words there may also be an over-learned processing bias that increases the prominence of phonemic encoding. Another feature that may be relevant is that the task used here was a reconstruction of order task. This type of task is particularly sensitive to factors that affect order encoding (Saint-Aubin & Poirier, 1999). As suggested by Avons & Mason (1999) it appears that visual similarity, like phonemic similarity, mainly affects order information recall. If this is the

case, it may be more difficult to find evidence of visual similarity effects with standard serial recall tasks, where both the item and its position must be recalled (see Saint-Aubin & Poirier for a more thorough discussion of these issues).

How then should the visual similarity effect observed here be interpreted? Perhaps the first point that needs to be made relates to the classic interpretation of the phonemic similarity effect: Phonemic confusability implies phonemic properties are maintained in the memory record (Conrad, 1964). Based on this logic, the robust visual similarity effect reported here implies that visual properties of the stimuli were integrated into the representation supporting performance. However, no one will be surprised by the statement that memory for the visual properties of stimuli is evidenced over the short-term (Phillips & Christie, 1977; Avons & Phillips, 1987; Walker & Davies, 2003; Walker, Hitch, Dewhurst, Whiteley, & Brandimonte, 1997; Smyth, Hay, Hitch, & Horton, 2005). The more novel aspect of the present findings is that evidence of visual coding was demonstrated for a sequence of verbally encoded items, in conditions where the phonemic information was clearly distinctive enough to support performance.

The results presented here are easy to account for if one assumes that many of the properties of a to-be-remembered stimulus are encoded into the memory record and that, under the right circumstances, similarity along any of these dimensions can hinder order recall. For example, one could suggest that a unitary episodic representation is produced at encoding that is then available for various processing modules – perhaps along the lines of the system suggested by the Working Memory model. The findings reported here are also compatible with the Feature model of short-term verbal recall (Nairne, 1988, 1990; Neath & Nairne, 1995). This model suggests that a multi-attribute representation supports performance and accounts for classic effects like phonemic similarity through a Luce-type choice rule.

It may well be possible to extend or apply other models to account for the reported findings, like for example, OSCAR (Brown, Preece, & Hulme, 2000) and SIMPLE (Brown, Neath, & Chater, 2002) and the Burgess & Hitch (1999) model. These models were developed to account for findings in the verbal domain and call upon context and distinctiveness to account for memory performance. In relation to this, Smyth et al. (2005) reported a visual similarity effect for visually similar faces when compared to visually dissimilar faces. When discussing how their results related to recent models they state: “There are elements of these models that need not be specific to the verbal domain. (...) Context signals (...) could be associated to other items, not just verbal ones. Jones, Farrand, Stewart, and Morris (1995) have proposed that serial order itself is the primary characteristics of short term recall (...) and that similar effects of serial order can be found in the verbal and spatial domain.”. It is clear that our findings are in line with this general view; we also found serial position curves that are typical of immediate memory performance with verbal materials across all the item types and response modalities that we employed. This is also in line with the functional similarities between verbal, spatial and visual short-term memory that have been pointed out by Jones et al. and Smyth et al. Finally, perhaps the main issue our findings highlight is the following. The phonemic similarity effect has been fundamental in the development of models of verbal short-term memory; we would suggest that the current findings are significant as they indicate that the importance of phonemic coding in immediate memory for verbal material may have been overstated and more specifically, may well be task dependent.

Conclusion

Our aim here was to provide evidence that visual similarity effects can be observed in immediate memory for materials that are easily nameable and verbally encoded. We observed a

visual similarity effect for stimuli that were not phonemically similar, that were presented sequentially, and without any correlated variation in spatial characteristics. Moreover, this effect was observed in silent and suppression conditions, when the stimuli had to be named out loud and when response required re-ordering the verbal labels associated with the to-be-remembered items. As with phonemic similarity, the pattern of results is most easily interpreted by suggesting that some of the visual characteristics of the to-be-recalled items are encoded into the memory record that supports performance. Hence, the idea that immediate memory for all verbal material is dominated by phonemic coding appears to be an overgeneralization. If early research on immediate memory had called more often upon simple line drawings rather than letters or short words, our models might not have insisted so heavily on phonemic information.

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Authors note

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Table 1. *Average performance as a function of visual and phonemic similarity conditions (standard deviation in brackets).*

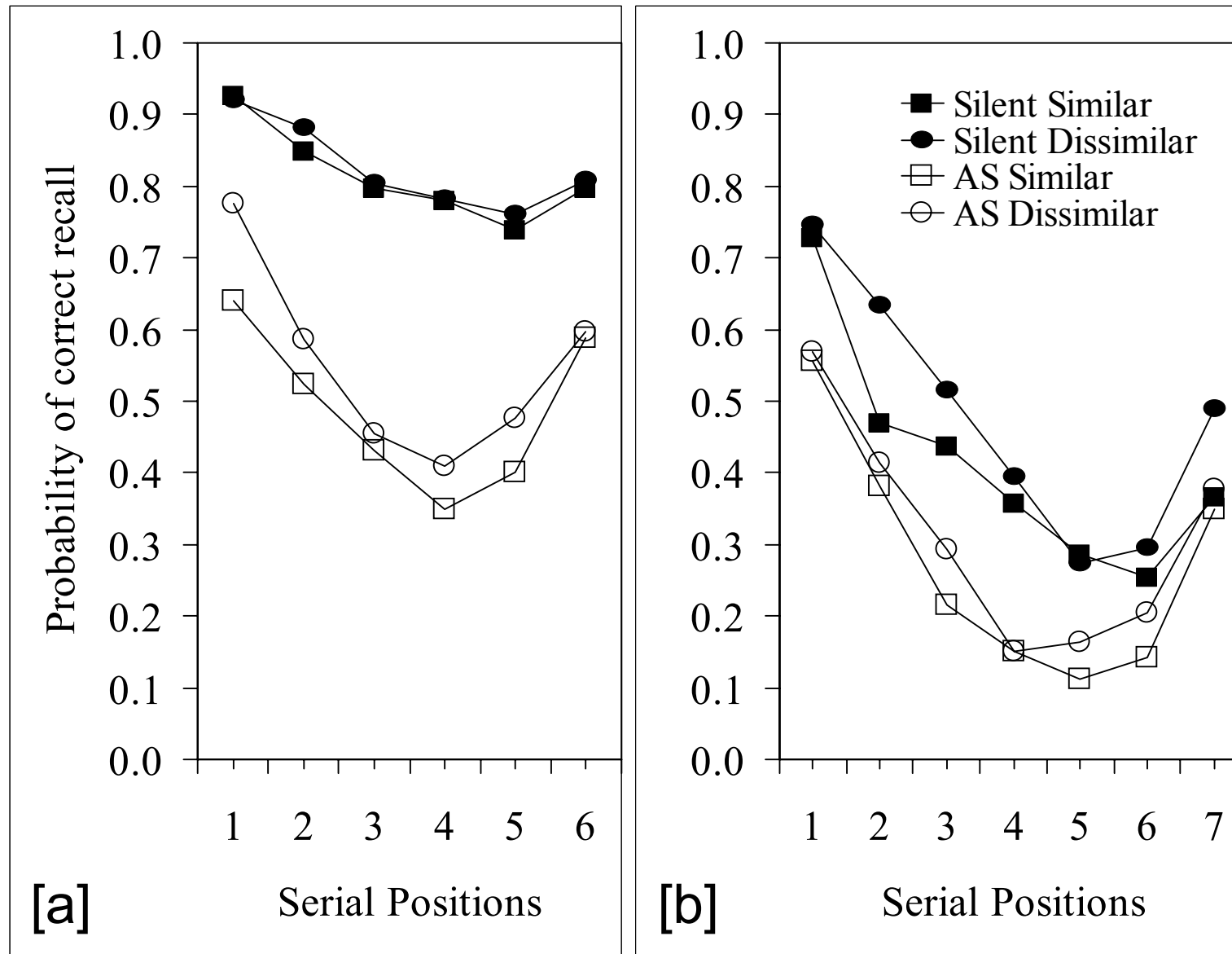
	Visually similar	Visually Distinct
Phonemically Similar	0.49 (0.15)	0.59 (0.18)
Phonemically Distinct	0.59 (0.12)	0.74 (0.09)

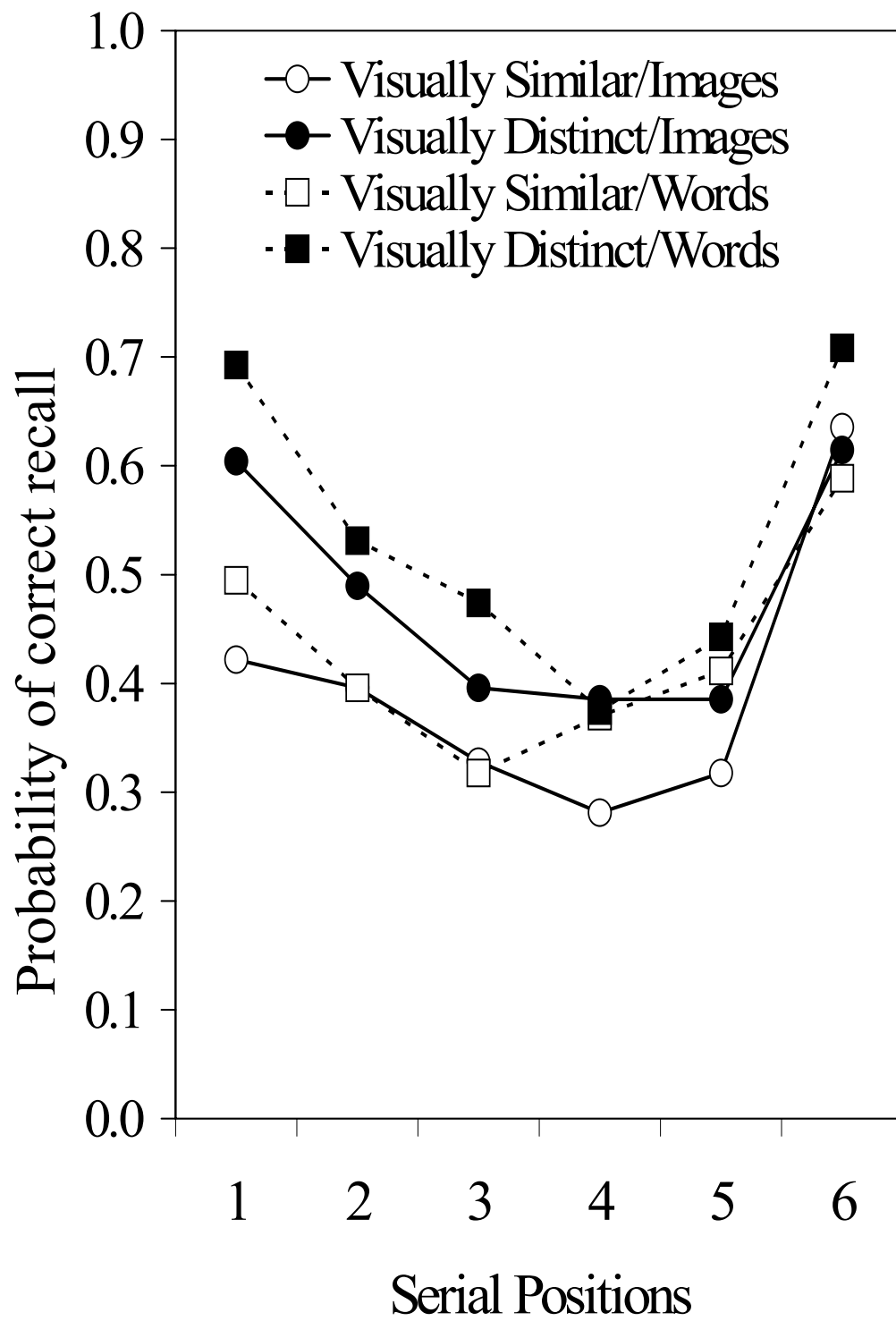
Figure Captions

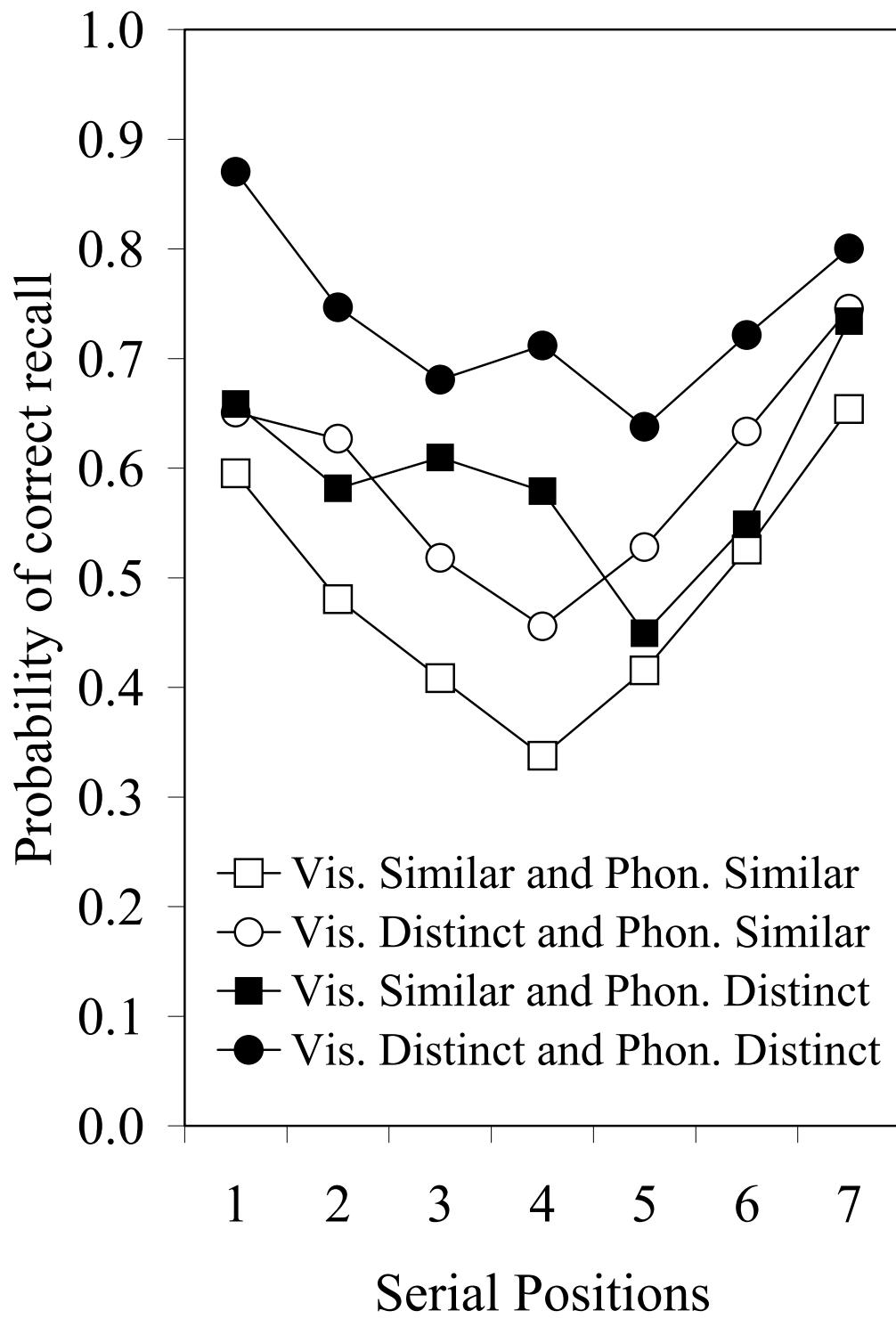
Figure 1. Probability of correct recall as a function of serial positions, visual similarity and articulatory suppression; Experiment 1 results are in the left panel [a] and Experiment 2 results can be found in the right panel [b].

Figure 2. Experiment 3: Probability of correct recall as a function of serial positions, visual similarity, and response modality (verbal labels or matrices).

Figure 3. Experiment 4. Probability of correct recall as a function of serial positions, visual similarity and phonemic similarity.

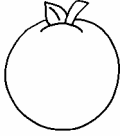
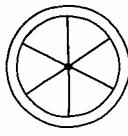
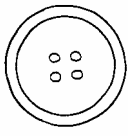
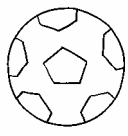
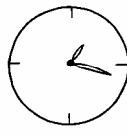
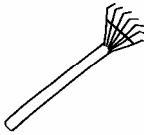
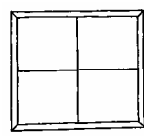
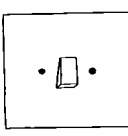
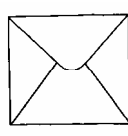
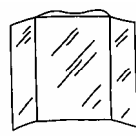
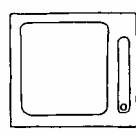




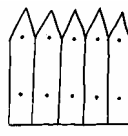
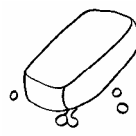
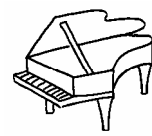
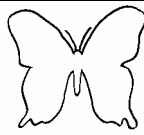
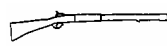
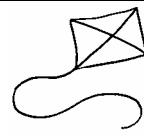
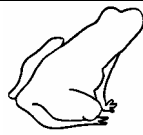
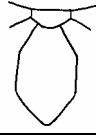
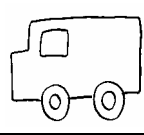
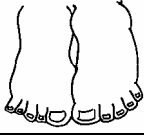


Appendix A – Visually similar & distinct stimuli used in Experiments 1, 2, 3 and 4.

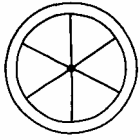
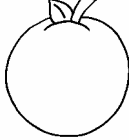
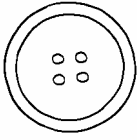
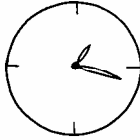
Experiment 1 - Visually similar stimuli

					
Apple	Wheel	Bomb	Button	Ball	Clock
					
Rake	Cigarette	Pencil	Dart	Ruler	Flute
					
Window	Switch	Envelope	Mirror	Television	Bag

Experiment 1 - Visually distinct stimuli

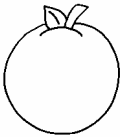
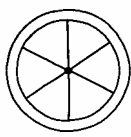
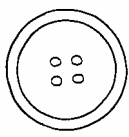
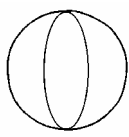
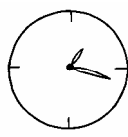
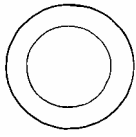
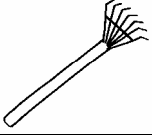
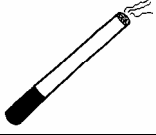
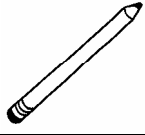
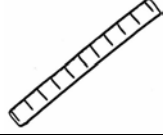
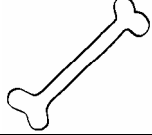
					
Fence	Pineapple	Fork	Soap	Piano	Whistle
					
Cat	Camel	Butterfly	Rifle	Kite	Frog
					
Shell	Tie	Truck	Feet	Lighter	Lion

Experiment 1 -- Answer sheet example: Participants had to number the stimuli in the order corresponding to the presentation order – This was done by writing the appropriate number in the box below the item – in the example below, the participant indicated that the apple was presented first.

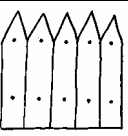
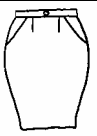
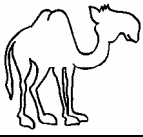
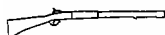
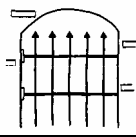
					
	1				

Appendix A – Visually similar & distinct stimuli used in Experiments 1, 2, 3 and 4.

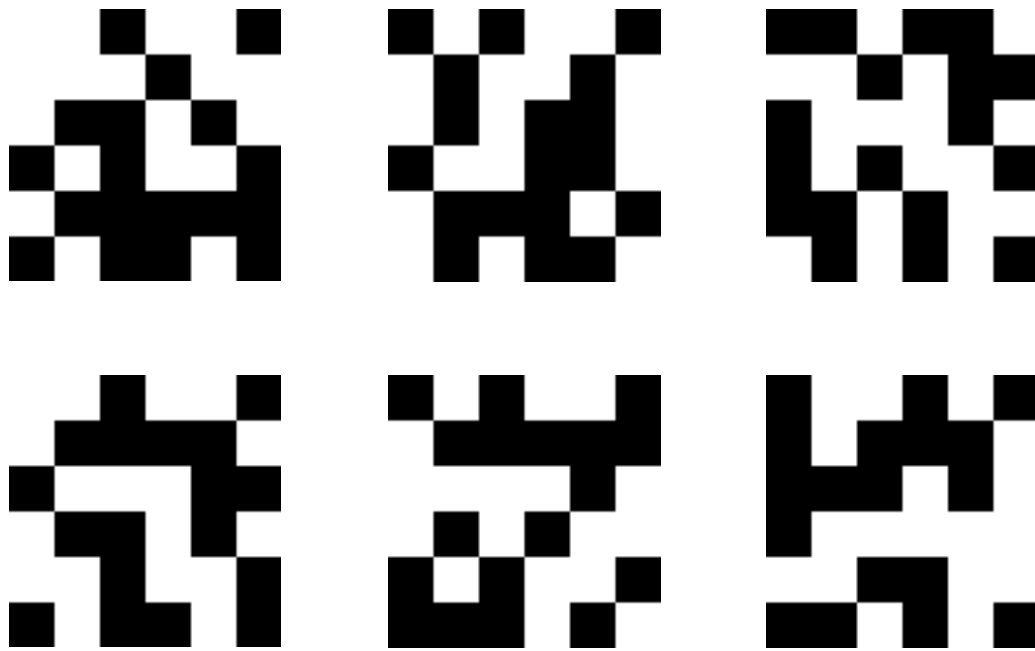
Experiment 2 – Visually similar stimuli

						
Apple	Wheel	Bomb	Button	Ball	Clock	Plate
						
Rake	Cigarette	Pencil	Dart	Ruler	Flute	Bone

Experiment 2 – Visually distinct stimuli

						
Fence	Bag	Fork	Shell	Piano	Whistle	skirt
						
Daisy	Camel	Cloud	Rifle	Kite	Umbrella	Gate

Experiment 3 - Visually distinct stimuli:

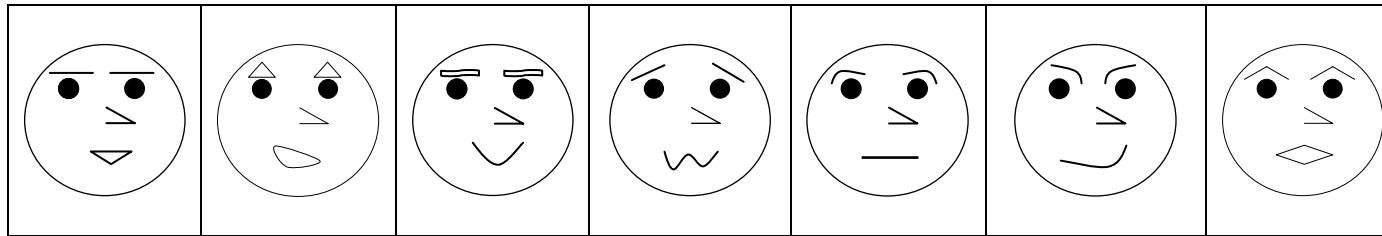


Experiment 3 - Visually similar stimuli



Appendix A – Visually similar & distinct stimuli used in Experiments 1, 2, 3 and 4.

Experiment 4 – Visually similar schematic faces



Experiment 4 – Visually distinct schematic faces

