Serial position effects in 2-alternative forced choice recognition: Functional equivalence across visual and auditory modalities

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Acknowledgements

Our thanks to Geoff Ward and an anonymous reviewer for their constructive comments on an earlier version of the paper. Thanks also to Georgina Powell for her enthusiastic testing of participants and to Justin Savage for his technical assistance. This study was supported by a joint Medical Research Council and School of Psychology, Cardiff University postgraduate studentship awarded to the first author.

Abstract

Two experiments examined Ward, Avons and Melling's (2005) proposition that the serial position function is task, rather than modality, dependent. Specifically, they proposed that for backward testing the 2-alternative forced choice (2AFC) recognition paradigm is characterised by single-item recency irrespective of the modality of the stimulus presentation. In Experiment 1 the same nonwords sequences, presented both visually or auditorially, produced qualitatively equivalent serial position functions with 2AFC testing. Forward testing produced a flat serial position function, whilst backward testing produced two-item recency in the absence of primacy. In order to rule out the possibility that the serial position functions for visual stimuli were the product of sub-vocal rehearsal, Experiment 2 employed articulatory suppression during the presentation phase. Serial position function equivalence was again observed together with a modest impairment in overall recognition rates. Taken together, these data are consistent with the Ward et al. proposition and further support the existence of a visual memory that can facilitate storage of visual-verbal material e.g. Logie, Della Sella, Wynn, and Baddeley (2000). However, the observation of two-item recency contradicts the original Duplex account of single-item recency traditionally observed for backwards recognition testing of visual stimuli (Phillips and Christie, 1977).

Introduction

In a series of influential studies, Phillips and Christie (1977) investigated recognition for hard-to-name stimuli via a series of single yes/no recognition probes. Participants were presented with a sequence of abstract matrices followed by a series of yes/no recognition test-probes. For backward testing, Phillips and Christie reported single-item recency with equivalent levels of recognition for the pre-recency items. They interpreted this finding via the two-component Duplex theory which proposes that recency reflects the action of a highly accurate, single-item capacity, visual short-term memory (STM). The equivalent level of recognition for pre-recency items was taken to reflect the action of a durable long-term store (LTS). Specifically, they argued that during the presentation phase, each list item is represented within the single-item visual STM. Presentation of each successive list item acts to displace attention from the current item to the new item. Thus all previously presented items are represented within a less accurate, large capacity, durable LTM. Following the backward testing of list items, a match occurs between the last sequence item (held within the visual STM) and the test item. This promotes strong recognition performance. At the point of test, since all pre-recency items have been displaced into the more durable and larger capacity LTS, recognition for these pre-recency items is equivalent, yet reduced compared to that for the last-sequence item.

More recently, Ward, Avons and Melling (2005) employed a 2AFC paradigm to investigate recognition for both unfamiliar face and nonword sequences. Each sequence was followed by a series of test-pairs comprising one item from the previous sequence and one novel item. Although both stimulus types are hard-to-name they were judged to reflect the action of distinct memory mechanisms i.e. the visuo-spatial sketchpad and phonological loop, respectively. For backward testing Ward et al. (2005) replicated the finding of single-item recency for both stimulus types. They proposed, therefore, that backwards 2AFC testing will always produce a pattern of data consistent with that predicted by the Duplex account, regardless of either the type or presentation modality of the stimulus. Further support for their proposal comes from the finding of recency following backward 2AFC recognition for sequences of olfactory stimuli (Johnson and Miles, 2007) who, additionally, observed a flat serial position function for forward 2AFC testing. The observation of a flat serial position function for forward 2AFC testing is consistent with Avons (1998) and Avons and

Mason (1999) using abstract patterns. These studies expand upon the initial proposal by Ward et al. that backward testing 2AFC testing is characterised by single-item recency, demonstrating that in contrast, forward 2AFC testing is characterised by a flat serial position function.

There are, however, notable methodological limitations to the Ward et al. study in which evidence for equivalent functions across stimulus types was claimed. In their study, 2AFC recognition for visual (unfamiliar-faces) and auditory (nonwords) stimuli was contrasted. However, at test the conditions of test-item presentation differed across modality. For the visual stimuli, test-pair items were presented simultaneously. In contrast, for the auditory stimuli participants were required to click on one of two speech bubbles in turn. Clicking on a speech bubble enabled participants to hear each of the test-pair words independently prior to providing a binary familiarity judgment. There were, therefore, two important methodological differences between the visual and auditory conditions.

1. In the visual condition the test-pair items were presented simultaneously. Comparison between memory traces for the test-pair items could, therefore, presumably be achieved via simultaneous evaluation. In contrast, sequential presentation in the auditory condition prevented such simultaneous comparison of memory traces for the test-items. Although one might argue that in the simultaneous test-pair procedure participants naturally scan from the left stimulus to the right stimulus, thereby creating a form of sequential presentation, it is equally plausible that if two words are presented adjacently participants view them simultaneously.

2. The visual and auditory stimuli differed not just in presentation modality but also with respect to characteristics of the stimuli employed. For example, unfamiliar-faces are multi-feature nonverbal stimuli, whereas nonwords are unfamiliar verbal stimuli.

The present study addresses directly these methodological concerns by comparing the serial position functions for 2AFC recognition for the same stimuli when presented either visually or auditorially. A within-subjects design is employed such that participants perform both forward and backward 2AFC recognition judgments for nonword sequences presented either visually or auditorially. The use of nonwords allows the same stimuli to be employed whilst manipulating the presentation modality only. Furthermore, the sequential test-pair presentation design (see, Johnson and Miles, 2007) ensures equivalence of test procedures across stimuli. If the functions are qualitatively equivalent for both presentation modalities, then there should be no evidence of an interaction between presentation modality, direction of testing, and serial position. In contrast, an interaction between direction of testing and serial position should be evident, such that backward testing produces single-item recency for both modalities, consistent with Ward et al., (2005) and forward testing produces a flat function for both modalities consistent with Avons (1998) and Johnson and Miles, (2007).

Experiment 1

Method.

Participants. Twenty-four (6 males, 18 females: mean age = 23 years 6 months) Cardiff University volunteer undergraduates from a variety of disciplines participated and each received a £5.00 honorarium upon completion of the study.

Materials. A corpus of 120 nonwords was created using the same construction method as reported by Ward et al. (2005). Single syllable nonwords were initiated by employing one of 32 initial consonants (or multiple consonant) e.g. “b”, “cl”, “m”, “pr”, “st”, “z”. These consonant(s) were then combined with one of 9 vowel sounds, such as “a”, “oo”, “u”, “ie”. The words were completed with one of 39 consonant (multiple consonant) endings, e.g. “dge”, “tch”, “g”, “sh”, “x”.

As described by Ward et al. (2005) constraints were imposed to limit the formation of peculiar or familiar sounding words. First, a single terminal consonant was always employed when the vowel sound comprised more than one letter. Second, a single letter vowel sound was always employed when the word ended with a consonant cluster. These constraints were proposed by Ward et al. in order to prevent the formation of idiosyncratic letter combinations such as “broodge”. Third, words were excluded from the corpus if they were known English words, or when presented auditorily sounded identical to known English words. The corpus of nonwords is available in Appendix 1.

In the visual presentation condition, the nonwords were displayed centrally on the computer screen in Times New Roman font size 100. In the auditory presentation condition, the nonwords were transformed into a single MP3 auditory file using the text-to-speech program IE speaker. The auditory file was then edited into single word files using the editing software Audacity. The nonwords were edited such that the articulation length of each did not exceed 600 ms. The nonwords were then presented by headphones at a volume of 75dB.

Design. A 2x2x6 within-subjects factorial design was adopted in a 2AFC recognition paradigm. The first factor refers to the modality of stimulus presentation (visual and auditory). The second factor refers to the direction of testing (forward versus backward) and the third factor refers to serial position (1-6). Direction of testing was intermixed across the 20 trials (10 forward and 10 backward). The order of these trials was pseudo-randomised across participants, with the proviso that no more than two consecutive trials employed the same testing procedure. Each of the 120 nonwords was presented on two occasions: once in each half of the experiment. Participants performed the experiment on consecutive days. The tasks were identical but for the visual/auditory stimuli presentation manipulation. The order in which these conditions were presented was counterbalanced.

Procedure. The procedure followed closely that described by Johnson and Miles (2007). Participants were tested individually in a well-ventilated, soundproofed laboratory and sat at a desk facing the computer screen at a distance of approx 50cms. The procedure for the auditory and visual conditions was identical except for the modality in which the nonwords were presented. For each trial the participant was presented with a sequence of 6 nonwords. Each nonword was presented for 600 ms with an inter-stimulus interval (ISI) of 400 ms. Trials were initiated by the experimenter and participants were instructed to view each nonword in a trial. This procedure continued to the presentation of the sixth nonword.

A retention interval of 1400ms followed presentation of the sixth nonword. For the test phase the participant was presented with a series of six 2AFC recognition tests. The nonwords within each test-pair were presented sequentially: one test nonword was the target nonword taken from the sequence and the other was a nonword novel to that trial. Both the rate of presentation of the test nonwords and their ISI were the same as those employed in the learning phase. Following presentation of the second test-nonword the participant was required to state verbally whether the first or the second nonword in the test-pair was familiar from the previous sequence by responding “first” or “second”. For the forward testing procedure the target nonword in the first test-pair presented was the nonword presented first in the previous sequence. This procedure was repeated with the second test-pair which comprised the nonword presented second in the previous sequence and a nonword novel to that trial. This pattern of testing continued until each nonword in the sequence had been tested against a nonword novel to that trial. The order of testing was, therefore, identical to the order of presentation. The backward testing procedure followed that described for the forward testing procedure, with the exception that the sequence of test-pairs tracked backwards through the sequence previously presented. Thus, the first test-pair presented comprised the nonword presented last in the preceding sequence paired with a nonword novel to that trial. The position of the target nonword within each test-pair (first or second) was randomly assigned with the proviso that it occurred an equal number of times in each position and that there was a maximum of two consecutive trials in which the position of the target nonword was unchanged. Each trial was followed by an interval of approximately 5 seconds and the participant was given the option of a 1 minute rest after every 5 trials. The complete experiment lasted approximately 20minutes.

Results and Discussion

Figure 1a shows the mean percentage correct recognition at each serial position for both the visual and auditory presentation following the forward testing procedure. Figure 1b shows the mean percentage correct recognition at each serial position for both visual and auditory presentation following the backward testing procedure.

Figure 1(a-b) about here please

A 3-factor (2x2x6) within-subjects ANOVA was computed on the correct recognition scores where the first factor represents presentation modality (visual versus auditory), the second factor represents direction of testing (forward versus backward) and the third factor represents serial position (1-6). A main effect of both presentation modality, $F(1,23)=16.02$, $MSe=3.91$ (mean correct recognition rates = 78.68% and 72.08%, for visual and auditory presentation, respectively) and serial position was found, $F(5,115)=13.55$, $MSe=1.28$. A null effect of testing procedure was observed, $F=1.86$. The interaction between modality and testing procedure and that between modality and serial position were non-significant, both Fs<1. As predicted the interaction between testing procedure and serial position was significant, $F(5,115)=21.65$, $MSe=1.42$. Further analysis (Newman-Keuls, $P<.05$) revealed that for forward testing there were no differences between recognition scores across the six serial positions. Following the backward testing procedure, recognition for serial position 6 was significantly greater than that for positions 1-5. Furthermore, recognition for position 5 was significantly greater than that for positions 1-4. In line with predictions, the three-way interaction between modality, testing procedure and serial position was non-significant, $F=1.02$. The finding indicates that the serial position functions following the forward and backward testing procedures did not differ as a function of presentation modality

These analyses provide two key findings. First, presentation modality did not qualitatively impact the serial position function for either the forward or backward testing procedures. Second, for both presentation modalities, the forward testing procedure produced an absence of serial position effects and the backward testing procedure produced recency extending over two serial positions. The finding of extended recency following the backward testing procedure contradicts the single-item recency function observed for other stimuli e.g. Phillips and Christie, (1977); Ward et al., (2005); Johnson and Miles, (2007, Experiment 2). Such a finding questions the proposal by Ward et al. (2005) that backward recognition is characterised by single-item recency irrespective of stimulus type. Nevertheless, the current findings are consistent with Ward et al.'s proposal that manipulation of stimulus modality does not qualitatively impact the serial position function.

Of course, one might speculate that the serial position functions observed in Experiment 1 are due to participants rehearsing sub-vocally the phonological forms of the nonwords. Indeed, the phonological loop component of Baddeley and Hitch's (1974) working memory model can easily accommodate such speculation.

Notwithstanding the observation that if this were the case one might not necessarily predict a flat serial position function for the forward testing procedure, Experiment 2 was designed to test directly the extent to which participants employed sub-vocal rehearsal strategies in Experiment 1.

Experiment 2

In Experiment 1 it is conceivable that both the visual and auditory serial position functions were underpinned by a common phonological code. Therefore, in Experiment 2, articulatory suppression was employed to discourage phonological coding of the visual stimuli, e.g. see abolition of the phonological similarity effect following articulatory suppression (Baddeley, Lewis, and Vallar, 1984). We employed articulatory suppression during the presentation phase but not the recall phase of the task: Smyth, Hay, Hitch and Horton (2005, Experiment 2) found a non-significant difference in performance for a condition employing partial articulatory suppression, i.e. articulatory suppression during the presentation phase only and a condition employing full articulatory suppression, i.e. articulatory suppression throughout both the presentation phase and the recall phase.

Evidence that serial order memory for visual-verbal stimuli is supported by a visual code both with and without articulatory suppression is provided by Logie, Della Sala, Wynn, and Baddeley (2000). In their study they examined the temporary retention of visually presented verbal material. Participants were required to serially recall sequences of words that varied in visual similarity or sequences of letters that varied in case. For both stimulus types, visual similarity impaired recall both with and without concurrent articulatory suppression. These effects were consistent across serial position in the sequence leading Logie et al. to conclude that in addition to a phonological code, a visual code is employed for retention of visually presented verbal sequences. It is argued, therefore, that participants utilize "a visual temporary memory, or visual ``cache'', in verbal serial recall tasks" (p. 626). Their interpretation is consistent with our findings for Experiment 1 where recognition for the visual stimuli exceeded that for the auditory stimuli. That is, the superior recognition for the visual stimuli reflects the operation of two forms of representation i.e. phonological and visual (Logie et al, 2000). Thus, the use of articulatory suppression in Experiment 2 will strengthen our conviction that the visual and auditory sequences were processed in different ways, i.e. graphemically and phonologically, respectively. If the resulting serial position functions are qualitatively equivalent this lends further support to the proposition that 2AFC recognition functions are task, rather than stimulus, dependent (Ward et al., 2005).

Method.

Participants. Twenty-four (4 males, 20 females: mean age = 25 years 9 months) Cardiff University volunteer undergraduates from a variety of disciplines participated and each received a £5.00 honorarium upon completion of the study. None had participated in Experiment 1.

Materials. The stimuli were identical to those described for Experiment 1.

Design. The design was identical to that described for Experiment 1.

Procedure. The procedure was identical to that described for Experiment 1 with the exception that during the presentation phase participants were required to whisper the number sequence "1, 2, 3, 4" repeatedly at an approximate rate of 2-3 numbers per second.

Results and Discussion

Figure 2a shows the mean percentage correct recognition at each serial position for both the visual and auditory presentation following the forward testing procedure. Figure 2b shows the mean percentage correct recognition at each serial position for both the visual and auditory presentation following the backward testing procedure. The same 3-factor (2x2x6) within-subjects ANOVA as described for Experiment 1 was computed. Main effects of both presentation modality, $F(1,23)=15.03$, $MSe=3.83$ (mean correct recognition = 71.53% and 65.17% for the visual and auditory presentations, respectively) and serial position were present, $F(5,115)=12.91$, $MSe=2.33$. A null effect of testing procedure was observed, $F=2.92$, $p=0.09$. Non-significant interactions between both presentation modality and testing procedure, $F<1$, and presentation modality and serial position, $F=1.58$, were observed. Once again, in line with Experiment 1, the interaction between testing procedure and serial position was significant, $F(5,115)=11.65$, $MSe=2.23$. Crucially however, the three-way interaction between presentation modality, testing procedure and serial position was non-significant, *F*=2.07. Consistent with Experiment 1, serial position functions following the forward and backward testing procedures did not differ for the visual and auditory presentation modalities.

Figure 2(a-b) about here please

Further analysis (Newman-Keuls, P<.05) of the interaction between testing procedure and serial position revealed that for forward testing recognition rates did not differ as a function of serial position. For backward testing, recognition for serial position 6 was significantly greater than that for serial positions 1-5. Furthermore, recognition for serial position 5 was significantly greater than that for serial positions 1-4.

Consistent with the findings for Experiment 1, presentation modality did not qualitatively impact the serial position function: forward testing produced a flat function whilst backward testing produced recency extending to two serial positions. Once again, the finding of extended recency contradicts the predictions of the Duplex account.

In order to assess directly the effect of articulatory suppression on recognition performance, a combined analysis incorporating the data for both experiments was computed. The same model ANOVA as described above with the additional between-subjects factor of Experiment showed, as expected, that articulatory suppression impaired recognition performance, $F(1,46)=12.14$, $MSe=11.73$, $p<0.05$; mean recognition accuracy = 75.38% and 68.35% for Experiment 1 and Experiment 2, respectively. This finding suggests that recognition performance in Experiment 1 was partially maintained by sub vocal rehearsal. Critically however, consistent with our predictions, the factor Experiment failed to interact with any other factor. Consistent with this, inspection of the serial position functions for both backward and forward testing following auditory presentation (Experiment 1) and visual presentation (Experiment 2) demonstrates qualitative equivalence. This observation is consistent with Logie et al.'s proposition that memory for the auditory sequences benefits from phonological representations whilst, in contrast, memory for the visual sequences (with suppression) benefits from visual representations.

General Discussion

Experiments 1 and 2 provide a comparison between visual and auditory 2AFC recognition when both the methodology and stimulus type are held constant. Both demonstrated qualitatively equivalent serial position functions following the visual and auditory presentation of nonwords. Specifically, backward testing revealed recency extending two serial positions whilst forward testing revealed a flat serial position function. Extended recency following backward testing contradicts the proposal (Ward et al., 2005) that 2AFC recognition is characterised by single-item recency. Although this difference might be interpreted as minor i.e. recency extended by one additional position, the serial position function differences suggest significant implications with respect to the Duplex theory originally proposed to account for 2AFC recognition. The Duplex account predicts single-item recency premised on the assumption that the last list item is represented within the visual STM, whilst pre-recency list items are represented within a stable long-term LTS. Importantly, the participants can only represent single items within the visual STM. Our observation of extended recency is clearly at odds with such an account.

The general finding of recency in the absence of primacy is consistent across a range of stimulus types within the 2AFC paradigm e.g. odours, Johnson and Miles (2007); matrix pattern, Avons, Ward and Melling (2004); Kerr, Avons and Ward (1999). Furthermore, the present findings are consistent with the proposal that the serial position function is task rather than stimuli/modality dependent (Ward et al. 2005). Specifically, phonological representations (auditory condition without articulatory suppression, Experiment 1) and visual representations (visual condition with articulatory suppression, Experiment 2) produced qualitatively equivalent serial position functions. Furthermore, the finding that the qualitative features of the serial position functions were maintained under conditions of articulatory suppression, is consistent with the proposal of Logie et al (2000) that a temporary visual memory can be employed for maintenance of visually presented verbal sequences (see also Jalbert, Saint-Aubin and Tremblay (2008) for visual similarity effects with sequence recall of coloured squares).

As a general point we should perhaps note that the finding of serial position function equivalence for different stimuli does not appear to generalise to order based recall tasks. For instance, Johnson and Miles (in press) employed a single-probe serial position recall task for olfactory, visual and auditory stimuli and reported a flat function, primacy and recency, and single-item recency, respectively. Together, these findings contradict Guérard and Tremblay (2008) who argue that functional equivalence generally arises from tasks that uniquely require retention of order regardless of stimulus type.

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Appendix 1
Nonword List
The nonword stimulus set was constructed using the method described in Ward et al. (2005). This process is also detailed in the materials section of Experiment 1.

BAF	FROVE	KIEB	RULCH
BESH	FOTCH	KALF	RUTCH
BLOVE	FRIEM	LALCH	SETCH
BIME	GACK	LESH	SOOB
BISH	GODGE	LUDGE	SNAB
BOVE	GIK	LUTCH	SNIBE
BUP	GUVE	LEEG	SHIG
BIEB	GROF	LIEG	SHISH
BRALCH	GELCH	LEEB	STOLF
BRAP	GROST	MALCH	SCADE
CELCH	GRUBE	MECK	STUST
COOB	GRANG	MIEF	SCALCH
CHATCH	GRUT	MALT	TABE
CHIB	HALCH	MOLF	TOOG
CHOOF	HADGE	MIB	TOTCH
CLADGE	HISH	NALCH	THADGE
CLOF	HUFT	NEFT	TRALCH
CLUPE	HIEB	NETCH	TUTCH
CROB	HOLCH	NILM	TROB
CROOG	HETCH	NIBE	THABE
DALCH	HELCH	NULCH	TREG
DOTCH	HEAB	NOOG	TROOB
DRUP	HOOG	NIEP	ZIBE
DADGE	JALCH	NULF	ZAB
DULF	JADGE	NODGE	ZABE
DRANG	JAFT	POLM	ZADGE
DRATCH	JOOB	PRUTCH	ZAF
DROD	JEX	PLAB	ZAPE
DREET	JETCH	PLIDGE	ZEFT
DRILM	JISH	PLIBE	ZIBE
FALF	JOLCH	PLOOG	ZILF
FUB	JIEM	PRABE	ZOOG
FOLCH	JEFT	PRISH	ZOTCH
FOOG	KALCH	PLATCH	
FEAG	KOFT	PLOG	
FRACK	KIEK	RALCH	
FRATCH	KULCH	ROLCH	

Figures

Figure 1a-b

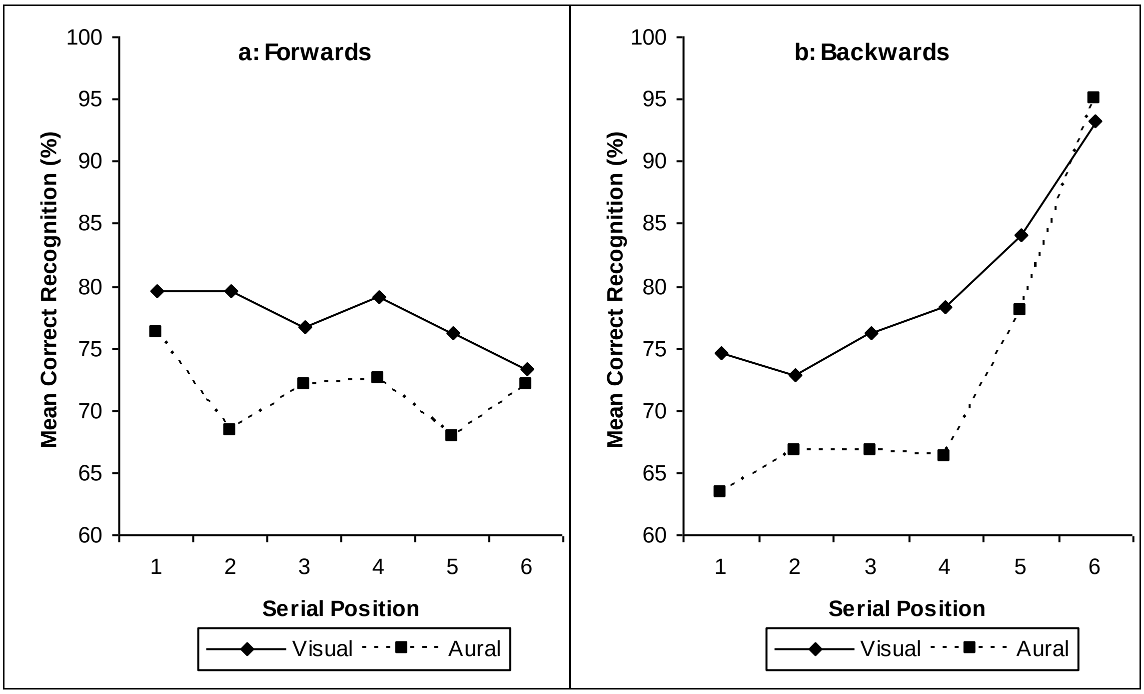
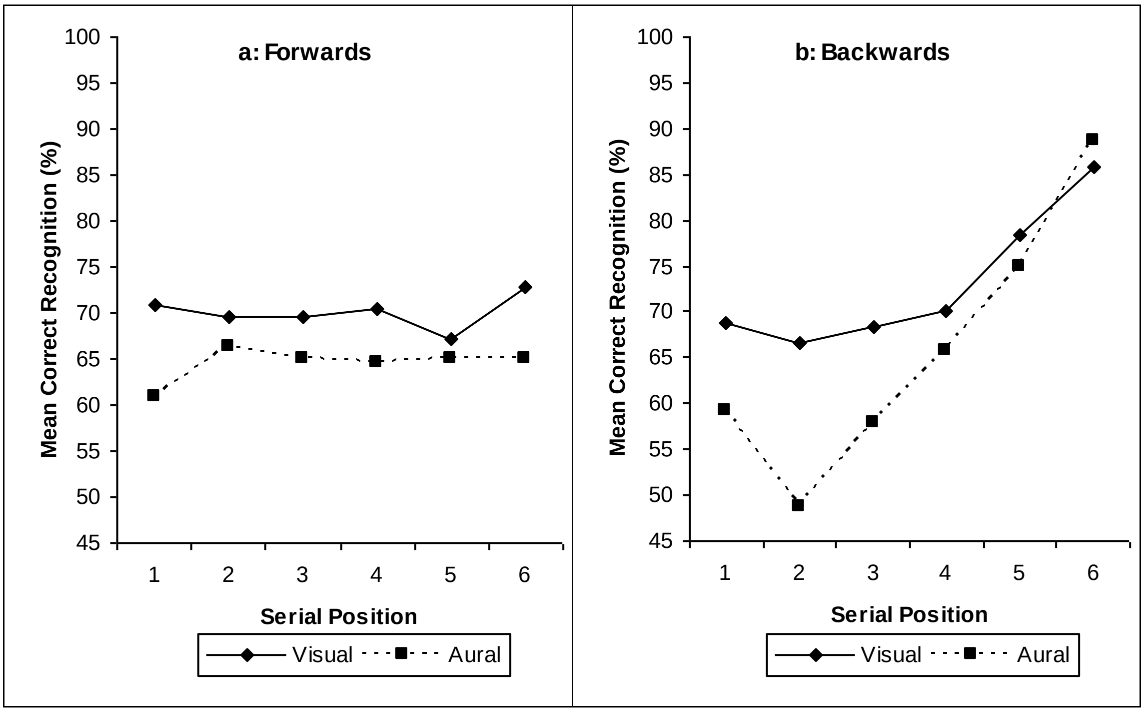


Figure 2a-b


a: Forwards
Mean Correct Recognition (%)
100
95
90
85
80
75
70
65
60
55
50
45
1
2
3
4
5
6
Serial Position
Visual
Aural
b: Backwards
Mean Correct Recognition (%)
100
95
90
85
80
75
70
65
60
55
50
45
1
2
3
4
5
6
Serial Position
Visual
Aural

Legends

Legend 1

Figure 1(a-b): Mean percentage correct recognition for the forward (a) and backward (b) testing procedures following both visual and auditory nonword presentation and as a function serial position.

Legend 2

Figure 2(a-b): Mean percentage correct recognition for the forward (a) and backward (b) testing procedures following both visual and auditory nonword presentation and as a function serial position.