Repetition Inhibition and Facilitation Effects for Visual-Verbal Stimuli under Conditions of Concurrent Articulation

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Abstract

The present study examines the effects of within-sequence repetitions for visually presented consonants under conditions of quiet and concurrent articulation (CA). In an immediate serial recall (ISR) procedure, participants wrote down the 6-consonants in the order of original presentation. CA reduced serial recall and abolished the phonological similarity effect. However, the effects of within-trial repetitions were broadly similar under quiet and CA. Specifically, adjacent repetitions facilitated recall of the repeated item, whereas spaced repetitions (separated by 3-intervening items) impaired recall accuracy for the repeated item (i.e. the Ranschburg effect). These data are the first to demonstrate the Ranschburg effect for visual-verbal stimuli under CA.

104 words

Keywords: Ranschburg effect; response suppression; immediate serial recall; phonological similarity effect; concurrent articulation

Introduction

The Ranschburg effect is a sequence memory phenomenon whereby recall is inhibited for an item repeated at encoding (e.g. Crowder, 1968; Duncan & Lewandowsky, 2005; Henson, 1998a; Jahkne, 1969). The effect has been attributed to response inhibition (also known as response suppression) at test (e.g. Armstrong & Mewhort, 1995; Vousden & Brown, 1998), such that, following the first retrieval of the repeated item, this item is then suppressed, inhibiting recall of its second presentation. This response inhibition mechanism is argued to produce the low proportion of within-trial repetitions observed in sequence memory trials that contain no repetitions (typically 2-5% of all responses, Henson, Norris, Page & Baddeley, 1996; Vousden & Brown, 1998).

Response inhibition is common within computational models of verbal serial order memory (e.g. Burgess & Hitch, 2006; Henson, 1998b; Page & Norris, 1998). One example is competitive queuing (CQ). Here, at test all list items are active in parallel, with the most active item outputted and then inhibited. Inhibition is important to list retrieval because without such a mechanism the item with the strongest activation level would be retrieved repeatedly. This is critical for ordinal models of serial order (e.g. the Primacy Model, Page & Norris, 1998) whereby activation along an exponentially declining primacy gradient is used uniquely to determine recall. Response inhibition is essential to both prevent perseveration (i.e., repeated recall of an item) and enable items with lower levels of activation to be recalled. For positional models where list items are associated with a dynamically changing context (e.g. Burgess & Hitch, 2006), response inhibition is less significant since the recall cue, i.e. position, changes for each item. That is, participants retrieve the item with the highest activation level for that position, rather than the highest overall level of activation.

These models are, therefore, able to accommodate the Ranschburg effect epiphenomenally following response inhibition.

These models are designed to account for verbal order memory but, as noted by Hurlstone, Hitch, and Baddeley (2014), the extent to which these models can be applied to other stimulus types is unknown. Indeed, with response inhibition operating as a fundamental process within these models, particularly with respect to ordinal models, examination of the Ranschburg effect is a powerful indirect test of cross-modal response inhibition. Intuitively, one might expect the Ranschburg effect to be present for non-verbal stimuli since cross-modal similarities for a range of serial order memory phenomena have been reported, including for example: serial position curves (e.g. Guérard & Tremblay, 2008; Horton, Hay, & Smyth, 2008; Ward, Avons & Melling, 2005), error distributions (Guérard & Tremblay, 2008; Johnson, Shaw & Miles, 2016), and Hebb repetition learning (e.g. Johnson et al., 2016; Horton et al., 2008; Page, Cumming, Norris, Hitch & McNeil, 2006). Such similarities led Hurlstone et al. (2014) to suggest that common order memory principles operate across memory modules, with a CQ mechanism employed universally.

To date, there exists only one study examining the Ranschburg effect cross modally (Roe, Miles & Johnson, 2016). Here, blindfolded participants received sequences of 6-touches to the fingers. At test, they retrieved the sequence by moving their fingers in the order of original presentation. Whilst Roe et al. (2016) reported evidence for response inhibition (i.e. the Ranschburg effect), it is possible that participants verbally recoded the tactile stimulations, thereby exhibiting the previously observed verbal Ranschburg effect (e.g. Crowder, 1968; Duncan & Lewandowsky, 2005; Henson, 1998a; Jahkne, 1969).

The present study is designed to examine the effects of within-sequence repetition when verbal recoding is restricted. Serial recall of a visual-verbal sequence under conditions of concurrent articulation has been shown to abolish both the phonological similarity effect (PSE, e.g. Baddeley, Lewis, & Vallar, 1984; Saito, Logie, Morita, & Law, 2008) and the word length effect (WLE, e.g. Baddeley, Thomson, & Buchanan, 1975; Baddeley et al., 1984); phenomena indicative of initial phonological representations being disrupted. In the classic modular Working Memory Model interpretation of this effect, it is argued that whilst auditory-verbal stimuli have direct access to the passive phonological store, visual-verbal stimuli require phonological recoding within the articulatory rehearsal loop; CA occupies the articulatory rehearsal loop and prevents phonological recoding (Baddeley et al., 1984). Residual performance under CA is supported by the episodic buffer, an amodal back-up store (Baddeley, 2000).

Despite abolition of both the PSE and WLE under CA, serial order recall of visual-verbal stimuli under CA exhibits a remarkably similar pattern of performance to that for a quiet condition. For example, Page et al. (2006) demonstrated that both the canonical bowed serial order reconstruction function and the Hebb repetition effect were observed under conditions of quiet and CA. Similarly, Spurgeon, Ward, and Matthews (2014) examined both immediate serial recall (ISR) and immediate free recall (IFR) under quiet and CA and showed that the serial position functions for both were comparable under quiet and CA for a range of list lengths. Furthermore, the order in which list items were recalled was similarly affected by list length. In short, patterns of ISR and IFR remained robust under conditions of both quiet and CA, suggesting that the 'back-up' episodic buffer has remarkably similar functionality to that of the phonological loop. Indeed, Spurgeon et al. (2014) question the parsimony of a model in which different mechanisms are used to explain very similar patterns of performance for visual-verbal stimuli under conditions of quiet and CA.

Irrespective of one's theoretical preference with regard to STM modularity, the findings of the above studies converge to propose that effects of within-sequence repetition should be similar for both quiet and CA. It is this proposition that is examined in the present study. As described earlier, although spaced repetition typically results in poorer recall for the repeated item, within-trial repetition is not exclusively inhibitory (e.g. Henson, 1998a; see also Crowder, 1968; Lee, 1976). Adjacent (massed) repetitions typically produce recall facilitation for the repeated item. Such facilitation has been linked to participant awareness of the repetition, such that repetition salience results in the participant mentally ‘tagging’ items for repeated retrieval at test (Henson, 1998a; Jahnke, 1969). In the present study, two experimental sessions, one in quiet and one with CA, are undertaken in which ISR of both phonologically similar and dissimilar letters is required. Abolition of the PSE under conditions of CA (evinced via an interaction between CA and phonological similarity) is used as a manipulation check to determine that phonological recoding has been prevented. To examine the effect of within-sequence repetitions we test three types of repetition spacing. When the repetitions are separated by either 1 or 3-intervening items, then impaired recall of the repeated item relative to matched control sequences should be observed (i.e. the Ranschburg effect). However, when the repeated items are adjacent/massed, then improved recall of the repeated item relative to the matched control sequences should be observed.

Method

Participants. Thirty-two Bournemouth University Psychology undergraduates (mean age = 19.7 years; 15 male and 17 female), participated in exchange for research participation credits. Ethical approval was obtained from the Bournemouth University Psychology Ethics Committee.

Materials. Sequences of six stimuli (upper case, black Times New Roman, size 72) were presented on a 23 inch (58.4cm) Hewlett-Packard (Palo Alto, USA) Elite Display E231 monitor using the experimental software Superlab 5.0 (Cedrus Corporation, San Pedro, USA). The sequences comprised phonologically similar (B, C, D, P, T, and V) or phonologically dissimilar (F, J, K, L, R, and Y) consonants. Small set sizes were used as the Ranschburg effect is maximised under such conditions (Jahnke, 1972). A response booklet was used, where each page was used for a trial and contained a grid where a row of 6 boxes were positioned vertically.

Design. A multi-factorial (2x2x3x6) within-participants design was adopted. The first factor refers to the CA condition (quiet versus CA), the second factor to the phonological similarity of the consonants (phonologically dissimilar versus phonologically similar), the third factor to repetition condition (adjacent repetition, 1-item spaced repetition, and 3-item spaced repetition), and the fourth factor to serial position (1-6). The experiment was divided into two sessions of 48 trials (separated by a 5-minute interval). One session was conducted under conditions of quiet, whilst the other was conducted under conditions of CA. The presentation order of these sessions was counterbalanced. Each session comprised two blocks of 24 trials. One block contained trials with phonologically similar consonants, whilst the other contained trials with phonologically dissimilar consonants. The presentation order of these blocks was counterbalanced within each session. Each block comprised 12 trials containing a within-sequence repetition and 12 matched control trials. Of the 12 within-sequence repetition trials, four trials comprised adjacent repetitions (one trial each for positions 2+3, 3+4, 4+5, and 5+6), four trials comprised repetitions separated by 1-intervening item (two trials each for positions 2+4 and 4+6), and four trials comprised repetitions separated by 3-intervening items (four trials for positions 2+6). The presentation order of these 24 trials was randomised within each block.

Each Ranschburg sequence was unique and had a corresponding matched control sequence that was identical with the exception that the repeated item was replaced by an unrepeated item. The control trials were not included in the above design as the repetition effect is analysed by subtracting recall for the critical items in the control trials from recall for the critical items in the repetition trials (a dependent variable termed 'delta', see Duncan & Lewandowsky, 2005; Henson, 1998a). Control trials are analysed as a manipulation check with respect to both abolition of the PSE and the canonical ISR serial position functions.

Procedure. Participants were tested individually in a quiet laboratory booth and sat facing the computer at a distance of 60cm. Each trial was initiated by a keyboard press and comprised the sequential presentation of 6 consonants (750ms on-time, 250ms inter-stimulus-interval). Following presentation of the final sequence item, a six-box vertical grid was displayed on the screen. This was the signal for participants to write down the 6 consonants from the preceding trial on the grid in the response booklet. The boxes in the grid corresponded, from top to bottom, to positions 1-6 in the sequence. Participants were instructed to recall the items in their order of presentation and to leave a box in the grid absent if they were unable to recall the item that was presented in that position. Once responses for a trial were complete, a keyboard press commenced the next trial. Participants received two practice trials followed by two 48 trial sessions. For the trials in the CA condition, participants were instructed to repeat the words "coca cola" aloud throughout each trial at a rate of 2-3 words per second.

Results

A strict scoring criterion was adopted such that a response was recorded as correct only if the correct item was recalled in the correct serial position.

Phonological Similarity Effects. As a manipulation check, the effects of CA on the PSE were examined for the control trials. The serial position functions for the phonologically similar and dissimilar words under conditions of quiet and CA are displayed in Figure 1(a-b). A 3-factor (2x2x6) within-participants ANOVA was computed where the first factor was CA (quiet or CA), the second was phonological similarity (similar or dissimilar), and the third was serial position (1-6). The ANOVA revealed main effects of: CA, reflecting poorer recall under CA, $F(1,31)=55.04$, $MSE=0.168$, $p<.001$, $\eta_p^2 = .64$ (mean proportion correct and 95% CI for the quiet and CA conditions = .73 [.68, .77] and .51 [.45, .56], respectively); phonological similarity, reflecting the PSE, $F(1,31)=7.89$, $MSE=0.052$, $p<.009$, $\eta_p^2 = .20$ (mean proportion correct and 95% CI for the similar and dissimilar conditions = .59 [.55, .63] and .64 [.60, .68], respectively); and serial position, $F(2.10,64.99)=22.60$, $MSE=0.10$, $p<.001$, $\eta_p^2 = .42$, reflecting strong primacy and recency. The predicted interaction between CA and phonological similarity was significant, $F(1,31)=7.33$, $MSE=0.06$, $p<.011$, $\eta_p^2 = .191$, reflecting a difference between phonologically similar and dissimilar words in the quiet condition only. Thus, CA acted to abolish the PSE, as predicted. In addition, the interaction between CA and serial position was also significant, $F(2.30,71.27)=5.74$, $MSE=0.07$, $p=.003$, $\eta_p^2 = .16$. All other interactions were non-significant.

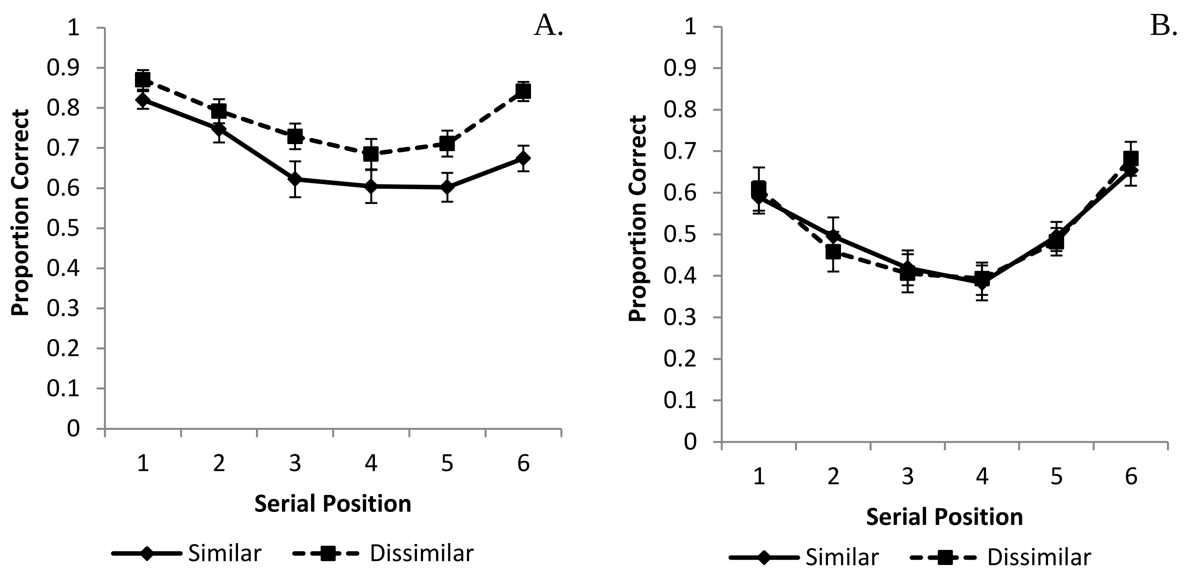

Figure 1(a-b). Mean proportion correct for the phonologically similar and phonologically dissimilar sequences as a function of serial position (1-6) under conditions of quiet (a) and CA (b). Error bars denote the mean standard error.

Repetition Analysis. The dependent variable delta (*d*) reflects the difference between the proportion of trials in which the repeated items [P(*r*)] and matched critical items in the control trials [P(*c*)] were recalled in the correct serial position (d = P(r) – P(c)). Scoring criterion was more liberal than that reported for the serial position analysis since critical items in the control trials were considered as correct if they exchanged positions. A positive difference reflected response facilitation and a negative difference reflected response inhibition. Figure 2(a-b) shows three repetition conditions (i.e. *d* scores for adjacent, 1-gap, and 3-gap repetitions) under conditions of quiet and CA. For both conditions of quiet and CA adjacent repetitions exhibit a facilitative effect and repetitions spaced with 3-intervening items exhibit an inhibitive effect.

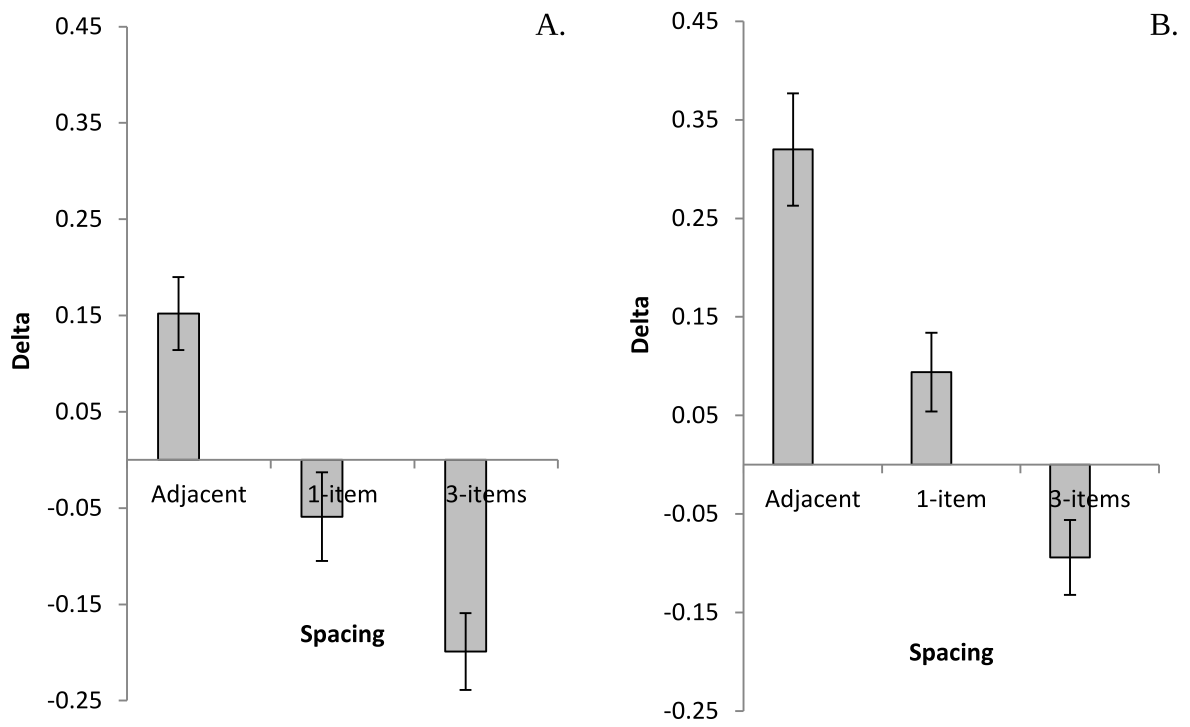

Figure 2(a-b). Mean delta for the three repetition spacing conditions for under conditions of quiet (a) and CA (b). Error bars denote the mean standard error.

A three factor (2x2x3) ANOVA was computed where the first factor was CA (quiet or CA), the second factor phonological similarity (similar and dissimilar), and the third factor was repetition spacing (adjacent, 1-item interval, and 3-item interval). The main effect of CA was significant, $F(1,31)=17.99$, $MSE=0.11$, $p<.001$, $\eta_p^2 = .37$. The main effect of phonological similarity was non-significant, $F<1$. The main effect of repetition spacing was significant, $F(2,62)=44.78$, $MSE=0.11$, $p<.001$, $\eta_p^2 = .59$. Bonferroni post-hoc comparisons ($\alpha = .017$) demonstrated that delta was significantly different between the adjacent (mean d = .24; 95% CI [.16,.31]), 1-gap (mean d = .02; 95% CI [-.05,.08]), and 3-gap (mean d = -.15; 95% CI [-.21,-.08]) repetitions. Specifically, adjacent repetitions produced significant facilitation relative to the 1-gap condition and the 3-gap repetition condition; whereas the 3-gap condition produced significant inhibition relative to the 1-gap and adjacent conditions. The important interaction between CA and repetition spacing was non-significant, $F<1$. This shows that the CA manipulation did not affect the pattern of effects across the repetition conditions. That is, adjacent repetitions facilitated recall and 3-gap repetitions inhibited recall across both the quiet and CA conditions. All other interactions were non-significant (all Fs<1). It is, however, worth noting that for the 1-item gap condition there is some disparity in terms of the direction of delta (mean d = -.06 and .09, for the quiet and CA conditions, respectively). When each delta value for the 1-gap condition is compared to the null of 0 (i.e. neither facilitation nor inhibition), there is a non-significant difference for the quiet condition ($t(31)=-1.285$, $p=.208$, $r=.225$) but significant facilitation for the CA condition ($t(31)=2.339$, $p=.026$, $r=.387$).

Discussion

We provide the first examination of within-trial repetitions for sequences of visually presented consonants under conditions of quiet and CA. ISR under conditions of CA is argued to prevent phonological recoding (e.g. Baddeley et al., 1984). Indeed, examination of our control trials indicates that the consonants were represented differently under conditions of quiet and CA. Specifically, under CA, recall was non-catastrophically impaired and the PSE was abolished; this is consistent with the inhibition of phonological recoding of consonants. Despite support for different representations under conditions of quiet and CA, both conditions are consistent with previous work in exhibiting recall facilitation when repetitions are adjacent (e.g. Crowder, 1968; Henson, 1998a; Lee, 1976), and recall inhibition when the repeated items within a sequence were separated by three intervening items (i.e. the Ranschburg effect: e.g., Crowder, 1968; Duncan & Lewandowsky, 2005; Henson, 1998a; Jahnke, 1969). Importantly, this is the first study to show that these repetition effects are equivalent under conditions of both quiet and CA.

Response inhibition (i.e. the Ranschburg effect) is argued to be epiphenomenal to the suppression of items following retrieval (e.g. Armstrong & Mewhort, 1995; Vousden & Brown, 1998) and this response inhibition mechanism is widely employed within computational models of sequence memory (see Hurlstone et al., 2014, for review). Inhibition functions to prevent perseveration of items with high activation levels and this is a crucial feature for ordinal models of memory that utilise a primacy gradient (e.g. Page & Norris, 1998). The presence of the Ranschburg effect for visual-verbal stimuli under CA, coupled with preliminary findings of the effect with tactile stimuli (Roe et al., 2016), suggest that these models may be generalizable beyond verbal stimuli presented in conditions of quiet.

Application of a Working Memory Model conceptualisation to the present data (e.g. Baddeley, 2000) suggests that repetition effects are broadly consistent when stimuli are represented within the phonological loop under conditions of quiet and within the episodic buffer under conditions of CA. We argue that this interpretation is problematic for two reasons. First, the Working Memory Model alone cannot explain these verbal repetition effects without recourse to appropriating distinct computational models into the loop (e.g. Burgess & Hitch, 2006). Second, our data is further evidence for analogous sequence memory effects when utilising the phonological loop and the episodic buffer (e.g. Page et al., 2006; Spurgeon et al., 2014). However, as noted by Spurgeon et al. (2014), "a disadvantage of the working memory model is that different mechanisms are assumed to underpin the similar patterns of recall observed in the visual silent and visual CA conditions" (p.1131). Indeed, cross modal commonality in order memory is an increasingly parsimonious explanation (see Hurlstone et al., 2014); with the present data adding to studies showing cross-modal behavioural similarity in order memory (e.g. Guérard & Tremblay, 2008; Horton et al., 2008; Ward et al., 2005).

Whilst the present data do not address directly the question of modularity in order memory, the data do support the utilisation of a common sequencing mechanism for verbal stimuli under conditions of quiet and CA. Hurlstone et al. (2014) have argued that sequence items, irrespective of modality, exhibit differential levels of activation and are selected at test through a process of competitive queuing. This process necessitates an inhibition mechanism to prevent preservation of highly active items (e.g. see Page & Norris, 1998). We have shown epiphenomenal evidence for such a response inhibition mechanism under conditions of quiet and CA via impaired recall for the repeated item when separated by 3-intervening items (i.e. the Ranschburg effect). Moreover, similar facilitative effects following adjacent repetitions highlight further similarities for recall under conditions of quiet and CA. It is has been suggested previously that facilitation following massed repetition is a consequence of participant awareness of the repetition, with awareness leading to a process of mentally ‘tagging’ the items for repeated retrieval at test (Crowder, 1968; Henson, 1998; Lee, 1976). This facilitative ‘tagging’ process appears evident both under conditions of quiet and CA.

It should be noted, for the data reported here, that whilst the interaction between repetition spacing and CA was non-significant ($F<1$), Figure 2 indicates different directional effects for the 1-gap condition for CA and quiet conditions, with further analysis revealing that facilitation was present for CA but absent for quiet. Therefore, whilst the general effects of facilitation and inhibition mediated as a function of repetition spacing are found under conditions of CA and quiet, any future attempts to model this effect should consider this difference. Indeed, such nuanced differences support the findings of Saito et al. (2008) suggesting that phonological and visual codes affect verbal memory differently.

A potential caveat to our interpretation of the present data was highlighted during the review process. CA, an encoding manipulation argued to disrupt the conversion of the list consonants into phonological codes (Baddeley et al., 1984), was employed here to examine a retrieval effect. However, one might argue that whilst the list consonants were initially represented each in a nonverbal code, during retrieval participants generated each consonant from memory and converted them into their phonological representations via a speech-based mechanism. Consequently, the reported Ranschburg effect might be interpreted as merely a demonstration of the well-established effect of response inhibition with verbal stimuli. We argue that such an interpretation is unlikely for two reasons. First, the PSE is strong evidence that CA disrupted phonological recoding of the consonants. Second, if CA disrupted the phonological conversion of external visual representations of sounds (i.e. the consonants displayed on the screen), it follows logically that CA (conducted throughout the trial) also disrupted the phonological conversion of internal visual representations of sounds (i.e. the consonants stored within memory). Therefore, CA at test arguably precludes a role for phonological recoding at test. This therefore suggests that these data represent a demonstration of the Ranschburg effect with non-phonological representations.

In summary, the present study is the first to examine the Ranschburg effect with visual-verbal stimuli under CA. We have shown that the effects of within-sequence repetition are broadly the same for quiet and CA, exhibiting both facilitation and inhibition, and that each is dependent upon repetition spacing. These effects are consistent with a growing body of data (see Hurlstone et al., 2014, for review) suggesting commonality of order memory function across stimuli, with the present data supporting the existence of a cross-modal response inhibition mechanism.

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