Cross-Modal Ranschburg Effects: Examining Within-Sequence Repetitions for Visual-Verbal, Non-Verbal-Visual, and Tactile Stimuli.

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Abstract

The Ranschburg effect is a serial order memory phenomena, which is illustrated by recall failure for spaced repeated elements in a sequence (e.g. 1R34R6). In contrast, facilitation (improved recall) is shown for repeated items that are adjacent in the sequence (massed repetitions, e.g. 1RR3456). This effect is well researched within the verbal modality of working memory; however, no research has been conducted investigating presence of the phenomena cross-modally. The current research aimed to establish this effect in the visual and tactile (touch) modalities. Three experiments were conducted. Experiment 1 (n=40) used unfamiliar faces, with further manipulation of set size, awareness, and repetition type (spaced and massed repetitions), using serial order reconstruction (SOR) as the recall method. Experiment 1 found repetition facilitation for massed repetitions but spaced repetition did not produce inhibition (i.e. no Ranschburg effect). Experiment 2 replicated the Experiment 1 method using visual verbal stimuli (letters). Experiment 2 revealed both repetition inhibition and facilitation, showing that it was not the SOR procedure that prevented inhibition in Experiment 1. Experiment 3 (n=40) used tactile stimuli, and applied it to an immediate serial recall (ISR) procedure. Both facilitation and inhibition was reported. Across the three experiments repetition awareness and set size had limited impact on the effects of repetition. The results are discussed in reference to theories on domain general/amodal accounts of working memory.

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Acknowledgments

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1. Introduction

1.1 Modularity Introduction

Serial order memory has been used as a key measure of short-term memory (STM), with verbal STM traditionally tested using immediate serial recall (ISR). In a typical ISR procedure, participants are presented a sequence of items and at test are required to recall those items in the original order of presentation. Performance on this task has been linked to a range of higher level cognitive abilities, most obviously language (Hurlstone, Hitch, & Baddeley, 2014). However, whilst order memory has been typically examined using verbal stimuli (Smyth, Hay, Hitch, & Horton, 2005) there exists a growing body of literature exploring non-verbal serial order memory.

Non-verbal serial order memory is of particular importance given the proposed modular structure of STM/working memory. The most well-known model of working memory, the working Memory Model (WMM: Baddeley & Hitch, 1974; Baddeley, 1986; Baddeley, 2001), states that short term memory is encoded and processed into domains (or modalities) according to the type of stimuli being used. Speech/auditory and verbal stimuli are encoded and processed within the phonological store, and the visuo-spatial sketchpad accounts for visual and spatial stimuli. That is, Baddeley (2001) argues that working memory functions in a domain specific manner. Domain specificity is the principle that each of the domains/modules is independent of the others, and each "*responds selectively to certain types of stimuli*" (Eysenck & Keane, 2010, p.17). The main support for a domain specific working memory is found from dual-task experiments and neuropsychological evidence. According to the WMM, if participants attempt two tasks that utilise the same modality (e.g. verbal sequence memory and counting),

performance on both tasks would be lower than if performing a single task. This is because the same store (the phonological loop) is used for both. In contrast, if the tasks use two separate modalities (e.g. verbal sequence memory and visualising a route), then performance on each task should not be affected by the addition of the other. This is because separate stores (the phonological loop and the visuospatial sketchpad) are used for the two tasks. Guérard and Tremblay (2008) found that articulatory suppression (repeating irrelevant speech concurrently with the memory task) negatively affected performance on a verbal order memory task more than performance on a spatial task. Likewise, a concurrent spatial task interfered more with the spatial order memory task than the verbal task. Indeed, research has found similar effects when using concurrent tasks derived from a different modality to the primary task (e.g. Farmer, Berman, & Fletcher, 1986; Logie, Zucco, & Baddeley, 1990). These findings are used as evidence that the two modalities operate independently of each other, as tasks from a different modality do not affect performance in another modality. Neuropsychological evidence also supports domain specific theories of working memory. Hanley, Young and Pearson (1991) conducted a case study with a patient (E.L.D) who, after a right-hemisphere aneurysm, had deficiencies in recall of visuo-spatial stimuli. E.L.D performed well on verbal based tasks (including tasks where the stimuli was presented visually), however had poor performance on the visuo-spatial tasks (such as the Corsi Blocks task). Another case study involving P.V, who experienced left hemispherical damage, displayed the separation of verbal and visuo-spatial working memory. P.V experienced deficiencies in verbal working memory (Vallar and Baddeley, 1984), however had an average level of performance for visuo-spatial tasks (e.g. the block tapping test, Basso, Spinnler, Vallar, & Zanobio, 1982). Combining the E.L.D case

study (Hanley et al., 1991) with the case study of P.V (Basso et al., 1982; Vallar & Baddeley, 1984), there is a clear double dissociation between the two modalities, indicating separate stores within working memory for different types of stimuli.

Despite the dual-tasking and double dissociation evidence for modularity, there also exists evidence that memory is amodal, or domain general. The domain general theory states that the encoding and processing of stimuli are performed in one modality, regardless of the type of stimuli used. This is supported by cross-modal research, which attempts to replicate effects found with verbal stimuli in other modalities. To date, research has found that verbal memory effects can be replicated across a range of stimulus types. One clear example of cross-modal similarity concerns order memory serial position functions (i.e. the pattern of accuracy for different positions in the sequence). Similarities with verbal serial position curves have been found with olfactory (e.g. Miles & Jenkins, 2000), audio-spatial (e.g. Parmentier & Jones, 2000), visual-spatial (e.g. Jones, Farrand, Stuart, & Morris, 1995), visual (e.g. Smyth et al., 2005) and tactile (e.g. Mahrer & Miles, 1999) stimuli. Cross modal research has therefore called into question the modular nature of the WMM, as similar effects found in the verbal domain appear within other modalities. Employing different stores that appear to operate analogously by producing the same serial position functions lacks parsimony. One might therefore argue that a domain general system is a more efficient account of the data. Hurlstone et al. (2014) however argued that the similarities between stimuli types are not caused by a single memory mechanism, instead suggesting that the separate domains evolved similarly (Hurlstone et al., 2014). That is, if the separate slave systems have evolved over a lengthy iterative process, it is not surprising that these systems have evolved to operate using the most effective (and analogous) methods. Such an

explanation can account for both the similarities found between the modalities (e.g. Jones et al., 1995), and also the double dissociations observed cross-modally. However, it is then questionable whether domain specificity is behaviourally falsifiable.

1.2 Evidence for Cross-Modal Similarity between Visual and Verbal Memory

As noted above, many of the phenomenon shown with serial order memory for verbal stimuli have been shown with visual stimuli (although as noted by Hurlstone et al., 2014, a number of phenomenon remain untested). The following section reviews some of these phenomena.

1.2.1 Serial Position Effects

As aforementioned, verbal order memory is traditionally assessed via the ISR procedure. This task typically produces a serial position curve with strong primacy and a hint of recency (e.g. see Bhatarah, Ward & Tan, 2008; Drewnowski & Murdock, 1980; Grenfell-Essam & Ward, 2012; Tan & Ward, 2007, 2008; Spurgeon, Ward, & Matthews, 2014). However, ISR necessitates that the participants reproduce the items at test (recalling the sequence in the order of original presentation). This is not possible with most non-verbal stimuli since participants are, for example, unable to generate a face at test. To circumvent this issue, serial order reconstruction (SOR: an analogue of ISR that requires order memory without item generation) is employed. In this task, participants are presented with a sequence of items. At test these items are simultaneously re-presented on the screen and participants are required to select them in the order of original presentation. To be clear, item generation is no longer required at test. This

enables order memory for a range of non-verbal visual stimuli to be tested (e.g. see Avons, 1998, and Smyth et al., 2005, for SOR of matrices and faces, respectively).

Smyth et al. (2005) investigated serial order memory with visual stimuli (unfamiliar faces). In this study, Smyth et al. (2005) manipulated sequence length (3/4/5/6 items), articulatory suppression, and item similarity. It was found that primacy and recency effects were similar to those found with verbal stimuli, with primacy over the first two serial positions, and moderate recency on the terminal item. Smyth et al. (2005) argued that the serial position similarities between the verbal and visual domains (across analogous ISR and SOR tasks) implies a functional equivalence in terms of serial order memory across domains. Importantly, the functions were not affected by articulatory suppression, suggesting that the similarity with previous verbal serial position curves was not due to verbal recoding of the faces.

Rather than relying upon cross-study comparisons, Ward, Avons, and Melling (2005) directly compared serial position curves for visual and verbal stimuli using SOR across differing list lengths. List length was included because it is known to affect accuracy in the verbal domain (Miller, 1956; Drewnowski & Murdock, 1980) and the authors wanted to assess if visual memory was similarly affected. In Experiment 1 Ward et al. (2005) manipulated list length (4, 6 or 8 item sequences) for SOR of unfamiliar-faces. Participants completed 45 trials (15 trials at each length) and found that accuracy significantly decreased as list length increased. However, the canonical serial position curve of strong primacy and reduced recency were found across list lengths. Experiment 3 replicated the methodology of Experiment 1 but employed auditorially presented non-words (and the list lengths of 4, 5, and 6). The findings replicated that of Experiment 1 with performance reducing

as a function of list length despite consistent serial position curves showing strong primacy and limited recency.

In Experiments 2 and 4, Ward et al. (2005) examined item memory using 2-alternative forced choice (2AFC) recognition for 5-item sequences. The 2-AFC method is a measure of item recognition and not order memory. In the task a list of items are presented followed at test by two stimuli (one from the preceding list and one not from the preceding list), participants are required to select the item which they recall to be in the sequence. Experiment 2 (unfamiliar-faces) and Experiment 4 (auditorially presented non-words) both produced serial position curves with no primacy, and significant recency, especially in respect to the most recent item. These serial position curves were similar to that reported by Phillips and Christie (1977) in their seminal paper on visual memory. This indicated that, as from Experiments 1 and 3, serial position effects found from specific methods in the verbal domain can also be replicated in the visual domain.

From these experiments Ward et al. (2005) concluded that previously reported sequence memory differences between memory domains is primarily a product of task differences, rather than stimulus differences. That is, traditionally, visual stimuli were applied to item memory tasks and verbal stimuli were applied to order memory tasks. These differing task constraints resulted in any cross-modal comparisons being confounded by methodological differences. However, when the stimuli are applied to the same task, the serial position curves are qualitatively equivalent. Ward et al.'s (2005) research demonstrated clear similarities between visual and verbal memory both in terms of serial position functions and the effects of list length.

1.2.2 Error Distributions

In addition to accuracy serial position curves, the distribution of errors has also been examined for visual and verbal stimuli. Guérard and Tremblay's (2008) research compared the verbal domain (memory for French monosyllabic words) to the visuo-spatial domain (memory for locations of dots on a screen) in both 7-item serial order recall and order reconstruction tasks. The serial position data was consistent with Ward et al. (2005), in that they reported primacy and recency across all conditions; with order reconstruction producing significantly higher levels of recency than serial order recall with both visuo-spatial and verbal stimuli. However, Guérard and Tremblay (2008) also examined errors and found that the distribution of errors in both serial recall and order reconstruction of sequences were similar across the verbal and visuo-spatial domain. The authors examined omissions (when an item was not recalled), intrusions (when an item not presented in the preceding list was erroneously recalled), and transpositions (when an item was recalled in the wrong serial position). Omissions of items had the same pattern according to serial position (increase in omissions as serial position increases) for both types of stimuli, although the verbal stimuli had a higher frequency of omissions in general. The same was found for the intrusion error distributions. Transposition errors were higher in the middle serial positions than the terminal positions in both spatial and verbal stimuli. The similar error distributions (across multiple types of errors) indicate a functional equivalence between the two domains in terms of serial order memory.

The above transposition errors were also found by Smyth et al. (2005) using SOR of unfamiliar faces. They reported that transposition errors were most prevalent for adjacent serial positions (an effect referred to as the locality constraint) and that the proportion of transpositions decrease the further one migrates from the correct serial

position (consistent with that found for verbal stimuli, e.g. Farrell & Lewandowsky, 2004). This produces a symmetrical transposition distribution that peaks at a displacement distance of 0 (i.e. a correct response).

1.2.3 The Hebb Repetition Effect

Another serial order memory phenomenon that has been examined cross-modally is the Hebb repetition effect (Hebb, 1961). The Hebb repetition effect refers to the incidental improvement in memory for a sequence that it surreptitiously re-presented (typically every third trial) across an experiment and was traditionally linked to verbal memory (e.g. Burgess & Hitch, 1999; see also Page, Cumming, Norris, McNeil & Hitch, 2013), and, in particular, associated with the acquisition of novel words (e.g. Szmalec, Duyck, Vandierendonck, Mata & Page, 2009; Szmalec, Loncke, Page & Duyck, 2011; Szmalec, Page & Duyck, 2012). Horton, Hay, and Smyth (2008) examined whether non-verbal visual memory produces a Hebb repetition effect. In this study participants were presented with sequences of 5 unfamiliar-faces followed by a SOR test procedure. There were three stimulus conditions: (1) unfamiliar-faces, (2) unfamiliar-faces with concurrent articulation (counting ascending numbers to suppress verbal re-encoding, Nairne, 1990), and (3) inverted unfamiliar-faces. Participants completed 18 trials, with every third trial comprising the repeated Hebb trial. As described previously (Guérard and Tremblay, 2008; Ward et al. 2005), serial position curves typically found in the verbal domain were reported across all stimulus conditions, i.e. primacy and reduced recency (bowed serial position curve). Importantly, it should be emphasised that these curves were found in Horton et al. (2008) under conditions of concurrent articulation; this indicates that removal of verbal recoding/rehearsal does not change the serial position curve (as also reported by Smyth et al., 2005). To be clear, if participants

were verbally labelling the faces (and thereby utilising verbal rather than visual memory) the functions would not be a reflection of visual memory. However, inclusion of concurrent articulation limits this recoding process and reduces the reliance upon verbal memory. Importantly, the Hebb repetition effect was observed with upright unfamiliar-faces (both under conditions of quiet and concurrent articulation). Moreover, the Hebb repetition effect has also been shown with pictures under concurrent articulation (Page, Cumming, Norris, Hitch & McNeil, 2006) and with SOR of dots in different spatial locations (Couture & Tremblay, 2006; Guérard, Saint-Aubin, Boucher & Tremblay, 2011; Tremblay & Saint-Aubin, 2009; Turcotte, Gagnon & Poirier, 2005). This again shows similarities between verbal order memory phenomena and visual memory.

The above summarised literature suggests that visual and verbal domains operate in very similar ways. One might argue, due to the principle of parsimony, that this is evidence for an amodal memory structure, or at least, that both modalities possess functional equivalence (Hurlstone et al., 2014; Ward et al., 2005; Guérard and Tremblay, 2008).

1.3 Evidence for Functional Equivalence in Tactile Memory

Compared to the more established domains of visual and verbal memory there is a paucity of literature examining order memory for tactile stimuli. However, the limited studies available do show some convergence with the visual and verbal domains.

The early research established that tactile memory can produce serial position functions similar to those found in verbal research. Watkins and Watkins (1974) presented participants with 8-item sequences (delivered to the four fingers of each

hand). At test participants were required to recall the sequence in the order of presentation by using verbal or visual recall methods, i.e. participants either verbally stated the label associated to the finger, or reconstructed the sequence on a diagram of the hands. Watkins and Watkins (1974) found that both primacy and recency effects were present when using tactile stimuli. However, in the Watkins and Watkins (1974) procedure, since participants were using either a verbal response or responding via a schematic of the hand, it is possible that participants were using verbal and/or visual memory rather than tactile representations. This limitation was addressed by Mahrer and Miles (1999). They instructed participants to close their eyes during the experiment; this was done with the aim of reducing verbal/visual recoding. In addition, participants recalled the sequences by raising their fingers in the order of original presentation/stimulation. Despite reducing the potential for verbal and/or visual recoding, primacy and recency were still found using this method. This provides tentative evidence that tactile memory operates similarly to that of the visual and verbal domains.

Using a similar procedure to that described by Mahrer and Miles (1999), Johnson, Shaw, and Miles (2016) replicated the bowed serial position effects. In addition, consistent with the aforementioned verbal and visual stimuli, they found a similar pattern of transposition errors (i.e. the locality constraint) and showed that tactile memory could produce a Hebb repetition effect (consistent with the Hebb effect being observed across other under researched domains, e.g. Johnson, Cauchi & Miles, 2013; Parmentier, Maybery, Huitson, & Jones, 2008).

Provisional work has also suggested that tactile sequences are recalled using a similar strategy to that of verbal stimuli. In a recent study, Cortis, Dent, Kennett and Ward (2015) examined immediate free recall (IFR) of tactile sequences (a sequence

of touches to the faces). At test participants recalled the location of touches (in any order) using a visual schematic of the face. Similar to verbal and visual memory (Spurgeon et al., 2012), Cortis et al. (2015) showed that when recalling shorter lists participants initiated recall with the early list items, but when recalling longer lists they initiated recall with the latter list items. Moreover, similar to verbal and visual stimuli, list length was found to affect recall accuracy with tactile stimuli.

1.4 Interim Summary

Whilst based upon a relatively limited literature, serial order phenomena shown with verbal stimuli can be replicated with both visual and tactile stimuli. These similarities were highlighted by Hurlstone et al. (2014) in their overview of the current cross-modal research. The purpose of the Hurlstone et al. review was also to determine future research routes, and they found that of the 8 phenomena investigated, the Ranschburg Effect (also known as response inhibition) was one of the few that had not been researched cross-modally. Due to the previous research suggesting a functional equivalence between modalities in respect to serial order memory, this presents a large gap within cross-modal research, which the current research intends to address.

1.5 The Ranschburg Effect

The Ranschburg Effect (also known as response inhibition) concerns the impaired recall for a repeated item within a sequence. This impairment occurs when the repeated items are spaced within the sequence. During recall of the sequence, recall accuracy for the repeated items (most typically the later item of the repeated pair) is lower than the equivalent items in matched control trials (with non-repeating items).

In contrast, adjacent (massed) within-sequence repetitions result in facilitative (improved recall) effects relative to items in matched control trials.

The Ranschburg Effect has received much research (although less studies of late), however as noted by Hurlstone et al. (2014) this has focussed upon verbal stimuli (i.e. digits, letters etc.). These studies have identified conditions under which the effect has occurred which may provide some insight into the mechanism underpinning the effect. These are discussed below.

1.5.1 Factors Affecting the Ranschburg Effect: Repetition Spacing

Crowder (1968a) first investigated if manipulating the spacing of the repeated critical items affects the magnitude of the Ranschburg Effect in 8-item verbal sequences. Consonants were used as the stimuli, with a set size of the same 12 consonants used throughout the experiment. Crowder (1968a) tested adjacent repetitions, intervals of 1 item (e.g. 1X3X5678), intervals of 2 items (e.g. 1X34X678), intervals of 3 items, intervals of 4 items, intervals of 5 items, and intervals of 6 items (e.g. X234567X). The sequences were presented vocally via a recording. Recall involved participants selecting a box (indicating serial position) on a grid given to them, and vocally recalling the stimuli. Recall for the repetition conditions were compared to control trials with no repetitions. Crowder (1968a) found that in the massed condition (no item intervals between repeating items), 11 out of 13 sequences had fewer errors than control trials (i.e. memory was facilitated). When items intervened between the critical (repeated) positions, recall inhibition was found in 12 of the 15 conditions ($p<.01$), this effect was amplified when 2 intervening items were present. This demonstrates that the spacing of the repetitions is important in determining the presence of repetition inhibition or facilitation.

Furthermore, in both the massed and intervening/spaced conditions, positioning of critical repeated items showed neither facilitation nor inhibition when first or last in the sequence (presumably due to the special status in memory that terminal items possess, e.g. Henson, 1998a). This shows that both the positioning and spacing of the critical repeated items is important in determining repetition effects.

Crowder (1968a) proposed that the repetition effects were a result of processes at both input and output (see below for discussion of output effects). For the recall facilitation effects found with massed repeated elements, Crowder (1968a) stated that an "*enhanced efficiency of coding processes*" (Crowder, 1968a, p. 449) caused the effects. Crowder (1968a) first suggested that the participants were coding massed repetitions as one item, therefore turning the 8 item sequences into 7 item sequences. A shorter sequence is, therefore, easier to recall (as outlined earlier, e.g. Ward et al., 2005). However, Crowder (1968a) then states that the combined error rate for the massed repetitions (e.g. at positions 4 and 5) is lower than those typically found at serial position 4 in 7-item sequences without repeating items, indicating that massed repetition items are not coded as one position. Crowder (1968a) offered the explanation that massed repeated items create a unique tag at input, reducing the competitiveness of the repeated items with the remainder of the sequence, in turn lowering the amount of errors for both critical items.

1.5.2 Factors Affecting the Ranschburg Effect: Outputting the Repeated Items at Test

Harris and Jahnke (1972) investigated whether the Ranschburg Effect is caused by output processes; specifically whether the act of recalling both repeated items causes the Ranschburg Effect. In their study half of the 56 trials were recalled completely, and in the other 28 trials participants had to omit serial position 2 in their recall. In

the Ranschburg trials, the critical repeated pair always involved serial position 2, with the second item being present either at serial position 5 or 6. As a consequence, when omitting serial position 2 at retrieval, only one of the repeated items were retrieved at test.

Harris and Jahnke (1972) found that when participants recalled the entire list, the Ranschburg Effect was present, with critical items 5 and 6 being significantly worse than the equivalent positions in matched non-repetition control trials. However, when position 2 was omitted at recall, the Ranschburg effect was greatly reduced.

This suggests that it is the process of outputting repeated items that causes the effect, and that the interference of recalling the first occurrence of a critical item leads to a failure of recall at the second event. However, Harris and Jahnke (1972) argued that the results could be caused by the lower amount of items to be recalled in general, as those in the partial recall condition had to recall 7 items, as opposed to 8. If this were the case, overall performance levels should be higher for the partial block condition due reduced output interference. However, this was not found with recall levels higher in the complete blocks.

Crowder (1968a) also attributed the inhibitory effects of spaced repetitions on output and response processes, however failed to explain the mechanism producing inhibition. To test the claim that repetition inhibition was an output effect, Crowder (1968b) ensured that the repeated item only occurred at recall by requesting that participants included a prearranged consonant in the recall of the 8-consonant sequence. This prearranged item was either a repetition of an item in the list or not. To be clear, a repetition was not present at encoding but was at retrieval due to inclusion of the prearranged item. In Experiment 1, the prearranged item was

recalled as a prefix to sequence recall and Crowder (1968b) found that that there was impaired recall when the prefix was the same as the third item in the list (a de facto 2-item interval). In Experiment 2 the prearranged item was recalled between positions 2 and 3. Crowder (1968b) found impaired recall for the items at positions 4, 5, and 6 when they were the same as the prearranged item (i.e. a de facto 1-, 2-, and 3-item interval, respectively). Both experiments show that inhibition was present despite there being no repetition at encoding. This suggests that the Ranschburg effect is due to processes at output.

1.5.3 Factors Affecting the Ranschburg Effect: Awareness

Jahnke (1969) investigated whether awareness of repetitions was a factor in the Ranschburg Effect. Participants were either given no information about repeating elements in the sequences, or were told before each experimental trial if there are repeated items. Using ISR of 7 auditorially presented digits, participants recalled 96 sequences in total, half of which were control trials containing no repetitions. The experimental sequences had critical items at either serial positions 2 and 5, or 3 and 6 (i.e. 2-intervening items).

Jahnke (1969) found that participants in the aware condition recalled a significantly higher amount of critical items (compared to control items), than those in the unaware condition. That is, the Ranschburg effect was attenuated (although not eliminated) in the aware condition. This suggests that once participants are aware of the repetition they will include that repetition at recall. This is consistent with the above explanation by Crowder (1968a) as to how adjacent repetitions produce facilitation. These findings were supported by Henson (1998a, Experiment 2a) who asked participants to identify the repeated items and then recall the entire sequence

in order. Henson (1998a) found a high correlation between detection of repetitions and the subsequent recall of the items in full recall. Moreover, he found that as intervening items increased, detection rates fell. This is consistent with facilitation of massed repetitions being underpinned by awareness of that repetition.

In Experiment 2 Jahnke (1969) tested whether being made aware of the repetition during the retention interval (i.e. after the repetition has been presented but before recall) affected the Ranschburg effect. They found that the magnitude of the Ranschburg effect did not differ to that of the control condition and argued that this is evidence against the Ranschburg effect being an output phenomenon. That is, if the repetition had been successfully encoded, then highlighting the repetition immediately before retrieval should facilitate memory; but this was not found. This is inconsistent with the Ranschburg effect being an output phenomenon. Indeed when participants were made aware of the repetition prior to presentation of the list it reduced the Ranschburg effect. Jahnke (1969) argued that this supported the proposition that the effect was an input/encoding process.

1.5.4 Factors Affecting the Ranschburg Effect: Set Size

Jahnke (1972) examined whether the set size of the stimuli (i.e. the number of items used throughout the experiment) can affect the magnitude of the Ranschburg effect. Jahnke (1972) proposed that recall for trials with a larger set size (300 words) would be higher compared to a smaller set size (10 words). Between participants, they compared the effects of large and small set sizes on recall of 7-item sequences where the repetitions had 2-intervening items. Jahnke (1972) found that recall for (repeated) critical items was significantly improved in the large set size, whereas there was some evidence of the Ranschburg effect (depending on the scoring protocol) for

small set sizes. The important finding was that set size appeared to affect recall of the (spaced) repeated items. Jahnke (1972) argued that when an item from a large set size is repeated within sequence, there is less proactive interference for that item and as a consequence that repetition is more salient. This leads to recall facilitation. However, with a small set size there is more proactive interference (since that items has been encountered more times in the experiment) and therefore the memory for the within-sequence repetition of that item is harder to discern from the general sense of familiarity.

Hinrichs, Mewdalt and Redding (1973) also examined set size. Using a 24-letter pool for the large set size condition and an 8-letter pool for the small set size condition, they examined repetitions separated by 2-intervening items within 7 item sequences. Hinrichs et al. (1973) found that with both set size groups, performance on the (repeated) critical items were significantly lower than those in control trials (i.e. a Ranschburg effect). However, the Ranschburg effect was greatly reduced with the larger set size. This finding replicated Jahnke (1972) and is consistent with the proactive interference explanation outlined above.

1.5.5 Factors Affecting the Ranschburg Effect: Scoring Protocol

There are different analytical approaches to testing the presence of repetition inhibition/facilitation. One method is to compare recall levels for the control trials to that of trials containing repetitions. Mewdalt and Hinrichs (1973) used both free recall scoring (IFR scoring) and serial position scoring to determine if scoring protocol affected the Ranschburg effect. It was found that IFR scoring was more sensitive when using longer sequence lengths, possibly due to the higher amount of errors found in longer sequences (Miller, 1956; Drewnowski & Murdock, 1980).

When using serial position scoring (ISR scoring), a Ranschburg effect was found at the second occurrence of the critical item, and not the first. However, when using IFR scoring, identification of the position of inhibition is obviously less precise since IFR is only a measure of item (and not positional) recall. Moreover, as noted by Mewdalt and Hinrichs (1973) removal of the critical items from scoring results in equivalent performance between experimental and control trials. Since the effect is caused by recall of the critical repeated pair, it makes sense to focus analysis on these items. As a consequence, inclusion of the other list items in the Ranschburg analysis serves only to dilute the effect if unaffected by the repetition. Therefore, an alternative approach is to focus on the 'critical' repeated items and compare recall to the same items in matched control trials that are identical but for the second repeated item being replaced by a non-repeated item. This approach is referred to as the delta analysis. Delta (d) is the proportion of trials in which the two repeated items are recalled in the correct serial position minus the proportion of trials in which the equivalent items (in the matched control trials) were correctly recalled. A negative delta score indicates response inhibition (the Ranschburg effect) and a positive delta score indicate response facilitation. Henson (1998b) found that Ranschburg effects were stronger with the delta analysis compared to that of a serial position analysis and therefore concludes that it is a more sensitive measure analysis.

1.5.6 Factors Affecting the Ranschburg Effect: Temporal Grouping

Temporal grouping (i.e. dividing a sequence into two mini sequences through the insertion of a temporal interval) has been shown to improve serial order memory across sequences (Hitch, Burgess, Towse, & Culpin, 1996; Maybery, Parmentier, & Jones, 2002). This benefit presumably results from the chunking of items. Henson (1998b) examined whether such temporal grouping can eliminate the Ranschburg

effect under conditions in which the repetition straddles the temporal interval. Henson (1998b) found that both the facilitative effect of massed repetitions and the inhibitive effects of repetitions spaced by 3-intervening items were abolished when those items straddled the temporal intervals. This suggests that repetition facilitation/inhibition is dependent upon participants representing the repeated pair within the same sequence. Since the temporal interval produces two separate sequence chunks, the effects of repetition are abolished.

1.5.7 Explanations for the Ranschburg Effect: Guessing Strategy

Greene (1991) suggested that rather than a genuine memory effect, the Ranschburg effect could be explained by a guessing strategy. Greene (1991) suggested that when unsure during a recall procedure, participants tended to guess. In addition, when guessing, participants had a tendency not to guess with an item that has already been recalled. This would typically be an effective strategy, as if one were guessing using one of the remaining items in the stimulus set, there is the possibility of a correct response through chance. However, as noted by Greene (1991): "such a strategy would greatly reduce the chances of getting the second occurrence of a repeated item correct by chance" (p.313). In short, it is proposed that the general memory performance for the second occurrence of the repeated item and the matched item in the control trial is poor (presumably because of the positioning towards the end of the sequence); however, recall for that critical item in the control trials is superior due to a more appropriate guessing strategy enabling more correct guesses.

Greene (1991) tested this proposal by manipulating pre-trial instruction, telling participants to guess a response if unsure or provide a blank response if unsure. Greene examined the effect on both spaced (repetitions at positions 2 and 5, and

positions 3 and 6) and massed repetitions (repetitions at positions 4 and 5, and 5 and 6). Greene (1991) found that the Ranschburg effect was evident when guessing but when instructed not to guess the effect was abolished, thus supporting the guessing explanation. In contrast, the facilitation effects of massed repetition were unaffected by the guessing instruction. Since massed and spaced repetition effects are differentially affected by guessing strategy it suggests that repetition inhibition and repetition facilitation are caused by different processes.

In Experiment 2a, Greene (1991) compared recall of the full list with partial recall. In the partial recall procedure, participants were given the first half of the list and were required to recall the second half. Both conditions produced a Ranschburg effect. This was compared with Experiment 2b, where in the partial recall condition participants received 'XXXX' and then recalled the second half of the list. Following this manipulation the Ranschburg effect was absent. Greene (1991) argued that this supported the guessing account since in Experiment 2a participants saw the first 4 items and ensured that those items were not used in subsequent guessing (thus preventing recall of the repeated items by chance). In contrast, this information was not present in Experiment 2b and as a consequence some of the repeated items may have been recalled through guessing.

Overall Greene (1991) concluded that participants were utilising a guessing strategy, and that this strategy contributes to the Ranschburg effect. Participants, when failing to recall an item in a sequence, will typically respond with an item that has not already been recalled. Indeed, in later work by Henson (1998b) participants were instructed to recall the sequence and indicate whether each response was a guess. Henson (1998b) found that when guessed responses were removed the Ranschburg effect was reduced but not eliminated. This suggests that whilst guessing may

contribute to the magnitude of the effect, it cannot uniquely account for the repetition inhibition effects.

1.5.8 Explanations for the Ranschburg Effect: Response Suppression

In their early work on the Ranschburg effect, Mewdalt and Hinrichs (1973) concluded that the poorer performance on critical items was caused by an omission of the item, as opposed to a transposition. To be clear, participants were not recalling the second occurrence of the repeated item (rather than simply recalling that repeated item but in an incorrect serial position). Whilst Henson (1998b) argues that the Ranschburg effect is affected to some extent by the aforementioned guessing strategy, he also argues that the omission of the second occurrence of the repeated item is caused by output interference. This output interference results from response suppression. That is, after recall of each item in the list, that item is suppressed.

Response suppression is an important mechanism in sequence recall as it prevents perseveration (i.e. repeated retrieval of the same item). Many models of STM involve retrieval of the item with the highest activation level (e.g. Brown, Neath, & Chater, 2007; Burgess & Hitch, 1999; Farrell & Lewandowsky, 2002; Page & Norris, 1998). However, if participants recalled a sequence by simply accessing the item with the highest activation level, then participants would repeatedly recall the same item (i.e. that item with the highest activation) and fail to retrieve items with lower activation levels. As a consequence, a response suppression mechanism is proposed so that once an item is retrieved, it is then suppressed to prevent preservation. Support for this mechanism is found by the low rate with which participants incorrectly repeat items when retrieving a sequence (Henson, Norris, Page & Baddeley, 1996; Johnson et al., 2016; Vousden & Brown, 1998). In addition,

response suppression is also thought to affect the shape of the serial position curve (Farrell & Lewandowsky, 2012; Page & Norris, 1998). Farrell and Lewandowsky (2012) argued that as the sequence is recalled a greater number of candidate items have been outputted (and therefore suppressed), consequently, there are less candidate items that can be recalled and therefore there exists an increased probability that later list items will be correctly recalled.

The Ranschburg effect is epiphenomenal to response suppression, i.e. in cases where an item is repeated in a sequence, retrieval of the second occurrence of that repeated item is impaired as that item has been suppressed following initial retrieval. Henson (1998b) argues that in instances where that repetition is massed, participants become aware of the repetition and 'tag' it for repeated retrieval (i.e. overriding the effects of response suppression).

1.6 The present research

As noted by Hurlstone et al. (2014) research on the Ranschburg effect has focussed uniquely on verbal memory, and to date, it is unknown to what extent the Ranschburg effect (and evidence for response suppression) is found cross-modally. There does, however, exist one recent study where the Ranschburg effect was applied to non-verbal stimuli. Roe, Miles, and Johnson (2016) conducted an experiment investigating the Ranschburg effect in the tactile modality. Using sequences of 6 finger touches they found evidence of repetition inhibition (following spaced repetitions separated by 2-intervening items) and repetition facilitation followed massed (adjacent repetitions). This provides some tentative evidence that the Ranschburg effect may be susceptible to the same conditions as found in previous verbal research (Jahnke, 1969).

The present work will build upon the initial cross-modal work of Roe et al. (2016) and examine the effects of within-trial repetition in both verbal and tactile memory. In addition to examining observation of the basic phenomenon (i.e. facilitation and inhibition as shown by Roe et al., 2016), the present experiments will also look at whether conditions which have been shown to affect verbal repetition inhibition/facilitation (i.e. awareness and set size) similarly affect visual and tactile memory.

The experimental work in this thesis will be divided up into two sections (the division is a function of the different recall tasks employed). Experiments 1 and 2 apply visual and verbal stimuli to a modified SOR procedure. Since SOR has not yet been used to investigate the Ranschburg effect, the verbal condition is included as a control (i.e. if the effect is not found with verbal stimuli, then it suggests that the task does not produce the effect). Identical methodological procedures for visual (Experiment 1) and visual-verbal stimuli (Experiment 2) allow direct cross-modal comparisons. The second section (Experiment 3) examines tactile Ranschburg effects and builds upon the findings of Roe et al. (2016). The memory task is ISR (with participants moving their fingers in the order of original presentation).

Across the experiments, the primary aim is to establish the presence of the Ranschburg Effect (and related facilitative effects) in both visual (Experiment 1, relative to verbal effects in Experiment 2) and tactile (Experiment 3) modalities, with the additional assessment regarding the effects of awareness and set size.

2. Experiment 1 (Visual)

Experiment 1 uses a modified version of the SOR procedure to examine within-sequence repetition effects for non-verbal visual stimuli (unfamiliar-faces). This modified task is required because faces cannot be applied to the typically employed ISR procedure (since participants are unable to generate list items at test). Instead, participants will be re-presented with the preceding list items at test in a circular array. To recall the list, they click on the items in the order of original presentation. The SOR procedure is modified on two accounts. First, in the standard SOR procedure participants are only permitted to select an item once at test (this item is then highlighted and cannot be re-selected). However, since the study is testing memory for repetitions, participants are permitted to click on items as many times as desired. However, to enable participants to monitor their retrieval following each click on a test faces, a number will briefly be displayed on the screen reporting how many items have been recalled thus far.

The second change concerns the number of items displayed in the test array. Since the number of unique items presented in a sequence will vary (depending on whether the list contains a repeated item or not), including only the unique sequence items at test would provide a cue to participants in respect to whether the preceding sequence contained a repetition. That is, participants could learn that if the test array contains *n* items then there has not been a repetition, but if the test array contains *n-1* items a repetition occurred. Consequently, it was decided that the test array will always contain 7 unique faces. In the non-repetition trials, the array comprises the 6 previously presented items and one non-presented lure. In the repetition trials, the array comprises the 5 previously presented items and two non-presented lures. The test procedure therefore contains the same number of unique items across conditions.

Experiment 1 will include massed repetitions and spaced repetitions (separated by 2-intervening items). Based upon the verbal literature (e.g. Crowder, 1968; Henson, 1998a; Jahnke, 1969) it is predicted that massed repetitions will result in facilitation, whereas spaced repetitions will cause inhibition. Furthermore, the present experiment will compare small and large set size, and manipulate pre-trial repetition awareness. Based upon past work it is predicted that the Ranschburg effect will be stronger for smaller set sizes (Jahnke, 1972) but reduced when participants were aware of the repetition (Henson, 1998a).

2.1 Method

2.1.1 Design

A 4-factor (2x2x3x6) mixed design was used. The between-participants independent variable was participant awareness of the repetition (informed/uninformed if the following sequence contained a repetition). The first within-participants factor was set size. The stimuli (faces) used in the sequences were pooled from a set of 19 faces in total, with the large set size sequences using the entire 19 faces, and the small set size using 8 faces from the set of 19. The second within-participants factor was repetition separation (control, adjacent repetition, and 2 intervening items). The third within-participants independent variable was serial position (1-6). Two dependent variables were used. First, serial position recall accuracy was used to assess serial position effects; a correct response necessitated an item recalled in the correct serial position. As described previously (Henson, 1998b), the repetition index (d_1) is calculated by the proportion of trials in which participants correctly recalled the repeated items in the correct position (P_{r1}) minus the proportion of trials in which participants correctly recalled the equivalent items in the corresponding matched

control trial (P_{c1}). As described by Duncan and Lewandowsky (2005), the corresponding (non-repeated) items in the matched control trials were scored as correct even if they exchanged position at recall. This is because it is impossible to know whether the critical items in the repeated trials were recalled in the correct order (since they are the same).

Participants recalled a total of 80 trials. Participants were presented with 40 repetition trials; 20 trials with critical (repeated) items in serial positions 2 and 5, 10 trials with massed repetitions in positions 2 and 3, and another 10 massed repetition trials in positions 3 and 4. Each repetition trial had an identical matched control trial that differed only in the repeated item being replaced by a non-repeated item. Trials consisted of 6 items, derived from the set sizes described above.

2.1.2 Participants

Forty participants collected primarily from Bournemouth University were recruited using volunteer sampling and received course credit for participation, or were compensated for their time with £8. 8 males (mean age=20.25, *s.d.* =3.20, range=18 to 28) and 32 females (mean age=21.03, *s.d.* =5.77, range=18 to 42) were tested. Ethical approval was obtained from Bournemouth University Ethics Committee.

2.1.3 Materials

The faces (19 faces) used were sampled from the Facial Recognition Technology (FERET, National Institute of Standard and Technology (NIST), 2011) database. Faces (which included only the face-the background and hair of each face was cropped out of the image) were all Caucasian males presented in greyscale. Aware participants received the same information sheet as unaware participants, however the aware participants had a title of "*Cross-Modal Ranschburg Effects: Visual*"

(Appendix A), whereas participants in the unaware condition had a title of "*Cross-Modal Sequence Effects: Visual*". A monitor with a resolution of 1920x1080 was used to display the sequences, the items of which were presented in an oval frame. Unaware participants received a questionnaire post-experiment to determine awareness of repetitions (Appendix B). This was developed by the researcher and included questions such as "Did you become aware of any repetitions in the sequences?" followed by Yes/No tick boxes, and a further box which prompted the participant to expand on the repetitions they noticed (if applicable).

2.1.4 Procedure

Participants signed consent forms following explanation of the task (which was adapted depending on awareness condition), and were sat in the experimental booths in Bournemouth University. As stated above, participants were given differing information sheets dependant on what awareness condition participants were assigned. Awareness was manipulated by visual cues prior to the commencement of each trial. For control trials, with no repetition, a cross was presented prior to sequence presentation (the cross was also present before each trial for participants in the unaware condition). For trials with repetitions present, a circle was displayed prior to each sequence. Participants in the aware condition were verbally instructed the meaning of each symbol, and were left with a sheet of paper which defined the symbols (to prevent confusion). These visual cues were not employed in the unaware condition. Participants undertook three practice trials, during which the experimenter explained how to conduct the task (e.g. if the participants held down the mouse for too long, the software would register that as multiple selections). For each sequence, participants were shown 6 faces sequentially. Faces were shown for 500ms, with an inter-item interval of 300ms. After presentation of the list, 7 faces (one of which was

not presented for control trials, two of which were not presented for trials featuring a repetition) were shown in a circular array (Figure 1).

Figure 1: Screenshot of recall method, showing the method used to present the stimuli, and the counter.

Due to the presence of repetitions in this experiment, participants could select the same face multiple times, therefore a counter was added in the centre of the array to confirm to the participant that they had selected a face more than once (see Figure 1 above for an example of this counter). Once 6 selections had been made, the array disappeared and instructions were given to the participants to press any key to begin the next trial (this was to enable participants to take breaks if needed). Following completion of the practice trials, the experimenter left the booth, and the participants completed 80 experimental trials. After completion of the trials, unaware participants were administered the questionnaire, followed by full debriefing (Appendix C). Aware participants were debriefed directly after experimental completion. The procedure took approximately 40 minutes total.

2.2 Results

2.2.1 Serial Position Analysis

For ease of comprehension, the serial position analysis is divided into the two repetition conditions: massed and spaced (2-intervening items).

Massed Repetitions: Figure 2(a-d) demonstrates the serial position curves for the control and massed repetition functions. For each figure there are two massed repetition functions since repetitions occurred at both positions 2+3 and positions 3+4. These conditions are not collapsed since the predicted facilitative effects of massed repetition would be diluted across positions 3 and 4. The figures are sub-divided into conditions based upon set size and explicit pre-trial instruction regarding the repetition (i.e. awareness).

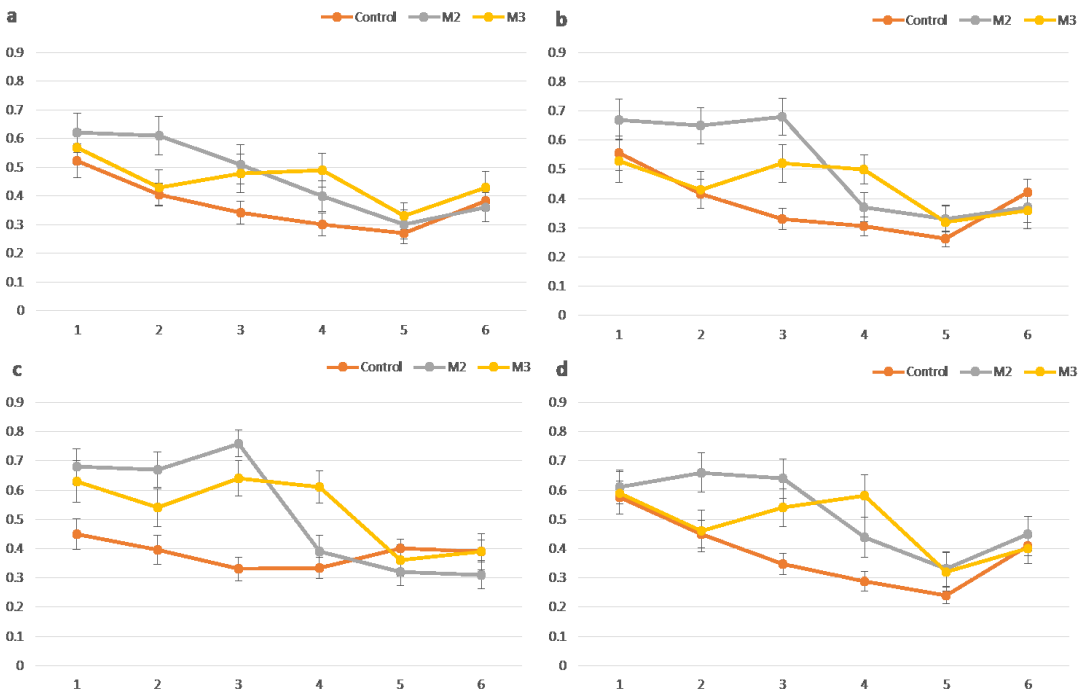

Figure 2(a-d): mean proportion correct for the control, 2+3 massed repetition, and 3+4 massed repetition conditions as a function of serial position (1-6) for the aware small set size (a), unaware small set size (b), aware large set size (c), and unaware large set size (d) conditions. Error bars denote the mean standard error.

Figure 2 shows evidence for facilitation following massed repetitions in both the M2 and M3 conditions. Serial position curves for the massed conditions exhibit spikes in recall which relate to the positions being repeated. The control conditions generally show the canonical bowed serial position curves demonstrated for SOR.

A 4-factor (2x3x2x6) mixed ANOVA was conducted where the between-participants factor was awareness (aware and unaware), the first within-participants factor was trial type (control, 2+3 repetition, and 3+4 repetition), the second within-participants factor was set size (large and small), and the third within-participants factor was serial position (1-6). The main effect of awareness was non-significant (F(1, 38)=.15, MSE=.12, p=.705, η_p^2=.004). The main effect of trial type was significant, F(2, 76)=18.55, MSE=2.02, p<.001, η_p^2=.33). Control trials had significantly lower recall accuracy compared to both the M2 and M3 trials (Bonferroni-corrected comparisons α=.016, p<.001; p=.001, respectively), whereas there was no significant difference in recall accuracy between M2 and M3 trials (p=.349). The ANOVA revealed significantly higher recall accuracy for large set sizes, F(1, 38)=5.60, MSE=.55, p=.023, η_p^2=.13 (small set size mean=.44, 95% CI [.39, .49]; large set size mean=.48, 95% CI [.43, .53]). The main effect of serial position was significant (F(3.05, 116.05)=64.17, MSE=4.35, p<.001, η_p^2=.63). Statistical evidence of primacy and recency was apparent, with Bonferroni-corrected comparisons (α=.003) showing that recall accuracy for serial position 1 was significantly higher than serial positions 2 to 6 and serial position 6 being significantly higher than serial position 5 (all ps<.001). Importantly, the predicted interaction between trial type and serial position was significant (F(6.91, 262.73)=18.05, MSE=.759, p<.001, η_p^2=.32). The three-way interaction between set size, serial position, and awareness was significant

($F(5, 190)=2.71$, $MSE=.10$, $p=.022$, $\eta_p^2=.07$), as was the four-way interaction between set size, trial type, serial position, and awareness ($F(10, 380)=1.90$, $MSE=.05$, $p=.044$, $\eta_p^2=.05$). All other interactions were non-significant.

To investigate the predicted interaction found between trial type and serial position, 6 one-way repeated measures ANOVA's were conducted (one for each serial position), with the within-groups factor being trial type (control/M2/M3). There was a main effect of trial type on serial position 1 ($F(2, 78)=6.21$, $MSE=.11$, $p=.003$, $\eta_p^2=.14$), with further analysis (Bonferroni-corrected comparisons, $\alpha=.016$) showing that recall accuracy in the M2 condition (mean=.66, 95% CI [.58, .73]) was significantly higher than control (mean=.55, 95% CI [.48, .62], $p=.001$). M3 accuracy (mean=.59, 95% CI [.50, .67]) was not significantly different from control or M2 accuracy ($p=.735$; $p=.112$). Serial position 2 was also affected by trial type ($F(2, 78)=33.89$, $MSE=.59$, $p<.001$, $\eta_p^2=.47$). Further analysis revealed that M2 accuracy (mean=.66, 95% CI [.57, .74]) was significantly higher than both control (mean=.43, 95% CI [.37, .49], $p<.001$) and M3 trials (mean=.47, 95% CI [.39, .55], $p<.001$), whereas control and M3 accuracy did not significantly differ ($p=.486$). Trial type had a significant effect on serial position 3 recall accuracy ($F(2, 78)=40.98$, $MSE=.96$, $p<.001$, $\eta_p^2=.51$). Further analysis found that control trial accuracy (mean=.35, 95% CI [.30, .40]) was significantly lower than both M2 (mean=.66, 95% CI [.58, .74], $p<.001$) and M3 (mean=.56, 95% CI [.48, .63], $p<.001$), and M2 accuracy was significantly higher than M3 accuracy ($p=.014$). The main effect of trial type was significant for serial position 4 ($F(2, 78)=41.11$, $MSE=.62$, $p<.001$, $\eta_p^2=.51$), with further analysis finding that M3 accuracy (mean=.55, 95% CI [.49, .61]) was significantly higher than both control (mean=.31, 95% CI [.26, .35], $p<.001$) and M2 (mean=.40, 95% CI [.34, .46], $p<.001$) trials. M2 accuracy was also

significantly higher than control trials (p=.009). There was no main effect of trial type for either serial position 5 (F(2, 78)=1.66, MSE=.03, p=.197, η_p^2=.04) or serial position 6 (F(1.63, 63.46)=.45, MSE=.01, p=.598, η_p^2=.01). This further analysis demonstrates facilitation at serial positions linked to the repeated positions.

Following the post-experiment questionnaire, 10 participants (50%) in the purportedly unaware condition actually self-reported awareness of the massed repetition. Speculative repetition of the 2x2x3x6 ANOVA with the 10 aware participants removed from the unaware condition did change the interaction between awareness and massed repetitions.

Spaced Repetitions (2-intervening items): Figure 3(a-d) demonstrates the serial position curves for the control and (2-interveing item) spaced repetition condition (repetition at serial positions 2 and 5). The figures are sub-divided into conditions based upon set size and explicit pre-trial instruction regarding the repetition (i.e. awareness). Visual inspection of Figure 3 shows no apparent effects of repetition. The functions again exhibit the established bowed functions shown previously for SOR.

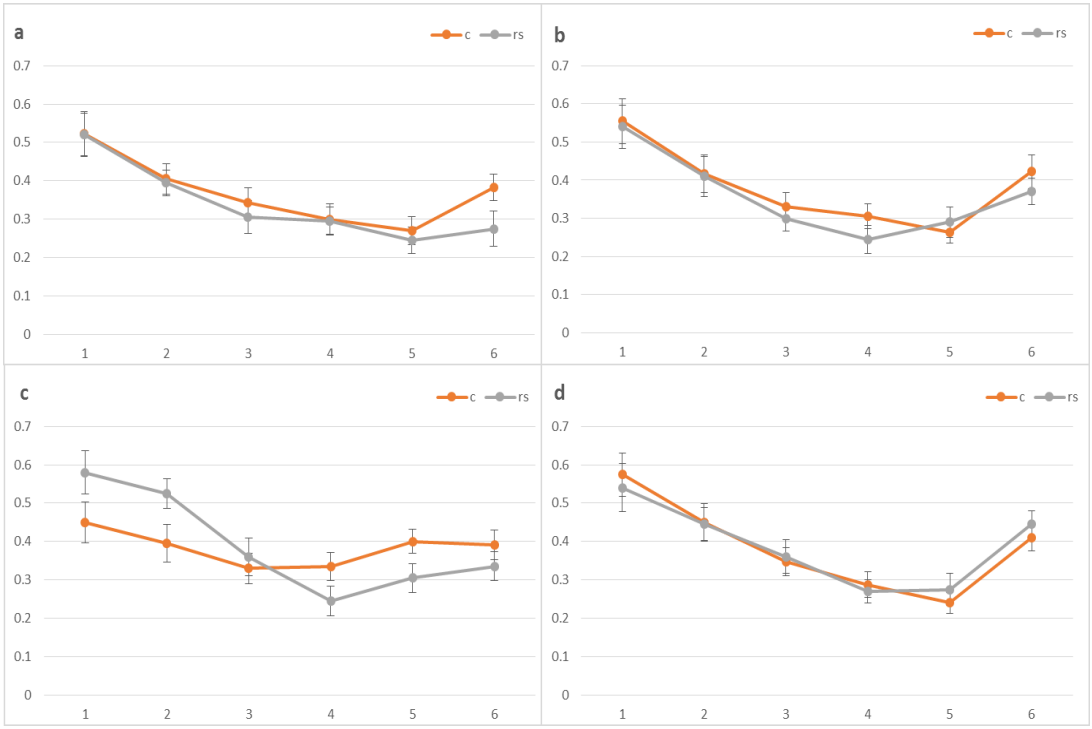

Figure 3(a-d): mean proportion correct for the control and 2+5 spaced repetition condition as a function of serial position (1-6) for the aware small set size (a), unaware small set size (b), aware large set size (c), and unaware large set size (d) conditions. Error bars denote the mean standard error.

A 4-factor (2x2x2x6) mixed ANOVA was conducted where the between-participants factor was awareness (aware and unaware), the first within-participants factor was repetition (control and 2+5 repetition), the second within-participants factor was set size (large and small), and the third within-participants factor was serial position (1-

6). There were non-significant main effects of awareness (F(1, 38)=.10, MSE=.01, p=.754, η_p^2=.03), repetition condition (F(1, 38)=.77, MSE=.05, p=.385, η_p^2=.02), and set size (F(1, 38)=2.59, MSE=.15, p=.12, η_p^2=.06). The main effect of serial position was significant, F(3.34, 126.98)=60.98, MSE=2.60, p<.001, η_p^2=.62. Statistical evidence of primacy and recency was apparent, with Bonferroni-corrected comparisons (α=.003) showing serial position 1 being significantly higher than positions 2-6 (all ps<.001), and serial position 6 being significantly higher than serial position 5 (p<.001). All interactions were non-significant.

Following the post-experiment questionnaire, 3 participants (15%) in the purportedly unaware condition actually self-reported awareness of the spaced repetitions. It therefore seems unlikely that the effects of awareness were masked by participants in the unaware condition being unintentionally aware of the massed repetitions.

The above analysis suggests an absence of repetition inhibition (i.e. the Ranschburg effect) for unfamiliar faces. However, it is possible that low performance for serial position 5 (=.28 in the control trials) masked the detection of the effect. This position is important since it has been argued that the Ranschburg effect is shown through recall omission of the second occurrence of the repeated item (e.g. Mewdalt & Hinrichs, 1973). That is, since baseline performance was low (chance level recall would be =.17), there is less scope for inhibitory effects to be detected, although, it should be noted that performance for serial position 5 for both control and spaced repetition trials were equal (mean=.28 for both conditions). This proposition was examined by exploring whether there was evidence for the Ranschburg effect amongst participants who performed better at the task. Participants were divided into a high or low accuracy group (via median split: overall recall accuracy of .38 was the cut-off). The 2x2x2x6 mixed measures ANOVA was repeated on the high and low

accuracy groups. The results from the "low" accuracy group matched those of the original ANOVA, with only serial position having a significant main effect on recall accuracy ($F(5, 90)=19.28$, $MSE=.46$, $p<.001$, $\eta_p^2=.52$). The "high" accuracy group analysis found that, as before, serial position had a significant effect on recall accuracy ($F(1, 90)=52.55$, $MSE=1.42$, $p<.001$, $\eta_p^2=.75$), but that set size also had a main effect on recall accuracy ($F(1, 18)=10.42$, $MSE=.57$, $p=.005$, $\eta_p^2=.37$). Importantly, however, the high group neither demonstrated a main effect of trial type ($p = .189$) nor a trial type by serial position interaction (although this approached significance, $p =.057$).

2.2.2 Repetition Analysis: Delta

For delta (δ) scoring, only the serial position for the critical items were analysed, i.e. 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 (δ = 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 4(a-d) demonstrates the delta values for massed repetition and 2-intervening items massed repetition conditions. The figures are sub-divided into conditions based upon set size and explicit pre-trial instruction regarding the repetition (i.e. awareness). For the massed conditions, delta scores are collapsed across the two versions of the repetition (i.e. 2+3 and 3+4 for massed). Figure 4(a-d) shows pronounced facilitative effects in the massed trial type, regardless of sub condition, however inhibitive effects are only present in the unaware conditions for spaced repetitions. This is an interesting result, as, from previous research (e.g. Hinrichs et al., 1973; Jahnke, 1972), there should be high inhibitive effects for the smaller set size, with aware participants (Figure 4a)

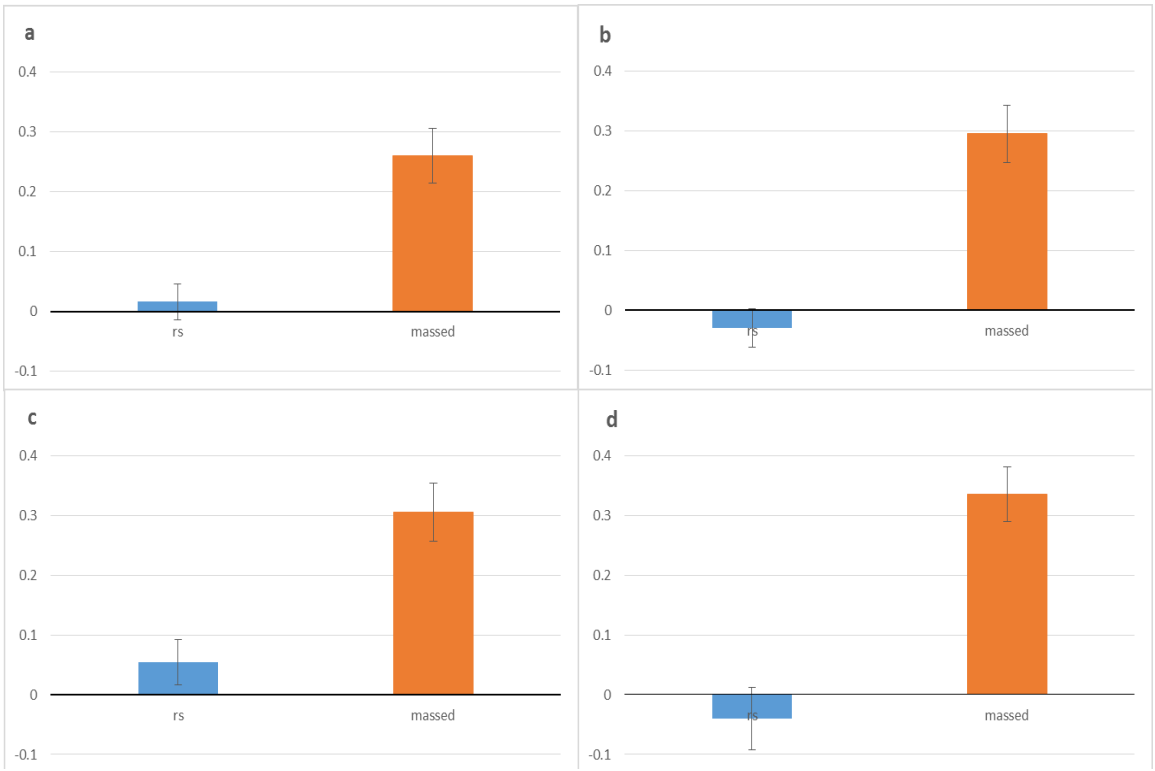

Figure 4(a-d): mean delta for the two repetition spacing conditions for the aware small set size (a), unaware small set size (b), aware large set size (c), and unaware large set size (d) conditions. Error bars denote the mean standard error.

A 3-factor (2x2x2) mixed ANOVA was conducted on the delta scores where the between-participants factor was awareness (aware and unaware), the first within-participants factor was repetition condition (massed and 2-item spaced), and the second within-participants factor was set size (large and small). The ANOVA revealed a significant main effect of repetition type ($F(1, 38)=99.90$, $MSE=5.57$, $p<.001$, $\eta_p^2=.724$), with massed repetition significantly higher than spaced repetitions. All other main effects and interaction were non-significant.

For awareness, 15% ($n=3$) of participants in the unaware condition became aware of any spaced repetitions, and inclusion of these participants into the aware condition does not affect the significance the effect of awareness on delta scores.

One-sample *t*-tests were conducted comparing each delta value to 0. A delta score of 0 would suggest no repetition or inhibition. Scores were collapsed across set size and

awareness conditions due to a lack of main effects and interactions. The massed repetitions were significantly higher than 0, ($t(39)=10.46$, $p<.001$, $r=.86$), whereas the delta scores from the spaced repetitions did not differ from 0 ($t(39)=.00$, $p=1.00$, $r=0$). This indicates facilitation following massed repetitions but a lack of inhibitive effects following spaced repetition.

To test whether the Ranschburg effect was masked due to low performance levels, analysis was again divided into a high and low accuracy group. Spaced repetition delta values were compared to 0 via eight one-sample *t*-tests that were split into performance category, and according to repetition type and set size. The spaced repetitions did not differ significantly from 0, whereas all of the massed repetition types did (for the low performance group: $t(19)=6.93$, $p<.001$, $r=.85$; $t(19)=5.72$, $p<.001$, $r=.80$ for the small and large set sizes respectively; for the high performance group: $t(19)=5.14$, $p<.001$, $r=.76$; $t(19)=8.10$, $p<.001$, $r=.88$ for the small and large set sizes respectively). As with the serial position scoring, separation into performance groups failed to produce significant inhibitive effects, indicating that floor effects do not account for the lack of phenomena in the visual modality.

2.3 Discussion

Experiment 1 has shown that the facilitative effects found in previous research (Crowder, 1968a; Henson, 1998b) using verbal stimuli with massed repetitions can be found with visual stimuli and using a modified SOR procedure. With both types of massed repetitions there were significant increases in recall accuracy at the serial positions that corresponded to the critical items. This effect was also evidenced following the delta analysis. It was predicted that awareness might accentuate the facilitative effects of massed repetitions, since awareness has been associated with mentally 'tagging' the items for repeated retrieval (Henson, 1998b), however this was not found. Set size significantly affected recall accuracy across the types of trials, with, as predicted, participants performing better in the larger set size trials compared to the small set size. One might explain this effect through reduced proactive interference in the high set size condition.

Despite the presence of facilitative effects, there was a lack of inhibitive effects (the Ranschburg effect) found following spaced repetitions. Awareness, as with the massed condition, did not affect performance. Set size also did not moderate inhibitive effects, contradicting the set size effects found with the massed repetitions (above) and previous research (Jahnke, 1972; Hinrichs et al., 1973; Jahnke, 1974). Critically, the spaced repetition condition failed to affect recall accuracy, with no significant difference being found between control trials and spaced repetition trials; this was observed both with the serial position analysis and the delta analysis.

There exist a number of explanations for the absence of the Ranschburg effect with visual stimuli. The most significant interpretation is that visual memory does not utilise response suppression; the mechanism purported to epiphenomenally result in

the Ranschburg effect. Such a conclusion would have profound implications on ordinal models of serial memory (discussed in more detail in the General Discussion). It is, however, more prosaic to consider two possible methodological explanations for this null finding. First, it is possible that low overall performance levels on the task (particularly at serial position 5) made it harder to detect any inhibitive effects. To be clear, mean recall at serial position 5 was .28, whereas chance would be .17. Since recall only had 11% in which to decrease, it may have hindered observation of the effect. This was examined by dividing participants into a high and low recall group (mean overall recall across the sequence for the high and low group =.42 and .34, respectively). However, following this split-analysis, there remained no evidence for response inhibition in the high accuracy group. This provides some preliminary evidence that floor effects were not masking the effect.

A second methodological explanation concerns the use of serial order reconstruction (SOR) at test. Traditionally, immediate serial recall (ISR) has been used to examine the Ranschburg effect (Henson, 1998b). In this task participants are required to both generate the items and recall them in the order of original presentation. However, such a methodology was not possible with faces (one cannot generate the faces at test) and, therefore, Experiment 1 employed a modified SOR procedure. At test participants were re-presented with 7 faces in a test array and were required to click on those faces in the order of original presentation. It is possible therefore that this different procedure may be responsible for the absence of inhibition reported in Experiment 1. This may have occurred because participants were no longer required to generate the items at test (sequence items were re-presented on the screen at test). Since response suppression is thought to cause the Ranschburg effect, it is possible

that individuals only employ response suppression when they generate the item at test.

Experiment 2 directly tests whether the modified SOR procedure prevents repetition inhibition by employing stimuli that has previously been shown to exhibit the effect (i.e. verbal stimuli). Experiment 2 therefore has two related aims. First, it aims to validate SOR as a valid method for measuring inhibitive effects (previous research involves verbally recalling the sequences), thereby eliminating the possibility that the results from Experiment 1 are caused by the recall method. Second, if repetition inhibition is shown with verbal stimuli using the SOR procedure, it suggests that item generation is not required for response suppression to occur.

3. Experiment 2 (Verbal)

Experiment 2 replicates the method of Experiment 1 with the exception that verbal stimuli (visually presented consonants are employed instead of faces). If the modified SOR procedure produces effects similar to when verbal stimuli are applied to ISR, it is predicted that repetition inhibition and repetition facilitation will follow spaced and massed repetitions, respectively. Moreover, it is predicted that the Ranschburg effect (repetition inhibition) will be stronger with small (relative to large) set sizes (e.g. Jahnke, 1972), whereas awareness will attenuate this effect (Henson, 1998b).

3.1 Method

3.1.1 Design

Experiment 2 utilises the same 4-factor (2x2x3x6) mixed design as Experiment 1. The difference between Experiment 1 and Experiment 2 is the stimuli used. Experiment 2 used letters as opposed to unfamiliar faces. Experiment 2 will use 19 letters (all letters of the alphabet excluding all 5 vowels, and the letters "Y" and "Z", as described by Oberaurer, Jones & Lewandowsky, 2015).

3.1.2 Participants

Forty participants collected primarily from Bournemouth University were recruited using volunteer sampling and received course credit for participation, or were compensated for their time with £8. 12 males (mean age=23.42, *s.d.*=6.61, range=19 to 44) and 28 females (mean age=22.11, *s.d.*=5.15, range=18 to 46). Ethical approval was obtained from Bournemouth University Ethics Committee.

3.1.3 Materials

Materials matched those described in Experiment 1, with the exception that letters (in Arial Unicode MS) were used instead of faces.

3.1.4 Procedure

The procedure replicates that from Experiment 1, with the difference being the stimuli used (see Figure 5).

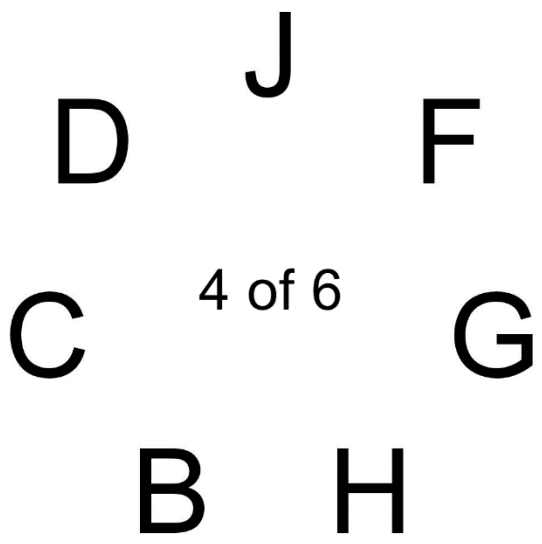

Figure 5: Screenshot of recall method, showing the method used to present the stimuli, and the counter.

3.2 Results

3.2.1 Serial Position Analysis:

As with Experiment 1, the serial position analysis of the verbal data has been divided into the two repetition conditions (massed and spaced).

Massed Repetitions: Figure 6(a-d) shows the serial position curves for the control and both massed repetition functions (2+3, 3+4). As with Experiment 1, these have not been collapsed due to dilution across serial positions 3 and 4. Once again the figures are subdivided into the set size and awareness conditions.

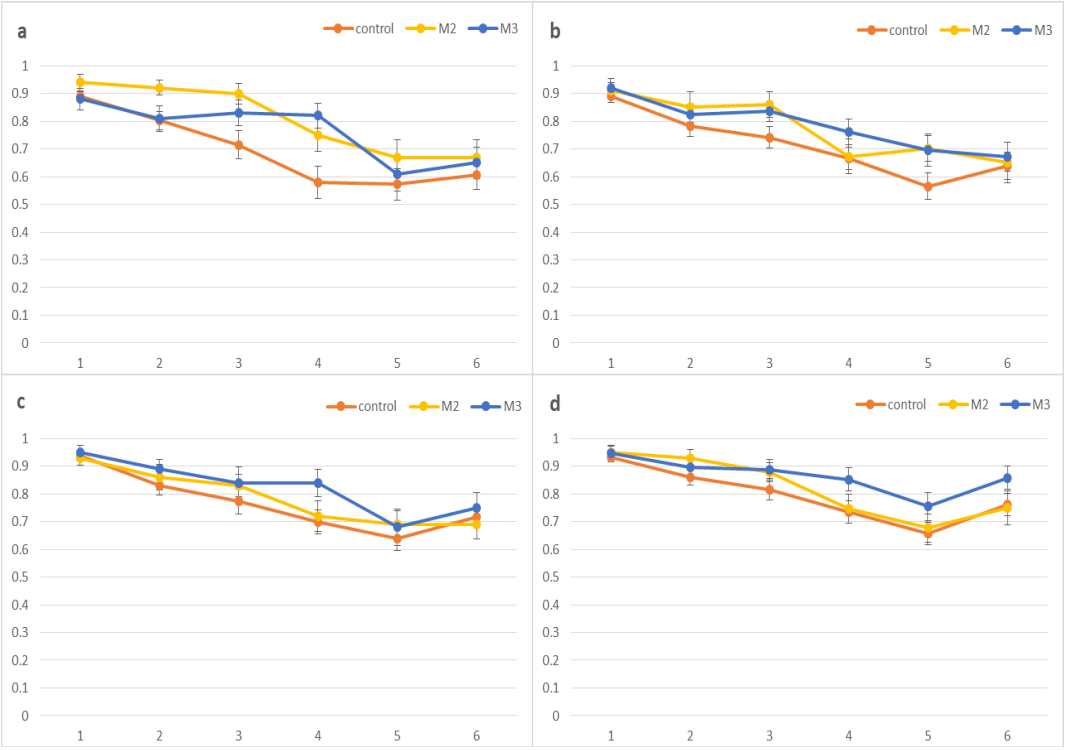

Figure 6(a-d): mean proportion correct for the control, 2+3 massed repetition, and 3+4 massed repetition conditions as a function of serial position (1-6) for the aware small set size (a), unaware small set size (b), aware large set size (c), and unaware large set size (d) conditions. Error bars denote the mean standard error.

Evidence for repetition facilitation can be qualitatively seen from Figure 6, for both the M2 and M3 conditions. Control trials also show the classic bowed serial position curve found for SOR of verbal data (e.g. Ward et al., 2005).

A 4-factor (2x2x3x6) mixed ANOVA was conducted wherein the between-participants factor was awareness condition (aware and unaware). The first within-participants factor was set size (large and small), the second was trial type (control, 2+3 repetition, and 3+4 repetition), and the third within-participants factor was serial position (1-6). The main effect of awareness was not significant ($F(1, 38)=.20$, $MSE=.12$, $p=.659$, $\eta_p^2=.01$). The main effect of set size was significant ($F(1, 38)=18.92$, $MSE=1.01$, $p<.001$, $\eta_p^2=.33$), with the larger set size exhibiting higher recall accuracy (mean=.81, 95% CI [.77, .85]) than the small set size (mean=.76, 95% CI [.71, .80]). As predicted, the main effect of trial type was significant ($F(2, 76)=10.55$, $MSE=.64$, $p<.001$, $\eta_p^2=.22$). Bonferroni-corrected comparisons ($\alpha=.016$) showed that control trial (mean=.74, 95% CI [.70, .79]) accuracy was significantly lower than both M2 (mean=.80, 95% CI [.75, .84], $p=.009$), and M3 (mean=.81, 95% CI [.77, .85], $p<.001$). There was no significant difference between M2 and M3 recall accuracy. The main effects of serial position was also significant ($F(2.72, 103.45)=61.56$, $MSE=4.46$, $p<.001$, $\eta_p^2=.62$). Further investigation of this main effect (Bonferroni-corrected comparisons $\alpha=.008$) found that serial position 1 (mean=.92, 95% CI [.90, .95]) was significantly higher than all other serial positions (all $ps<.001$). Serial position 2 (mean=.86, 95% CI [.82, .89]) was significantly higher than serial positions 4-6 (all $ps<.001$). Serial position 3 (mean=.83, 95% CI [.78, .87]) was significantly higher than position 4-6 (all $ps<.001$). Serial position 4 (mean=.74, 95% CI [.69, .79]) was significantly higher than serial position 5 ($p<.001$), but not serial position 6 ($p=1.00$). Serial position 5 (mean=.66, 95% CI

[.60, .72]) was not significantly lower than serial position 6 (mean=.70, 95% CI [.64, .76]). A significant interaction was found between trial type and serial position (F(5.94, 225.59)=4.44, MSE=.13, p<.001, η_p^2=.11) and between set size and serial position (F(3.66, 138.92)=3.25, MSE=.07, p=.017, η_p^2=.08).

To investigate the predicted interaction between trial type and serial position, 6 one-way repeated measures ANOVAs were conducted (collapsing data across both set size and awareness). Each ANOVA was conducted with trial type as the variable (control, 2+3 repetition, and 3+4 repetition), according to serial position. For serial position 1, trial type was non-significant (F(2, 78)=.83, MSE=.00, p=.440, η_p^2=.02). At serial position 2 trial type was significant (F(2, 78)=6.46, MSE=.05, p=.003, η_p^2=.14), with further analysis (Bonferroni-corrected comparisons α=.016) showing that control trials (mean=.82, 95% CI [.78, .86]) had significantly lower recall accuracy than M2 trials (mean=.89, 95% CI [.84, .94], p=.004). M3 performance (mean=.86, 95% CI [.81, .90]) did not significantly differ to control (p=.128) or M2 trials (p=.327). There was also a main effect of trial type at serial position 3 (F(1.70, 66.35)=9.14, MSE=.15, p=.001, η_p^2=.19), with further analysis (Bonferroni-corrected comparisons α=.016) finding that control trial performance (mean=.76, 95% CI [.70, .82]), was significantly lower than both M2 (mean=.87, 95% CI [.82, .92], p=.005) and M3 (mean=.85, 95% CI [.79, .90], p=.002) trial performance. M2 and M3 performance did not differ (p=1.00). At serial position 4 trial type was significant (F(2, 78)=11.41, MSE=.23, p<.001, η_p^2=.23), with further analysis (Bonferroni-corrected comparisons α=.016) showing control trial performance (mean=.67, 95% CI [.61, .73]) being significantly lower than the M3 trials (mean=.82, 95% [.77, .87], p<.001), and M2 (mean=.72, 95% CI [.65, .79], p=.035) trials were also significantly lower than M3 trials. There were no significant differences between M2 accuracy

and control (p=.283). Trial type also affected serial position 5 recall accuracy (F(2, 78)=6.00, MSE=.08, p=.004, η_p^2=.13). Further analysis (Bonferroni-corrected comparisons α=.016) found that control performance (mean=.61, 95% CI [.55, .67]) was significantly lower than both M2 (mean=.69, 95% CI [.62, .75], p=.009) and M3 (mean=.69, 95% CI [.62, .75], p=.013) performance, with no significant difference between M2 and M3 performance (p=1.00). Trial type was not significant at serial position 6 (F(2, 78)=2.22, MSE=.03, p=.115, η_p^2=.05). This further analysis demonstrates facilitation at serial positions linked to the repeated positions. There is also some evidence of facilitation on positions following the repeated items (e.g. position 5).

The interaction between set size and serial position was not of theoretical interest to the present study, but was underpinned by superior recall for larger set sizes at positions 2 and 6 only.

50% of participants in the unaware condition self-reported awareness of the massed repetitions in the post-experiment questionnaire. When accounting for this (i.e. repeating the analysis with n=10 for the genuinely 'unaware' condition), no differences are found for main effects in terms of what variables caused a main effect.

Spaced Repetitions (2-intervening items): Figure 7(a-d) shows the serial position curves for the control and spaced repetition functions (2+5). Once again the figures are subdivided into the set size and awareness conditions. The serial position curves show the predicted effect of lower serial accuracy for trials with a spaced repetition compared to control, with lower accuracy across entire trials, with serial position 5 being consistently lower in the spaced trials compared to control.

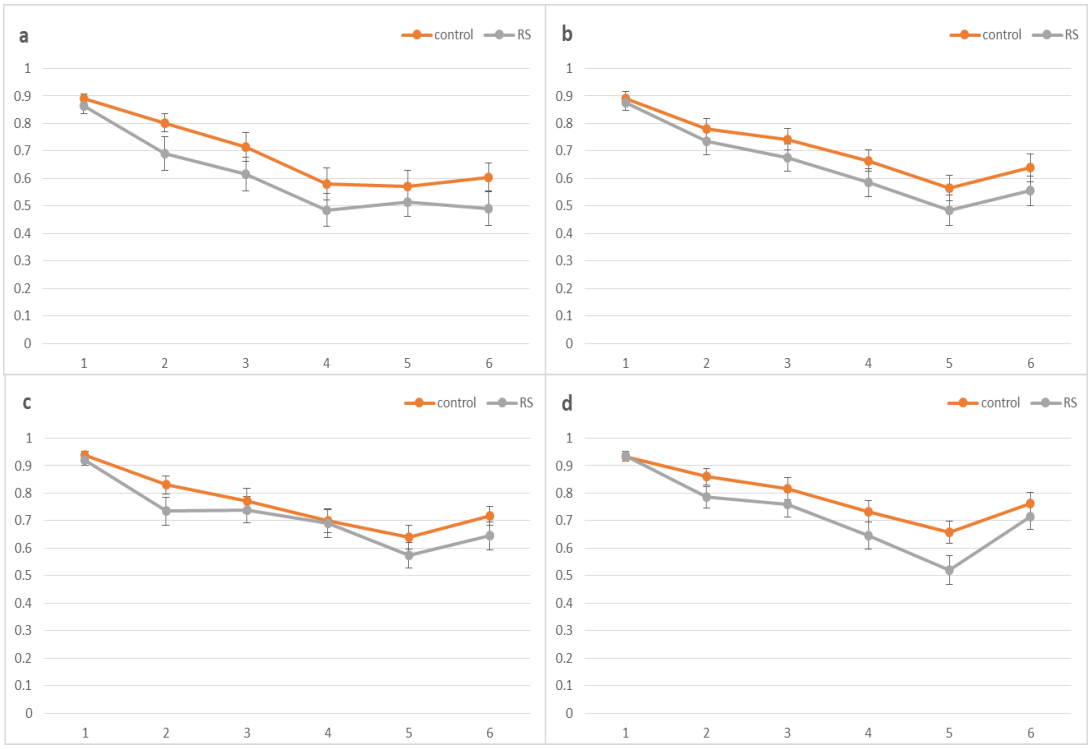

Figure 7(a-d): mean proportion correct for the control and 2+5 spaced repetition condition as a function of serial position (1-6) for the aware small set size (a), unaware small set size (b), aware large set size (c), and unaware large set size (d) conditions. Error bars denote the mean standard error.

A 4-factor (2x2x2x6) mixed ANOVA was conducted wherein the between-participants factor was awareness condition (aware and unaware). The first within-participants factor was set size (large and small), the second was trial type (control and 2+5 repetition), and the third within-participants factor was serial position (1-6).

Awareness was found to have no significant effect on recall accuracy ($F(1, 38)=.27$, $MSE=.14$, $p=.609$, $\eta_p^2=.01$). The main effect of set size was significant ($F(1, 38)=32.41$, $MSE=1.68$, $p<.001$, $\eta_p^2=.46$), with the larger set size exhibiting higher recall accuracy (mean=.75, 95% CI [.71, .80]) than the small set size (mean=.68, 95% CI [.61, .72]). Trial type had the predicted significant effect on recall accuracy ($F(2, 38)=32.68$, $MSE=1.03$, $p<.001$, $\eta_p^2=.46$). Specifically, control trial (mean=.74, 95% CI [.70, .79]) accuracy was significantly higher than spaced repetition trials (mean=.68, 95% CI [.62, .73]) The main effect of serial position was also significant ($F(3.10, 117.63)=71.58$, $MSE=2.37$, $p<.001$, $\eta_p^2=.65$). Further investigation of this main effect (Bonferroni-corrected comparisons $\alpha=.008$) found that serial position 1 (mean=.91, 95% CI [.88, .93]) was significantly higher than all other serial positions (all $ps<.001$). Serial position 2 (mean=.77, 95% CI [.73, .83]) was significantly higher than serial positions 4-6 (all $ps<.001$). Serial position 3 (mean=.73, 95% CI [.67, .80]) was significantly higher than positions 4-6 (4 and 5 $ps<.001$, 6 $p=.008$). Serial position 4 (mean=.64, 95% CI [.57, .70]) was significantly higher than serial position 5 ($p<.001$), but not serial position 6. Serial position 5 (mean=.57, 95% CI [.51, .63]) was significantly lower than serial position 6 (mean=.64, 95% CI [.58, .70], $p=.001$). The predicted interaction between trial type and serial position was also significant ($F(3.31, 125.61)=3.00$, $MSE=.04$, $p<.029$, $\eta_p^2=.07$), as was the interaction between set size and serial position ($F(5, 190)=5.27$, $MSE=.05$, $p<.001$, $\eta_p^2=.12$).

To investigate the interaction between trial type and serial position, 6 paired-sample *t*-tests were conducted. Each *t*-test corresponded to a serial position, with the variable being trial type (control and 2+5 spaced repetition). There was no significant difference between trial type for serial position 1 ($t(39)=1.39$, $p=.174$, r=.22). At

serial position 2, control trials (mean=.82, 95% CI [.78, .86]) were significantly higher than the spaced repetition trials (mean=.74, 95% CI [.67, .80]) (t(39)=4.01, p<.001, r=.54). At serial position 3, control trials (mean=.76, 95% CI [.70, .82]) were also significantly higher than spaced repetition trials (mean=.70, 95% CI [.63, .77]) (t(39)=4.01, p<.001, r=.54). Control trials for serial position 4 (mean=.67, 95% CI [.61, .73]) were significantly higher than spaced repetition trials (mean=.60, 95% CI [.54, .67], t(39)=3.79, p<.001, r=52), with the same trend found with serial position 5 (control (mean=.61, 95% CI [.55, .67]) being higher than experimental (mean=.52, 95% CI [.46, .59], t(39)=4.05, p<.001, r=54). Finally, at serial position 6 control trials (mean=.68, 95% CI [.62, .74]) were also significantly higher than spaced repetition trials (mean=.60, 95% CI [.53, .67]) (t(39)=3.90, p<.001, r=.53).

The interaction between set size and serial position was not of theoretical interest to the present study, but was underpinned by superior recall for larger set sizes at all positions except 2.

Of the unaware participants, 10% (n=2) reported spaced repetitions. Therefore it seems unlikely that awareness in the unaware condition diluted the effects of the awareness manipulation.

3.2.2 Repetition Analysis: Delta

Delta scoring procedure for Experiment 2 followed that described in Experiment 1. Figure 8(a-d) displays the delta values for massed repetitions (collapsed across the two versions of repetition) and spaced repetitions. The figures are once again subdivided into set size and the pre-trial instruction regarding repetition.

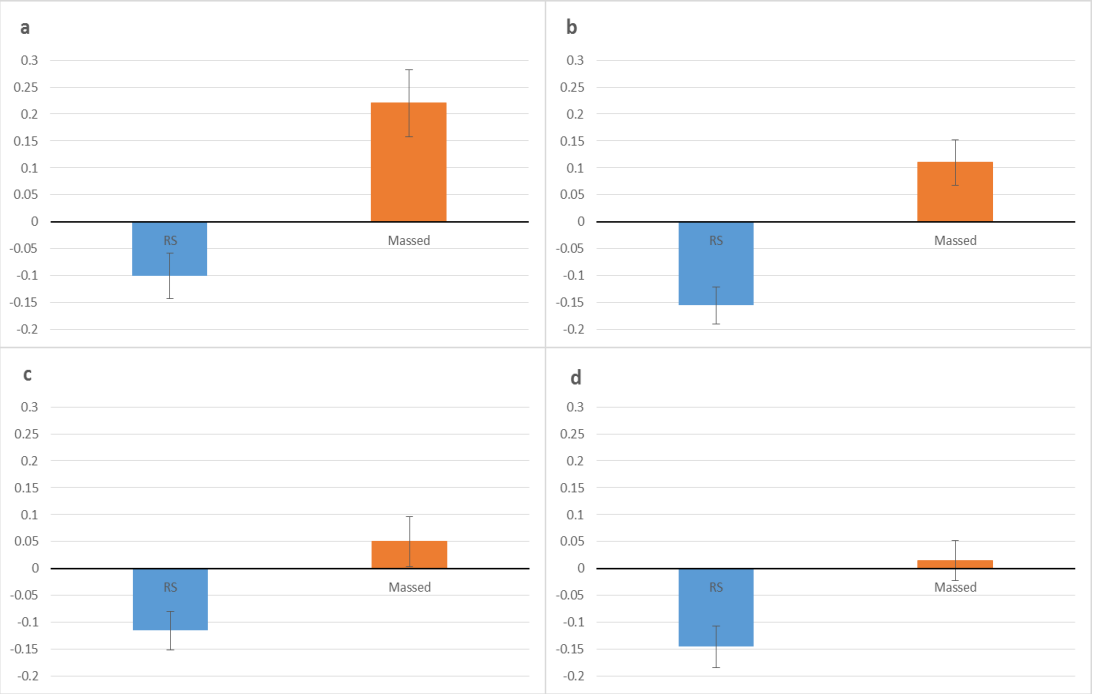

Figure 8(a-d): mean delta for the two repetition spacing conditions for the aware small set size (a), unaware small set size (b), aware large set size (c), and unaware large set size (d) conditions. Error bars denote the mean standard error.

A 3-factor (2x2x2) mixed ANOVA was conducted on the delta scores where the between-participants factor was awareness (aware and unaware), the first within-participants factor was repetition condition (massed and 2-item spaced), and the second within-participants factor was set size (large and small). The main effect of

awareness was non-significant ($F(1, 38)=.77$, $MSE=.03$, $p=.386$, $\eta_p^2=.02$). Repetition type was significant ($F(1, 38)=52.25$, $MSE=2.07$, $p<.001$, $\eta_p^2=.58$), with massed repetitions (mean=.10, 95% CI [.04, .15]) exhibiting a significantly higher delta score than spaced repetitions (mean=-.13, 95% CI [-.17, -.09]). The main effect of set size was also significant ($F(1, 38)=5.88$, $MSE=.18$, $p=.002$, $\eta_p^2=.13$), with the larger set size delta (mean=-.05, 95% CI [-.09, -.01]) being significantly lower than the small set size delta (mean=.02, 95% CI [-.03, .07]). The interaction between set size and trial type was significant ($F(1, 38)=5.88$, $MSE=.18$, $p=.02$, $\eta_p^2=.13$). Further investigation of this interaction was conducted by comparing small and large set sizes for the massed and spaced repetition conditions. Two paired sample *t*-tests found a significant difference in delta scores between the massed repetition delta scores according to set size ($t(39)=3.23$, $p=.022$, $r=.46$), with the larger set size (mean=.03, 95% CI [-.03, .09]) being significantly lower than the smaller set size (mean=.17, 95% CI [.09, .24]), there was no significant difference between set size performance in the spaced repetition condition ($t(39)=.07$, $p=.947$, $r=.01$). No other interactions were present between the variables.

One-sample *t*-tests were conducted comparing each delta value to 0. Scores were collapsed across the awareness condition due to a lack of main effect and interactions. Massed repetition scores in the small set size condition (mean=.17, 95% CI [.09, .24]) were significantly higher than 0 ($t(39)=4.34$, $p<.001$, $r=.57$), however the larger set size trials (mean=.03, 95% CI [-.03, .09]), did not differ significantly from 0 ($t(39)=1.11$, $p=.276$, $r=.17$). Both the spaced repetitions were significantly lower than 0 (mean=-.13, 95% CI [-.18, -.07], $t(39)=4.72$, $p<.001$, $r=.60$; mean=-.13, 95% CI [-.18, -.08], $t(39)=4.98$, $p<.001$, $r=.62$, for the small and large set sizes respectively).

3.3 Discussion

The verbal results for the massed repetitions were similar to Experiment 1, with the critical items 2, 3, 4, and 5 being significantly higher in comparison to control in the respective repetition trials (using serial position scoring). Set size also had an effect, as predicted, with the larger set size having a higher overall recall accuracy compared to the smaller set size, when using serial position scoring. As stated for Experiment 1, this may be explained by reduced levels of proactive interference.

Awareness, as in Experiment 1, did not have an effect on recall accuracy. This is consistent with Experiment 1 and, as stated previously may be explained by high levels of repetition awareness in the purportedly unaware condition.

Response inhibition was found when analysing the serial position scores for the spaced repetitions compared to control. Serial position 5 was found to be significantly lower than control, which is indicative of the Ranschburg effect (i.e. reduced recall for the repeated item, Jahnke, 1969; Henson, 1998b). As with massed repetitions, recall was unaffected by awareness. This contradicts the prediction that awareness of the repetition should attenuate the negative effects of response inhibition. Set size, as predicted, did affect recall performance, but, contrary to our prediction (and the work of Jahnke, 1972, 1974) did not affect the magnitude of the Ranschburg effect.

Experiment 2 therefore makes two important contributions. First, it shows that the failure to obtain response inhibition (the Ranschburg effect) in Experiment 1 cannot be explained by the modified SOR procedure. That is, Experiment 2 has applied verbal stimuli (consonants) to the same recall procedure as used for faces (in

Experiment 1) and found evidence for the Ranschburg effect. This suggests that non-verbal visual stimuli (i.e. faces) might not exhibit a Ranschburg effect – a point discussed in more detail in the General Discussion.

The second, and related contribution of Experiment 2 is that it has shown the Ranschburg effect using a recall procedure that does require item generation. To be clear, in the modified SOR procedure, the to-be-remembered sequence is re-presented at test in a circular array with an additional 1-2 lures (depending upon if the current trial contains a repetition or not). Since it is assumed that the Ranschburg effect is epiphenomenal to response suppression, it is unknown whether suppression follows generation of the item (as one might in ISR) or whether simply responding with an item (by clicking on it within the test array) will prompt response suppression of that item. The data from Experiment 2 suggests the latter, i.e. that generation of the item is not required for response suppression. There is, however, one caveat to this claim; since the stimuli are verbal, participants may be sub-vocally recalling the sequence at test in order to click on the items in the correct order. If this is the adopted strategy then participants will be generating the list items and this may be resulting in response suppression. Whilst beyond the timeframe of the present project, future studies should replicate Experiment 2 with the inclusion of concurrent articulation at test. This should serve to limit verbal outputting at test (a manipulation that has been shown to still produce the Ranschburg effect in ISR of visual verbal stimuli, Johnson, Hawley, & Miles, under review).

In summary, Experiments 1 and 2 have applied the modified SOR procedure to verbal and non-verbal visual stimuli. The studies have shown that (1) SOR of consonants and faces show facilitation following massed repetition, (2) SOR of consonants show response inhibition following spaced repetition but faces do not,

(3) item generation (possibly) is not required for the Ranschburg effect, and (4) these effects are not affected by either set size or awareness. Point 2 (above) provides the tantalising proposition that the Ranschburg is not found cross-modally. Experiment 3 examines cross-modal effects in more detail by focussing upon tactile memory. Preliminary work has shown that the Ranschburg effect is found with tactile stimuli (Roe et al., 2016), Experiment 3 seeks to build upon this work by examining whether the effect is influenced by awareness. The role of awareness in repetition inhibition and facilitation has been questioned by Experiments 1 and 2; however, it should be noted that this was using the modified SOR procedure. Experiment 3 will seek to replicate the findings of Roe et al. (2016) using a tactile ISR procedure and test whether these effects are influenced by pre-trial instruction regarding the repetition.

4. Experiment 3 (Tactile)

Experiment 3 builds upon the initial findings of Roe et al. (2016) and explores the effects of within-sequence repetition for tactile sequences. Participants are presented with sequences of 6-tactile stimulations to their fingers and are required to recall the sequence by moving their fingers in the order of original presentation. Massed and spaced repetitions will be examined. Since the maximum set size is limited by the number of fingers, only awareness is manipulated. Based upon the initial findings of Roe et al. (2016), repetition inhibition and repetition facilitation is predicted following spaced and massed repetition respectively. The previous work of Henson (1998b) with verbal ISR suggests that awareness should accentuate the Ranschburg effect, and potentially accentuate repetition facilitation.

4.1 Method

4.1.1 Design

A 3-factor (2x3x6) mixed design was employed. The between-participants independent variable was participant awareness of the repetition (informed or not informed about trials containing a repetition). The first within-participants factor was repetition separation (control, adjacent repetition, and separation of 2-intervening items). The second within-participants independent variable was serial position (1-6). As in Experiments 1 and 2, two dependent variables were used. First, serial position recall accuracy was used to assess serial position effects; a correct response necessitated an item recalled in the correct serial position. The second dependent variable examined the repeated (critical) items only. As described previously (Henson, 1998b), the repetition index delta (d_1) is calculated by the proportion of trials in which participants correctly recalled the repeated items in the correct

position (P_{r1}) minus the proportion of trials in which participants correctly recalled the equivalent items in the corresponding matched control trial (P_{c1}). As described by Duncan and Lewandowsky (2005), the corresponding items in the matched control trials were scored as correct if they exchanged position, as it is impossible to know whether the repeated items were recalled in the correct order (since they are identical). Participants recalled a total of 40 experimental trials. Participants were presented with 20 repetition trials; 10 trials with critical (repeated) items in serial positions 2 and 5 (i.e. spaced repetition), 5 trials with massed repetitions in positions 2 and 3, and another 5 massed repetition trials in positions 4 and 5. Each repetition trial had an identical matched control trial that differed only in the repeated item being replaced by a non-repeated item. Trials consisted of 6 items, derived from a set size of 8 (fingers available to the researcher).

4.1.2 Participants

Forty participants collected primarily from Bournemouth University were recruited using volunteer sampling and received course credit for participation. 14 males (mean age=22.00, *s.d.* =1.92, range=19 to 26) and 26 females (mean age=21.12, *s.d.* =5.74, range=18 to 46). Ethical approval was obtained from Bournemouth University Ethics Committee.

4.1.3 Materials

Awareness was manipulated by explicit information about the repetitions in the pre-experiment information sheet (see Appendix D). The document stated: "*Before each sequence you will be alerted by the researcher if the sequence contains a repeating item or not. If you recall a repetition of an item, raising the finger again will count as a response*". This was absent for participants in the unaware condition. For

participants in the unaware condition, a questionnaire was also administrated post-experiment to determine awareness of the repetitions (Appendix B). To prevent the participants from seeing their hands, a wooden screen was used. Tactile stimulation was administrated to the intermediary phalange of the digitus secondus, digitus theritus, digitus quartus, and digitus quintus on the dorsal aspect of both the right and left hands. A Panasonic HC-V750 Video Camera, mounted on a tripod, was used to record the participants' responses (for offline coding).

4.1.4 Procedure

Participants were tested individually in a quiet laboratory. After participants had read the information sheet (alongside the researcher giving an explanation of the task), participants were sat at a table with the wooden screen, and asked to pass their hands through the gap at the base of the screen. Participants received 10 practice trials, during the practice trials, participants were asked to give feedback to the researcher (e.g. the researcher is pressing too hard/soft). This was followed by 40 experimental trials. Each trial was initiated by a verbal signal from the experimenter and comprised of the experimenter touching a sequence of 6 digits (see Figure 9, below). Tactile stimulations were presented at an approximate rate of 1 per second. Following the sequence, participants were required to recall the preceding sequence by moving their fingers in the order of stimulation. There was an approximate 5 second inter-trial interval. Participants were offered a break after every 10 trials. The procedure for those in the unaware condition was as described above. Participants in the aware condition were told before each trial whether a repetition would be present (by the research saying "this is control" or "this has a repetition").

Figure 9: Screenshot from a recording, showing the method used to present the stimuli.

After completion of all 40 trials, participants in the unaware condition were asked if they had noticed anything about the trials. If the participants responded that they had noticed repetitions, they were then given the questionnaire, which asks for specifics on the type of repetitions they identified (as it was likely participants would notice the massed repetitions). If participants stated that they did not notice anything about the trials no more questions were asked. The procedure took approximately 30 minutes in total.

4.2 Results

4.2.1 Serial Position Analysis:

Massed Repetitions: Figure 10(a-b) displays the serial position curves for the control and massed repetition conditions, split by awareness condition. Both figures show each massed repetition condition (repetitions at 2 and 3, and 4 and 5). Figure 10 clearly shows facilitative effects at the repeated serial positions across both repetition type conditions, with the control trial showing a serial position function with strong primacy.

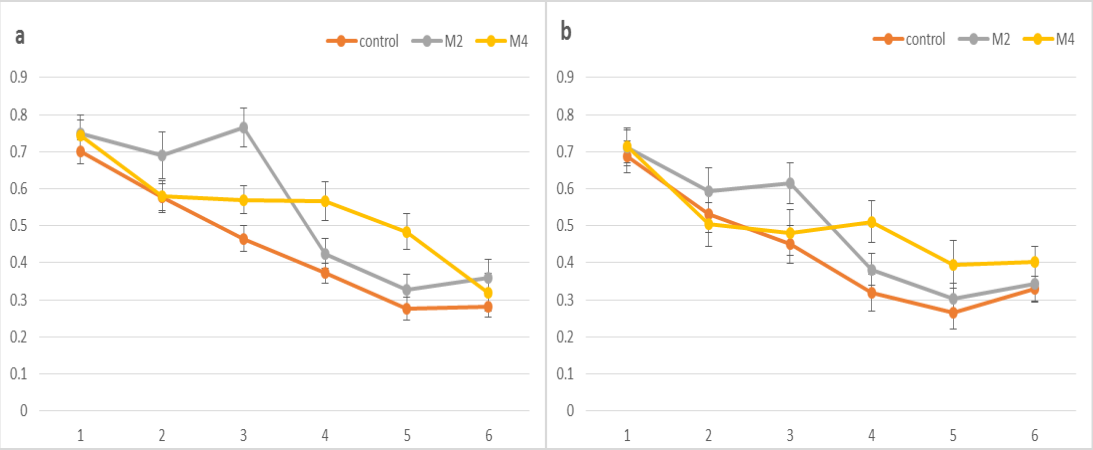

Figure 10(a-b): mean proportion correct for the control, 2+3 massed repetition, and 4+5 massed repetition conditions as a function of serial position (1-6) for the aware (a) and unaware (b) groups. Error bars denote the mean standard error.

A 3 factor (2x3x6) mixed ANOVA was conducted, where the between participants factor was awareness (aware/unaware), the first within participant factor was trial type (control/2 and 3 repetition/ 4 and 5 repetition), and the second within participant factor was serial position (1-6). The ANOVA revealed that awareness had no main effect on recall accuracy ($F(1, 38)=.81$, $MSE=.28$, $p=.374$, $\eta_p^2=.02$). Trial type had a significant main effect on recall accuracy ($F(2, 76)=12.20$, $MSE=.57$, $p<.001$, $\eta_p^2=.24$), with control trials (mean=.44, 95% CI [.39, .49]) having a significantly

lower recall accuracy than the M2 trials (mean=.52, 95% CI [.47, .57]; p=.001, Bonferroni-corrected comparisons α=.016) and M4 trials (mean=.52, 95% CI [.47, .58], p<.001, Bonferroni-corrected comparisons α=.016). Serial position was shown to have a main effect on recall accuracy (F(3.02, 114.88)=89.52, MSE=4.47, p<.001, η_p^2=.70). Further investigation (Bonferroni-corrected comparisons α=.008) of this effect found that serial position 1 (mean=.72, 95% CI [.66, .77]) was significantly higher than all other serial positions (all ps<.001). Serial position 2 (mean=.58, 95% CI [.52, .64]) was significantly higher than serial positions 4-6 (all ps<.001). Serial position 3 was significantly higher than serial positions 4-6 (all ps<.001). Serial position 4 (mean=.43, 95% CI [.38, .48] was significantly higher than serial positions 5 and 6 (p<.001 for both). All other comparisons were non-significant. A significant interaction was found between trial type and serial position (F(5.90, 224.20)=8.39, MSE=.30, p<.001, η_p^2=.18). No other significant interactions were found. There were 8 participants (40%) in the unaware condition that self-reported awareness of the massed repetitions. When the analysis was speculatively repeated with those 8 aware participants removed, the results were unchanged.

To investigate the interaction between trial type and serial position, 6 one-way repeated measures ANOVAs were conducted. Each one used trial type as the main factor (3 levels, control, M2 and M4), with each ANOVA individually examining the 6 serial positions. The ANOVAs found no main effect of trial type for serial position 1 (F(2, 78)=1.36, MSE=.02, p=.262, η_p^2=.03). The main effect at serial position 2 was non-significant following Bonferroni correction (F(1.65, 64.46)=4.20, MSE=14, p=.026, η_p^2=.10). Trial type was significant at serial position 3 (F(2, 78)=20.96, MSE=.57, p<.001, η_p^2=.35), with further analysis (Bonferroni-corrected comparisons α=.016) showing that M2 (mean=.69, 95% CI [.61, .77]) recall accuracy is

significantly higher than both control (mean=.46, 95% CI [.40, .52], p<.001) and M4 (mean=.53, 95% CI [.45, .60], p<.001) trials. Control and M4 trial recall accuracy did not significantly differ (p=.106). Trial type was also significant at serial position 4 (F(1.71, 66.64)=14.72, MSE=.46, p<.001, η_p^2=.27). Further analysis (Bonferroni-corrected comparisons α=.016) found that M4 trial recall accuracy (mean=.54, 95% CI [.46, .62]) was significantly higher than both the control (mean=.35, 95% CI [.29, .40], p<.001) and M2 (mean=.40, 95% CI [.35, .46], p=.010) trials. The difference between control and M2 trials was non-significant (p=.244). Recall at serial position 5 was also affected by trial type (F(2, 78)=9.46, MSE=.31, p<.001, η_p^2=.20). Further analysis (Bonferroni-corrected comparisons α=.016) found that M4 trial recall accuracy (mean=.44, 95% CI [.36, .52]) was significantly higher than both the control (mean=.27, 95% CI [.22, .32], p<.001) and M2 trials (mean=.32, 95% CI [.26, .37], p=.034). Recall accuracy for serial position 5 was not significantly different between control and M2 trials (p=.699). Serial position 6 was found to be unaffected by trials type (F(1.71, 66.64)=1.58, MSE=.04, p=.215, η_p^2=.04). This additional analysis is consistent with accentuated recall accuracy for the repeated positions in the M2 and M4 trials. This further analysis demonstrates facilitation at serial positions linked to the repeated positions. There is also some evidence of facilitation on positions that followed the repeated items (e.g. position 5).

Spaced Repetitions (2-intervening items): Figure 11(a-b) shows recall accuracy as a function of serial position according to trial type (control or spaced repetitions) and awareness (aware/unaware). The functions again show strong primacy.

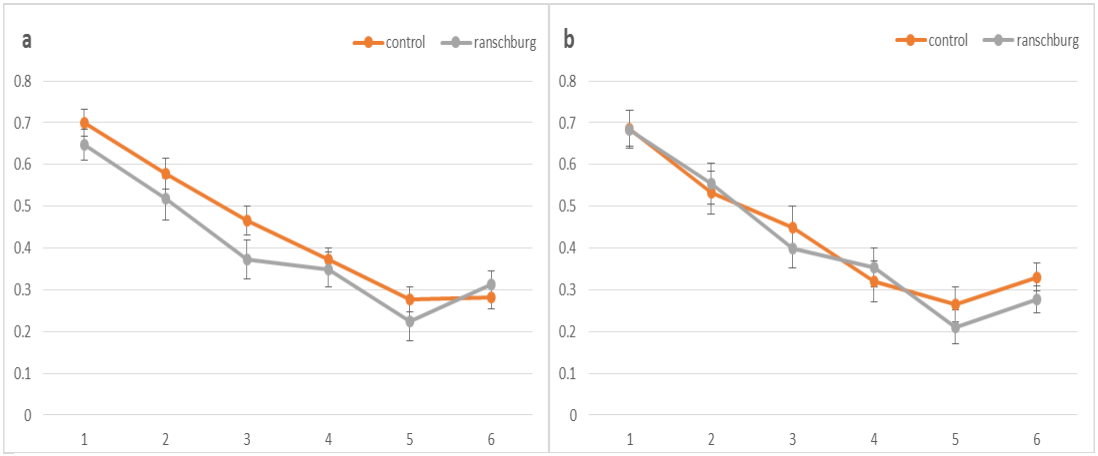

Figure 11(a-b): mean proportion correct for the control and 2+5 spaced repetition condition as a function of serial position (1-6) for the aware (a) and unaware (b) groups. Error bars denote the mean standard error.

A 3-factor (2x2x6) mixed measures ANOVA was conducted with awareness as the between-participants factor (aware/awareness), the first within-participants factor was trial type (control/spaced repetitions), and the second within-participants factor was serial position (1-6). The main effect of awareness was non-significant (F(1, 38)=.005, MSE=.001, p=.946, η_p^2=.00). The main effect of trial type did not reach statistical significance (F(1, 38)=3.23, MSE=1.04, p=.080, η_p^2=.08). The main effect of serial position was significant (F(3.73, 141.56)=119.12, MSE=2.87, p<.001, η_p^2=.76). Further analysis (Bonferroni-corrected comparisons α=.003) found that serial position 1 (mean=.68, 95% CI [.63, .73]) was significantly higher than all other positions (all ps<.001). Serial position 2 (mean=.55, 95% CI [.49, .61]) was significantly higher than position 3-6 (all ps<.001). Serial position 3 (mean=.42, 95% CI [.37, .48]) was significantly higher than serial position 4 (mean=.35, 95% CI [.29,

.40], p=.001), and 5 and 6 (both ps<.001). Serial position 4 was significantly higher than serial position 5 (mean=.24, 95% CI [.20, .29], p<.001), but not serial position 6 (mean=.30, 95% CI [.26, .34], p=.26). Serial position 6 was significantly higher than serial position 5 (p=.022). No interactions were present.

In the post-experiment question, 4 participants (20%) in the unaware condition self-reported being aware of the spaced repetition. When the analysis was speculatively repeated with those 4 aware participants removed, the results were unchanged.

4.2.2 Repetition Analysis: Delta

Delta (δ) scoring for the tactile trials is identical to the scoring used in both Experiments 1 and 2. Figure 12(a-b) illustrates the delta values for massed repetitions (collapsed across the two versions of the repetition) and the 2-intervening items (spaced) conditions. The figures are divided into the two pre-trial instruction conditions (aware and unaware). From the diagram, the massed trials show a facilitative effect, with the 2-intervening item repetition type trials showing an inhibitive effect on recall.

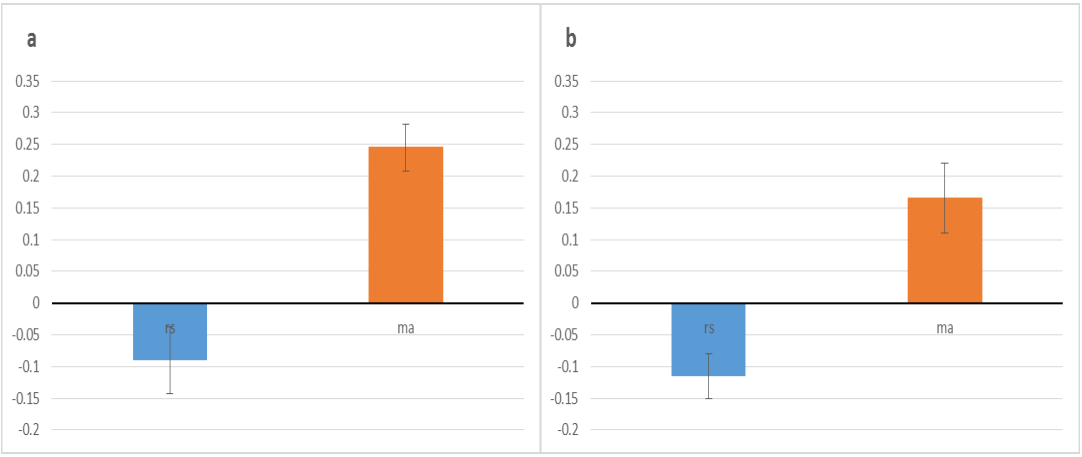

Figure 12(a-b): mean delta for the two repetition spacing conditions for the aware conditions (a), unaware conditions (b). Error bars denote the mean standard error.

A 2x2 mixed ANOVA with repetition type (spaced or massed) as the first variable and awareness (aware or unaware) as the second variable was conducted. The main effect of trial type was significant ($F(1, 38)=44.67$, $MSE=1.89$, $p<.001$, $\eta_p^2=.54$), with massed repetition (mean=.21, 95% CI [.14, .27]) having a significantly higher delta score than the spaced repetition (mean=-.10, 95% CI [-.17, -.04]). The main effect of awareness was non-significant ($F(1, 38)=1.32$, $MSE=.06$, $p=.258$, $\eta_p^2=.03$),

as was the interaction between repetition type and awareness ($F(1, 38)=.36$, $MSE=.02$, $p=.554$, $\eta_p^2=.01$).

One-sample *t*-tests were conducted comparing each delta score to 0, which was collapsed across awareness due to the absence of both a main effect and interaction for awareness. The spaced repetition delta score was significantly lower than 0 ($t(39)=3.27$, $p=.002$, $r=.46$). The massed repetition scores were significantly higher than 0 ($t(39)=6.14$, $p<.001$, $r=.70$). The delta scores confirm the inhibitive effects typically found with spaced repetitions (e.g. Jahnke, 1969), with the facilitative effects also being found from massed repetitions (e.g. Henson, 1998a).

4.3 Discussion

As with Experiments 1 and 2, the massed repetitions produced facilitative effects when compared with control. These effects were found with serial positions 3, 4, and 5, in concurrence with the respective critical repeated items. In addition, inhibitive effects were found with the spaced repetition condition but only following the delta analysis. Both facilitative and inhibitive effects replicate the early findings reported by Roe et al. (2016) and extend those findings to conditions in which a larger set size is employed (a set size of 8, rather than 6, fingers are employed in the present study). For the control trials, analysis of the serial position curves revealed strong primacy and only a hint of recency. This finding adds to a growing body of studies that have demonstrated a tactile ISR serial position function that is broadly similar to that shown with verbal stimuli (Johnson et al., 2016; Mahrer & Miles, 1999; Roe et al., 2016).

Experiment 3 extended the work of Roe et al. (2016) to include an examination of awareness. As in Experiments 1 and 2, awareness did not affect performance in the massed repetition trials, indicating that the pre-trial instruction of a forthcoming repetition is not necessary for facilitative effects of massed repetition. This finding is perhaps unsurprising since it is suggested that massed repetition enable participants to become aware of the repetition and then mental tag the item for repeated retrieval (Henson, 1998a; Jahnke, 1969).

For the spaced repetitions, there was no evidence of inhibition following the serial position analysis, i.e. the predicted interaction between serial position and trial type was non-significant. However, the delta analysis revealed an inhibitive effect for the spaced repetition condition. This discrepancy is consistent with Henson (1998b) who

stated that delta is a more sensitive measure of response inhibition. Nevertheless, this reveals a weaker inhibitive effect compared to that of Roe et al. (2016), who reported evidence of inhibition from both the serial position and delta analysis. Indeed, comparisons of the effect size measures for inhibition was reduced for the present study (r = .46) compared to Roe et al. (r = .84). One explanation for this could be the use of an increased set size in the present experiment, in which the 6-item sequence was selected from a possible stimulus set of 8 different fingers. In contrast, Roe et al. (2016) used the same 6 fingers throughout. This is potentially important since it has been argued that the Ranschburg effect is accentuated with a smaller set size (Jahnke, 1972; 1974).

The results from Experiment 3 are consistent with response suppression (Henson, 1998b), as it has been shown that participants' performance for serial position 5 in the spaced repetition trials are lower than the corresponding control trials. According to the response suppression mechanism, participants could have suppressed the response upon first recall, forcing participants to guess the second occurrence of the repetition (Henson, 1998b). It should be noted that in the current experiment, there was no option for "do not know" option, and participants had to make 6 responses, which would encourage guessing (and presumably accentuate the effect).

It has been suggested this tactile memory may involve verbal recoding (Mahrer & Miles, 2002). Indeed, despite both the fact that participants could not view their hands during the experiment and the observation that ISR of tactile stimuli survives concurrent backward counting (Mahrer & Miles, 1999), there remains the possibility that participants attempted to verbally recode the stimuli. Under such conditions the effect would simply reflect the classic verbal Ranschburg effect (e.g. Crowder, 1968a; Henson 1998a; Jahkne, 1969). Future research should utilise concurrent

articulation in order to prevent recoding, and determine if the effect can be present in the tactile modality.

Overall both the facilitative and inhibitive effects expected were found within the tactile modality, supporting the hypothesis that the Ranschburg effect is not confined to the verbal domain.

5. General Discussion

The current research aimed to determine the presence of the Ranschburg effect in the visual and tactile modalities. In addition, the work sought to explore whether the Ranschburg effect was still present when applied to a modified SOR procedure.

Experiments 1 and 2 employed the same modified SOR procedure and compared the effects of within-trial repetition across verbal (consonants) and visual (unfamiliar-faces) stimuli. This modified procedure was needed because faces could not be applied to an ISR procedure (typically used for verbal serial memory, e.g. Henson, 1998b), as at test ISR necessitates generation of the list items. In the modified SOR procedure, the to-be-remembered list items were re-presented at test in a circular array including 1-2 lures. Participants were required to click on the items in the order of original presentation. Experiment 2 applied verbal stimuli (sequences of 6-consonants) to this task and found evidence for both repetition inhibition (i.e. the Ranschburg effect) and repetition facilitation. Experiment 2 therefore served as a paradigm check, since verbal stimuli has been shown to show repetition inhibition/facilitation with verbal stimuli (e.g. Crowder, 1968a; Henson, 1998b, Jahnke, 1969 etc.). Experiment 2 also showed that recall was superior with larger set sizes, consistent with that reported with ISR (Jahnke, 1972; Hinrichs et al., 1973). Previously it was argued that awareness accentuates response facilitation and attenuates response inhibition (e.g. Henson, 1998b). However, Experiment 2 revealed no effect of awareness on within-sequence repetition effects.

Experiment 1 found repetition facilitation (following massed repetitions) with faces but an absence of repetition inhibition (following spaced repetitions). This finding is important as it may suggest fundamental cross-modal differences between verbal and

visual stimuli. This is particularly important since the Ranschburg effect is thought to be epiphenomenal to response suppression. Since many models of serial memory (e.g. Burgess & Hitch, 2006; Page & Norris, 1998) rely upon response suppression, it might suggest that these models cannot be applied to visual stimuli. Moreover, such a finding would be more problematic for ordinal models of serial order memory where recall is based purely upon activation level (e.g. Primacy Model, Page & Norris, 1998). Without response suppression, participants would repeatedly recall the same item with the highest level of activation. However, the absence of response suppression is not catastrophic for positional models of serial order memory (e.g. The Start-End-Model, Henson, 1998a). In positional models the item with the highest level of activation for each position is recalled. That is, activation level is dynamic and relative to the position being recalled. This may avoid any perseverative effects in the absence of response suppression. However, any conclusions regarding the absence of response suppression in visual memory are, of course, premature and the effect requires replication. There are also some more prosaic explanations for the absence of the visual Ranschburg effect. These are discussed below.

First as mentioned earlier, it is possible that the Ranschburg effect is masked in Experiment 1 due to low performance levels. Since the Ranschburg effect usually follows omission of the second occurrence of the repeated item (Henson, 1998b), poor baseline recall for position 5 (= 28%; chance 17%) may have masked the effect. That is, performance did not have much scope to decline. This proposition was tentatively checked by conducting separate analyses on the top and bottom 50% of the sample. Even when those who performed better on the task (the top 50%) were analysed separately, the Ranschburg effect was not present. To increase performance

levels, the task could be replicated with a short list length (e.g. 5-faces). The problem, however, is that a 5-item list causes issues with respect to observing the Ranschburg effect. This is because the optimal repetition interval is 2-intervening items and this cannot be achieved with a 5-item list without repeating one of the terminal list items (a manipulation shown to affect repetition effects, Crowder, 1968a).

A second explanation for the absence of the Ranschburg effect with faces is that the modified SOR procedure prevents the effect. It was argued that since the effect has been found with verbal stimuli (Experiment 2), item generation is not needed for the Ranschburg effect. Moreover, if the Ranschburg effect results from response suppression, it was argued response suppression occurs even when selecting items in the SOR test array (without the requirement to generate the items at test). However, it is possible participants were still generating the items in the verbal condition. That is, participants may have been performing ISR mentally and then using retrieval of that sequence to complete the SOR task. Retrieving each item when performing ISR mentally may have been followed by response suppression of each item, therefore leading to the Ranschburg effect. However, this strategy is arguably not available for faces (i.e. ISR for non-verbal stimuli is harder). This explanation could be tested by replicating Experiment 2 with concurrent articulation. Such a manipulation would make it harder for participants to perform verbal ISR at test.

A third explanation concerns the choice of non-verbal visual stimuli. It is possible that there is something 'special' about faces (e.g. they are processed separately in the Fusiform Face Area, Kanwisher, Stanley, & Harris, 1999) that means they cannot be inhibited following recall (thereby preventing a Ranschburg effect). This may have an evolutionary social explanation, as faces serve an integral function in human

interaction (Bate, 2013). The study should therefore be replicated with other hard-to-name visual stimuli (e.g. abstract matrices, Avon 1998). However, this explanation is not terribly parsimonious given that faces produce the standard serial position curves (Horton et al., 2008; Smyth et al., 2005; Ward et al., 2005), error distributions (Smyth et al., 2005), and Hebb effect (Horton et al., 2008). It seems odd that order memory for faces should only differ for the Ranschburg effect.

Notwithstanding the above methodological caveats, if the absence of the Ranschburg effect for visual stimuli can be substantiated this raises issues for both the (1) domain general argument of a unitary memory store, and (2) models that rely on response suppression. Previous studies have shown order memory similarities between visual and verbal stimuli in respect to serial position curves (e.g. Smyth et al., 2005), error distributions (e.g. Guérard & Tremblay, 2008), and Hebb repetition effects (e.g. Horton et al., 2008); therefore, cross-modal inconsistencies in the Ranschburg effect is an unexpected finding. Such a finding however remains broadly consistent with Hurlstone et al. (2014) who proposed separate memory systems cross-modally but argued that these systems generally work in a similar way. The present data may simply serve as a small exception to functional equivalence. Although it is noted that this interpretation then makes the Hurlstone et al. (2014) account non-falsifiable.

In Experiment 3, tactile ISR exhibited the standard repetition facilitation and inhibition effects shown with verbal stimuli (e.g. Crowder, 1968a) and replicated recent findings from this laboratory (Roe et al., 2016). It is perhaps too premature to argue that this is evidence for a cross-modal Ranschburg effect since due to the time constraints of the research, the addition of a concurrent articulation condition was not included. It is therefore possible that participants were verbally recoding the tactile information, thereby creating the inhibitive effect found in verbal stimuli (e.g.

Crowder, 1968a). An obvious future research idea is to replicate Experiment 3 with concurrent articulation; although it should be noted that when concurrent articualtion has been applied to tactile memory, the serial position curve has been unaffected (Mahrer & Miles, 1999).

The present experiments found little support for the effect of awareness on either repetition inhibition or facilitation. This contradicts previous findings (e.g. Henson, 1998a; Jahnke, 1969) where the Ranschburg effect was reduced, and overall performance for critical items improved, when participants are made aware of a repetition prior to sequence presentation. In both the visual and verbal condition awareness was administered by a visual cue (symbol on the screen) prior to each trial. It is possible that this method was ineffective and participants neither noticed nor remembered the meaning of the symbol. In past studies, awareness was administered verbally (e.g. Jahnke, 1969). It is possible, therefore, that verbal administration is more effective than a visual cue.

Experiments 1 and 2 manipulated set size and, contrary to prediction, this was not found to affect the Ranschburg effect. In Experiment 1, there was an overall main effect of set size, showing superior recall for the large set size (presumably a result of reduced proactive interference). The delta analysis showed that set size failed to mediate the Ranschburg effect with the spaced repetitions, contradicting previous research, wherein a larger set size reduces the effect (e.g. Hinrichs et al., 1973). Although it should be noted that in Experiment 1, there was no Ranschburg effect for which set size could moderate.

The set size manipulations present in Experiment 2 (verbal stimuli) affected performance similarly to Experiment 1, the larger set size trials yielded an overall

higher recall accuracy level compared to the smaller set size in the massed trials. However, the delta analysis showed that the Ranschburg effect was not reduced with larger set sizes as predicted.

The overall lack of main effects from set size manipulations contradicts previous research that has found diminished Ranschburg effects when increasing set size. It is unclear why the effects of set size were not found in the current research. It is possible that the differences in set size between the large (n = 19) and small (n = 8) conditions was insufficiently big. For example, Jahnke (1972) compared set sizes of 10 and 300. However, Experiment 3 provided some tentative cross-study evidence for set sizes effects. In Experiment 3, repetition inhibition was weaker than the effect reported by Roe et al. (2016), and it is possible that this results from a difference in set size (6 in Roe et al. compared to 8 in Experiment 3).

In summary this project is the first attempt at demonstrating repetition inhibition (the Ranschburg effect) with visual stimuli. Experiments 1 and 2 are methodologically matched in order to enable a direct cross-modal comparison. Experiment 3 builds upon the recent finding of Roe et al. (2016) which was, purportedly, the first demonstration of the Ranschburg effect with non-verbal stimuli. As outlined above, this work is preliminary and more follow-on experiments are needed. Indeed, it would of interest to expand the study to examine other stimulus types such as visuo-spatial (e.g. Guérard & Tremblay, 2008) and audio-spatial stimuli (Parmentier & Jones, 2000; Parmentier et al., 2008). The modified SOR procedure could be applied to both of these stimulus types since the spatial locations could be re-presented at test in the array.

In conclusion, tentative evidence against the visual Ranschburg effect but in support of the tactile Ranschburg effect is reported. Further work is required to ascertain if the absence of the visual effect is due to methodological constraints and/or the presence of the tactile effect is due to verbal recoding. Answering these questions will help to determine if the Ranschburg effect is a truly cross modal phenomenon.

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7. Appendices

7.2 Appendix A: Information Sheet for Aware Participants

Cross Modal Ranschburg Effects: Experiment 1: Visual.

Participants Information Sheet.

The Purpose of the Study.

You are being invited to participate in a study being conducted by Masters by Research Bournemouth University student Rachel Skinner, which aims to determine whether or not the Ranschburg Effect is prevalent in other modalities besides the verbal domain. This study is being supervised by Dr. Andrew Johnson, and has been ethically approved by Bournemouth University.

What is Involved in the Task?

For this study, you will be asked to recall of the order of a sequence of 6 faces using Serial Order Reconstruction. You will be presented with 6 faces sequentially, at test those faces will be re-presented on the screen in a circle and you are required to click on the faces in the order of original presentation. In the centre of the screen will be a counter which displays the number of responses you have given. If you recall a repetition of an item, clicking on the item again will register the response (hence the counter). **Do not worry if this sounds complicated! You will receive practice trials!** This study involves 80 memory trials.

How long will the study take?

Including briefing, gaining informed consent, the trials and debriefing, this study should take around 40 minutes to complete.

Your Rights as a Participant.

If at any point during this study you feel that you do not wish to continue, you may withdraw at any point. If you wish to do this, please notify the researcher, Rachel Skinner, as soon as possible. Unfortunately, due to the fact that your data will be anonymised after the study is completed, it would be impossible to find your data, therefore you cannot withdraw your data post completion.

What Happens After the Study?

As stated before, your data will be kept anonymised and confidential after the study. Your data and consent form will be kept for 12 months after the study, and then destroyed.

After completion, you will be awarded 0.75 SONAR credit(s).

If you are willing to participate, please read and sign the consent form provided. If you are not willing to participate (which is within your participant rights), please notify the researcher.

Feel free to ask the researcher any additional questions if you have any.

Researcher Contact Details:

Name: Rachel Skinner

Email: i7232698@bournemouth.ac.uk

Supervisor Contact Details:

Name: Dr. Andrew Johnson

Email: andjohnson@bournemouth.ac.uk

If you wish to make a complaint about this study, feel free to email Dr. Katherine Appleton

k.appleton@bournemouth.ac.uk

7.1 Appendix B: Post-Experimental Questionnaire for Unaware Participants

Cross Modal Sequence Effects: Experiment 2: Visual

Post-Experimental Questionnaire.

1. Did you notice anything about the sequences?

   YES ☐ **NO** ☐

2. If **YES**– what did you notice?

   ☐

3. Did you become aware of any repetitions in the sequences?

   YES ☐ **NO** ☐

4. If **YES**, which positions did you notice being repeated?

   ☐

5. What were the gaps between the repetitions?

   ☐

6. Did you notice any other repetitions?

   YES ☐ **NO** ☐

7. If **YES**, what were the gaps between the repetitions?

   ☐

7.3 Appendix C: Debriefing Sheet for all Participants

Participant Debriefing Form

Cross Modal Ranschburg Effects.

Thank you for participating in this study. The present study involved participants recalling sequences in the order of original presentation. However, we were particularly interested in recall of sequences which contained a repeated item. Previous work has shown that, depending on the position of the item, recall of a repeated item in the list can be improved or impaired (this is called the Ranschburg effect). However, previous studies showing this effect have been undertaken with verbal stimuli. The data you have provided will be used to determine whether the Ranschburg Effect is present across other modalities (visual, verbal, audio spatial and tactile). The presence of the effect across other modalities could lend support to domain general or domain specific theories of working memory.

We also manipulated the effect of awareness. Some participants were told to expect repetitions and some were not told about the repetitions. Research has shown that participants who are aware of the repetitions have improved recall for the repeated items (Jahnke, 1969), therefore this experiment was also investigating this cross modally.

If you wish to find out more about the study, feel free to contact the researcher (contact details below). Also if you wish to find out the results from the study, the researcher can also be contacted for that purpose.

Rachel Skinner

i7232698@bournemouth.ac.uk

The following references may be of interest:

Jahnke, J. C. (1969). The Ranschburg Effect. *Psychological Review, 76*(6), 592-605.

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7.4 Appendix D: Information Sheet for Aware Participants (Experiment 3)

Cross Modal Ranschburg Effects: Experiment 4: Tactile.

Participants Information Sheet.

The Purpose of the Study.

You are being invited to participate in a study being conducted by Masters by Research Bournemouth University student Rachel Skinner, which aims to determine whether or not the Ranschburg Effect is prevalent in other modalities besides the verbal domain. This study is being supervised by Dr. Andrew Johnson, and has been ethically approved by Bournemouth University.

What is Involved in the Task?

For this study, you will be asked to recall of the order of a sequence of 6 tactile stimuli using Serial Order Reconstruction. You will be presented with 6 touches to your fingers. At test you will be asked to repeat the sequence by lifting your fingers in the order they were touched. Before each sequence you will be alerted by the researcher if the sequence contains a repeating item or not. If you recall a repetition of an item, raising the finger again will count as a response. **Do not worry if this sounds complicated! You will receive practice trials!** This study involves 40 memory trials. Throughout the study, your hands will be recorded. This ensures that the researcher collects all data. After your responses have been transcribed, the recording will be deleted.

How long will the study take?

Including briefing, gaining informed consent, the trials and debriefing, this study should take around 40 minutes.

Your Rights as a Participant.

If at any point during this study you feel that you do not wish to continue, you may withdraw at any point. If you wish to do this, please notify the researcher, Rachel Skinner, as soon as possible. Unfortunately, due to the fact that your data will be anonymised after the study is completed, it would be impossible to find your data, therefore you cannot withdraw your data post completion.

What Happens After the Study?

As stated before, your data will be kept anonymised and confidential after the study. Your data and consent form will be kept for 12 months after the study, and then destroyed.

After completion, you will be awarded 0.75 SONAR credit(s).

If you are willing to participate, please read and sign the consent form provided. If you are not willing to participate (which is within your participant rights), please notify the researcher.

Feel free to ask the researcher any additional questions if you have any.

Researcher Contact Details:

Name: Rachel Skinner

Email: i7232698@bournemouth.ac.uk

Supervisor Contact Details:

Name: Dr. Andrew Johnson

Email: andjohnson@bournemouth.ac.uk

If you wish to make a complaint about this study, feel free to email Dr. Katherine Appleton

k.appleton@bournemouth.ac.uk