Tactile Order Memory: Evidence for Sequence Learning Phenomena found with other Stimulus Types

Andrew J. Johnson*, Jordan Shaw, & Christopher Miles

Department of Psychology,
Faculty of Science & Technology,
Bournemouth University,
Poole, UK

*Corresponding author

Address for Correspondence:
Department of Psychology
Bournemouth University
Poole House
Talbot Campus
Fern Barrow
Poole, UK
Tel: +0044 (0)1202 965977
Email*: andjohnson@bournemouth.ac.uk

Word count: 3657 (excluding references)

Running head: Tactile order memory

Abstract

We examine serial order memory for sequences of tactile stimuli and investigate whether established characteristics of order memory, namely serial position effects, error distributions, and Hebb repetition learning, are observed with tactile memory. Visually obscured participants received six tactile stimulations: one to each of six fingers. At test, participants lifted the six fingers in the order of stimulation. For every third trial participants received the same order of stimulation (i.e. the Hebb sequence). Serial recall accuracy produced the canonical bowed serial position function found for immediate serial recall. In addition, recall for the Hebb sequence improved relative to the filler sequences, providing the first demonstration of the Hebb repetition effect with tactile stimuli. Analysis of errors revealed close similarities to that reported with verbal and visual stimuli. This experiment further generalises established features of order memory to tactile memory, supporting the utilisation of an analogous order memory mechanism across stimuli.

150 words

Keywords: Tactile memory; order memory; Hebb repetition effects; error distribution; serial position effects;

Introduction

The present experiment examines serial order memory for sequences of tactile items and we focus on the extent to which serial position curves, error distributions, and repetition learning, differ to those for more researched domains of memory.

A small number of studies have examined serial position curves for tactile stimuli. For instance, Watkins and Watkins (1974) examined immediate serial recall (ISR) for tactile stimulations. Participants received a series of eight-item tactile sequences presented to the labelled four fingers of each hand. Half of the sequences were followed by a tactile suffix (a post-sequence task-irrelevant brisk stroke across all eight fingers), and half were followed by a control suffix (post-sequence task-irrelevant auditory tap). Regardless of whether participants recalled the lists verbally (Experiment 1) or by pointing out the sequence on a diagram (Experiment 2), reliable primacy, recency, and suffix effects were evident. Watkins and Watkins (1974) suggested that their pattern of results was consistent with the existence of a tactile memory with characteristics similar to those of verbal short-term memory.

A later study (Mahrer & Miles, 1999) developed the Watkins and Watkins (1974) paradigm further, and sought to minimise verbal/visual recoding strategies. Participants completed the task with their eyes closed and recalled tactile sequences by raising each finger in the order of stimulation. This manipulation produced a sequence span of 5(+/- 1), but the bowed serial position functions were again evident. In addition, Mahrer and Miles (1999) demonstrated recency attenuation following a same modality (tactile) suffix, but not following a control (auditory) suffix. These findings are consistent with the proposal that recall is facilitated via tactile representations of the items, at least with respect to the recency component of the sequence.

The ISR functions observed for both of the above experiments are consistent with a number of studies showing strong primacy and recency for ISR of verbal stimuli (e.g. (Spurgeon, Ward, & Matthews, 2014). Moreover, similar functions are reported for serial order reconstruction (a variant of ISR without the requirement for item generation) with both visual (e.g. unfamiliar-faces, Smyth, Hay, Hitch, & Horton, 2005; Ward, Avons, & Melling, 2005) and visual-spatial stimuli (e.g. Guèrard & Tremblay, 2008). These findings indicate similarity in the order memory for tactile stimuli relative to other stimulus types, and supports the proposal that serial position curves are task, rather than stimulus, dependent (Ward et al., 2005).

More recently, the immediate free recall (IFR) paradigm has been applied to tactile stimuli (Cortis, Dent, Kennett, & Ward, 2015). Here, participants (with eyes closed) received sequences comprising discrete touches to the face and varying in length between 1 and 15 items. At test, participants were presented with a (mirror-image) schematic of their face and were required to click on any of the locations touched in the preceding sequence (i.e. item memory without the requirement to recall order). The serial position function mirrored those of IFR for both verbal (e.g. Spurgeon et al., 2014) and visuo-spatial stimuli (Cortis et al., in 2015, Experiment 1), exhibiting both primacy and recency advantages. Moreover, detailed analysis of the tactile IFR functions demonstrated subtle changes in the serial position curves as a function of sequence length. Consistent with both verbal (e.g. Spurgeon et al., 2014) and visuo-spatial stimuli (Cortis et al., 2015, Experiment 1), shorter sequences exhibited pronounced primacy resulting from a tendency to initiate recall with the early sequence items. In contrast, longer sequences exhibited pronounced recency, resulting from a tendency to initiate recall with the latter sequence items. Thus, the findings of Cortis et al. (2015) demonstrate that tactile memory operates in a fashion analogous to that for other stimulus types, both in terms of IFR serial position functions and the strategic shift in recall following increases to sequence length.

In addition to serial position effects, another classical feature of serial order memory, and one that has been thus far neglected in tactile memory research, is the distribution of errors. Analysis of errors can be important in understanding how items are represented in memory. Consequently, if similarities in order memory errors are established between tactile memory and other modalities, it may suggest commonality of function. One well-established finding follows when an item is recalled in the wrong serial position, i.e. transposition error. Across verbal (e.g. Farrell & Lewandowsky, (2004), visual (e.g. Smyth et al., 2005), and visuo-spatial domains (Guèrard & Tremblay, 2008), it has been shown that (i) transpositions are most prevalent for adjacent serial positions items (i.e. the locality constraint) and, (ii) the proportion of transpositions decreases as a function of migration distance from the correct serial position. Together, these produce a symmetrical distribution that peaks at a displacement distance of zero (e.g. Farrell & Lewandowsky, 2004).

A further type of error that can be examined with ISR concerns erroneous within-trial item repetitions. Many models of serial order memory (e.g. the Primacy Model, Page & Norris, 1998) incorporate a response suppression mechanism once an item has been outputted at test. Such a mechanism prevents perseveration and thereby results in a relatively small number of erroneous repetitions (estimated at between 2-5% of all responses, see Hurlstone et al., 2014, for review). These repetitions are separated by a mean distance of 3-4 serial positions (Henson, Norris, Page, & Baddeley 1996, report an average separation of 3.4 output positions). Finally, in verbal serial recall, omission errors are substantially less frequent than order errors (see Hurlstone, Hitch, & Baddeley, 2014, for review).

The final memory phenomenon examined in the current experiment is repetition learning (the Hebb repetition effect, Hebb, 1961). The Hebb repetition effect refers to the incidental acquisition of order memory following the surreptitious re-presentation of a sequence. Across a series of trials, repeated presentation of a specific sequence order (often every third trial and termed 'the Hebb sequence') results in a gradual increase in recall accuracy for that sequence relative to the non-repeated and unique ('filler') sequences. Initially, this effect was thought to be restricted to the verbal domain (indicative of rehearsal in the phonological loop) and linked to the acquisition of novel words (e.g. Page, Cumming, Norris, McNeil, & Hitch, 2013). However, the Hebb repetition effect has been shown across a range of stimulus types, including visual stimuli (e.g. Horton, Hay, & Smyth, 2008), the spatial position of dots (e.g. Tremblay & Saint-Aubin, 2009), the spatial position of auditory stimuli (Parmentier, Maybery, Huitson, & Jones, 2008), and odours (Johnson, Cauchi, & Miles, 2013). Taken together, these findings suggest that the repetition learning mechanism is a general characteristic of memory, akin to task-dependent serial position functions (Ward et al., 2005; for discussion see also Hurlstone et al., 2014). Whilst, serial position curves and error distributions provide insight into short-term order memory, the Hebb repetition effect is a measure of longer-term sequence memory; the present study therefore examines characteristics of both short- and long-term tactile order memory and compares with previous findings across other stimulus types.

The present experiment is designed to examine the three primary characteristics of serial order memory (as described above) with tactile stimuli, using a paradigm initially described by Watkins and Watkins (1974, and revised by Mahrer & Miles, 1999). The results of such will further our understanding of the extent to which order memory for tactile stimuli is governed by a mechanism analogous to that for other stimulus types. We presented blindfolded participants with a series of sequences each comprising the presentation of 6-

tactile stimuli presented to three different fingers on each hand. At test, participants reconstruct the sequence by moving their fingers in the order of original presentation. Across experimental trials, a repeated (Hebb) sequence is presented every third trial. This paradigm will, therefore, provide data on the serial position curves, analysis of within-trial errors (transpositions, repetitions, and omissions), and Hebb repetition learning (exhibited by a steeper learning gradient across the experiment for the Hebb sequence relative to the filler sequences). Such data will be informative in ascertaining whether tactile memory utilises similar processes to that of other stimulus types. Specifically, does tactile memory provide evidence for modularity or functional equivalence when compared to established findings with visual and verbal stimuli?

Method

Participants. Twenty-four Bournemouth University Psychology undergraduates (mean age = 22.33 years; 2 male and 22 female), participated in exchange for research participation credits. Ethical approval was obtained from the Bournemouth University Psychology Ethics Committee.

Materials. Participants were required to wear an eye-mask throughout the experiment. Tactile stimulation was administered via a plastic pen probe. A single tactile stimulation was administered to the intermediary phalange of the *digitus secondus, digitus thertius,* and *digitus quartus* on the dorsal aspect of both the right and left hands. A video camera (Panasonic V750, Japan) recorded the participants' motor responses and these were coded and scored off-line.

Design. The structure of our Hebb repetition learning paradigm is consistent with that reported for a range of previous studies (e.g. Horton et al., 2008; Johnson et al., 2013). A 2x10x6 within-participants design was adopted, where the first factor refers to sequence type (filler versus Hebb), the second refers to experimental epoch (1-10), and the third refers to serial position (1-6). All participants completed 30 experimental trials comprising 20 filler trials and 10 Hebb trials. An experimental epoch comprised three sequences: two filler sequences followed by one Hebb sequence. Each of the 20 filler sequences comprised a different random combination of the six fingers.

Sequence length was set at 6-items following a pilot study (*n* = 6). This established a mean correct serial recall of 53.33% for 6-item sequences compared to sequences of 4–items (88.75%) and 8-items (34.37%).

Four Hebb sequences were constructed, each comprising a different random combination of the six fingers. In addition, four different sets of the 20 filler sequences were constructed. These filler sequences were different to the four Hebb sequences. Each Hebb sequence was combined with one of the sets of 20 filler sequences. Four groups of six participants were each presented with one of the four Hebb sequences and the corresponding set of filler trials.

Both the filler and Hebb sequences were determined via the random generation of the numbers 1-6 (with these numbers corresponding to the left hand *digitus quartus*, the left hand *digitus thertius,* the left hand *digitus secondus,* the right hand *digitus secondus,* the right hand *digitus thertius,* and the right hand *digitus quartus,* respectively). Sequences comprising three or more adjacent fingers were excluded.

Procedure. Participants were tested individually in a quiet laboratory and sat facing the experimenter across a table with each hand placed palm down on the table. Participants had an eye-mask placed over both eyes. Participants received 10 practice trials followed by 30 experimental trials. The 10 practice trials were employed to mitigate the concern that poor tactile memory performance is a result of unfamiliarity with such tasks (Bliss & Hämäläinen, 2005). Each trial was initiated by a verbal signal from the experimenter and comprised the experimenter stimulating each intermediary phalange of the dorsal aspect of the hand. Tactile stimulations were presented at an approximate rate of 1 per second aided by a digit clock on the table. Following presentation of the sixth tactile stimulation, participants were required to immediately reconstruct the preceding sequence by lifting each finger in the order of original stimulation. Sequence reconstruction was self-paced. There was an approximate 5s inter-trial interval between recall of the last item in the current trial and commencement of the next trial.

Results

A strict scoring criterion was adopted such that a response was recorded as correct only if the correct finger was moved at the correct serial position within the reconstructed sequence.

Serial Position Analysis. Figure 1 shows the serial position functions for the filler and Hebb sequences. The serial position functions exhibit strong primacy and some recency.

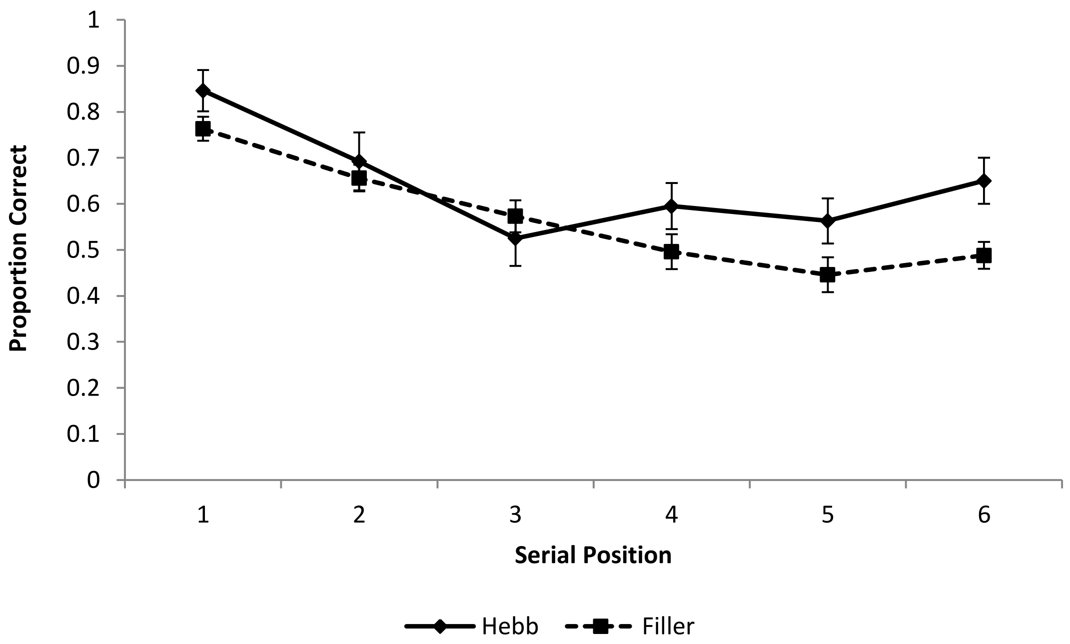

Figure 1. Mean proportion correct for the filler and Hebb sequences as a function of serial position. Error bars denote the mean standard error.

Serial position functions were analysed by a 2-factor (2x6) within-participants ANOVA with the factors sequence type (filler versus Hebb) and serial position (1-6). The ANOVA revealed main effects for both sequence type, $F(1,23)=13.28$, $MSE = .03$, $p=.001$, $\eta_p^2 = .37$ (mean proportion correct and 95% CI for the filler and Hebb sequences = .57 [.52, .63] and .64 [.57, .72], respectively), and serial position, $F(5,115)=20.13$, $MSE = .03$, $p<.001$, $\eta_p^2 = .47$. Further analysis (Bonferroni-corrected comparisons: $\alpha=.003$) revealed that correct recall was significantly higher for: serial position 1 compared to serial positions 2-6, and for serial position 2 compared to serial positions 3 and 5. The sequence type by serial position interaction was significant, $F(5,115)=2.32$, $MSE = .03$, $p=.048$, $\eta_p^2 = .09$.

Error Analysis: Errors were analysed for the filler sequences only. The most common errors were transpositions and comprised 87.35% of all errors (38.85% of all responses). Figure 1b illustrates the transposition gradients and shows a symmetrical spiked distribution such that the number of errors reduces as a function of transposition distance. Further analysis was conducted on transpositions when an item (i) was erroneously recalled in the position preceding the correct position (i.e. adjacent anticipations). Under such instances the next response is, by default, incorrect (unless a repetition). We recorded the number of instances in which that incorrect response was a fill-in error (i.e. the item that should have been recalled in the preceding position: i-1) or a follow-on error (i.e. the item that followed the preceding response at learning: i+1). The ratio of fill-in to follow-on errors was 2.88:1. Thus, when an item was recalled prematurely by one position, participants were more likely to follow that error with recall of the item that should have been recalled in the preceding position (fill-in). Consequently, participants were therefore less likely to recall the item that should follow the preceding erroneous response (follow-on).

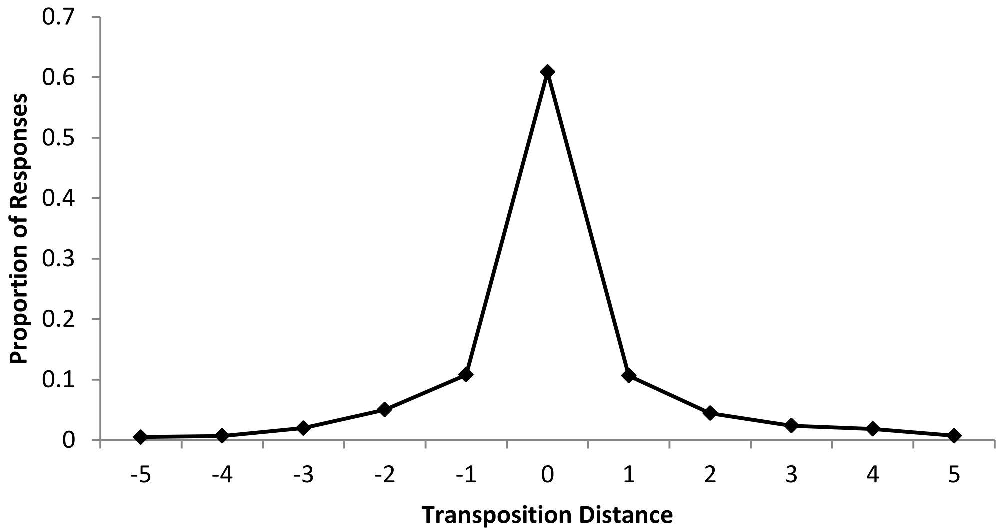

Figure 2. Mean proportion of responses as a function of transposition distance.

The second most frequent error type was repetitions and comprised 9.45% of all errors (4.20% of all responses). The average interval between repetitions was 3.34. The third most error type was omissions and comprised 3.20% of all errors (1.42% of all responses).

Hebb Effect Analysis: Figure 3 shows the mean correct recall scores for the filler and Hebb sequences as a function of experimental epoch (1-10).

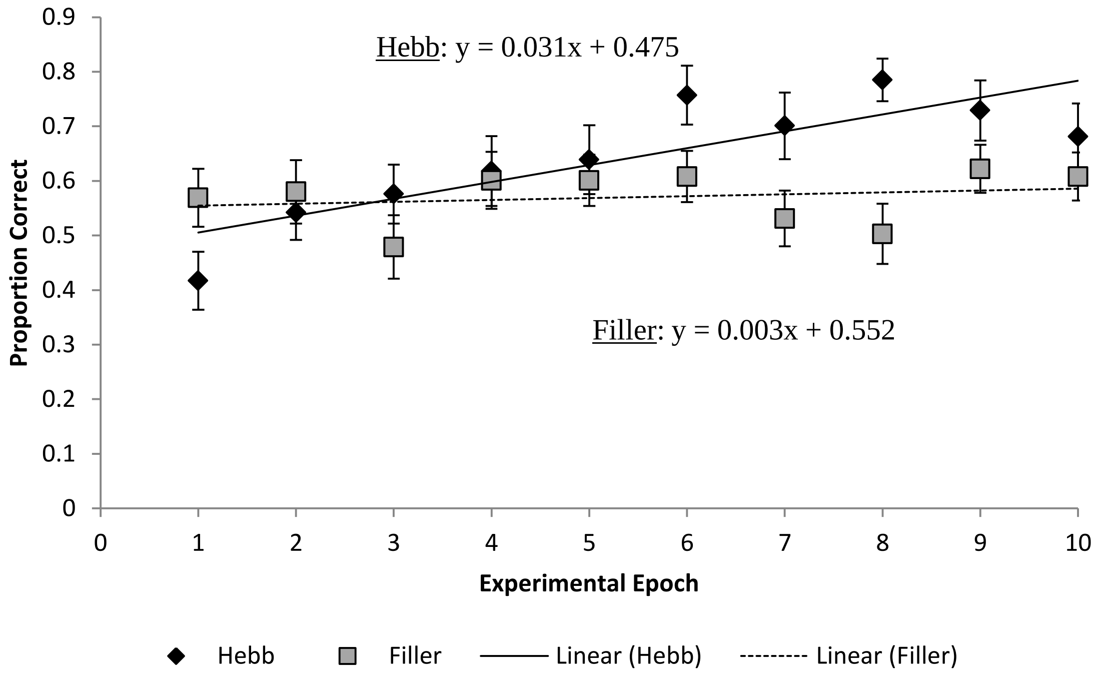

Figure 3. Mean proportion correct recall scores for the filler and Hebb sequences as a function of experimental epoch (1-10). Line of best fit depicts the learning gradient for both sequence types. Error bars denote the mean standard error.

The learning gradients produced by each participant for both the filler and Hebb sequences were compared via a related t-test and, consistent with the prediction for Hebb repetition learning, a significant difference was evident, $t(23)=4.15$, $p<.001$, $r=.65$, (mean gradient and 95% BCa CI for the filler and Hebb sequences = .003 [-.006, .013] and .031 [.022, .040], respectively), reflecting the steeper gradient for the Hebb sequence.

Discussion

The present experiment reports stark similarities in serial memory characteristics of tactile memory compared to that of both verbal and visuo-spatial memory reported in previous studies. The study is the first to both (i) investigate error distributions in tactile memory, and, (ii) demonstrate Hebb repetition learning for sequences of tactile stimuli. In addition, we replicate past serial position order memory effects.

The examination of ISR serial position accuracy functions replicate that of previous tactile studies (e.g. Mahrer & Miles, 1999; Watkins and Watkins, 1974) producing strong primacy and moderate recency. Indeed, such an ISR function is consistent with ISR of verbal stimuli (e.g. Spurgeon et al., 2014) and serial order reconstruction of visual (e.g. Horton et al., 2008; Smyth et al., 2005; Ward et al., 2005) and spatial (e.g. Guèrard & Tremblay, 2008) stimuli. This finding is consistent with Ward et al.'s (2005) proposal that the serial position function is defined by the task, not the stimuli employed. Additionally, the finding adds further weight to the conclusion of Hurlstone et al. (2014) that "given the existence of a common set of behavioural features, it is clearly more parsimonious to assume that at least some core sequencing principles exist that apply across domains" (p.340).

Moreover, both the pattern of error distributions and the existence of the Hebb repetition effect support analogous order memory processes for tactile memory, which could be interpreted as evidence for amodality in order memory. The distribution of errors for the tactile memory task closely matched that reported for other stimulus types (e.g. Farrell & Lewandowsky, 2004; Guèrard & Tremblay, 2008). As previously reported (see Hurlstone et al., 2014, for review), transposition errors were by far the most frequent type. The distribution of transposition errors adhered to the symmetrical peaked distribution function (e.g. Farrell & Lewandowsky, 2004), with transpositions more frequent for nearby positions (i.e. the locality constraint). Adjacent transpositions were more frequently followed by a fill-in than a follow-on error (ratio of 2.88:1). This ratio approximates closely to the range of ratios (1.9-3.6:1) reported previously by Guèrard & Tremblay (2008, see also Page & Norris, 1998). One might interpret that as a stronger tendency to recall the order of items based upon absolute position within the list rather than sequential chaining to adjacent list items. To be clear, if sequential recall was achieved by each item cueing recall of the following item via an associative chain, one might predict more follow-on errors, since the erroneous response would cue the item that it was originally followed by in the presentation phase. This was not found. Instead, since the initial position of the fill-in error item is closer to the correct response than the initial position of the follow-on error, it suggests that items are being recalled based upon their association to a position within the sequence.

Repetitions errors in the present study were infrequent representing 4.20% of all responses, and again, this is consistent with the previously reported repetition rate of 2-5% with verbal stimuli (see Hurlstone et al., 2014, for review). Moreover, the average number of items between repetitions (3.34 items) was close to that reported previously (3.4, Henson et al., 1996). The low frequency of repetition errors is consistent with the response suppression mechanism proposed previously (e.g. Page & Norris, 1998). That is, once an item is retrieved it is suppressed to prevent perseveration. Furthermore, that repetition errors occurred after approximately 3 intervening items suggests that if release from response suppression does occur, it follows the outputting of a large proportion of the sequence (for further exploration of the release from response suppression see Duncan & Lewandowsky, 2005). Indeed, response suppression in tactile memory could be examined further through examination of the Ranschburg Effect. This effect refers to the impaired memory for a repeated item within the sequence. This impairment is proposed to arise from the item being suppressed following its initial recall, resulting in low activation levels for the attempted retrieval of the repetition (e.g. Duncan & Lewandowsky, 2004). This effect is yet to be explored in non-verbal stimuli (Hurlstone et al., 2014) and would test cross-modal similarities in response suppression. Omission errors were less frequent than repetition errors (1.42 of all responses). This is consistent with previous work showing that item errors are less frequent in verbal memory than transposition errors (see Hurlstone et al., 2014 for review).

This study is the first demonstration of Hebb repetition learning with tactile stimuli and contributes to a growing number of studies showing the effect with non-verbal stimuli (e.g. Horton et al., 2008; Johnson et al., 2013). Indeed, the learning gradient for our tactile stimuli (.031) is broadly similar to that reported, for example, with verbal stimuli (=.028, under conditions of full stimulus overlap, Page et al., 2013), unfamiliar-faces (=.034, Horton et al., 2008) and odours (=.024, Johnson et al., 2013).

The one caveat for these data concerns the possibility of verbal and/or visuo-spatial recoding of the tactile sequences. Under such circumstances, one might suppose that the memory phenomena reported here are not indicative of tactile memory per se, but rather, replicate the features of verbal and/or visual-spatial memory previously reported (e.g. Guèrard & Tremblay, 2008; Page et al., 2013; Spurgeon et al., 2014; Tremblay & Saint-Aubin, 2009). However, whilst, Mahrer and Miles (2002) argue that tactile memory is supported by verbal recoding, it should be noted that tactile ISR persists under conditions of backward counting (Mahrer & Miles, 1999). Indeed, despite a main effect of the secondary verbal task, Mahrer and Miles (1999) reported that the canonical ISR function remained for tactile memory. These findings undermine the proposal that tactile ISR reflects a dependence upon verbal recoding of the tactile sequences.

In summary, the present study has shown that tactile order memory exhibits similar memory characteristics to that of other previously researched domains of memory. The study adds support to other non-verbal memory research showing that the canonical ISR serial position curve and Hebb repetition effect is not resultant from a language specific memory mechanism. Moreover, tactile error distributions that are analogous to verbal memory suggest that order memory is represented in a similar way for tactile stimuli. Whilst the data by no means falsifies modularity in order memory (Hurlstone et al., 2014, argue for modularity based upon selective interference, neuropsychological double dissociations, and imaging data), it does add further support for a common (or at the very least analogous) mechanism underpinning order memory across stimulus types.

References

Bliss, I., & Hämäläinen, H. (2005). Different working memory capacity in normal young adults for visual and tactile letter recognition task. *Scandinavian Journal of Psychology, 46*(3), 247-251. doi:10.1111/j.1467-9450.2005.00454.x

Cortis, C., Dent, K., Kennett, S., & Ward, G. (2015). First things first: Similar list length and output order effects for verbal and nonverbal stimuli. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(4), 1179-1214. doi:10.1037/xlm0000086

Duncan, M., & Lewandowsky, S. (2005). The time course of response suppression: no evidence for a gradual release from inhibition. *Memory, 13*(3-4), 236-246.

Farrell, S., & Lewandowsky, S. (2004). Modelling transposition latencies: Constraints for theories of serial order memory. *Journal of Memory and Language, 51*, 115-135. doi:10.1016/j.jml.2004.03.007

Guérard, K., & Tremblay, S. (2008). Revisiting evidence for modularity and functional equivalence across verbal and spatial domains in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(3), 556-569. doi:10.1037/0278-7393.34.3.556

Hebb, D. O. (1961). Distinctive features of learning in the higher animal. In J. F. Delafresnaye (Ed.), *Brain mechanisms and learning* (pp. 37-46). Oxford: Blackwell.

Henson, R. N. A., Norris, D. G., Page, M. P. A., & Baddeley, A. D. (1996). Unchained Memory: Error Patterns Rule out Chaining Models of Immediate Serial Recall. *Quarterly Journal of Experimental Psychology: Section A, 49*(1), 80-115. doi:10.1080/027249896392810

Horton, N., Hay, D. C., & Smyth, M. M. (2008). Hebb repetition effects in visual memory: The roles of verbal rehearsal and distinctiveness. *Quarterly Journal of Experimental Psychology, 61*(12), 1769-1777. doi:10.1080/17470210802168674

Hurlstone, M. J., Hitch, G. J., & Baddeley, A. D. (2014). Memory for serial order across domains: An overview of the literature and directions for future research. *Psychological Bulletin, 140*(2), 339-373. doi:10.1037/a0034221

Johnson, A. J., Cauchi, L., & Miles, C. (2013). Hebbian learning for olfactory sequences. *Quarterly Journal of Experimental Psychology, 66*(6), 1082-1089. doi:10.1080/17470218.2012.729068

Mahrer, P., & Miles, C. (1999). Memorial and strategic determinants of tactile recency. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(3), 630-643. doi:10.1037/0278-7393.25.3.630

Mahrer, P., & Miles, C. (2002). Recognition memory for tactile sequences. *Memory, 10*(1), 7-20. doi:10.1080/09658210143000128

Page, M. P. A., Cumming, N., Norris, D., McNeil, A. M., & Hitch, G. J. (2013). Repetition-spacing and item-overlap effects in the Hebb repetition task. *Journal of Memory and Language, 69*(4), 506-526.

Page, M. P. A., & Norris, D. (1998). The primacy model: A new model of immediate serial recall. *Psychological Review, 105*(4), 761-781. doi:10.1037/0033-295X.105.4.761-781

Parmentier, F. B. R., Maybery, M. T., Huitson, M., & Jones, D. M. (2008). The Perceptual Determinants of Repetition Learning in Auditory Space. *Journal of Memory and Language, 58*(4), 978-997.

Smyth, M. M., Hay, D. C., Hitch, G. J., & Horton, N. J. (2005). Serial position memory in the visual—spatial domain: Reconstructing sequences of unfamiliar faces. *Quarterly*

Journal of Experimental Psychology: Section A, 58(5), 909-930. doi:10.1080/02724980443000412

Spurgeon, J., Ward, G., & Matthews, W. J. (2014). Examining the relationship between immediate serial recall and immediate free recall: Common effects of phonological loop variables but only limited evidence for the phonological loop. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(4), 1110-1141. doi:10.1037/a0035784

Tremblay, S., & Saint-Aubin, J. (2009). Evidence of anticipatory eye movements in the spatial Hebb repetition effect: Insights for modeling sequence learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(5), 1256-1265. doi:10.1037/a0016566

Ward, G., Avons, S. E., & Melling, L. (2005). Serial position curves in short-term memory: functional equivalence across modalities. *Memory, 13*(3-4), 308-317.

Watkins, M., & Watkins, O. (1974). A tactile suffix effect. *Memory & Cognition, 2*(1), 176.