The effect of selective attention and a stimulus prefix on the output order of immediate free recall of short and long lists

Rachel Grenfell-Essam[1] and Geoff Ward[2]

[1]Loughborough University

[2]University of Essex

Correspondence to:

Rachel Grenfell-Essam or
School of Sport, Exercise and Health Sciences
Loughborough University,
Loughborough,
Leicestershire,
LE11 3TU,
UK
Telephone: +44 1509 223497
E-mail: R.E.Grenfell-Essam@lboro.ac.uk

Geoff Ward
Department of Psychology,
University of Essex,
Wivenhoe Park,
Colchester, Essex,
CO4 3SQ,
UK
Telephone: +44 1206 873799
E-mail: gdward@essex.ac.uk

Running header: Attention, temporal distinctiveness, and Immediate Free Recall

Abstract

Participants tend to initiate immediate free recall (IFR) of short lists of words with the first word in the list (serial position 1, SP1), and then proceed in forward serial order. Two potential explanations for this finding were examined: that the first items have increased selective attention (Experiment 1A and 1B) and enhanced temporal distinctiveness (Experiment 2), relative to subsequent list items. In Experiments 1A and 1B, participants were presented with lists of coloured words for IFR. The experimental group was told that some trials would contain a red word, and when this occurred they should output this word first in recall, before recalling as many other words as they could. This instruction was designed to shift attention away from SP1 and towards the red item. The control group received identical stimuli, but were unaware of the importance of the coloured fonts and had no output order constraints. The overall recall of SP1 was not greatly affected in either experiment. In Experiment 2, participants were presented with lists containing between 2 and 12 words. Half of the trials contained a triple word stimulus prefix. For short lists in IFR, the overall recall of SP1 and the tendency to initiate recall with SP1 were reduced but far from eliminated by the stimulus prefix. We argue that our findings may be explained within a grouping interpretation, where the tendency to initiate recall with the first to-be-remembered item may reflect participants' tendency to output the first word in a highly salient participant-determined group.

250 words

Keywords: free recall, attention, temporal distinctiveness, output order, list length.

Immediate free recall (IFR) and immediate serial recall (ISR) are two widely-used and highly-influential tasks for studying immediate memory. In both tasks, participants are presented with a sequence of items, one at a time, and immediately after the presentation of the last item, they must try to recall as many items as possible, either in the same order as they were presented (ISR), or in any order that they wish (IFR). Both tasks provided classic empirical findings that were taken as evidence in support of a separate, limited-capacity short-term store (STS).

In ISR, participants can often accurately recall a complete sequence of up to 4-5 items without error, but as the list length is increased, so a list length is reached at which accurate performance breaks down. The memory span is defined as the list length at which an individual participant can accurately recall the entire sequence on half the trials, and this limitation is often considered to be a measure of the capacity of that individual's STS.

In IFR, participants are typically presented with longer sequences of around 10-40 words. At these longer list lengths, participants exhibit a recall advantage for the first few items in the list (known as the *primacy* effect), and an even larger recall advantage for the last few items in the list (known as the *recency* effect), relative to the middle items (e.g. Murdock, 1962; Roberts, 1972). It is often assumed that recency effects in IFR reflect the direct output from a limited-capacity STS, or buffer (e.g., Atkinson & Shiffrin, 1971; Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann, & Usher, 2005; Farrell, 2010; Glanzer, 1972; Raaijmakers, 1993; Raaijmakers & Shiffrin, 1981; Unsworth & Engle, 2007). As the list is presented, so the buffer fills up and as new items arrive, so they displace the earlier contents. At test, items from the end of the list are most likely to be in the STS as they are least likely to have been overwritten. At the start of recall, the items in the buffer are the first to be output, followed by items in the long-term store.

Perhaps somewhat surprisingly, different theories of immediate memory have been used to explain ISR and IFR. As discussed by Ward, Tan, and Grenfell-Essam (2010), theories of ISR must primarily explain primacy effects observed in the immediate recall of short lists, whereas theories of IFR must primarily explain recency effects in the immediate recall of long lists. The two tasks were often assumed to be influenced by different variables. However, Ward *et al.* reviewed evidence that both tasks were similarly affected by a wide range of different variables, and showed that there were strong similarities in the serial positions and output orders of words recalled on the two tasks when they were tested using the same methodology, scoring systems, and list lengths.

Critically, Ward *et al*. showed that when participants are presented with a short list of words for IFR, such as “apple, table, hat, dog”, participants often recall in forward serial order (that is, they say: “apple, table, hat, dog”) despite there being no forward order requirement within the task to do this (see also: Corballis, 1967; Grenfell-Essam & Ward, 2012; Neath & Crowder, 1996). Ward *et al.* argued that this finding may encourage greater theoretical integration between IFR and ISR (as championed by only a small subset of accounts, e.g., Anderson, Bothell, Lebiere, & Matessa, 1998; Brown, Neath & Chater, 2007; Brown, Chater &Neath, 2008; Farrell, 2012; Grossberg & Pearson, 2008). They also argued that the finding is potentially problematic (without additional assumptions) for those recency-based accounts of IFR that are largely based on data from longer lists, and which tend to assume (correctly for longer lists) that the most recent items will be the most highly accessible and most likely to be recalled first (e.g., Brown *et al.*, 2007; Howard & Kahana, 2002; Tan & Ward, 2000; Ward, 2002).

This strong tendency for participants to initiate IFR of short sequences of words with the first item has been replicated many times (e.g., Grenfell-Essam & Ward, 2012; Grenfell-Essam, Ward & Tan, 2013; Spurgeon, Ward & Matthews, 2014a, b). Recent research has investigated the reason why participants perform IFR of short lists in an “ISR-like” manner.

One discounted possibility was that the “ISR-like” IFR of short lists relied upon selectively rehearsing the first few list items. Selective rehearsal of the early list items has often been used to explain primacy effects in IFR (e.g., Laming, 2006, 2008, 2009, 2010; Tan & Ward, 2000; Ward, 2002; Ward & Tan, 2004; Ward, Woodward, Stevens & Stinson, 2003). In support of a selective rehearsal explanation, participants tend to rehearse early list items more often than later list items (e.g. Rundus, 1971; Tan & Ward, 2000, Ward, 2002). At slower presentation rates participants tend to distribute their rehearsals more widely throughout the list (e.g. Modigliani & Hedges, 1987; Tan & Ward, 2000), and rehearse closer to recall (e.g., Brodie & Murdock, 1977; Tan & Ward, 2000). However, Grenfell-Essam *et al.* (2013) found that the tendency to initiate IFR of short lists of words with the first list item did not change greatly when the presentation rate was increased from 1 word per second to 2 words per second, nor was it eliminated by concurrent articulation. They argued that rehearsal was not necessary for the effect under normal conditions.

A second discounted possibility was that the “ISR-like” IFR of short lists relied upon a phonological ISR-like recall mechanism (such as the phonological loop, Baddeley, 1986). Contrary to this hypothesis, Spurgeon *et al.* (2014a) found that “ISR-like” recall of short lists occurred (albeit to a reduced extent) in both IFR and ISR using silent visual presentation and concurrent articulation, conditions in which the stimuli should not enter the phonological loop.

A third explanation, that the items in a short list were stored in a STS buffer store, (such as is sometimes used to explain recency effects in IFR), was also discounted as an explanation for the effect. Spurgeon *et al.* (2014b) showed that the tendency to initiate IFR of short lists with the first list item was still present (albeit attenuated) in delayed free recall and in the continuous distractor free recall task, in which 16 seconds of maths activity was performed at the end of the list, or after each list item, respectively. They concluded that a short-term buffer could not be solely responsible for the tendency to initiate recall with first list item for short lists in IFR.

In the current series of experiments, we focus on attentional and/or distinctiveness factors that have been argued to contribute to enhanced recall of list items in IFR. Many accounts of IFR and ISR argue that the first item in the list benefits from being highly distinctive or that participants pay particular attention to that item. In Experiment 1, we sought to shift attention away from the first list item, by requesting participants initiate their recall with a word presented in red font. In Experiment 2, we examined whether the tendency to initiate IFR with the first list item would be reduced by a stimulus prefix, a manipulation that reduced the temporal distinctiveness of the first list item.

Experiment 1

The aim of Experiment 1 was to manipulate participants' allocation of attention during list presentation in order to assess the role of selective attention on the tendency to initiate recall with the first list item.

Many leading accounts of immediate memory argue that through selective attention, a relatively small subset of information can be kept in a highly accessible state. For example, in Cowan's embedded processes theory (1988, 1999, 2005), which is a general theory of memory and attention, it is assumed that a small subset of perhaps 3-4 chunks of information are readily accessible as they are in the 'focus of attention'. Similarly, a leading account of the working-memory span task, the time-based resource-sharing model of Barrouillet, Bernardin and Camos (2004), proposes that participants are able to refocus their attention on earlier list items during list presentation.

Attention and attentional control are also assumed to play a role in maintaining specific items in IFR and ISR. For example, in Davelaar *et al.'s* (2005) account of IFR, a dynamic activation-based short-term memory buffer is proposed that through attentional control mechanisms, such as selective updating, can maintain earlier items that are deemed particularly significant. In addition, in some influential models of ISR (e.g., OSCAR, Brown, Preece, & Hulme, 2000), a "reducing attention" parameter contributes to the primacy effect, by reducing the strength of encoding for each successive list item at presentation. One justification for this decline, is that as the list progresses, so each new item becomes less novel and so is less attention-demanding leading to weaker encoding (for related accounts, see also the influential accounts of SOB and cSOB that also propose that primacy is due to the decline in the novelty of successively presented list items, Farrell & Lewandowsky, 2002; Lewandowsky & Farrell, 2008).

We aimed to manipulate participants' attention by presenting lists of words for IFR with each word presented in a different colour. On two thirds of trials, the list contained a word that would be presented in red font. Half of the participants were *Control* participants: they were told nothing about the meaning of the red word – indeed they were told to ignore the colours. The other half of the participants were the *Experimental* participants: they were told to pay particular attention to a word if it appeared in red font, and if a trial did contain a red word, they were told to write that red word down first when recall began and then continue to recall as many of the other words as they could in any order that they wished. Participants in the Experimental group were not told in advance whether or not a trial would contain a red word, nor were they informed in advance of the serial position of a red word in the list. Rather, the red words were allocated evenly throughout the serial positions.

We predicted that participants would be able to allocate extra attention to the red item in the Experimental group, as evidenced by increased probability of first recall (and indeed, enhanced overall recall) of the red item. We would then be interested in comparing how well the first word in the list would be remembered, and where in recall it was output on experimental trials which did and did not contain a red item, relative to control trials. If some of the attention normally allocated to the first list item was later reallocated to a later red item then one might expect a reduction in primacy on those trials, particularly for trials in which participants were successful in starting recall with the red item. In addition, we were interested in whether some of the attention normally allocated to the first list item would be withheld in the experimental condition, as might be the case if some participants anticipate a later red item to which they should pay attention. This would be evidenced by a reduction in the tendency to initiate recall of the first list item on those trials with no red word in the experimental relative to the control group. Finally, we were interested in the recall dynamics following the first recall. Following the successful recall of a red word on a trial in the Experimental group, would recall tend to proceed with the word following the red word (a temporal contiguity effect) and would there be a reduction in accessing the first list item, if that item was not accessed first?

It is worth noting that the way in which we chose to manipulate attention resembles a von Restorff manipulation (von Restorff, 1933). The von Restorff effect refers to the enhanced recall for items that are specifically isolated and made salient during encoding. von Restorff effects can occur early in the list at serial positions 1 and 2 (e.g., Bone & Goulet, 1968; Kelley & Nairne, 2001; von Restorff, 1933). When the von Restorff effect occurs in these early list positions it cannot be due to differential attention paid to the first few items as depending on how the isolation is implemented, the participant may not be aware until the third item is presented which one of the first three is the isolated item. Additionally, the von Restorff effect is not due to the isolated item being output earlier in recall (Bireta, Surprenant & Neath, 2008).

There are two key differences in our experiment. First, the isolated item is always presented in red font colour and so participants know that a red word is the isolated item as soon as it appears. Second, in our experiment however, we require that participants try to initiate their recall with the ‘isolated’ red item.

Experiment 1A: The role of attention in 8-item lists

In this experiment we examined the effect of selective attention on the recall of the first list item in IFR for lists containing eight items. This legnth was chosen because the level of recall of SP1 tends to be moderate, at about 50%, (Grenfell-Essam *et al*., 2013; Grenfell-Essam & Ward, 2012; Ward *et al*., 2010) so performance at this list length was predicted to be sensitive to any improvement or otherwise in recall.

Method

Participants. Forty participants from the University of Essex took part in this experiment.

Materials and Apparatus. The materials consisted of a subset of 576 words that were randomly selected for each participant from the 1,000 words of the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982). The words were presented visually in 62-point Times New Roman font in the centre of an Apple eMac computer monitor using the Supercard 4.5 application. Each of the eight words on a trial was presented in one of 12 different coloured fonts (red, dark green, light green, pink, orange, turquoise, blue, dark brown, light brown, grey, gold, and purple) such that the frequency of all 12 colours occurred equally overall across the experiment.

Design. The experiment used a mixed design. The between-subjects independent variable was Group with two levels (Control group and Experimental Group). Location of red word was a within-subjects variable for the participants in the Experimental Group only, and reflected the absence of a red item (SP0) or the serial position of the presented red word. The variable consisted of nine levels (SP0, SP1, SP2, SP3, SP4, SP5, SP6, SP7, and SP8). The Control group trials acted as a baseline for the un-cued (SP=0) trials for the Experimental group. The main dependent variables were the proportion of words recalled (in any order) and the probability of initiating recall with a particular list item.

Procedure. Participants were allocated into one of the two groups. The Control group were told nothing about the meaning of the red word, whereas the Experimental group were told of the importance of the colours and asked to pay particular attention if a word appeared in red font; they would be required to try to initiate their recall with this word. All participants were encouraged to try to recall as many of the words as they could. Both groups performed the same experiment; the only difference was whether they were informed of the importance of the red coloured items.

Participants were tested individually and they were informed that they would be shown two practice lists, followed by 72 experimental lists of words of eight words. For both groups, one practice trial contained no red word, and the other practice trial contained a red word that could appear in any of the eight possible serial positions. After the practice trials were completed, the experimenter ensured that all participants in the Experimental group were familiar with the importance of the red font colour and that they were able to pick examples of such words out from a list. The experimental trials were arranged into two blocks of 36 trials; each block contained the eight cue locations (trials where a red word appears) repeated three times at each serial position and the uncued trials (trials where no red word appears, SP=0) repeated 12 times. The order of the type of trials was randomised within a block.

Each trial started with a fixation cross displayed for 2 s, followed after 1 s of a blank screen, by a sequence of eight words presented one at a time in the centre of the screen. Words were each displayed for 750 ms with an additional 250 ms inter-stimulus interval in which the stimulus field was blank. Participants were instructed to read each word aloud as it was presented. Participants in the Control group were instructed to recall as many words they could remember from the list in any order they wished. Participants in the Experimental group were instructed to initiate their recall with the red word if one had appeared, and write it in the first box on the response sheet, and then continue recalling any other words they could remember in any order from the list. When there was no red word on a trial, the Experimental group simply performed standard IFR and recalled as many words as they could remember in any order from the list. Participants in the Experimental group were not informed before the trial started whether the trial would contain a red word or not; only during list presentation would participants discover whether a red word was going to appear. Trials had no maximum recall period; rather, participants ended recall when they felt they had remembered all the words that they could.

Results

An item was scored correct if it was recalled at any time in the recall period immediately following its presentation (*FR scoring*). The data were considered in six different analyses: the proportion of words recalled, the serial position curves, the probability of first recall (PFR), the resultant serial position curves, the output order sequences and the degree of forwards order. Some analyses have been moved to Supplementary Materials; where applicable this has been referred to in the text. Two comparisons were made in most analyses. First, performance of participants in the Experimental group when there was no red word (SP=0) was compared with the performance of the Control group, in order to determine whether the mere anticipation of the possibility of a red word might make participants withhold some attention that would otherwise have been bestowed on the first list item.

Second, performance of participants within the different conditions in the Experimental group was examined to ascertain the effect of the red word appearing in different serial positions.

Proportion of words recalled. The mean proportion of words recalled for the Experimental group and Control Groups was .50 and .53, respectively. A one-way between-subjects ANOVA compared the mean proportion of words recalled by the Control group across all trials with the mean proportion of words recalled by the Experimental Group when there was no red word (SP=0). There was a non-significant effect of group, F (1, 38) = 0.816, MSE = .008, p = .372, confirming that performance by the Control group was similar to the SP=0 trials for the Experimental group.

For the Experimental group, there was relatively little difference in the mean proportion of words recalled (means varied between .48 to .52) when the red word was either absent (SP=0) or was in SP1-8.A one-way within-subjects ANOVA showed that there was a non-significant effect of location of red word, F (8, 152) = 1.15, MSE = .002, p = .337, confirming that the overall proportion of words recalled in the Experimental group was unaffected by the serial position (and indeed the presence or absence) of the red word. The overall recall scores are plotted in Figure S1 (see Supplementary Materials).

Analyses of the serial position curves of all the data. Figure 1 shows the serial position curves for the Control and Experimental groups. The two panels separate the data into the two comparisons of interest, and this format will be used throughout the paper.

--Figure 1 about here--

Figure 1A shows trials where there was no red word (the SP=0 trials) for the Experimental group and all the data averaged for the Control group. Performance was very similar across all serial positions, although there was a slight recall advantage at SP5 in the

Control group. A 2 (Group: Experimental and Control) x 8 (serial position: SP1-SP8) mixed ANOVA revealed that there was a non-significant effect of Group, F (1, 38) = 0.85, MSE = .061, p = .372, a significant effect of serial position, F (7, 266) = 68.4, MSE = .022, p < .001, and a non-significant interaction, F (7, 266) = 0.43, MSE = .022, p = .886. The significant effect of serial position reflected a small 1-item primacy, and an extended recency effect.

Despite the non-significant main effect of location of the red word, we were specifically interested in whether recall of the very first word in the SP=0 condition differed compared to any of the conditions where a red word actually appeared. Planned comparisons were performed and found that SP=0 differed significantly only from SP=4 [t(19) = 2.16, p = .044, all other p values exceeded p > 0.05]. Thus, there was little or no difference in recall of SP1, as even the more sensitive planned comparisons only found one borderline significant difference.

Figure 1B shows the serial position curves for the nine different conditions of the Experimental group: trials in which there was a red word at each of the eight different serial positions and when there was no red word. Participants were reasonably successful at recalling the red word during recall: minimum mean recall was 73%. A 9 (location of red word: SP=0, SP=1-SP=8) x 8 (Serial position: 1-8) within-subjects ANOVA revealed a non-significant main effect of location of red word, F (8, 152) = 1.15, MSE = .020, p = .337, a significant main effect of serial position, F (7, 133) = 36.1, MSE = .146, p < .001, showing a small 1-item primacy, and extended recency effect. There was also a significant interaction, F (56, 1064) = 14.2, MSE = .034, p < .001. Recall was always higher in the serial position of the red word relative to the other serial positions in that trial, showing that participants were able to follow instructions.

Interestingly, the recall of the red word across conditions itself follows an ‘IFR-like’ serial position curve, with increased recall when the red word is in SP1, and an extended recency effect when the red word is towards the end of the list. There was also an asymmetry in the data: recall of the item immediately following the red word showed an elevated level of recall and the item immediately preceding the red word showed reduced recall.

The Probability of First Recall (PFR) data. Figure 2 shows the proportion of trials in which a particular list position was recalled first for both the Control and Experimental groups. Figure 2A shows all trials for the Control group and the SP=0 trials for the Experimental group; Figure 2B shows performance for all nine conditions of the Experimental group.

--Figure 2 about here--

Considering first the PFR data of Figure 2A, a 2 (Group: Experimental and Control) x 8 (serial position: SP1-SP8) mixed ANOVA revealed that there was a non-significant effect of Group, F (1, 38) = 0.09, MSE < .001, p = .771, a significant effect of serial position, F (7, 266) = 10.8, MSE = .018, p < .001, and a non-significant interaction, F (7, 266) = 1.05, MSE = .018, p = .394. The significant main effect of serial position was driven by the enhanced likelihood of starting recall with SP1 compared to SPs 2-4, and the enhanced likelihood of starting recall with SPs 5-8 compared to SPs 2-4. The probability of initiating recall with SP1 was not significantly different from initiating recall with serial positions 5-8.

Considering next the PFR data of Figure 2B, a 9 (location of red word: SP=0, SP=1-SP=8) x 8 (Serial position: 1-8) within-subjects ANOVA revealed a non-significant main effect of location of red word, F (8, 152) = 1.52, MSE < .001, p = .154, a significant main effect of serial position, F (7, 133) = 8.68, MSE = .014, p < .001. There was also a significant interaction, F (56, 1064) = 114.9, MSE = .012, p < .001. In the conditions with a red word, the likelihood of starting recall with the red word was higher relative to the other serial positions in that trial, showing that participants were able to identify the red word and successfully initiate recall with it. The serial position curve of the red word, like in the overall proportion data, itself shows an 'IFR-like' recall trend, with increased recall of the red word when it was in SP1 or a recency serial position, relative to the middle serial positions.

The effect of the first word recalled on the resultant serial position curves. We examined the effects of different starting serial position on the resultant serial position curves. In summary, participants showed enhanced recall for the word immediately subsequent to the red word and slightly reduced recall for the word immediately preceding the red word. Similar trends were observed in experimental group trials starting with red words and in control and experimental group trials with no red words. The data are fully displayed in Supplementary Figure S2. Thus, whether the initial starting point was experimenter chosen or participant chosen, once recall is initiated from that serial position the resulting recall pattern is similar.

Of specific interest was whether recall of SP1 had been affected for the Experimental group when they initiated their recall with the red word, removing the trials in which the red word was in SP1. A one-way within-subjects ANOVA compared the seven conditions (SP=2-8) of the Experimental group, to examine the effect of location of red word on resultant recall of SP1. There was a non-significant effect of location of red word, F (6, 114) = 0.869, MSE = .041, p = .520, confirming that the resultant probability of recalling SP1 did not differ as a function of starting with the red word in the list.

Output order sequences. We examined the most common output order sequences made by the Control group and Experimental group as a function of location of the red word. We were specifically interested in where in recall the red word was output as well as where in recall participants would output the very first list item. The Control group choose to recall sequences which nearly always contain some combination of the final four serial positions.

The two most common sequences of the Experimental group SP=0 trials exactly mirrored those of the Control group. For the Experimental group for trials in which there was a red word, the most common sequences show that the words that were the second words that were output were most likely to be either the serial position immediately following the red word, or an end item (SPs 5-8). A full list of the most common sequences for each group and condition can be Supplementary Tables S1 and S2.

The degree of forward-ordered recall. The final analysis examined the degree of forward serial order recall in the output sequences. The mean proportion of CRP of lag +1 transitions was .53 and .57 for the Experimental and Control Groups, respectively. For the Experimental group, the data were subdivided by when the red word was in different serial positions. The data show fairly wide variability in the degree of lag +1 transitions; performance across all conditions varied from .35 to .66.

A one-way between-subjects ANOVA compared the Control group to the (SP=0) trials of Experimental group on the proportion of lag +1 transitions. There was a non-significant effect of group, F (1, 38) = 1.98, MSE = .019, p = .168, confirming that the degree of forwards serial order in the Control group did not differ significantly from the trials without a red word in the Experimental group. Full plots of the lag +1 transitions can be found in Supplementary Figure S3.

A one-way within-subjects ANOVA compared the nine conditions of the Experimental group, to examine the effect of the location of the red word. There was a significant effect of location of red word, F (8, 152) = 8.78, MSE = .027, p < .001, which was driven by the degree of forwards serial order being significantly lower when the red word was in SP=1-4 and SP=8 conditions compared to SP=0 and SP=5-7. Full lag-CRP curves can be found in Supplementary Figure S4. These showed typical asymmetric lag recency effects, coupled with somewhat enhanced probability of transitioning from SP8 to SP1 (lag -7).

Discussion

This experiment examined the role of attention in underpinning the finding that participants tend to initiate IFR of short lists with the first list item and show elevated levels of primacy. We attempted to manipulate participants' attention away from SP1 in the Experimental Group by requesting that they reallocated attention toward a later red item that was present on the majority of trials. Our findings showed that participants showed a reasonably good ability to obey task instructions and they were able to recall the red item at least 73% of the time and were able to start recall with the red item at least 66% of the time.

However, there was little or no evidence that participants had withheld attention or had withdrawn attention away from the first list item in the Experimental Group, as might have been the case, if participants anticipated that attention should be reserved for later list items. Similar serial position curves, PFR data, output order sequences, and lag transition data were found in those trials in the Experimental group with no red word, and the trials for the Control group. Moreover, there was very little reduction in the recall of the first word in the list when participants had to initiate recall with a later red item.

Overall, the findings showed that disrupting participants' normal encoding by cueing participants to initiate their recall with a later list item did not significantly affect the overall level of recall of SP1 or its PFR. Thus, the tendency to initiate recall with the first list item does not seem to be solely due to the extra attention paid to it.

Experiment 1B: The role of attention in 5-item lists

One potential limitation of Experiment 1A was that the baseline tendency to initiate free recall of an 8-word list with the first list item was a little lower than expected – at around 25%. One might argue that given this lower level of performance, we should seek to confirm these same findings at a shorter list length, where the tendency to initiate recall with the first word might well be expected to be far higher, and any reduction caused by the manipulation of attention would be easier to identify. Thus, In Experiment 1B we repeated the experiment whilst reducing the list length from 8 items to 5.

Method

Participants. A total of 32 participants from the University of Essex took part in this experiment. None had participated in the previous experiment.

Materials and Apparatus. This was the same as Experiment 1A, except that the materials now consisted of a subset of 320 words that were randomly selected for each participant from the 1,000 words of Toronto Word Pool (Friendly *et al*., 1982). Also each of the five words on a trial was presented in one of seven different coloured fonts (red, dark green, light green, pink, orange, turquoise, blue, and dark brown).

Design. The design was the same as Experiment 1A, except that the location of the red word now had only six levels (SP0, SP1, SP2, SP3, SP4 and SP5).

Procedure. The procedure was the same as Experiment 1A, except that the two practice lists now contained five words and there were 64 experimental lists of words. The experimental trials were arranged into two blocks of 32 trials; each block contained four trials with the red word appearing at each of the five serial positions, and 12 trials where there was no red word presented (SP=0). Again, both groups received the same stimuli; the only difference was whether the participants were informed of the significance of the red word.

Results

The data were considered in the same analyses as were performed in Experiment 1A. Due to the gross similarities between the results of Experiment 1A and 1B, a summarised version of the results for Experiment 1B appears here. For the full results please see the Supplementary Materials.

Proportion of words recalled. The mean proportion of words recalled was .78 and .79 for the Experimental group and Control Groups, respectively. A one-way between-subjects ANOVA confirmed that there was no significant difference between the Control group and the trials in the Experimental group where there was no red word, F (1, 30) = 0.019, MSE = .017, p = .891.

For the Experimental group, there was relatively little difference in the mean proportion of words recalled (means varied between .76 to .80) when the red word was either absent (SP=0) or was in SP1-5. A one-way within-subjects ANOVA confirmed that performance was unaffected by the location of the red word, F (5, 75) = 2.26, MSE = .002, p = .057. The overall recall scores are plotted in Supplementary Figure S5.

Analyses of the serial position curves of all the data. Figure 3 shows the serial position curves for the Control and Experimental groups.

--Figure 3 about here--

Figure 3A shows trials where there was no red word (the SP=0 trials) for the Experimental group and all the data averaged for the Control group. Performance is very similar across all serial positions except SP2, where the Control group show a slight increase in performance. A 2 (Group: Experimental and Control) x 5 (serial position: SP1-SP5) mixed ANOVA revealed that there was a non-significant effect of Group, F (1, 30) = 0.019, MSE = .085, p = .891, a significant effect of serial position, F (4, 120) = 11.1, MSE = .018, p < .001, and a non-significant interaction, F (4, 120) = 1.23, MSE = .018, p = .301. The significant effect of serial position reflected a small 1-item primacy, and an extended recency effect.

These findings suggest that there was little difference between participants performing standard IFR and participants who might reasonably be withholding attention whilst waiting for a red word (that did not subsequently appear).

Additional planned comparisons revealed that recall of SP1 in the un-cued SP=0 condition differed significantly from SP=3 and SP=5. There appears to be a weak effect of having a red item in a trial on the recall of SP1 compared to a trial containing no red word.

Figure 3B shows the serial position curves for the six different conditions of the Experimental group: trials in which there was a red word at each of the five different serial positions and when there was no red word. Participants were reasonably successful at recalling the red word during recall: minimum mean recall was 84%. A 6 (location of red word: SP=0, SP=1-SP=5) x 5 (Serial position: 1-5) within-subjects ANOVA revealed a non-significant main effect of location of red word, F (5, 75) = 2.26, MSE = .010, p = .057, a significant main effect of serial position, F (4, 60) = 6.78, MSE = .098, p < .001, showing a small 1-item primacy, and extended recency effect. There was also a significant interaction, F (20, 300) = 7.66, MSE = .022, p < .001. Recall was always higher in the serial position of the red word relative to the other serial positions in that trial, showing that participants were able to follow instructions.

Again, the recall of the red word itself follows an 'IFR-like' serial position curve, with increased recall when the red word was in SP1 or a recency serial position, relative to SP2. There was also an asymmetry in the data: recall of the item immediately following the red word showed elevated recall and the item immediately preceding the red word showed reduced recall.

The PFR data. Figure 4 shows the proportion of trials in which a particular list position was recalled first for the Control and Experimental groups.

--Figure 4 about here--

Considering first the PFR data of Figure 4A, a 2 (Group: Experimental and Control) x 5 (serial position: SP1-SP5) mixed ANOVA revealed that there was a non-significant effect of Group, F (1, 30) = 1.21, MSE < .001, p = .280, a significant effect of serial position, F (4, 120) = 25.3, MSE = .059, p < .001, and a non-significant interaction, F (4, 120) = 0.036, MSE = .059, p = .998. The significant main effect of serial position was driven by the high likelihood of starting recall with SP1, and a greater likelihood of starting recall with SP5 compared to SP2, but no difference was found between serial positions 2-4.

Considering next the PFR data of Figure 2B, a 6 (location of red word: SP=0, SP=1-SP=6) x 5 (Serial position: 1-5) within-subjects ANOVA revealed a non-significant main effect of location of red word, F (5, 75) = 2.01, MSE < .001, p = .087, a significant main effect of serial position, F (4, 60) = 9.34, MSE = .023, p < .001. There was also a significant interaction, F (20, 300) = 134.0, MSE = .018, p < .001. In the conditions with a red word, the likelihood of starting recall with the red word was higher relative to the other serial positions in that trial, showing that participants were able to identify the red word and successfully initiate recall with it. The serial position curve of the red word, like in the overall proportion data, itself shows an 'IFR-like' recall trend, with increased recall of the red word when it was in SP1 or a recency serial position, relative to the middle serial positions.

The effect of the first word recalled on the resultant serial position curves. We examined the effects of different starting serial position on the resultant serial position curves. In summary, participants showed enhanced recall for the word immediately subsequent to the red word and slightly reduced recall for the word immediately preceding the red word. Similar trends were observed in experimental group trials starting with red words and in control and experimental group trials with no red words. The data are fully displayed in

Supplementary Figure S6. Thus, whether the initial starting point was experimenter chosen or participant chosen, once recall is initiated from that serial position the resulting recall pattern is similar.

Additionally recall of SP1, for the Experimental group in trials where they successfully initiated their recall with the red word, was unaffected by the location of the red word, F (3, 45) = 0.206, MSE = .026, p = .892.

Output order sequences. We examined the most common output order sequences made by the Control group and Experimental group as a function of location of the red word. The most common sequence for the Control group and Experimental group in SP=0 and SP=1 trials was perfect serial recall of the entire sequence. In the less common sequences, the trend is still for serial recall with one item missing. For the Experimental group for trials in which there was a red word the most common sequence was to recall all five words in serial order, starting with the red word and then outputting the sequence from SP1 missing out the red word e.g. red word was presented at SP3, so the recall sequence was 3, 1, 2, 4, 5. The second output item is again either the serial position immediately following the red word, or SP1. A full list of the most common sequences for each group and condition can be Supplementary Tables S3 and S4.

The degree of forward-ordered recall. The final analysis examined the degree of forward serial order recall in the output sequences. The mean proportion of CRP of lag +1 transitions was .68 and .72 for the Experimental and Control Groups, respectively. For the Experimental group, the data were subdivided by when the red word was in different serial positions. The data show a fairly consistent degree of lag +1 transitions, apart from the low value for trials where the red word appears in SP2; performance across all conditions varied from .53 to .74.

A series of two one-way ANOVAs confirmed the degree of forwards serial order was equivalent for the Control group and the Experimental group, F (1, 30) = 0.040, MSE = .026, p = .843, and the degree of forwards serial order was affected by the location of the red word, F (5, 75) = 3.89, MSE = .027, p = .003. It was lower for SP=2 compared to SP=0, SP=3 and SP=5. Supplementary Figure S7 plots the proportion of CRP of lag +1 transitions and Supplementary Figure S8 shows the full CRP-lag curves that show asymmetric lag recency curves.

Discussion

This experiment was conducted to determine whether the low baseline primacy found in the 8-item lists in Experiment 1A masked any potential role of attention in the high tendency to initiate IFR with the first list item at short list lengths. The list length was reduced to five items and replicated the basic findings from Experiment 1A. Participants tended to initiate their recall with the first list item and show elevated levels of primacy, even when attention was reallocated to a later list item.

Participants in the Experimental group showed a pronounced tendency to both recall the red item (at least 84% of the time) and to initiate recall with the red item (at least 77% of the time). Very similar serial position curves, PFR data, output order sequences, and lag transitions were found in the trials in the Experimental group in which there was no red word and all the trials for the Control group. There was very little reduction in primacy for the Experimental group in trials containing no red word compared to the Control group. This suggests that if participants in the Experimental group were withholding attention from SP1 in anticipation of a red item appearing, it did not substantially alter their performance from that of the Control group who were free to allocate their attention as they chose.

Turning now to the performance of the Experimental group where there was a red word, there appears to be on average a 10% reduction in recall of SP1 on trials with a red word relative to trials without a red word; a reduction that only proved significant in planned comparisons when the red word was at SP3 and SP5. The average recall of SP1 for the Experimental trials with red word at SP2-5 was 66% in the overall serial position curve as well as 66% in trials where recall was started with the red word. Therefore, recall of SP1 was the same in the overall data and the conditionalised data, even though the levels of recall were more than adequate to show any potential difference if it was to be found.

The output sequences showed high similarity; both the Control and Experimental groups showed a strong tendency for forwards recall, with both showing a recall asymmetry around the initially recalled serial position. The item immediately preceding the first item output showed reduced recall; the item immediately following the first item output showed increased recall. Participants in the Experimental group for trials containing a red word showed a strong tendency for their second item output to be the serial position following the red word or SP1. Indeed, the most common sequence was to recall the red word and then return to SP1 and recall the rest of the list in serial order, omitting the already recalled red word. As mentioned during the results, both the overall recall and PFR of the red words showed a bowed 'IFR-like' trend. It is interesting that the accessibility of the red item follows the same accessibility trend of that item in normal recall.

Overall, the findings show that disrupting participants' normal encoding by cueing participants' to initiate their recall with a specific item in the list did not affect the overall level of recall of SP1, or its PFR. Recall of SP1 does not seem to be solely due to the extra attention paid to it.

Summary of Experiment 1

Several theories include a role for attention in their explanations of primacy (Barrouillet *et al*., 2004; Brown *et al*., 2000; Cowan, 1988, 1999, 2005; Farrell & Lewandowsky, 2002; Lewandowsky & Farrell, 2008; Raaijmakers & Shiffrin, 1981). They all posit that extra attention is paid to SP1, or that SP1 is more novel and so more attention-demanding, and so would predict that decreasing attention from the first item should decrease recall of that item. However, we found that requiring participants to focus attention on a later red item had little effect on the recall of SP1. Our findings show that extra attention paid to SP1 was not necessary for the tendency to initiate recall with SP1 found for both 8-item and 5-item lists in previous experiments.

Several similarities in performance are evident across Experiment 1A and 1B between 5- and 8-item lists. Participants in the Experimental group showed a high ability to not only recall the red item, but also to initiate their recall with the red item. Recall of SP1 was relatively unaffected by whether participants might have been withholding attention due to anticipating a red word that never appeared, compared to participants who were free to allocate their attention as they chose. Recall of SP1 was reduced, more so in the 5-item lists, but only rarely significantly for either 5- or 8-item lists, for participants in the Experimental group in trials containing a red word compared to trials which did not contain a red word. Additionally, for participants in the Experimental group in trials containing a red word, the average recall of SP1 in the overall serial position curves did not differ from trials in which recall was initiated with the red word. Both Control and Experimental groups showed a strong tendency for forwards recall, with both showing a recall asymmetry around the initially recalled serial position. Both the overall recall and PFR of the red words showed a bowed ‘IFR-like’ trend.

There were, however, a few differences in performance between Experiment 1A and 1B. The levels of primacy were clearly rather low in Experiment 1A, hence the need for

Experiment 1B to be conducted. The output sequences in the two experiments differed. For 8-item lists the second item participants output was most likely to be the serial position following the red word, or one of the last four serial positions. However, for 5-item lists the second item output was most likely to be the serial position following the red word, or SP1. However, for both 8- and 5-item lists, when SP1 was recalled it was most likely to be output second. There was also evidence in the PFR data of the 8-item lists that participants may have been grouping the list into two 4-item chunks, in line with Farrell's (2012) view of encoding, whereas no grouping was evident in the 5-item list PFR data.

Despite these subtle differences, the overall findings from both Experiment 1A and 1B are clear. The recall of SP1 is unlikely to be due to the extra attention paid to it, since primacy was not greatly reduced, and certainly not eliminated, when attention was successfully shifted away from SP1 and towards the red word.

Experiment 2: The effect of a prefix

The previous experiment investigated the effects of attention on primacy in IFR for short lists and found that primacy was not greatly affected when attention was shifted away from the first item. In Experiment 2, we investigated whether the first word has a recall advantage due to its increased temporal distinctiveness: it has no items preceding it in temporal space, compared to the other items in the list. Temporal distinctiveness accounts, such as SIMPLE (Brown *et al*., 2007), state that the first item has greater temporal distinctiveness since it only has one neighbour, and thus is less temporally crowded. Items which have larger temporal distinctiveness are less confusable and thus are more likely to be retrieved successfully.

The temporal distinctiveness of the first word in the list can be reduced by the addition of a stimulus prefix. The stimulus prefix effect is the finding that recall of a target string is reduced when a redundant element is presented immediately preceding the initial to-be-remembered (TBR) list item, compared to a list of the same length without a prefix. Participants are told to ignore the prefix and that it is not to be recalled at test, yet the prefix still lowers recall. In the following prefix research the prefix was always presented in presentation only. Additionally all of the research discussed was conducted using ISR.

Dallett (1964) found the addition of a single prefix in a seven-item list reduced recall of the entire list as much as the addition of an extra TBR list item – both of which reduced performance relative to an un-prefixed list. Dallett posited that the prefix might change the way the list is encoded, and that at the start of recall participants were actively suppressing recall of the prefix. Crowder (1967) replicated this basic finding with an 8-item list. Crowder also plotted the serial position curves, which showed that the detrimental effect of the stimulus prefix was present over the whole list.

Savin (1968) investigated the possible use of grouping strategies by inserting pauses after the third and sixth digits of each list. He found the addition of a single prefix was almost as damaging as an extra non-redundant digit, but only for the items before the first pause. He concluded that if the first pause in the list was long enough the effects of the prefix may be completely mitigated.

Neisser, Hoenig, and Goldstein (1969) investigated whether the prefix effect is due to the prefix being perceived as part of the target string. They used three prefixed zeros instead of one, arguing that three zeros would be perceptually grouped as more distinct from the target items compared to a single zero. Neisser *et al*. found that the addition of a triple prefix eliminated the prefix effect; performance was equivalent to trials containing no prefix. However, a triple prefix has not always eliminated the prefix effect. Routh and Walker (1975), Jahnke (1975) and Mills and Martin (1974, 1977) all continued to observe a prefix effect with a triple prefix.

Jahnke and Perez (1981) examined the importance of the prefix's semantic relatedness to the target stimuli in the prefix effect, arguing that if the prefix is semantically related to the target string recall will be poorer relative to an un-prefixed string because the prefix and target stimuli will share a common retrieval cue. They found that a prefix was only detrimental to recall when it was encoded as semantically related to the target string. Interestingly they also showed that the prefix effect was driven by the prefix making it more difficult for participants to access SP1.

More recently temporal distinctiveness accounts, such as SIMPLE (Brown *et al*., 2007) have attempted to explain primacy as due to edge effects. A natural prediction of SIMPLE is that the prefix would act to reduce the temporal distinctiveness of the beginning of the list, and as such cause a reduction in primacy. In SIMPLE each item is often likened to a telegraph pole; in an un-prefixed list the first list item is the first telegraph pole, but in a list with a single prefix the first list item now becomes the second telegraph pole in the series. This may help to account for the common finding that the addition of a single stimulus prefix reduced recall as much as the addition of an extra TBR list item (Crowder, 1967; Dallett, 1964; Mills & Martin, 1974, 1977; Neisser *et al*., 1969, Routh & Walker, 1975; Savin, 1968).

The aim of Experiment 2 was manipulate the temporal distinctiveness of the start of the list by the addition, on half of the trials, of a triple word stimulus prefix. A triple prefix was chosen rather than a single prefix, since according to temporal distinctiveness theories, this should reduce the temporal distinctiveness of SP1 more than a single prefix. No previous experiments have examined the prefix effect using IFR, an open set of stimuli, a range of list lengths, or three changing prefixes unique to each trial. We feel our paper makes an additional contribution to the field in its use of IFR rather than the traditional ISR task. Our aim was to make the prefix easily discriminable from the target items during encoding (by presenting the prefix in red font colour and the TBR in black font colour) but to otherwise make the encoding (e.g., stressing to participants to verbalise all items in the same manner), physical properties (e.g., font type and font size), and semantic relatedness, of the prefix and target items as similar as possible. In fact, the prefix and target words were taken from the same pool, so the prefix for one participant was free to be a target item for another participant.

Thus, this experiment manipulated the presence of a stimulus prefix and list length. Participants were presented with lists of between two and 12 TBR words in black font – half of which contained a triple word stimulus prefix presented in red font. The prefix was a set of three unique words taken from the same word pool as the experimental words with no constraints, so that prefix items and target items did not differ. Participants read all words out loud but were instructed that the red (prefix) items were not to be recalled. The trials were randomised such that participants did not know in advance of its presentation the length of the list, or whether the trial would contain a prefix. The colour of the first item presented informed participants whether the trial contained a prefix (red font) or was un-prefixed (black font).

If the tendency to initiate IFR of short lists with SP1 is due to the increased temporal distinctiveness of SP1, then reducing its distinctiveness, by the addition of a stimulus prefix, should eliminate primacy and also reduce participants' likelihood of initiating recall with SP1, in line with the finding of Jahnke and Perez (1981). We predict that given a participant has managed to initiate their recall with SP1 their recall should now show no prefix effect and be statistically equivalent to un-prefixed trials.

Method

Participants. A total of forty participants from the University of Essex took part in this experiment.

Materials and Apparatus. The materials consisted of a subset of 561 words that were randomly selected for each participant from the 1,000 words of the Toronto Word Pool (Friendly *et al*., 1982). Of these words 99 were selected randomly as prefix items and the remaining 462 words were TBR items. All words were presented visually in 60-point Times New Roman font in the centre of an Apple eMac computer monitor using the Supercard 4.6 application. The prefix items appeared in red font and the TBR items appeared in black font.

Design. The experiment used a within-subjects design. There were two within-subjects independent variables: Prefix condition with two levels (No prefix or 3 changing words prefix), and list length with eleven levels (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12). The main dependent variables were the proportion of words recalled (in any order) and the probability of initiating recall with a particular list item.

Procedure. Participants were tested individually and were informed that they would be shown two practice lists of six experimental TBR words. The first practice trial was always a 3 changing words prefix condition type, and the second practice trial was always the No prefix condition type. The three prefix items always appeared in red font colour at the start of the list and participants were instructed not to recall these words. Participants were instructed that the words they should remember would always be in black font colour. The practice trials were followed by 66 experimental lists of words, with each of the eleven list lengths repeated three times in both conditions. The experimental trials were arranged into two blocks of 33 trials. Due to the three repetitions of each trial type at each list length the two blocks could not contain exactly the same composition of trial types. Within each block each list length was repeated three times, once with No prefix and once with the 3 changing words prefix, with the remaining trials split between the two blocks. One block contained: the non-prefixed trials 2, 4, 6, 8, 10 and the prefixed trials 3, 5, 7, 9, 11; the other block contained the opposite arrangement. The order of the blocks was counterbalanced across participants, and within a block the order of all the list lengths was randomised. Participants were not informed in advance whether the trial would contain a prefix or not.

Each trial started with a fixation cross displayed for 2 s, followed after 1 s by a sequence of between two and 15 words (3 prefix items and a maximum of 12 possible TBR items) presented one at a time in the centre of the screen. The presentation rate was one word every second; each word was displayed for 750 ms with an additional 250 ms inter-stimulus interval in which the stimulus field was blank. Participants were instructed to read each word aloud as it was presented, regardless of its colour. It was also heavily stressed that they should read both red and black words in the same way, e.g., with the same volume, stress or emphasis etc. At the end of the list an empty grid was displayed on the screen containing the same number of numbered rows as there had been of black TBR words on that trial to inform participants of the list length of that trial. Participants were instructed to recall as many TBR words as they could on the paper response sheet in any order they wished. Trials had no maximum recall period; participants ended recall when they felt they had remembered all the words they could.

Results

An item was scored correct if it was recalled at any time in the recall period immediately following its presentation (*FR scoring*). The data were considered in five analyses: the proportion of words recalled, the serial position curves, the PFR, the resultant serial position curves, and the degree of forwards order. As a note, participants mistakenly recalled the prefix items on a very small proportion of trials (less than 0.05% of the time).

Proportion of words recalled. The mean proportion of words recalled was .64 and .62 for the No prefix and 3 changing words prefix conditions, respectively. There were clear list length effects for both conditions: in each case the proportion of words recalled decreased as list length increased. A 2 (prefix condition: No prefix or 3 changing words prefix) x 11 (List length: 2-12) within-subjects ANOVA revealed a significant main effect of prefix condition, F (1, 39) = 13.1, MSE = .007, p = .001, where performance was superior in the No prefix condition compared to the 3 changing words prefix condition. There was also a highly significant main effect of list length, F (10, 390) = 582.5, MSE = .008, p < .001, reflecting that a lower proportion of words were recalled at longer lists, but a non-significant interaction, F (10, 390) = 1.69, MSE = .005, p = .080. The overall recall scores are plotted in Figure S9 (see Supplementary Materials).

Analyses of the serial position curves of all the data. Figure 5 shows the serial position curves for both the No prefix or 3 changing words prefix conditions, for each of the different list lengths: LL2 (Panel A), LL3 (Panel B), LL4 (Panel C), LL5 (Panel D), LL6 (Panel E), LL7 (Panel F), LL8 (Panel G), LL9 (Panel H), LL10 (Panel I), LL11 (Panel J), and LL12 (Panel K).

--Figure 5 about here--

Figure 5 shows that the prefix appears to have little effect on recall in the recency and asymptote portions of the serial position curves. However, at some list lengths it appears to have an effect in the primacy portion of the serial position curves, with the 3 changing words prefix decreasing recall of the first or second item(s) in the list, compared to the No prefix condition. The serial position curves for both prefix conditions at each list length were analysed by a 2 (prefix condition: No prefix or 3 changing words prefix) x n (serial position, where n is the LL) within-subjects ANOVA. The exact p-values of all the main effects and interactions for each list length can be found in the Appendix S1 (see Supplementary Materials). To summarise these analyses: there is a significant effect of prefix at LL8 only.

We were specifically interested in how far into the list the prefix effect extended. A series of one-way (prefix condition: No prefix or 3 changing words prefix) within-subjects ANOVAs were conducted on the proportion of words recalled at SP1 and then again for SP2 and onwards. The exact *p*-values of all the main effects and interactions for each list length can be found in Appendix S2 and S3, respectively. Note the Bonferroni correction was not applied since these were specific ANOVAs performed due to a priori predictions. To summarise these analyses: there was a significant reduction in recall of SP1 when the 3 changing words prefix was present at list lengths 4, 5, 6, and 8. Thus, for short to mid length list lengths, the addition of a prefix significantly reduced recall of SP1. There was a significant reduction in recall of SP2 when the 3 changing words prefix was present at list lengths 5, 8, and 11. Thus, for list lengths 5, and 8, the prefix effect was not limited to only SP1. This analysis was then extended back to SP3 but no significant differences were found. Therefore, the prefix effect included SP1 only for list lengths 4 and 6, and SP1 and SP2 for list lengths 5 and 8.

The PFR data. Figure 6 shows the proportion of trials in which recall was initiated with either the first word “Start”, one of the last four words “Last 4”, a serial position from elsewhere in the list “Other”, and an error “Error” for both the 3 changing words prefix and No prefix conditions. The full data summarised in Figure 6 can be found in Table S5 (see Supplementary Materials). Both conditions show grossly similar distributions: participants tended to initiate their recalls with SP1 for short lists, but as the list length increased they were more likely to start their recall with one of the last four list items.

--Figure 6 about here--

An analysis was conducted on the proportion of trials in which the first word recalled from a list was from SP1. A 2 (prefix condition: No prefix or 3 changing words prefix) x 11 (List length: 2-12) within-subjects ANOVA revealed a significant main effect of prefix condition, $F\ (1, 39) = 24.2$, $MSE = .041$, $p < .001$, a highly significant main effect of list length, $F\ (10, 390) = 190.3$, $MSE = .053$, $p < .001$, and a significant interaction, $F\ (10, 390) = 2.70$, $MSE = .029$, $p = .003$. The probability of initiating recall with SP1 was superior in the No prefix condition compared to the 3 changing words prefix condition. Simple main effects revealed that a greater proportion of trials were initiated with SP1 in the No prefix condition compared to the 3 changing words prefix condition at list lengths 4, 5, 7, and 8.

A second analysis examining only the proportion of trials starting with one of the last four words for each of the six conditions produced essentially complementary effects, and so it is not reported here.

The effect of the first word recalled on the resultant serial position curves. We consider first the effect of initiating recall with the first word in the resultant serial position curves. When recall started with SP1 there was generally elevated recall of the early list items, and recency was often limited to a single item. The data are fully displayed in Supplementary Figure S10.

The serial position curves for both prefix and No prefix conditions at each list length were analysed by a 2 (prefix condition: No prefix or 3 changing words prefix) x *n-1* (Serial position: 2-*n*, where *n* is the LL) within-subjects ANOVA. The data from SP1 of each list were omitted from these analyses because, by definition for inclusion in these analyses, their values are exactly 1.00. The exact *p*-values of the main effects and interactions for each list length can be found in Appendix S3 (see Supplementary Materials). It should be noted that there are decreasing numbers of participants who contribute to these analyses at longer list lengths.

Partitioning the data by trials starting with the first list item reduced the number of significant main effects and interactions within the analyses compared to Appendix S1. All main effects and interactions were non-significant. These analyses show that small primacy effects and elevated recall of early serial positions are mostly attributable to those trials in which recall started with SP1, and that the prefix effect is greatly reduced/abolished in trials where recall was initiated with SP1.

We consider next the effect of initiating recall with one of the last four words in the resultant serial position curves. When recall started with one of the last four words there were extended recency effects, with a hint of primacy at some list lengths. The data are fully displayed in recency-justified serial position curves in Supplementary Figure S11.

The serial position curves for both prefix and No prefix conditions at each list length were analysed by a 2 (prefix condition: No prefix or 3 changing words prefix) x *n* (serial position, where *n* is the LL) within-subjects ANOVA. The exact *p*-values of the main effects and interactions for each list length can be found in the Appendix S4 (see Supplementary Materials). It should be noted that that there are decreasing numbers of participants who contribute to these analyses at shorter list lengths.

Partitioning the data by trials starting with one of the last four items reduced the number of significant main effects for the prefix condition and interactions – none remained significant. The main effect of serial position remained significant from LL5 onwards. These analyses show that extended recency effects and elevated recall of late serial positions are mostly attributable to those trials in which recall started with one of the last four words.

The degree of forward-ordered recall. The final analysis examined the degree of forward serial order recall. The mean proportion of CRP lag +1 transitions was .69 and .71 for the No prefix and 3 changing words prefix conditions, respectively.

A 2 (prefix condition: No prefix or 3 changing words prefix) x 11 (List length: 2-12) within-subjects ANOVA revealed a significant main effect of List length, F (10, 390) = 53.4, MSE = .053, p < .001, indicating that as the list length increased so a lower proportion of lag +1 transitions were performed, but a non-significant main effect of prefix condition, F (1, 39) = 3.56, MSE = .046, p = .067, and a non-significant interaction, F (10, 390) = 0.716, MSE = .057, p = .709. Full plots of the lag +1 transitions can be found in Supplementary Figure S12.

Discussion

This experiment examined the effect of a stimulus prefix on the finding that participants tend to initiate their recall with the first list item and show elevated levels of primacy for short lists in IFR. We reduced the temporal distinctiveness of the start of the list by adding a triple word stimulus prefix. Temporal distinctiveness accounts predict that the first item has greater temporal distinctiveness since it only has one neighbour, and so therefore is in a less temporally crowded region of space, and thus will be more likely to be recalled. If temporal distinctiveness does cause primacy and the tendency for participants to initiate recall with SP1, then the addition of a triple stimulus prefix should significantly reduce primacy, and significantly reduce the tendency for participants to initiate recall with SP1, compared to an un-prefixed list.

Consistent with the predictions of temporal distinctiveness accounts, we found that the addition of a stimulus prefix significantly reduced participants' ability to initiate recall with SP1 for short to mid length list lengths, and significantly reduced their primacy. For list lengths where a significant prefix effect was found (list lengths 4-6, and 8) the difference in the PFR of SP1 was between 5-20%, whereas for the list lengths where a significant prefix effect was not found (list lengths 2-3 and 9-12) the difference in the PFR of SP1 was 5% or less. It would appear that the accessibility to the first list item was reduced when the first list item was made less temporally discriminable by the stimulus prefix. Our findings could therefore be considered in line with Jahnke and Perez (1981), who found that the prefix made it harder for their participants to access and initiate their recall with SP1.

The claim that the effect of the prefix was principally to reduce accessibility to the start of the list was further supported by the finding that the effect of the prefix disappeared on trials in which participants initiated their recall with SP1. Moreover, on these trials the degree of forward serial order did not differ between prefix and No prefix lists.

However, there was also some effect of prefix on early serial positions that remained for list lengths 4, 6, and 8 when recall was initiated with one of the last four words. It is possible that the reduction in accessibility to the first list item continued later into recall, reducing participants' ability to transition from the last list item back to the start item (reducing 'wrap around') during recall.

We note that although the tendency to initiate recall of short lists with the first list item was reduced following a prefix, the tendency was far from eliminated. One possibility is that the temporal distinctiveness of an item contributes to the subjective grouping that a participant imposes upon a list (Farrell, 2012), and it is the temporal grouping structure, rather than the temporal distinctiveness per se that defines accessibility. Our data suggest that participants can to some extent circumvent the effect of the prefix by subjectively defining the first TBR word as the start of the first TBR group of items. Access to this group may benefit from greater temporal distinctiveness of the first word (in the No Prefix condition), but is not entirely reliant on temporal distinctiveness when the distinctiveness of the first TBR items are reduced (3 changing words prefix condition).

Finally, we note that the prefix appeared to affect recall only in the primacy portion of the serial position curves, which is in contrast to the previous findings that the prefix acts to depress recall fairly evenly across the whole curve, such that the prefix serial position curve is parallel but below the un-prefixed curve (Jahnke, Nowaczyk, & Wozniak, 1976; Jahnke & Perez, 1981; Mills & Martin, 1977). We posit that the use of IFR rather than ISR caused this difference. In ISR, errors early in recall have detrimental knock-on consequences for later serial positions in the list, but when ISR is scored using FR scoring performance in ISR more closely resembles IFR.

General Discussion

This research investigated two potential interpretations as to why participants tend to initiate their free recall of short lists with the first list item. Experiment 1A and IB examined the effects of selective attention and Experiment 2 examined the effects of a stimulus prefix, which might arguably reduce the temporal distinctiveness of the first list item.

Experiment 1A and 1B investigated whether extra attention allocated to SP1 might cause its enhanced recall. Several theories posit that the first item has a recall advantage due to the extra attention paid to it (Barrouillet *et al*., 2004; Brown *et al*., 2000; Cowan, 1988, 1999, 2005; Farrell & Lewandowsky, 2002; Lewandowsky & Farrell, 2008; Raaijmakers & Shiffrin, 1981). We attempted to shift attention away from SP1 by focusing it toward a different specified list item, and requiring participants to initiate their recall with this red item. Regardless of whether the list length was 8-items (Experiment 1A) or 5-items (Experiment 1B), recall of SP1 was not greatly reduced, and certainly not eliminated, when attention was successfully shifted away from SP1 and towards the red word. The act of potentially withholding attention from the red word also did not greatly change performance compared to participants who were free to allocate their attention as they chose. Therefore, extra attention paid to SP1 does not appear to play a major factor in participants tendency to initiate IFR of short lists with the first list item. We note that where there was some hint at an effect of attention, there was also an effect of grouping – 8-item lists appeared to be spontaneously grouped into two clusters of four items, and there was evidence of increased forward ordered runs (terminal sequences) when the red word was positioned at middle-late serial positions.

Experiment 2 examined whether decreasing the temporal distinctiveness of the first list item would greatly reduce the tendency of participants to initiate their free recall of short list lengths with the first list item. Consistent with temporal distinctiveness accounts, such as SIMPLE (Brown *et al*., 2007), a stimulus prefix did reduce accessibility to the beginning of the list. However, participants appeared to be able to somewhat circumvent the prefix, perhaps by subjectively assigning the first TBR list item to the first TBR group (Farrell, 2012).

A grouping interpretation is further supported by an as yet unpublished experiment performed by Grenfell-Essam (2013 PhD thesis) in which different groups of participants were presented with 7-item lists for different variants of IFR and ISR. Critically, across all methods, the words in the list were temporally isolated to differing degrees by interpolating different numbers of digits in between the TBR words that had also to be spoken during list presentation (using a similar method to Brown, Morin, & Lewandowsky, 2006). Across all tasks, the effects of the temporal isolation before and after each list showed similar patterns. Rather than a large temporal duration always having a positive effect, recall tended to initiate recall with words that were preceded by a large temporal interval and that were followed by a shorter temporal interval. We interpret these findings as evidence that the temporal distinctiveness contributes to the patterns of grouping: a large preceding gap may encourage the start of a new group, a short following gap may encourage the continuation of the same group, resulting in the likelihood of the pair of words being output in forward order.

Summary and conclusions

We have presented two experiments that have examined the tendency to initiate IFR of short lists of words with the first list item. We found little evidence that the first list item benefitted from additional attention paid to maintain that item during the encoding of the list. When participants were encouraged to reallocate their attention to later red list items, they were able to do so, but this did not greatly reduce the tendency to later recall the first list item, nor was the tendency to initiate recall with the first list item disrupted when an expected red word was not presented on a list. A stimulus prefix reduced but did not eliminate the tendency, suggesting that temporal distinctiveness contributes to the accessibility of the list items. The fact that the prefix did not reduce the tendency still further was interpreted as evidence that participants can subjectively determine the start of the list – effectively calling the first TBR item the first word in the first TBR group. We believe that our results support both temporal distinctiveness accounts of memory and accounts that emphasise the importance of temporal grouping.

References

Anderson, J. R., Bothell, D., Lebiere, C., & Matessa, M. (1998). An integrated theory of list memory. *Journal of Memory and Language, 38*, 341-380.

Atkinson, R. C., & Shiffrin, R. M. (1971). The control of short-term memory. *Scientific American, 225*, 82-90.

Baddeley, A. D. (1986). *Working memory*. Oxford: Clarendon Press.

Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology: General, 133,* 83-100.

Bireta, T. J., Surprenant, A. M., & Neath, I. (2008). Age-related differences in the von Restorff isolation effect. The Quarterly Journal of Experimental Psychology, 61, 345-352.

Bone, R. N., & Goulet, L. R. (1968). Serial position and the von Restorff isolation effect. Journal of Experimental Psychology, 76, 494-496

Brodie, D. A., & Murdock, B. B. (1977). Effect of presentation time on nominal and functional serial-position curves of free recall. *Journal of Verbal Learning and Verbal Behavior, 16*, 185-200.

Brown, G. D. A., Chater, N., & Neath, I. (2008). Serial and free recall: Common effects and common mechanisms? A reply to Murdock (2008). *Psychological Review, 115,* 781-785.

Brown, G. D. A., Morin, C., & Lewandowsky, S. (2006). Evidence for time-based models of free recall. *Psychonomic Bulletin & Review, 13*, 717-723.

Brown, G. D. A., Neath, I., & Chater, N. (2007). A temporal ratio model of memory. *Psychological Review, 114*, 539-576.

Brown, G. D. A., Preece, T., & Hulme, C. (2000). Oscillator-based memory for serial order. *Psychological Review*, *107*, 127-181.

Corballis, M.C. (1967). Serial order in recognition and recall. *Journal of Experimental Psychology, 74*, 99-105.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin*, *104*, 163-191.

Cowan, N. (1999). An Embedded-Processes Model of working memory. In: A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 62-101). Cambridge, U.K.: Cambridge University Press.

Cowan, N. (2005). *Working memory capacity*. Hove, East Sussex, UK: Psychology Press.

Crowder, R. G. (1967). Prefix effects in immediate memory. *Canadian Journal of Psychology, 21*, 450-461.

Dallett, K. M. (1964) Effects of a redundant prefix on immediate recall. *Journal of Experimental Psychology, 67*, 296-298.

Davelaar, E. J., Goshen-Gottstein, Y., Ashkenazi, A., Haarmann, H. J., & Usher, M. (2005). The demise of short-term memory revisited: Empirical and computational investigations of recency effects. *Psychological Review, 112*, 3-42.

Farrell, S. (2010). Dissociating conditional recency in immediate and delayed free recall: A challenge for unitary models of recency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*, 324-347.

Farrell, S. (2012). Temporal clustering and sequencing in short-term memory and episodic memory. *Psychological Review, 119*, 223-271.

Farrell, S., & Lewandowsky, S. (2002). An endogenous distributed model of ordering in serial recall. *Psychonomic Bulletin and Review, 9*, 59-79.

Friendly, M., Franklin, P. E., Hoffman, D., & Rubin, D. C. (1982). The Toronto Word Pool: Norms for imagery, concreteness, orthographic variables, and grammatical usage for 1,080 words. *Behavior Research Methods and Instrumentation, 14*, 375-399.

Glanzer, M. (1972). Storage mechanisms in recall. In G. H. Bower, (Ed.), *The psychology of learning and motivation: Advances in research and theory.* (Vol. 5. pp. 129-193). New York: Academic Press.

Grenfell-Essam, R., Ward, G., & Tan, L. (2013). The role of rehearsal on the output order of immediate free recall of short and long lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39,* 317-347.

Grenfell-Essam, R., & Ward, G. (2012). Examining the relationship between free recall and immediate serial recall: The role of list length, strategy use, and test expectancy. *Journal of Memory and Language, 67,* 106-148.

Grossberg, S., & Pearson, L. R. (2008). Laminar cortical dynamics of cognitive and motor working memory, sequence learning and performance: Toward a unified theory of how the cerebral cortex works. *Psychological Review, 115*, 677-732.

Howard, M. W., & Kahana, M. J. (2002). A distributed representation of temporal context. *Journal of Mathematical Psychology, 46*, 269-299.

Jahnke, J. C. (1975). Stimulus and response prefixes interfere differentially with short-term recall. *Journal of Experimental Psychology; Human Learning and Memory, 1,* 727-732.

Jahnke, J. C., Nowaczyk, R. H., & Wozniak, W. (1976). Stimulus redundancy and immediate recall. *Memory & Cognition, 4*, 357-360.

Jahnke, J. C., & Perez, W. A. (1981). Semantic encoding and the stimulus prefix effect. *Journal of Verbal Learning and Verbal Behavior, 20*, 470-477.

Kelley, M. R., & Nairne, J. S. (2001). von Restorff revisited: Isolation, generation, and memory for order. Journal of Experimental Psychology: Learning, Memory, and Cognition, 27, 54-66.

Laming, D. (2006). Predicting free recalls. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1146-1163.

Laming, D. (2008). An improved algorithm for predicting free recalls. *Cognitive Psychology, 57*, 179-219.

Laming, D. (2009). Failure to recall. *Psychological Review, 116*, 157-186.

Laming, D. (2010). Serial position curves in free recall. *Psychological Review, 117*, 93-133.

Lewandowsky, S., & Farrell, S. (2008). Short-term memory: New data and a model. In B. H. Ross (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 49. pp. 1-48). New York, NY: Academic Press.

Mills, C. B., & Martin, J. G. (1974). Articulatory organization in the prefix effect. *Perception & Psychophysics*, *16*, 309-314.

Mills, C. B., & Martin, J. G. (1977). Articulatory organization in digit perception and recall. *Perception & Psychophysics, 21*, 463-468.

Modigliani, V., & Hedges, D. G. (1987). Distributed rehearsals and the primacy effect in single-trial free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 426-436.

Murdock, B. B., Jr. (1962). The serial position effect of free recall. *Journal of Experimental Psychology, 64*, 482-488.

Neath, I., & Crowder, R. G. (1996). Distinctiveness and very short-term serial position effects. *Memory, 4*, 225-242.

Neisser, U., Hoenig, Y. J., & Goldstein, E. (1969). Perceptual organization in the prefix effect. *Journal of Verbal Learning and Verbal Behavior, 8*, 424-429.

Raaijmakers, J. G. W. (1993). The story of the two-store model of memory: Past criticisms, current status, and future directions. In D. Meyer & S. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience* (p. 467-488). Cambridge, MA: MIT Press.

Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of Associative Memory. *Psychological Review, 88*, 93-134.

Roberts, W. A. (1972). Free recall of word lists varying in length and rate of presentation: A test of total-time hypotheses. *Journal of Experimental Psychology, 92*, 365-372.

Routh, D. A., & Walker, D. J. (1975). 'Next-to-nothings' and nothingness: A study of attention, attenuation and the stimulus prefix effect. *Quarterly Journal of Experimental Psychology*, *27*, 393-403.

Rundus, D. (1971). Analysis of rehearsal processes in free recall. *Journal of Experimental Psychology, 89*, 63-77.

Savin, H. B. (1968). On Conrad's prefix and grouping in short-term memory. *Quarterly Journal of Experimental Psychology*, *20*, 123-128.

Spurgeon, J., Ward, G., & Matthews, W. J. (2014a). 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*, 1110-1141..

Spurgeon, J., Ward, G., & Matthews, W. J. (2014b). Why do participants initiate short lists of words with the first list item? Toward a general episodic memory explanation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Advance online publication.

Tan, L., & Ward, G. (2000). A recency-based account of primacy effects in free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 1589-1625.

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review, 114*, 104-132.

von Restorff, H. (1933). The effects of field formation in the trace field. [Über die Wirkung von Bereichsbildungen im Spurenfeld] Psychologie Forschung, 18, 299-334.

Ward, G. (2002). A recency-based account of the list length effect in free recall. *Memory & Cognition, 30*, 885-892.

Ward, G. & Tan, L. (2004). The effect of the length of to-be-remembered lists and intervening lists on free recall: A re-examination using overt rehearsal. *Journal of Experimental Psychology: Learning, Memory and Cognition, 30,* 1196-1210.

Ward, G., Tan, L., & Grenfell-Essam, R. (2010). Examining the relationship between free recall and immediate serial recall: the effects of list length and output order. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 1207-1241.

Ward, G., Woodward, G., Stevens, A., & Stinson, C. (2003). Using overt rehearsals to explain word frequency effects in free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 186–210.

Figure Captions

Figure 1. Experiment 1A: Serial position curves for Control and Experimental groups using FR scoring.

Figure 2. Experiment 1A: Probability of First Recall data for the Control and Experimental groups.

Figure 3. Experiment 1B: Serial position curves for Control and Experimental groups using FR scoring.

Figure 4. Experiment 1B: Probability of First Recall data for the Control and Experimental groups.

Figure 5. Experiment 2: Serial position curves for the No prefix and 3 changing words prefix conditions using FR scoring.

Figure 6. Experiment 2: Probability of First Recall data for the No prefix and 3 changing words prefix conditions.

Figure 1.

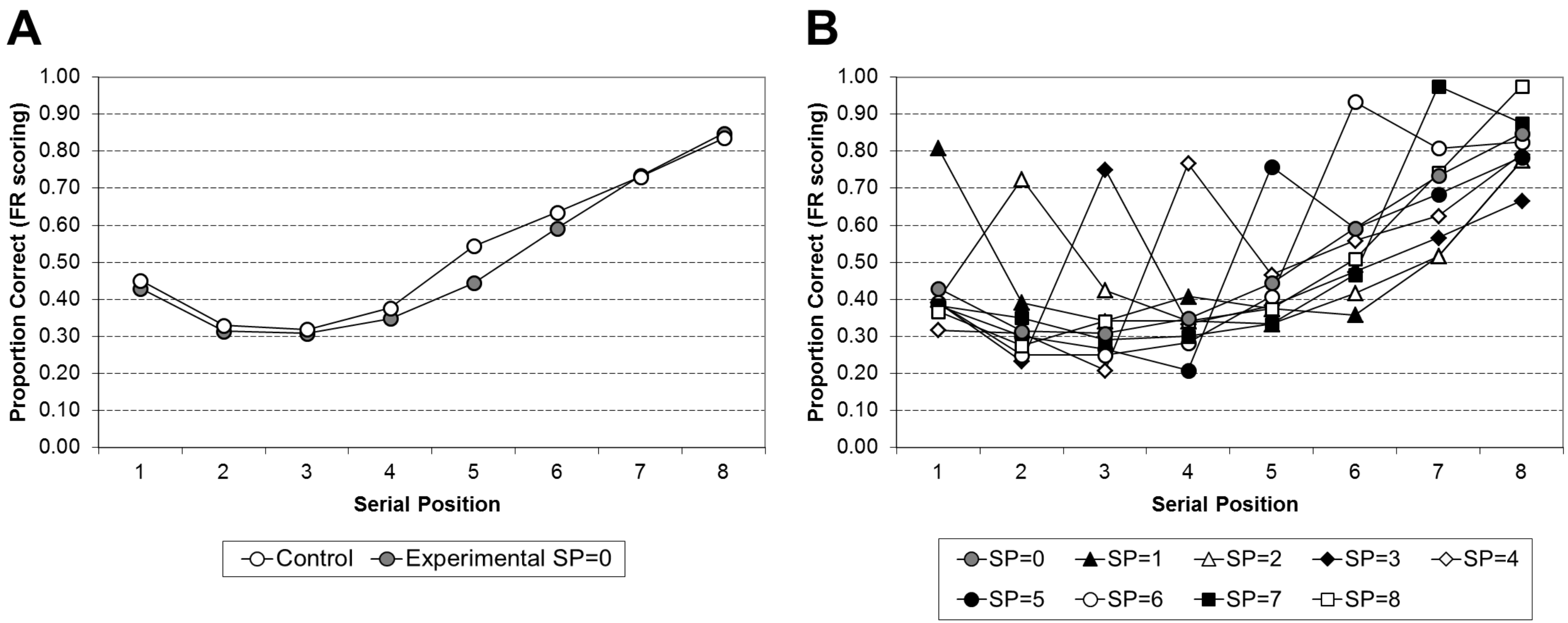

A
B
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion Correct (FR scoring)
1 2 3 4 5 6 7 8
Serial Position
Control
Experimental SP=0
SP=0
SP=1
SP=2
SP=3
SP=4
SP=5
SP=6
SP=7
SP=8

Figure 2.

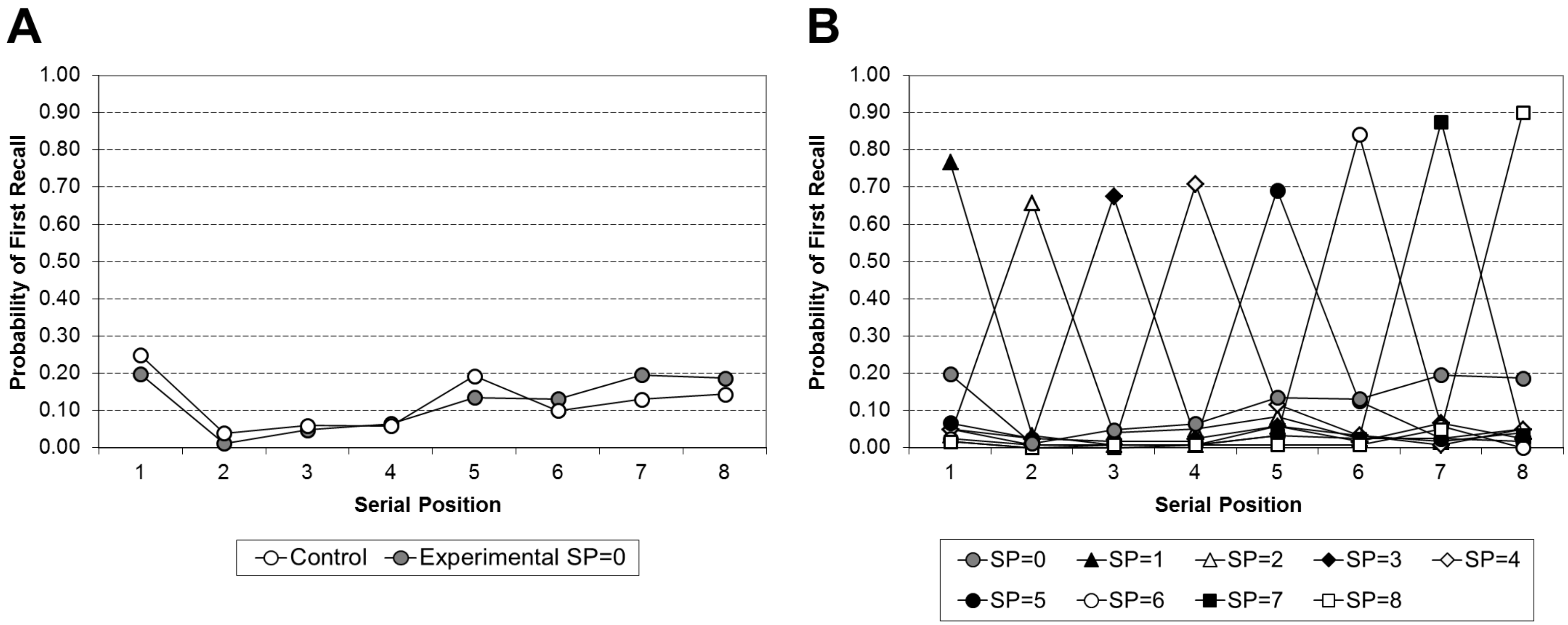

A
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of First Recall
1
2
3
4
5
6
7
8
Serial Position
Control
Experimental SP=0
B
Probability of First Recall
Serial Position
SP=0
SP=1
SP=2
SP=3
SP=4
SP=5
SP=6
SP=7
SP=8

Figure 3.

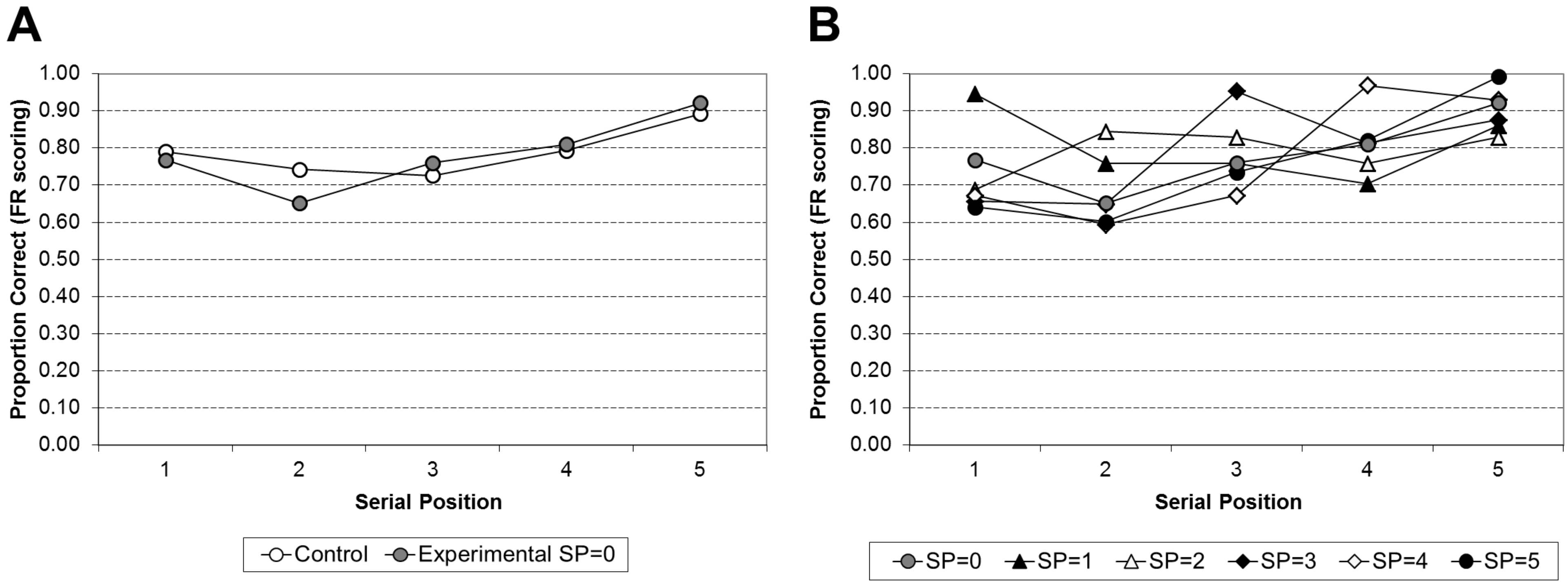

A
B
Proportion Correct (FR scoring)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
Serial Position
Control
Experimental SP=0
SP=0
SP=1
SP=2
SP=3
SP=4
SP=5

Figure 4.

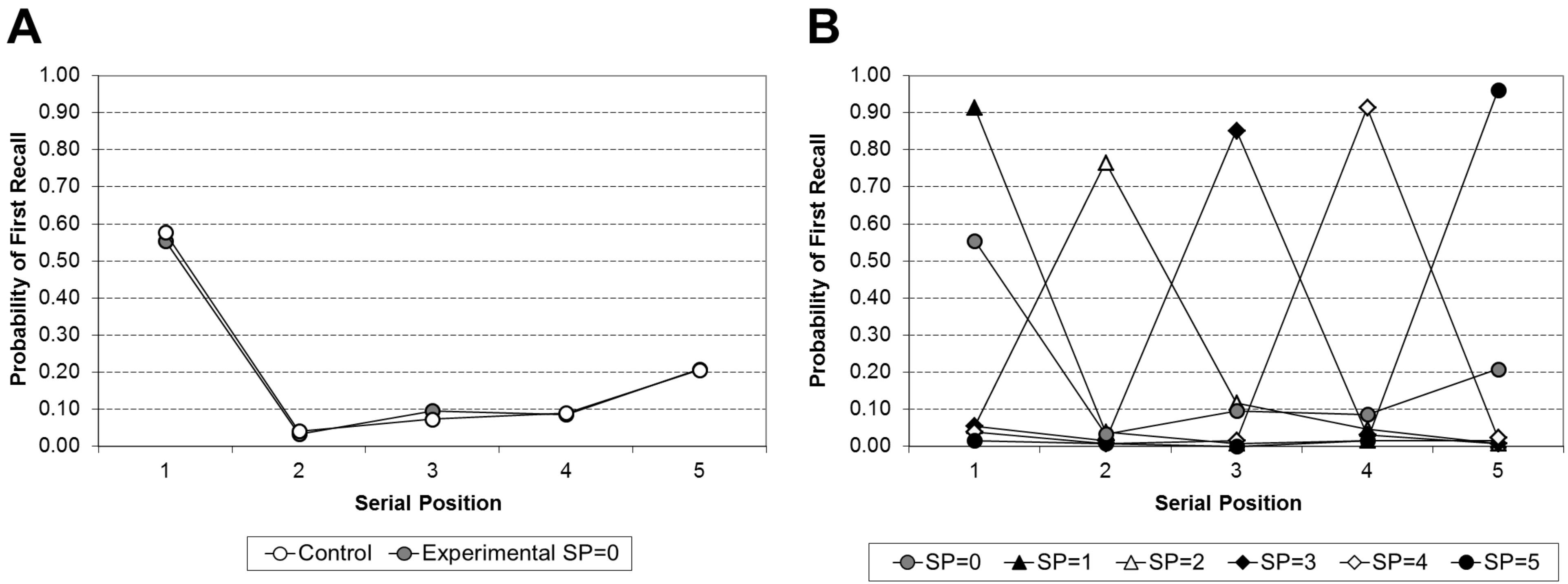

A
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of First Recall
1
2
3
4
5
Serial Position
Control
Experimental SP=0
B
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of First Recall
1
2
3
4
5
Serial Position
SP=0
SP=1
SP=2
SP=3
SP=4
SP=5

Figure 5.

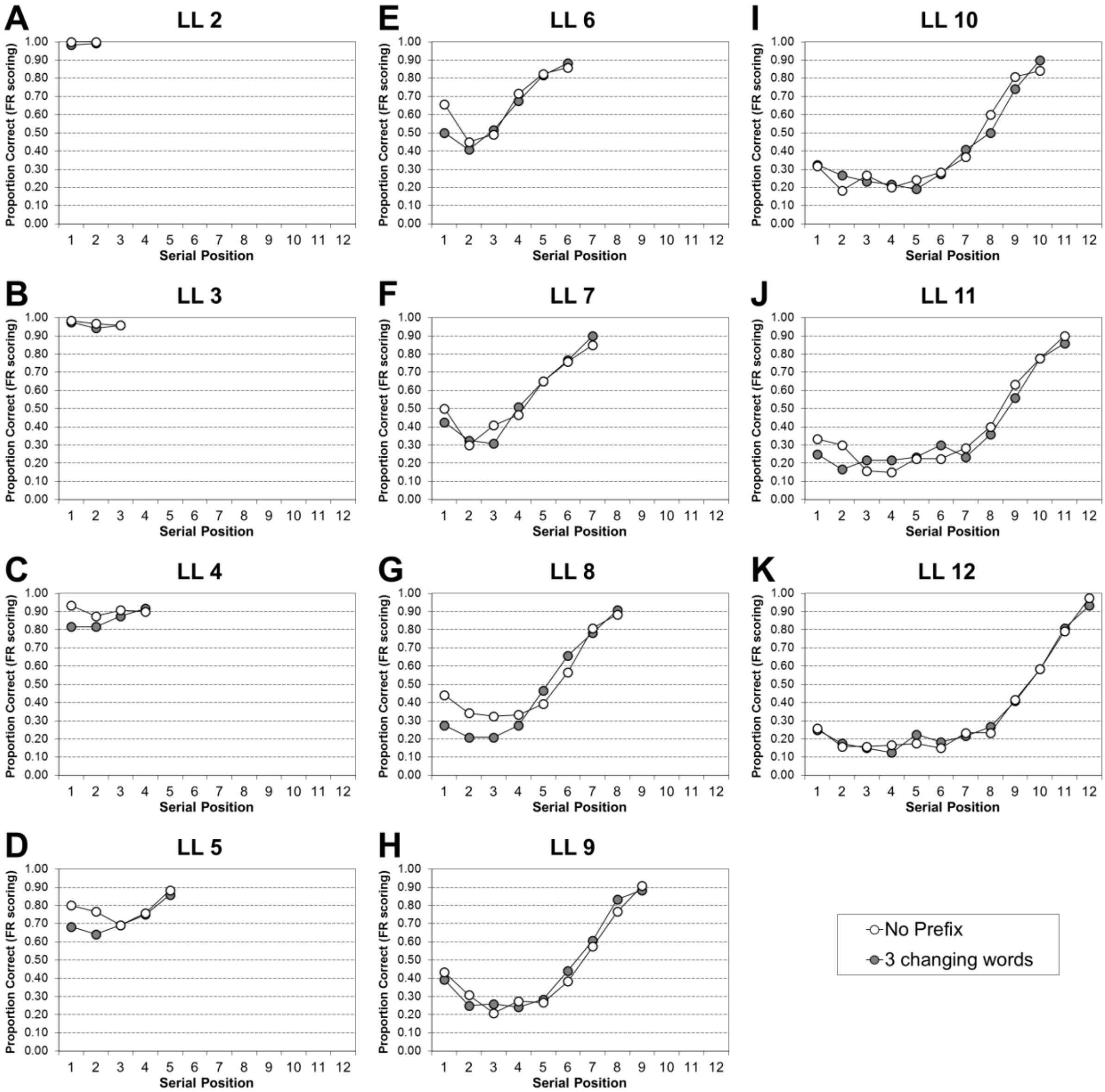
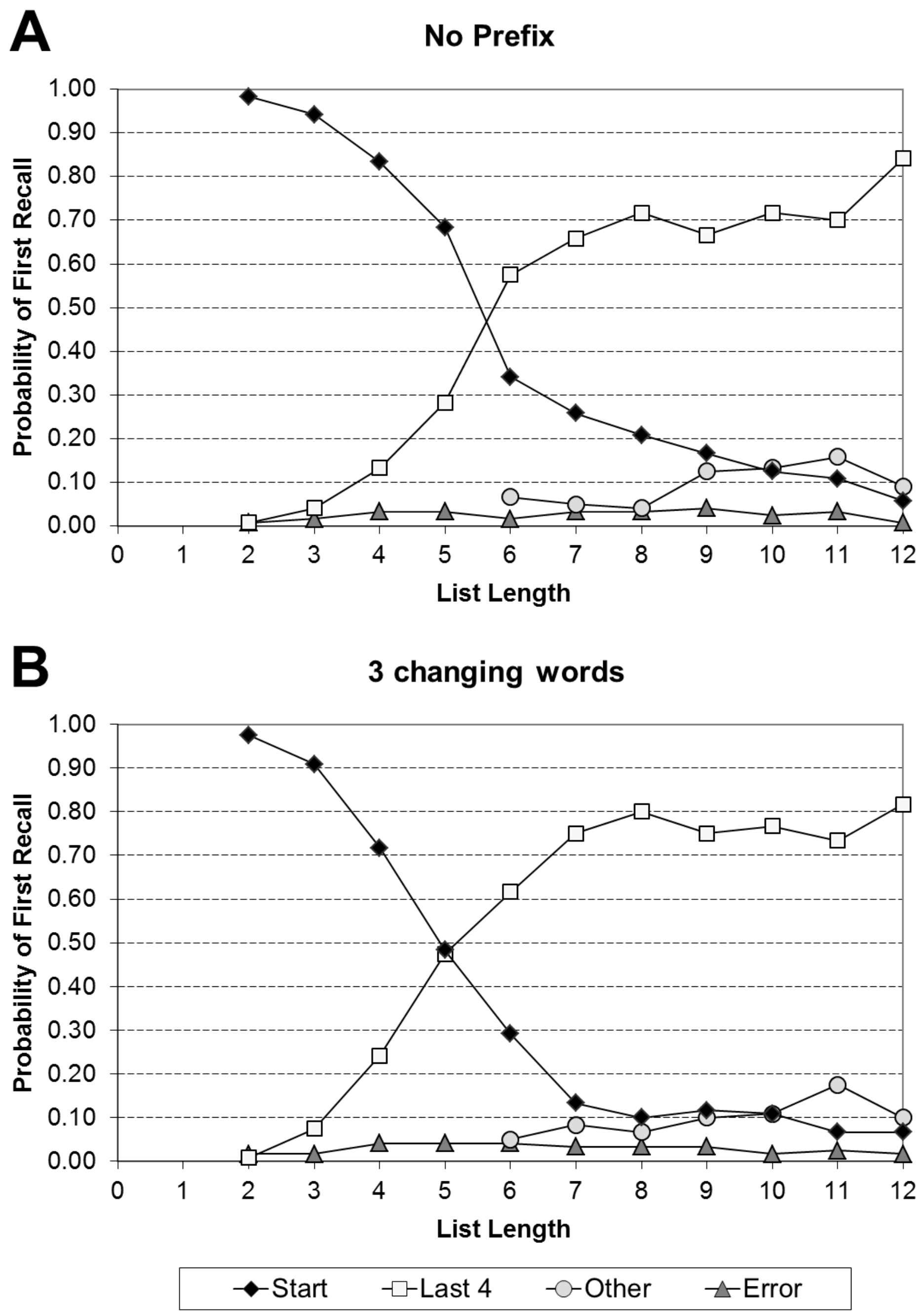

A
LL 2
B
LL 3
C
LL 4
D
LL 5
E
LL 6
F
LL 7
G
LL 8
H
LL 9
I
LL 10
J
LL 11
K
LL 12
Proportion Correct (FR scoring)
Serial Position
No Prefix
3 changing words

Figure 6.


A
No Prefix
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of First Recall
0
1
2
3
4
5
6
7
8
9
10
11
12
List Length
B
3 changing words
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of First Recall
0
1
2
3
4
5
6
7
8
9
10
11
12
List Length
Start
Last 4
Other
Error