The death of recency: Relationship between end-state comfort and serial position effects in serial recall: Logan and Fischman (2011) revisited

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The death of recency: Relationship between end-state comfort and serial position effects in serial recall: Logan and Fischman (2011) revisited

Abstract

Two experiments examined the dynamic interaction between cognitive resources in short-term memory and bimanual object manipulation by extending recent research by Logan and Fischman (2011). In Experiment 1, 16 participants completed a bimanual end-state comfort task and a memory task requiring serial recall of 12 words or pictures. The end-state comfort task involved moving two glasses between two shelves. Participants viewed the items, performed the end-state comfort task, and then serially recalled the items. Recall was evaluated by the presence or absence of primacy and recency effects. The end-state comfort effect (ESCE) was assessed by the percentage of initial hand positions that allowed the hands to end comfortably. The main findings indicated that the ESCE was disrupted; the primacy effect remained intact; and the recency effect disappeared regardless of the type of memory item recalled. In Experiment 2, 16 participants viewed six items, performed an end-state comfort task, viewed another six items, and then serially recalled all 12 items. Results were essentially the same as in Experiment 1. Findings suggest that executing a bimanual end-state comfort task, regardless of when it is completed during a memory task, diminishes the recency effect irrespective of the type of memory item.

Key words: Motor processes; Learning & Memory

1. Introduction

The end-state comfort effect (ESCE) is defined as the preference of individuals to maximize comfortable hand and arm positions at the completion of object transport tasks, rather than at the beginning. The ESCE has been studied for over 25 years, beginning with the pioneering work of Rosenbaum et al. (1990), as a way to investigate the relationship between the cognitive and physical components of motor behavior. See Rosenbaum, Chapman, Weigelt, Weiss, and van der Wel (2012) for a comprehensive review of the ESCE. The effect has been observed for unimanual and bimanual bar-transport tasks (Fischman, Stodden, & Lehman, 2003; Rosenbaum et al., 1990; Short & Cauraugh, 1999) as well as the overturned glass task (Breslin & Fischman, 2015). For this task, the planning constraint of end-state comfort is apparent when adults reach for an overturned glass to turn it right side up. Typically, initial contact with the glass is made with an awkward pronated grip (thumb-down), followed by supination of the hand at the end of the movement, which ensures a comfortable thumb-up ending posture (Breslin & Fischman, 2015). The overturned glass task is also a simple and functional task that is ecologically relevant (Hughes & Franz, 2008).

Memory performance has received extensive investigation in the field of psychology. Working memory includes processes required for holding and manipulating information while performing cognitive tasks (Baddeley, 2000). A consistent finding of studies examining working memory performance is the serial position effect (Glanzer & Cunitz, 1966; Murdock, 1962). When individuals must recall a sequence of items recall is better for information presented at the beginning (primacy effect) and at the end of the sequence (recency effect), with much lower recall of information towards the middle of the sequence.

Research indicates that the primacy and recency effects can be disrupted through various task manipulations. Recall of primacy and middle items of a sequence can be affected by item presentation rate (Glanzer & Cunitz, 1966), frequency (Raymond, 1969), and list length (Murdock, 1962). The recency effect can be disrupted if participants perform an intervening task after item presentation but before recall of the items. The intervening task does not disrupt the primacy effect. This finding has been demonstrated with an intervening task of mental arithmetic (Glanzer & Cunitz, 1966; Postman & Philips, 1965) and a backward counting task (Bjork & Whitten, 1974). The most common interpretation of this result is that the intervening task clears items from short-term memory (recency items) but items that have already been transferred to long-term memory (primacy items) are unaffected.

Evidence suggests that memory performance is influenced by the level of processing of stimuli (Craik & Tulving, 1975; Paivio, 1969; 1976). Research has demonstrated that in general, pictures are remembered better than words in free recall (Madigan, McCabe, & Itatani, 1972), associative recognition (Hockley & Bancroft, 2011), and item recognition tasks (Defeyter, Russo, & McPartlin, 2009). This finding is known as the picture superiority effect. An explanation of the effect includes the dual-coding hypothesis that holds that pictures are coded at the visual and verbal levels, thus increasing the depth of processing (Paivio, 1969; 1976).

Recently, a line of research has emerged that examined the end-state comfort and serial position effects in the same study (Logan & Fischman, 2011; Weigelt, Rosenbaum, Huelshorst, & Schack, 2009). Participants in Weigelt et al. (2009) used free or serial recall of a memory task (recalling 11 letters) while simultaneously performing the end-state comfort task of opening drawers of different heights. End-state comfort was measured by whether the dominant hand was used and if participants used a “palms up” or “palms down” grip, which should vary according to drawer height. Weigelt et al.’s (2009) results provided partial support for a motor interference hypothesis that stated the serial position effect, including both the primacy and recency aspects, may be affected by performing an intervening motor task. The end-state comfort and primacy effects remained intact and the recency effect disappeared in serial and free recall. Weigelt et al. (2009) suggested that proactive interference might account for the disappearance of the recency effect. Proactive interference suggests that the motor task was sufficiently demanding to influence memory performance and that recall of primacy letters was not influenced because there was not much motor activity yet. However, as the participants continued to open drawers to reveal letters, proactive interference disrupted recall of recency items.

Logan and Fischman (2011) extended the work of Weigelt et al. (2009) by examining the relationship between unimanual and bimanual end-state comfort tasks and memory performance in serial and free recall. The purpose was to determine if the findings of Weigelt et al. (2009) could be replicated during both more complex (bimanual overturned glass task) and simpler (unimanual cylinder task) motor tasks that were completed after all information of the memory task had been presented. In Experiment 1, participants viewed 11 letters, performed the bimanual overturned glass task, and then recalled the letters using serial or free recall. Similar to Weigelt et al. (2009), results indicated that the ESCE remained salient and the recency effect disappeared in serial and free recall, but with greater disruption for serial recall. These results provided partial support for the motor interference hypothesis. Logan and Fischman hypothesized that the results could be due to retroactive interference from the competition between cognitive resources needed for motor planning of the intervening end-state comfort task and mental rehearsal of items for memory recall.

Therefore, Logan and Fischman (2011) conducted a second experiment and hypothesized that simpler motor tasks might “bring back” the recency effect because fewer cognitive resources would be needed for motor planning. In Experiment 2, participants completed a bimanual or unimanual motor task that involved moving one or two plain, non-descript cylinder(s) from an upper shelf to a lower shelf. Participants viewed 11 letters, performed the motor task, and used serial or free recall. Similar to Experiment 1, the primacy effect remained intact and the recency effect disappeared for serial and free recall. Again, the disappearance of the recency effect was more prominent for serial recall. Logan and Fischman suggested that the disruption of the recency effect may have been due to a basic concurrence cost which holds that performance of a primary task is diminished due to the simple awareness of an upcoming secondary task (Navon & Gopher, 1979; Noble, Sanders, & Trumbo, 1981).

A recent series of systematic studies by Spiegel and colleagues (Spiegel, Koester, & Schack, 2013, 2014; Spiegel, Koester, Weigelt, & Schack, 2012) further investigated Logan and Fischman’s (2011) concurrence cost hypothesis within a broader theoretical framework. We briefly review their work next. Spiegel et al. (2012) manipulated high-precision and low-precision movements during the retention phase of a working memory task requiring the recall of 9 random English consonants presented in a 3 x 3 matrix. They found that having to replan high-precision movements produced greater reduction in memory performance than replanning low-precision movements, with the locus of the effect occurring in the planning phase rather than the execution phase. There were no effects of replanning on movement execution time.

Spiegel et al. (2013) conducted three experiments in which the working memory tasks involved the recall of 8 English consonants or 8 symbols (triangles, circles, or squares). The goal of these experiments was to clarify what kind of working memory processes (verbal, spatial, or both) are recruited during movement planning and movement execution. The movement task required high precision. Results showed that movement execution disrupted spatial memory more than verbal memory, regardless of the difficulty of the working memory task (Experiments 1 and 2). However, when a new motor plan had to be implemented during a retention phase (Experiment 3), performance was reduced equally in both types of working memory tasks. Spiegel et al. (2013) interpreted their findings as evidence for distinct roles of working memory in motor actions, where motor execution requires mainly modality-specific capacities, but action replanning requires modality-general memory resources.

Spiegel et al. (2014) also used a spatial working memory task, similar to Spiegel et al. (2013), involving recall of 8 triangles, circles, or squares appearing in a 4 x 4 symbol matrix. This was combined with a grasp-to-place task that required a shift in spatial attention during a retention phase. The shift in spatial attention involved manipulating the spatial compatibility of the tasks. Results showed that preparing a leftward movement produced better memory performance when the stimulus appeared on the left side of the display, while the preparation of a rightward movement resulted in better memory performance for the right stimulus side.

Taken together, the recent work by Speigel and colleagues (Spiegel et al., 2013, 2014; Spiegel et al., 2012) suggests that there are complex interactions among processes involved in movement planning, spatial attention, and visuospatial working memory. To be sure, their work extends our knowledge of concurrence costs in combined motor and memory tasks. However, there are important differences between their work and the research reported here. First, the current experiments required the recall of 12 items (words or pictures), with recall in a serial order. This allowed us to again investigate primacy-recency effects. Second, our motor task is a bimanual end-state comfort task, which is considerably different than the grasp-to-place tasks used by Spiegel and colleagues.

The purpose of the present experiments was to extend the work of Logan and Fischman (2011) by presenting two different types of items during the memory task (Experiment 1 and 2) and presenting the information using a different format (Experiment 2). Because Logan and Fischman found the recency effect disappeared more dramatically during serial recall than free recall, we used only serial recall in the current study. Also, since they were unable to ‘bring back’ the recency effect using a unimanual task, only the bimanual task was used here.

In Experiment 1, participants were presented a sequence of words or pictures, completed the bimanual overturned glass task, and then recalled the items in serial order. Based on previous research (Logan & Fischman, 2011; Weigelt et al., 2009), we expected to find partial support for the motor interference hypothesis. Specifically, three hypotheses were created: 1) the ESCE would remain salient; 2) the primacy effect would remain intact; and 3) the recency effect would remain intact for pictures but not words.

Experiment 1

2. Method

2.1. Participants

Participants were 16 undergraduate students (4 male and 12 female) from Auburn University. All participants were self-reported right-handers and reported no disabilities that could impair performance. They were naïve to the hypotheses being tested. Participants were randomly assigned to one type of information (words or pictures), with the restriction that each condition included two males and six females. All participants completed a bimanual end-state comfort task. Participants provided informed consent before being tested.

2.2. Apparatus, materials, and conditions

The metal shelving unit consisted of two shelves (see Logan & Fischman, 2011 for a picture of the apparatus). The upper shelf was 139.7 cm and the lower shelf was 92.7 cm from the floor. The two drinking glasses were the same size (14.6 cm high, 7.1 cm diameter) and had a band of blue tape (2.6 cm wide) around the bottom for clear identification of glass orientation. At the start of each trial, the glasses were placed 27.9 cm apart on the upper shelf. The lower shelf contained two taped locations for the glasses to be placed, also spaced 27.9 cm apart. Centered midway between the tape marks was a 2½-cup plastic measuring cup containing about ½ cup of water, with the cup's handle facing the participant. Below the two tape marks and cup of water was a rectangular piece of paper (3.8 cm height x 21.6 cm width) divided into 12 equal squares. Participants used this as an aid to recall each item in serial order.

There were two conditions of the bimanual end-state comfort task: (1) Left glass upright, right glass overturned, and (2) Left glass overturned, right glass upright (see Figure 1). The hands were expected to end up symmetrically (i.e., thumbs up) in both conditions because the goal of the task was to ensure that water could be poured into the glasses. Logan and Fischman (2011) analyzed the ESCE by comparing across glass orientations that required symmetrical initial hand positions versus asymmetrical hand positions to satisfy end-state comfort. In the present study, only the two asymmetrical glass orientations were used to allow a different analysis of the ESCE.

Insert Figure 1 About Here

The memory task had two conditions containing either 12 words or 12 pictures. For both conditions, items were presented on a personal computer located on a desk adjacent to the end-state comfort shelves. Participants faced the computer and the shelves were located next to and behind them, out of view. As the items were presented, an experimenter placed the glasses on the upper shelf according to the condition being tested. The words and pictures were presented in one of the following two sequences (see Figure 2):

(1) Shirt, Frog, Clock, Star, Heart, Flag, Truck, Hose, Flute, Tent, Phone, Cake

(2) Flute, Tent, Heart, Frog, Truck, Flag, Shirt, Cake, Phone, Hose, Clock, Star

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Insert Figure 2 About Here

The information was presented using Microsoft PowerPoint. The words were presented in capital letters, on a white background, in bolded black text, using Times New Roman font (size 120), and centered in the middle of the screen. The pictures were presented in color, on a white background, and were similar in size as the words. The pictures were found through a Google search of clip art images.

The words we used, and the order in which they were presented, met the following characteristics: First, they contained only one syllable. Serial recall performance is influenced by word length (i.e., number of syllables and phonemes; Baddeley, Thomson, & Buchanan, 1975). This is because the amount of time needed for participants to articulate the information during recall influences memory performance (Hulme, Maughan, & Brown, 1991). Second, we arranged the two different sequences of items so that words with phonological similarity were not adjacent to each other (e.g., Flag and Flute were not presented consecutively). Third, no words could be combined to form a compound word and the words did not rhyme. Previous research has indicated that recall for items that rhyme (i.e., phonologically confusable) is worse compared to non-similar phonological items (Baddeley, 1966a, b, 1968; Conrad & Hull, 1964). Fourth, we chose words that were common in the English language and could be easily recognized as pictures.

2.3. Design and procedure

A verbal and written description of the task was provided to participants prior to the start of the experiment. Instructions included the following: *"1) You will be presented* *with 12 words or pictures (according to the condition being tested) on a computer screen and each item will remain on the screen for three seconds before advancing to the next item, 2) At the end of the presentation of items you will turn to the shelves and there will be two drinking glasses placed on the upper shelf, 3) Grasp both drinking glasses around the middle at the same time and move them to the tape marks on the lower shelf, 4) On the lower shelf, there will be a measuring cup of water and you are to fill each glass with about an inch of water, 5) You will recall the items that had been presented to you in the same order in which they were presented."*

Participants completed the end-state comfort task for both glass orientations and both of the item sequences (total two trials). The sequences of memory presentation and glass orientation were tested in a balanced order using the same combinations within each condition, with participants randomly assigned to a particular order.

Twelve boxes were printed horizontally on a small, rectangle-shaped piece of paper to aid participants with the serial recall of items. The participants pointed to a box as they recalled each item in order and said the word "something" if that particular item could not be recalled. Participants performed the motor task at a comfortable speed, while trying to remember as many items as possible in order. The items were recalled verbally to the researcher who recorded the responses. At the conclusion of the experiment, participants were asked to describe what, if any, strategies they used to help remember the items. Also, participants were asked if there were any specific aspects of the study that were difficult.

2.4. Performance Measures

The ESCE was evaluated by the percent of initial hand positions that allowed the hands to end up comfortably. For example, in Condition 1, when the right glass is overturned, the initial grasps should be a "thumb down" position in the right hand, and a "thumb up" position in the left hand. This would ensure when the glasses are turned over and placed on the lower shelf, both hands end up in the comfortable "thumbs up" position. It is important to note that in both end-state comfort conditions, the hands were expected to end up symmetrically (thumbs up). In both conditions, the glasses were oriented in opposite positions. Thus, to satisfy end-state comfort, the initial grasps of the hands should be asymmetrical.

The following measures of memory performance were calculated: number of total items recalled in any order, in the correct serial order, and items of the primacy positions (first three items to evaluate the primacy effect) and recency positions (last three items to evaluate the recency effect).

3. Results

3.1. End-State Comfort Effects

Results indicated the following percentages of participants that demonstrated initial hand positions that satisfied the ESCE for condition (1) Left glass upright (100%), right glass overturned (68.75%), and (2) Left glass overturned (68.75%), right glass upright (93.75%). These percentages are similar to those reported in Logan and Fischman (2011): 100% (left hand) and 75% (right hand) for Condition 1 and 66.7% (left hand) and 91.7% (right hand) for Condition 2. However, as mentioned, their analyses did not statistically compare these two conditions.

A 2 (glass orientation) x 2 (hand) ANOVA with hand as a repeated measures factor revealed no significant main effect of glass orientation (F (1, 30) = .13, p = .72, partial eta^2 = .004) or hand (F (1, 30) = .11, p = .74, partial eta^2 = .004), but a significant interaction between the factors (F (1, 30) = 9, p = .005, partial eta^2 = .23). This suggests that depending upon glass orientation, the left and right hands did not always act in conjunction with each other to satisfy end-state comfort. All participants were self-reported right-handers and it appears that condition 2 (left glass overturned, right glass upright) was more difficult for participants, suggesting that when the non-dominant hand must plan for end-state comfort, planning of the dominant hand is also affected.

3.2. Memory

Participants reported that the amount of information and the requirement to recall items in serial order were difficult aspects of the experiment. Also, participants reported several common strategies to aid recall of the words such as mental repetition, attempting to group words together by sound or category, making sentences, creating a story, or visually imagining the object the word represented. Similar strategies were reported by participants to aid in recall of pictures, with the exception of using visual imagery.

For analysis, memory performance was combined across both end-state comfort conditions. See Table 1 for the mean number of items recalled in any order, in serial order, and of the primacy and recency positions. See Figure 3 for a graphical representation of the serial position curves. The curves suggest a primacy effect, but no recency effect. A 2 (memory type) x 2 (serial position items) ANOVA with primacy and recency items as a repeated measures factor confirmed this suggestion. There was a significant difference between primacy and recency items (F (1, 30) = 102.8, p < .001, partial eta $^2 = .77$) indicating that recall for primacy items was significantly higher than recency items. There was no significant main effect of memory type (F (1, 30) = .02, p = .88, partial eta $^2 = .001$) or interaction effect (F (1, 30) = .65, p = .43, partial eta $^2 = .02$). Thus, memory performance was similar across words and pictures.

Insert Table 1 and Figure 3 About Here

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4. Discussion

The main findings of Experiment 1 include: 1) the ESCE was disrupted; 2) the primacy effect remained intact; and 3) the recency effect disappeared regardless of the type of memory item used.

The disruption we found in the ESCE indicates that depending on the glass orientation, the left and right hands did not act together to satisfy end-state comfort. This finding lends support to the cognitive interference hypothesis that suggests the mental rehearsal of items of a memory task may influence motor planning. This result also supports other research that found motor planning difficulties under bimanual conditions (Hughes et al., 2011; Janssen et al., 2010), especially for the non-dominant hand (Janssen et al., 2009; Seegelke et al., 2012).

Each of the previous studies that examined the relationship between end-state comfort and serial position effects presented letters during the memory task (Logan & Fischman, 2011; Weigelt et al., 2009). Logan and Fischman speculated that perhaps the serial position curve was susceptible to disruption because only a low level of processing was required to recall letters. Thus, we wanted to determine if an intervening motor task disrupts the serial position curve for different types of information, such as words and pictures, which is thought to require a deeper level of processing. Our hypothesis that the primacy effect would remain intact was supported but our hypothesis that the recency effect would remain intact for pictures but not words was not. Thus, it appears that an intervening motor task diminishes the recency effect similar to cognitive intervening tasks across different types of memory items (Bjork & Whitten, 1974; Glanzer & Cunitz, 1966; Postman & Philips, 1965). This suggests motor planning and physical movement clears items from short-term memory and disrupts recall of recency items, but long-term memory is not affected, as evidenced by the presence of the primacy effect.

Navon & Gopher (1979) showed that the performance of a primary task might be affected by the mere presence of a secondary task because each will draw upon shared cognitive resources. This phenomenon is known as a concurrence cost (Navon & Gopher, 1979) and is supported by research on performance of motor tasks (Fischman, McAlister, & Kinley, 2005; Hart, Dornier, & Reeve, 2006; Noble, Sanders, & Trumbo, 1981). Logan and Fischman (2011) suggested that the awareness of the upcoming motor task might have affected typical recall performance, which supports the notion of a concurrence cost. However, neither Weigelt et al. (2009), Logan and Fischman (2011), nor Experiment 1 of the current study presented the memory task items *after* completion of the end-state comfort task. Thus, previous research on the end-state comfort and serial position effects has not directly tested the concurrence cost hypothesis (Also see work by Spiegel et al., 2013, 2014, and Spiegel et al., 2012 for another perspective on concurrence costs, but for different motor and memory tasks than those used here).

The purpose of Experiment 2 was to determine the effect of performing an intervening motor task halfway through item presentation on the serial position curve during serial recall. Since this experiment presented six of the memory items before and six after performance of the end-state comfort task, the definition of primacy and recency items were modified to include four variables: $Primacy_1$ (Items 1-3), $Recency_1$ (Items 4-6), $Primacy_2$ (Items 7-9), and $Recency_2$ (Items 10-12). This modification allowed primacy and recency items to be defined for each half of the items according to whether they were presented before or after the end-state comfort task.

We tested two hypotheses: 1) the ESCE would be disrupted (based on results from Experiment 1); 2) recall of $Primacy_1$ and $Recency_1$ would be lower compared to $Primacy_2$ and $Recency_2$. Participants were aware of a secondary motor task during the presentation of the first six items. After completion of the motor task, the next six items were presented with no additional secondary motor task. Thus, we expected typical memory performance of the last six items presented.

Experiment 2

5. Method

5.1. Participants

Participants were 16 undergraduate students (4 male and 12 female) from Auburn University. All participants were self-reported right-handers and reported no disabilities that could impair performance. They were naïve to the hypotheses being tested. Participants were randomly assigned to one type of information (words or pictures), with the restriction that each condition included two males and six females. All participants completed a bimanual end-state comfort task. Participants provided informed consent before being tested.

5.2. Apparatus and materials

These were the same as in Experiment 1.

5.3. Design and procedure

All design and procedure aspects of Experiment 2 were the same as those in Experiment 1, with one exception. In Experiment 2, the memory items (words or pictures) were presented six items at a time. The first six items were presented, participants completed the end-state comfort task, the last six items were presented, and then the 12 words or pictures were recalled in serial order.

A verbal and written description of the task was provided to participants prior to the start of the experiment. Instructions included the following: *"1) You will be presented with 6 words or pictures (according to the condition being tested) on a computer screen and each item will remain on the screen for three seconds before advancing to the next item, 2) At the end of the presentation of the first 6 items you will turn to the shelves and there will be two drinking glasses placed on the upper shelf, 3) Grasp both drinking glasses around the middle at the same time and move them to the tape marks on the lower shelf, 4) On the lower shelf, there will be a measuring cup of water and you are to fill each glass with about an inch of water, 5) Turn back to the computer screen and press the right arrow on the keyboard to start the presentation of the next 6 items, 6) After all the information has been presented, you will recall the items that had been presented to you in the same order in which they were presented."* The sequences of memory presentation and glass orientation were tested in a balanced order using the same combinations within each condition, with participants randomly assigned to a particular order.

5.4. Performance Measures

All performance measures were the same as in Experiment 1, with one exception. Since this experiment presented six of the memory items before and six after the end-state comfort task, the definition of primacy and recency items were modified to include four variables: $Primacy_1$ (Items 1-3), $Recency_1$ (Items 4-6), $Primacy_2$ (Items 7-9), and $Recency_2$ (Items 10-12). Alpha level was set to .05 a priori.

6. Results

6.1. *End-state comfort*

Results indicated the following percentages of participants that satisfied the ESCE for condition (1) Left glass upright (87.50%), right glass overturned (56.25%), and (2) Left glass overturned (68.75%), right glass upright (87.50%). Similar percentages were found as those reported by Logan and Fischman (2011) with one exception. For Condition 1, 56.25% of participants initially grasped the glass with the right hand with a thumb position that satisfied the ESCE. This percentage is somewhat lower than previously reported in the same condition of the bimanual overturned glass task (Logan & Fischman, 2011). A 2 (glass orientation) x 2 (hand) ANOVA with left and right hands as a repeated measures variable was conducted. Results indicated no significant main effect of glass orientation (F (1, 30) = .38, p = .54, partial eta ^{2} = .01) or hand (F (1, 30) = .32, p = .58, partial eta ^{2} = .01) but a significant interaction between the factors (F (1, 30) = 5.1, p = .03, partial eta ^{2} = .14). This suggests that depending upon glass orientation, the left and right hands did not always act in conjunction with each other to satisfy end-state comfort.

6.2. *Memory*

Participants reported similar difficult aspects of the study and strategies to aid memory recall of words and pictures as those reported in Experiment 1. Several reported that completing the motor task in the middle of the memory task was difficult. Memory performance was combined across both trials of each end-state comfort task for analysis. See Table 2 for the mean number of items recalled in each condition. See Figure 4 for a graphical representation of the serial position curves.

Insert Table 2 and Figure 4 About Here

A 2 (memory type) x 4 (serial position items) ANOVA with $Primacy_1$, $Recency_1$, $Primacy_2$, $Recency_2$ as repeated measures variables was calculated. Results indicated a significant main effect of serial position items (F (1, 30) = 71.4, p < .001, partial eta ^{2} = .7). There was no significant main effect of memory type (F (1, 30) = .07, p = .8, partial eta ^{2} = .002) or interaction effect (F (1, 30) = .49, p = .49, partial eta ^{2} = .02). Planned contrasts were calculated for all pairwise comparisons across serial position items. Results indicated that recall for $Primacy_1$ was significantly higher compared to $Recency_1$, $Primacy_2$, and $Recency_2$ (p < .001). Recall of $Primacy_2$ was also significantly higher compared to $Recency_2$ (p = .03). No other significant differences were found.

A Cochran’s Q test was calculated to determine if a significant difference in recall existed between item 6 and item 7. Cochran’s Q is a non-parametric test for repeated measures of a binary variable (yes/no item recall). Cochran's Q indicated a significant difference in recall of item 6 and item 7, suggesting higher recall for item 7 ($Q(1) = 14.2$, $p < .001$).

7. Discussion

The main findings of Experiment 2 include: 1) the ESCE was disrupted, as in Experiment 1; 2) there was no concurrence cost. It appears that the ESCE was disrupted to the same extent regardless of the number of items being rehearsed.

The concurrence cost hypothesis states that the mere awareness of an upcoming secondary task may draw upon shared cognitive resources required for successful completion of a primary task (Navon & Gopher, 1979). Based on this hypothesis, we predicted that recall of Primacy_1 and Recency_1 would be diminished compared to Primacy_2 and Recency_2. However, we did not find this result. In fact, items of Primacy_1 were recalled significantly better compared to all other portions of the sequence, suggesting a strong primacy effect regardless of when the end-state comfort task was completed. We thought that awareness and performance of the motor task would clear the six items from participants' working memory, thus freeing up cognitive resources for better recall performance of items presented after the motor task. Furthermore, recall of Recency_1 items was significantly better than Recency_2 items. Again, the Primacy_2 and Recency_2 items of the current experiment were presented after completion of the secondary motor task. Thus, there was no awareness of an upcoming task. Yet, recall of these items suffered. It appears that our results do not support a concurrence cost hypothesis.

Logan and Fischman's (2011) explanation for the disappearance of the recency effect included the retroactive interference hypothesis which holds that the completion of an intervening task affects previously presented items of a memory task (Glanzer & Cunitz, 1966). However, during Experiment 2 the items were presented *before* and *after* the intervening motor task. Thus, retroactive interference cannot account for the current results because recall of $Primacy_1$ items was better compared to other portions of the sequence.

Perhaps a better explanation of the current results is a traditional one. Primacy and recency effects have been attributed to the relative contribution of long-term memory (LTM) and short-term memory (STM), respectively, to memory recall (Glanzer & Cunitz, 1966). We suggest that the primacy effect may be due to contributions of LTM because participants have more time to rehearse items presented at the beginning of the sequence (Hockey, 1973; Rundus, 1971; Tam & Ward, 2000). The recency effect may be due to retrieval of items that are still present in STM since a limited amount of time passed between item presentation and recall. This explanation accounts for the salience of recall of $Primacy_1$. It is possible that simply too much time elapsed from the presentation of $Recency_2$ items to recall for STM to contribute to the recency effect.

Between-Experiments Analyses

Based on our results, we created two hypotheses: Recall might be higher for Experiment 2 because participants may treat each half of the list separately, thereby 1) recalling more total items; and 2) recall of item 7 may be higher due to the emergence of a second primacy effect for the second half of the list.

Based on similar recall performance for both words and pictures, results were combined for each type of memory items. An independent samples t-test was calculated to determine if overall serial recall was different between Experiment 1 and 2. Results indicated no significant difference in serial recall between experiments (t (62) = -1.5, p = .77). After visual inspection of the serial position curves, a post-hoc independent samples t-test was calculated to determine specifically if recall of item 7 was different between Experiment 1 and 2. Results indicated significantly better recall of item 7 for Experiment 2 (54.7%) compared to Experiment 1 (7.8%; t (62) = -5.69, $p < .001$).

We also found four categories of participants across the two experiments (n = 32) in terms of demonstrating end-state comfort: Participants that showed (1) end-state comfort for both hands across both glass sequences (n = 10), (2) end-state comfort for both hands across only one glass sequence (n = 18), (3) end-state comfort only for the hand that moved the upright glass of both glass sequences (n = 3), and (4) end-state comfort only for the hand that moved the upright glass during one glass sequence (n = 1). These individual differences in sensitivity to end-state comfort in bimanual tasks have also been reported in other studies. For example, Hughes, Seegelke, Reißig, and Schütz (2012) found that 40% of their participants used an overhand grip in all conditions and thus were insensitive to end-state comfort (also see Fischman et al., 2003; Janssen et al., 2010; and Rosenbaum et al., 1990 for additional examples). Janssen et al. (2010) speculated that such a subset of individuals may have impaired motor planning abilities. This is certainly a question worthy of further research.

8. General Discussion

This study builds upon previous work by presenting two different types of items during the memory task (Experiment 1 and 2) and presenting the information using a different format (Experiment 2). Regardless of the type of information presented (i.e., words or pictures) or presentation format, the primacy effect remained intact, but the recency effect was disrupted. The number of primacy and recency items recalled is strikingly similar between experiments and the pattern is similar to that found by Logan and Fischman (2011). The present study demonstrates that performing an intervening motor task yields similar results to performing an intervening cognitive task (Logan & Fischman, 2011; Weigelt et al., 2009). Our results suggest that there was sufficient competition between cognitive resources that led to a decrease in performance on each task. This lends further support to the dynamic interaction between cognition, action, and object manipulation (see Rosenbaum et al., 2012 for a review). One potential explanation for "death" of the recency effect may be due to how technology has changed the way people use working memory in the rehearsal and recall of information. Technology, in particular 'smart' phones, provides instant access to the ability to record and access information. It is possible that traditional rehearsal and recall patterns are changing. Recent work by Barr, Pennycook, Stolz, and Fugelsang (2015), who studied a large sample of individuals (N = 398 across two studies; M_{age} = 35 years) provides an interesting negative perspective on the use of smartphones, and their position certainly warrants further investigation.

Our hypothesis that total serial recall would be greater in Experiment 2 compared to Experiment 1 was not upheld. Chunking of information is a common strategy that aids recall performance. We thought that perhaps in Experiment 2 serial recall would be higher because presentation of the 12 items was already separated into two “chunks”, thereby providing an additional aid for recall. However, no difference was found. Two interesting findings include the “bumps” in memory performance of item 7 of Experiment 2 compared to item 7 of Experiment 1 and item 7 compared to item 6 in Experiment 2. Because item 7 is the first item presented after the completion of the motor task, this result can potentially be accounted for by the traditional interpretation that performance of an intervening activity “clears” items from STM, resulting in a disruption of recall of recency items, but not primacy items. It is possible that by performing the motor task, items of $Recency_2$ were somewhat cleared and allowed item 7 to be recalled. It is also possible that not enough time elapsed from presentation of item 7 to recall in order for this item to be cleared from STM.

Our findings suggest that the physical execution of an end-state comfort task, regardless of when it is completed during a memory task, disrupts the end-state comfort and recency effects. This suggests that there was sufficient competition between cognitive resources that led to a decrease in performance on each task. However, a limitation of the present study is the lack of control conditions in which participants performed the end-state comfort task and the memory task in isolation of other tasks. This is important to keep in mind and our results should be interpreted with caution. Future research should continue examining the relationship between end-state comfort and memory. One potential research direction would be to determine if serial position effects exist for physical movements. That is, if participants perform a sequence of end-state comfort movements and are then asked to recall those movements using serial recall, are serial position effects present? This experiment is currently underway in our laboratory.

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Table 1. Mean (± SD) number of items recalled for each condition (Experiment 1).

Item Type	Total (no order)	In Order	Primacy Items 1-3	Items 4-6	Items 7-9	Recency Items 10-12
Words	6.6 (1.9)	3.1 (2.5)	2.1 (1.2)	.5 (.97)	.31 (.6)	.25 (.45)
Pictures	6.9 (1.2)	3.8 (1.8)	2.2 (.9)	1.3 (1.1)	.25 (.45)	.06 (.25)

Table 2. Mean (± SD) number of items recalled for each condition (Experiment 2).

Item Type	Total (no order)	In Order	$Primacy_1$ Items 1-3	$Recency_1$ Items 4-6	$Primacy_2$ Items 7-9	$Recency_2$ Items 10-12
Words	6.1 (1.5)	4.1 (1.9)	2.3 (.78)	.81 (.98)	.88 (1)	.19 (.4)
Pictures	7.7 (2.2)	4.3 (2.2)	2.3 (1.1)	.69 (.95)	.94 (1)	.44 (.73)

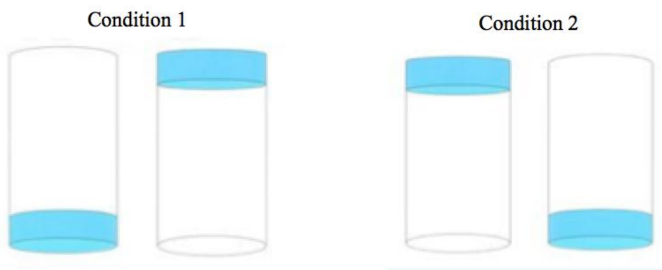

Figure 1. Representation of each bimanual end-state comfort task condition. Blue tape was placed around the bottom of each glass. This allowed clear distinction of the top and bottom of the glass.

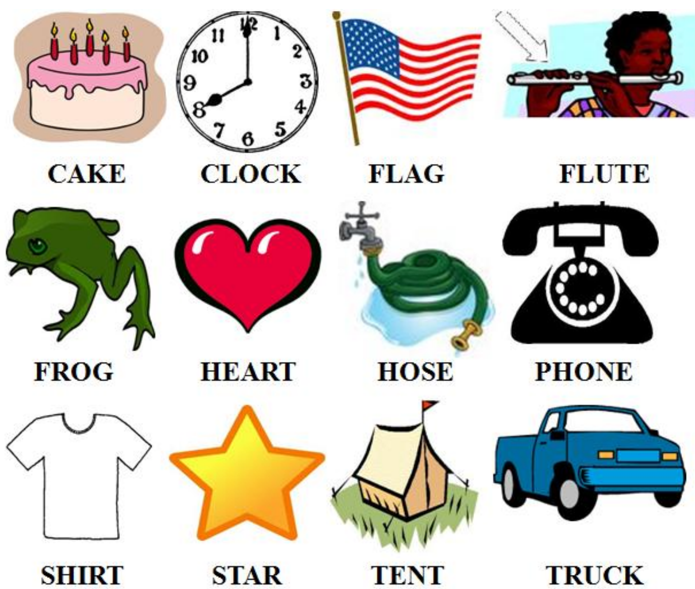

Figure 2. Visual representation of the words and pictures used in the present study.

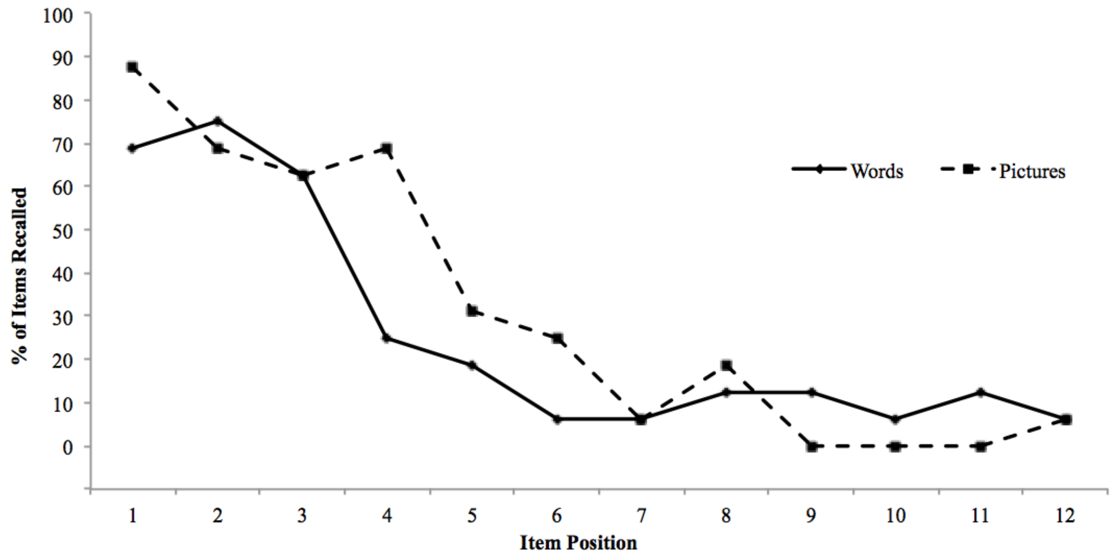

Figure 3. Serial position curves for Experiment 1. Separate lines are provided for each combination type of memory items. Percentages of items recalled for positions 1 to 12 in the random sequence of items.

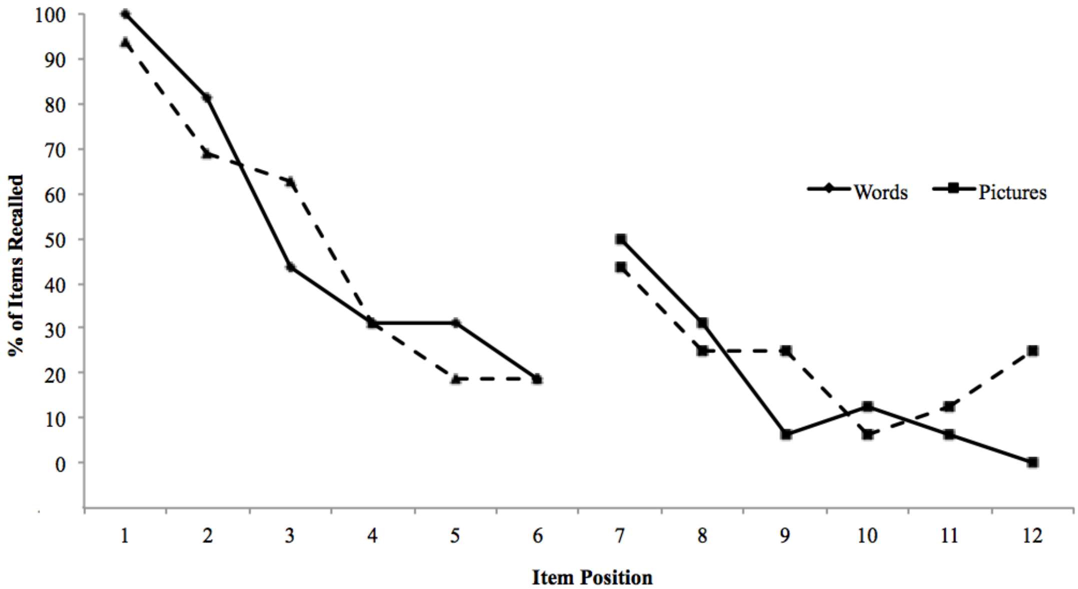

Figure 4. Serial position curves for Experiment 2. Separate lines are provided for each type of memory items. Percentages of items recalled for positions 1 to 12 in the random sequence of items.

Table(s)

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Item Type	Total (no order)	In Order	Primacy Items 1-3	Items 4-6	Items 7-9	Recency Items 10-12
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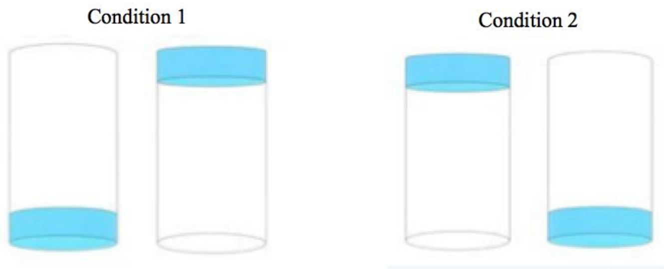
Pictures	6.9 (1.2)	3.8 (1.8)	2.2 (.9)	1.3 (1.1)	.25 (.45)	.06 (.25)

Table 2. Mean (± SD) number of items recalled for each condition (Experiment 2).

Item Type	Total (no order)	In Order	$Primacy_1$ Items 1-3	$Recency_1$ Items 4-6	$Primacy_2$ Items 7-9	$Recency_2$ Items 10-12
Words	6.1 (1.5)	4.1 (1.9)	2.3 (.78)	.81 (.98)	.88 (1)	.19 (.4)
Pictures	7.7 (2.2)	4.3 (2.2)	2.3 (1.1)	.69 (.95)	.94 (1)	.44 (.73)

Figure(s)



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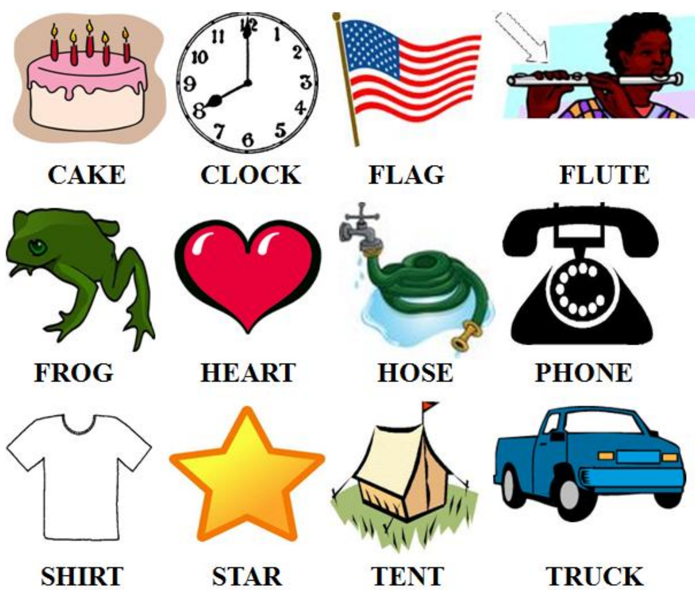

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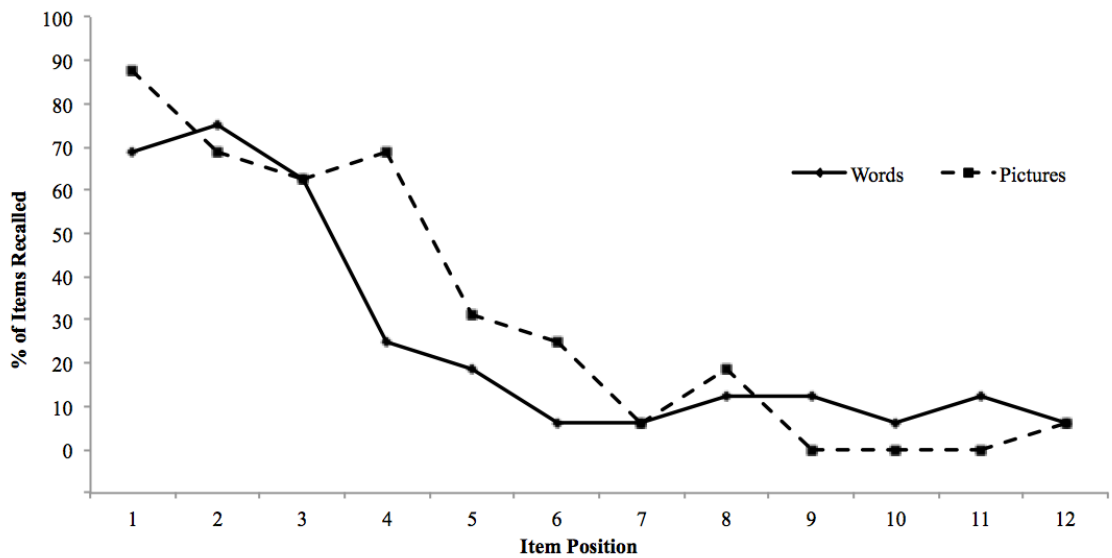

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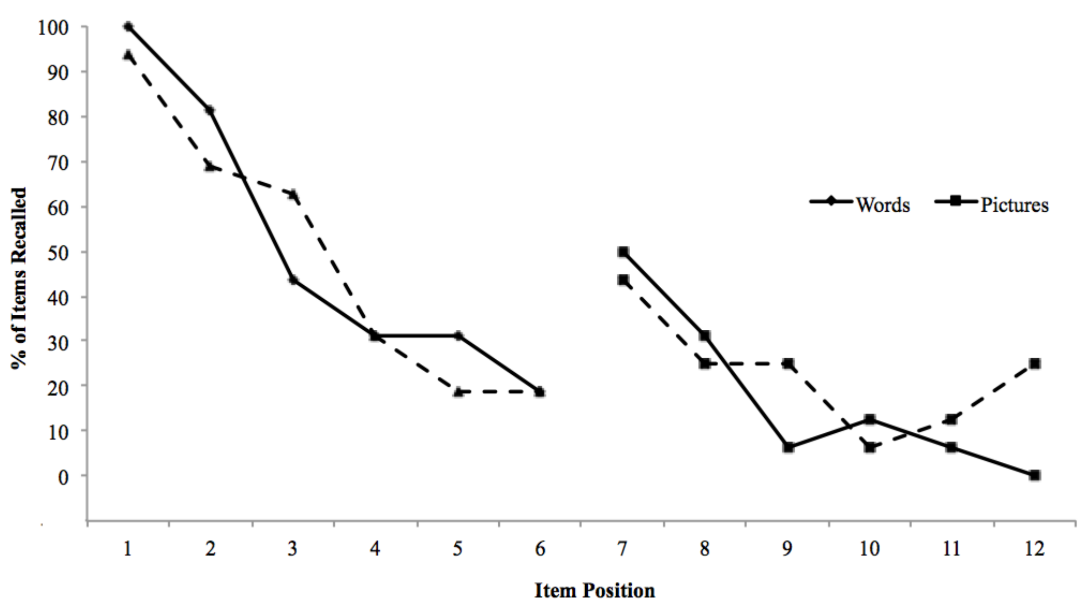

Figure 4. Serial position curves for Experiment 2. Separate lines are provided for each type of memory items. Percentages of items recalled for positions 1 to 12 in the random sequence of items.