The Recall Dynamics of Importance in Delayed Free Recall

by

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ABSTRACT

An emerging literature on the relation between memory and importance has shown that people are able to selectively remember information that is more, relative to less important. Researchers in this field have operationalized importance by assigning value to the different information that participants are asked to study and remember. In the present investigation I developed two experiments, using a slightly altered value-directed-remembering (VDR) paradigm, to investigate whether and how value modifies the dynamics of memory organization and search. Moreover, I asked participants to perform a surprise final free recall task in order to examine the effects of value in the recall dynamics of final free recall. In Experiment 1, I compared the recall dynamics of delayed and final free recall between a control and a value condition, in the latter of which numbers appeared next to words, in random order, denoting the value of remembering each word during recall. In Experiment 2, I manipulated the order of presentation of the values by adding an ascending and a descending condition where values were presented in either an ascending or a descending order, respectively. Overall, my results indicated that value affected several measures of delayed and final free recall, without, in most cases, taking away the serial position effects on those same measures.

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Chapter 1

INTRODUCTION

Why does our memory system prioritize and organize information and how does the subjective importance of that information interact with this process? Humans encounter a vast amount of information on a daily basis that has no importance or bearing on their lives. Thus, the ability to select and successfully remember information that is more important, while simultaneously ignoring information that is less important is an essential cognitive ability. For example, students want to remember information that is important for an upcoming test, professionals want to remember information that is important for an upcoming meeting, and family members want to remember information that is important for them and the people they love. Recently, researchers have begun exploring the relation between the memorability of information and the importance of that information. The current project aims to extend our understanding of the relation between importance and memory by bringing importance into the context of a delayed free recall paradigm.

In his article entitled "What memory is for" Glenberg (1997) argues that the human memory system could not have evolved simply to serve intentional learning and voluntary retrieval. In fact, one important function of the human memory system is that it can adapt to environmental relations to enable accessibility of important information at appropriate moments in time (Anderson & Schooler, 2000). Therefore, the memory system likely evolved sophisticated mechanisms to assist us with remembering information that is behaviorally relevant, valuable, and important for survival.

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Many studies have demonstrated that memory is sensitive to the value of information, either at encoding or retrieval. These findings include enhanced memory for information relating to one's self (Rogers, Kuiper, & Kirker, 1977; Symons & Jonson, 1997) as well as other people close to them (Rogers et al., 1977), enhanced memory for information relating to survival needs (Nairne, Thompson, & Pandeirada, 2007), enhanced memory for salient events (flashbulb memories; Brown & Kulik, 1977), and enhanced memory for meaningful aspects of an event (e.g. Wanner, 1968). It therefore appears that individuals can flexibly assess the importance of information during encoding, and that this assessment influences what information is likely to be retrieved. What remains unclear is whether assessing the importance of information at encoding modifies the manner in which individuals organize and search their memory during recall.

Free recall studies typically give participants the freedom to subjectively organize the encoding and retrieval of word lists into episodic memory (Tulving, 1962). This research has failed to take into account the possibility that information value may guide the organizational principles at encoding and possibly influence search principles at retrieval. Employing mnemonic materials that are either inherently important (e.g. self-relevant) or are given arbitrary importance values is a necessary step for evaluating whether many principles of episodic memory hold up under more ecological conditions. Making memory research more ecologically representative will facilitate the development of theories that are based on a broader variety of mnemonic experiences and allow researchers to apply theoretical explanation at a higher-level of generality rather than at the level of individual tasks (Hintzman, 2011).

The goal of the present investigation is to develop novel insights about how value modifies the dynamics of memory organization and search in free recall. We intend to achieve this goal by investigating the effects of value at encoding on free recall regularities that emerge at retrieval (e.g., serial position effects). Anderson and Schooler (2000) previously argued the importance of studying "detailed, nonobvious predictions" (p. 568) in regards to importance and memory. While free recall is not the most ecologically representative task, we believe that studying free recall within the context of value will make the task more ecologically representative and will bring us a step closer to understanding how memory actually works in naturalistic settings.

Importance And Memory

Human memory research suggests that motivation to remember, especially when it arises before rather than after the information is encoded (Loftus & Wickens, 1970; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000), allows people to attend and organize information in ways that facilitate storage in long-term memory (Kassam, Gilbert, Swencionis, & Wilson, 2009). One way of increasing motivation to remember is assigning importance values to the to-be-remembered items (Watkins and Bloom, 1999). While assigning importance values to options has been a central component in the decision making literature, especially in regards to choice behavior (Tversky, 1969, 1972), little research has investigated the effects of importance on memory.

The majority of studies that have investigated the relation between memory and importance have implemented a value-directed remembering paradigm (VDR), a procedure developed by Watkins and Bloom (1999). In a typical VDR paradigm,

participants are given a list of words to study for a later memory test. These words vary in importance values. The way to achieve this is to assign an importance "value" to each word (illustrated by a number next to the word; i.e., chicken 4). Participants are instructed that, during a subsequent recall test, they will be awarded the associated point value of the words they are able to recall. The participants' goal is to maximize the points they accumulate through recall.

A general finding from the studies that have used the VDR paradigm is that participants tend to remember the more important (higher-value) words significantly more than the less important (lower-value) words (Castel, Farb, & Craik, 2007; Castel, 2008; Ariel et al., 2009; Soderstrom, & McCabe, 2011; Castel, Rhodes, McCabe, Soderstrom, & Loaiza; 2012). However, Madan and Spetch (2012) observed a U-shaped relation between importance and memory, supporting the idea that value salience, and not value per se, affects memory. Madan and Spetch showed that in a VDR paradigm participants remembered both the high-value and the low-value words significantly more often than the words with medium values. This result suggests that the salience of the values might be equally as important and interesting to explore as the importance values themselves.

Several other studies have provided additional insight regarding the relation between memory and importance. Castel et al. (2002) showed that while younger adults recall more words than older adults, older adults are more successful at selecting the more important words. Castel argued that as we get older, and as cognitive and memory resources become more limited, we begin to use our memory system in different ways.

Given that individuals are aware that they cannot remember everything, these strategies allow them to focus on what they deem more important (Castel, 2008).

In a later study, using the aforementioned VDR paradigm, Castel et al. (2012) showed that not only do participants remember higher value words more often, but that they also misremember the values such that remembered words are erroneously given higher values. Also, when participants were given the list of the words they had initially studied and were asked to try to recall the value that was associated with each word during study phase, they generally remembered lower values for the words they had not recalled. Therefore, participants deemed remembered information as more important and forgotten information as less important. Bui et al. (2013), using a hybrid of the VDR and the Deese-Roediger-McDermott (DRM) paradigms, also showed that lists with high-value words led to increased false memories compared to a list with low-value words. Taking these results a step further, unpublished research from our laboratory demonstrated that when judging the importance of scientific theories participants based their judgments, in part, on memory accessibility for that information (Stefanidi & Brewer, manuscript in preparation). Specifically, when participants were able to recall the name of a theory they had previously studied they assessed it as more important than theories whose names they were not able to recall. Together, these findings provide evidence that memory is sensitive to value at encoding and organized at retrieval based on the subjective importance of information.

Importance And Metacognition

The use of values to study the effects of importance within the metacognitive framework is a great illustration of how the study of importance within different

experimental paradigms may allow us to generalize our understanding of memory processes across tasks. Until recently, most self-regulated study theories focused on item difficulty. A literature review by Son and Metcalfe (2000), demonstrated that in 31 experiments and 46 conditions, participants allocated more study time to difficult items in 35 conditions, intermediate items in 3 conditions, while participants did not show any preference in 8 conditions. Additional research has focused on the importance of perceived item difficulty in study regulation, demonstrating that task constraints, like the amount of study-time available, will also influence study time allocation (Metcalfe & Kornell, 2005; Koriat, Ma'ayan, & Nussinson, 2006).

Until recently, the two most well-known theories regarding self-regulating study, namely the discrepancy reduction hypothesis (Dunlosky & Hertzog, 1998) and the region of proximal learning hypothesis (Metcalfe, 2002), made their predictions primarily based on item difficulty. Ariel, Dunlosky, and Bailey (2009) utilized the VDR paradigm within the metacognitive framework to develop a theory that complimented previous theories of self-regulated study. According to the agenda-based regulation of study-time allocation (Ariel et al., 2009) participants use agendas to make decisions regarding study time allocation depending on their goals as well as on task constraints. Ariel et al. asked participants to study word pairs, of varying difficulty that were parametrically manipulated to have high and low value. Critically, participants were also given the opportunity to restudy some of those word-pairs before attempting recall. Ariel et al. observed that participants spent more time studying higher-values word-pairs, regardless of their level of difficulty. Moreover, participants chose to restudy higher-value word-pairs more often than lower-value words, regardless of their level of difficulty.

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Ariel et al. (2009) proposed that their results demonstrate that participants develop agendas that guide their study-time allocation decisions as well as their restudy decisions. Most importantly, they argued that "agendas can dominate regulation, whereas the aforementioned theories focus on how monitoring item difficulty drives regulation" (p. 444). In a more recent experiment, Soderstrom and McCabe (2011) replicated Ariel et al. by showing that participants spent more time studying higher-value than lower-value word-pairs. Moreover, Soderstrom and McCabe (2011) demonstrated that participants provide higher judgments of learning (JOLs) for those higher-value word-pairs.

It appears that learners are able to exhibit some meta-awareness regarding the significance of item importance. Most importantly, it appears that the utilization of materials that differ in their value of importance allowed researchers in the field of metacognition to develop a theory that compliments all previous theories regarding self-regulated study. Moreover, utilizing such materials within the metacognitive framework allowed researchers to understand the processes of self-regulated study from a more ecological perspective. The aim of the present investigation is to utilize such materials in the study of delayed free recall in order to investigate delayed free recall within a more ecological framework and ultimately compliment previous memory theories.

Recall Dynamics In Delayed Free Recall

Memory researchers have investigated the dynamics of delayed free recall for well over half a century to explore the organization and search of episodic memory (Murdock, 1974; Kahana, 2012; Tulving, 1968). In a delayed free recall paradigm participants are presented with several lists of words each in a random order. After participants study each list, they perform a brief distractor task and are then asked to

retrieve as many words from the list as possible. Several systematic effects, that we now consider regularities of episodic memory, have been established via examination of delayed free recall data (Kahana, 2012).

In 1962 Murdock reported his classic findings on the relation between serial position and recall probability. Participants exhibited superior memory for the items that appeared at the beginning (primacy effect) and the end (recency effect) of the study list, even though the recency effect is diminished in delayed free recall. The primacy effect spans the first three or four items of each list, while the recency effect spans over the last eight items. Moreover, Hogan (1975) and Laming (1999) showed that subjects initiate recall with one of the last items of the study list, even though this effect is also diminished in delayed free recall (Howard & Kahana, 1999). More specifically, Howard and Kahana (1999) showed that probability of first recall – which item in the list that a participant outputs at the beginning of recall - is higher for either the last word presented in the list (immediate free recall) or the first word presented in the list (delayed free recall).

Temporal contiguity during study has also shown to affect output dynamics at retrieval. Kahana (1996) demonstrated that participants tend to successfully recall items from nearby list positions, as seen by plotting the lag conditional-response probability functions based on recall output, which is a sharply decreasing function of lag. A lag conditional-response probability function shows the conditional probability of recalling an item from serial position i +/- lag immediately after recalling the item from serial position i. Positive values of lag correspond to forward recall relations and these are

generally stronger than negative values of lab that correspond to backward recall relations (Kahana, 1996).

In 2007, Dougherty and Harbison modified the traditional free recall paradigm, allowing participants to decide when to terminate retrieval themselves, via a keypress. This introduced a new measure for delayed free recall researchers, search termination. Measures of search termination include three important variables. Time-to-last response refers to the time from the beginning of the recall period to when the last response is given. Exit latency refers to the time between the last response and the termination decision. Lastly, the total time spent searching, refers to the time between the beginning of the recall period to the termination decision (Dougherty & Harbison, 2007; Unsworth, Brewer, & Spillers, 2011). Exit latency and time-to-last response change as a function of the number of items recalled (Harbison et al., 2009). Participants who recall fewer items tend to have longer exit latencies and time-to-last recall (Dougherty & Harbison, 2007; Harbison et al., 2009). Retrieval errors are also an important component of search termination, with the probability of terminating recall being a lot higher after an error (Kahana et al., 2010).

Final Free Recall

When investigating the dynamics of retrieval from episodic memory researchers have also utilized a slightly more complex task, that of final free recall. In final free recall, participants are presented with a surprise final free recall task where they are asked to retrieve as many of the words from all the study lists as possible. Most words in this final free recall task tend to come from the most recently presented list and fewer words come from the first presented list (Glenberg et al., 1980; Unsworth, 2008), thus

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exhibiting a strong recency effect of list position that is independent of item position. In terms of lag recency between lists, Howard et al. (2008) showed that transitions between nearby lists are more frequent than transitions between lists that were further apart during the study phase, although, unlike delayed free recall, the backward and forward transitions are relatively symmetrical (Unsworth, 2008).

Examination of final free recall output also includes examination of the within-list lag-recency. Participants tend to retrieve items presented at the beginning of the most recently presented lists, thus exhibiting a primacy effect for the items within a list (Unsworth, 2008). Unsworth (2008), also, demonstrated that participants are more likely to retrieve an item that was more proximate to the item they just retrieved, than they are to retrieve items that were less proximate to the item they just retrieved.

The aforementioned findings regarding final free recall are systematic effects found in final free recall that are consistent with a two-stage hierarchical sampling framework, structured on temporal-contextual cues (Rundus, 1973). According to this framework, retrieval begins with the establishment of a context, which is achieved by sampling a list. Once the participant has established a context, he samples an item within that particular list. The first item is sampled based on its associative strength to the list context. Following retrieval of the first item, the list context and the first recalled item are used to generate the next item. Once items of the initially sampled context are retrieved, a new context is established by sampling a different list. An updated version of this model (Farell, 2012) distinguishes itself from previous connectionist models of memory by assuming a hierarchical structured context, with temporal order being represented at coarse and fine time scales.

The Present Investigation

        The present investigation aims to expand our knowledge regarding the relation between memory and importance in the context of a traditional episodic memory task. We attempted to accomplish this by exploring the effects of value on the associative processes and retrieval dynamics of delayed free recall. Previous research, using a similar version of the delayed free recall paradigm, demonstrated that more important information is generally better remembered than less important information (Castel, Farb, & Craik, 2007; Castel, 2008; Ariel et al., 2009; Soderstrom, & McCabe, 2011; Castel, Rhodes, McCabe, Soderstrom, & Loaiza; 2012). Our primary goal was to gain further knowledge regarding the underlying cognitive processes that drive this relation via the analysis of retrieval dynamics of free recall, order of recall, measures of latency, contiguity effects, memory errors, recall termination decisions and final free recall. Measuring and analyzing recall dynamics is going to provide us with an enriched understanding of the memory processes operating under conditions in which some of the information is considerably more important than other information.

Chapter 2

EXPERIMENT 1: OVERVIEW

The purpose of Experiment 1 was to investigate whether presenting participants with to-be-remembered words that vary in value, in the context of a delayed free recall paradigm, alters some of the widely accepted memory regularities observed in delayed free recall paradigms as well as several other memory paradigms. We measured and compared several standard measures of delayed free recall between two conditions. Participants in both the control and the experimental (value) condition were asked to study lists of words and then try to recall them after a short distractor task. The only difference between the two conditions was that the words in the value condition were coupled with a value that pertains to the importance of remembering that word during the recall period.

Participants And Design

Forty Participants were recruited from the Arizona State University participant pool and were randomly assigned to either a value or a control condition so that we ended up with 20 participants in each condition. Participants received course credit for their participation. Each participant was tested individually in laboratory sessions lasting approximately one hour. Participants performed two practice lists with letters and 20 lists of 10 words each. Words were 200 nouns selected from the Toronto word pool (Friendly, Franklin, Hoffman & Rubin, 1982).

Procedure

Items were presented next to a number (i.e. Chart 4) for 2 s each. In the value condition participants were informed that a value will appear next to each word they

study. This value pertained to the importance of remembering that specific word later. Therefore if a participant studied "Chart 4" and "Kitten 9" it will be more important for the participant to remember and retrieve the word "Kitten" than the word "Chart". The values ranged from 1 to 10 and no numbers appeared more than once within the same list. Therefore, if a participant studied "Chart 4", no other word in that list will have a value of 4. Importantly, the values appeared in random order within each list. The participants were informed of all this information prior to the experiment. Additionally, participants were instructed to try to maximize their points by remembering more high-value words. In the control condition participants were instructed that they would see a number next to each word but that number did not mean anything and that they should not be attending to it. We decided to include numbers for the control condition in order to control for any potential associative learning effects as a result of having the study items coupled with numbers.

After each list presentation, participants engaged in a 16s distractor task before recall. In the distractor task participants saw 8 three-digit numbers and were asked to write the digits in descending order (e.g., Rohrer & Wixted, 1994; Unsworth, 2008). At recall participants saw three question marks appear in the middle of the screen and were asked to recall as many items from the most recently studied list as possible. Participants had 1 min to complete their recall for each one of the lists. Participants were also instructed that when they decided that they were done recalling words from the current list, they could press the slash key to terminate the recall period for that list and move on to the next list. Therefore participants did not have to recall for the entire 1 min. Immediately after the recall period for the last list participants were presented with a

surprise final free recall task. During this final free recall task participants were asked to recall all of the words from any list in any order they wanted. Importantly, they were not asked to maximize their points by remembering higher-value words. In fact, there was not mentioning of values during the instructions of this final recall phase. We incorporated this final recall phase to examine whether imbuing words with value affects subsequent memory in a subsequent memory task where maximizing points was not a goal. Participants had 5 min to attempt to recall as many words as possible. Participants were informed that they could again press the slash key to end recall when they decided they were done retrieving all the words they could retrieve. They had 5 min to attempt to recall as many words as possible. Participants were informed that they could again press the slash key to end recall when they decided they were done retrieving all the words they could retrieve.

Results

The results will be divided in two sections: one section devoted to the delayed free recall and a second section devoted to the final free recall. Both sections will cover retrieval and termination decisions associated with each task.

Delayed Free Recall – Retrieval Measures

Overall participants recalled roughly half of the presented items. As expected, participants in the two conditions recalled essentially the same number of items. Participants in the control condition recalled an average of 102 items (51%) and participants in the value condition recalled an average of 101 items (50.5%). Probability of recall for both conditions is consistent with previous research (Glanzer and Cunitz, 1966), demonstrating a large primacy effect and a small or nonexistence recency effect

(Figure 1a). More specifically, we found no main effect of condition, a main effect of serial position, $F(9, 342) = 26.125$, $p < .001$, partial $\eta^2 = .407$ and no interaction between condition and serial position. In both conditions, participants were significantly more likely to recall a word that they studied in serial position "1" compared to a word that they studied in any other serial position ($p < .001$ for all comparisons). Participants were also significantly more likely to recall a word they studied in serial position "2" than a word they studied in any other serial position other than serial position 1 ($p < .005$ for all comparisons). Participants were also significantly more likely to recall a word they studied in serial position "3" than a word they studied in any other serial position other than "1" or "2" ($p < .01$ for all comparisons). This demonstrated a large primacy effect for both conditions. Participants, in both conditions, were significantly more likely to recall a word that they studied in the beginning of each study list.

We had hypothesized that probability of recall would also be a function of value for only the value condition. Our results indicated no main of condition, a main effect of value, $F(9, 342) = 8.402$, $p < .001$, partial $\eta^2 = .181$, as well as a significant interaction between value and condition, $F(18, 342) = 12.462$, $p < .001$, partial $\eta^2 = .181$ (Figure 1b). Post-hoc comparisons indicated that participants in the value condition recalled significantly more items of value 9,8, and 10 compared to participants in the control condition ($p < .015$ for all comparisons). Additionally, participants in the value conditions recalled significantly less items of value 1,2, and 3 compared to participants in the control condition ($p < .037$ for all comparisons). This indicated that participants in the value condition were sensitive to value and were successful in maximizing their points. Considering that participants of both conditions recalled an equal number of items

participants in the value condition recalled more high-value items and less low-value items compared to participants in the control condition.

Figure 1. a. Probability of recall as a function of serial position. b. Probability of recall as a function of value.

a   b
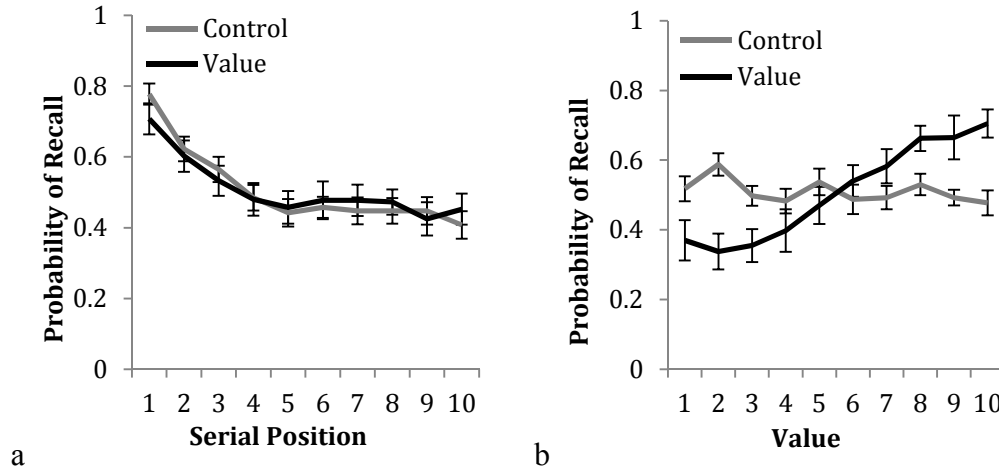
We found the pattern of results in Figures 1a and 1b particularly interesting due to the fact that the serial position effect seems to be identical for the two conditions, however, value is only affecting probability of recall for participants in the value condition. To better understand the above results we tested for which serial positions there was an interaction between condition and value. We found that condition and value interacted only for serial positions 1, $F(9, 342) = 2.55$, $p = .008$, partial $\eta^2 = .063$, and 2 $F = 2.801$, $p = .003$, partial $\eta^2 = .069$ (Figure 2a and 2b). Our results indicated that for items that were studied in serial positions 1 and 2 participants in the value condition were more likely to recall a high-value item and less likely to recall a low-value item compared to participants in the control condition.

Figure 2. a. Probability of recall as a function of value conditionalized for serial position 1. b. Probability of recall as a function of value conditionalized for serial position 2.

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a   b
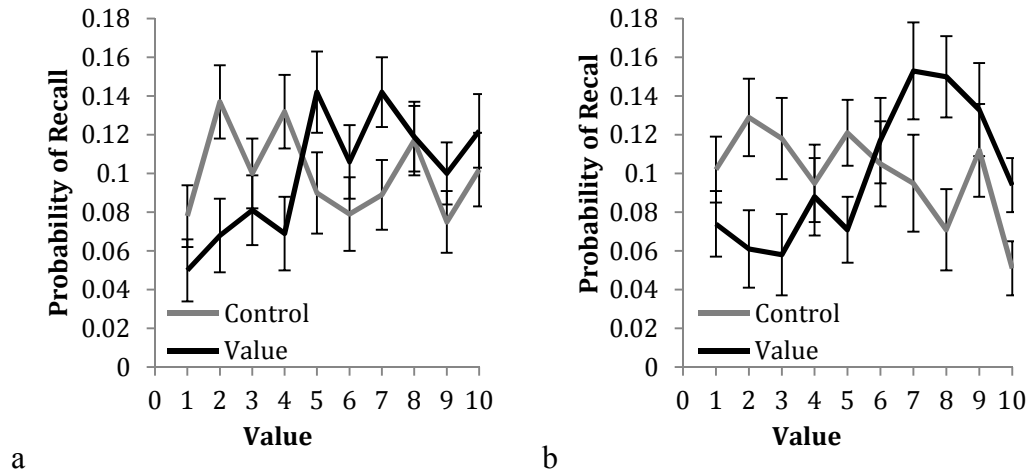
Regarding probability of first recall (Figure 3a), we found no main effect of condition, a main effect of serial position in probability of first recall, $F(9, 342) = 22.99$, $p < .001$, partial $\eta^2 = .63$, and a marginal interaction between serial position and condition, $F(18, 342) = 2.035$, $p < .07$, partial $\eta^2 = .1$. Specifically, participants in both conditions were significantly more likely to initiate their recall with an item they studied in serial position 1. This is consistent with all previous research showing that participants tend to begin their recall with a primacy item, but inconsistent with our hypothesis that there would be no serial position effect for probability of first recall for the value condition.

We had also hypothesized that probability of first recall would be a function of value for the value condition. Consistent with this hypothesis, we found no main effect of condition, a main effect of value, $F(9, 342) = 5.56$, $p < .001$, partial $\eta^2 = .14$, and an interaction between value and condition, $F(18, 342) = 5.6$, $p < .001$, partial $\eta^2 = .12$ (Figure 3b). Participants in the value condition were significantly more likely to initiate their recall with an item of value 8,9 or 10 ($p < .017$ for all comparisons) than participants in the control condition. Additionally, participants in the value condition were

significantly less likely to initiate their recall with an item of value 1,2, or 3 ($p < .036$ for all comparisons) compared to participants in the control condition. This again indicated that participants in the value condition were sensitive to value in terms of probability of first recall. Therefore, participants in the value condition began their recall with more high-value items and less high-value items than participants in the control condition

Figure 3. a. Probability of first recall as a function of serial position. b. Probability of first recall as a function of value.

a   b
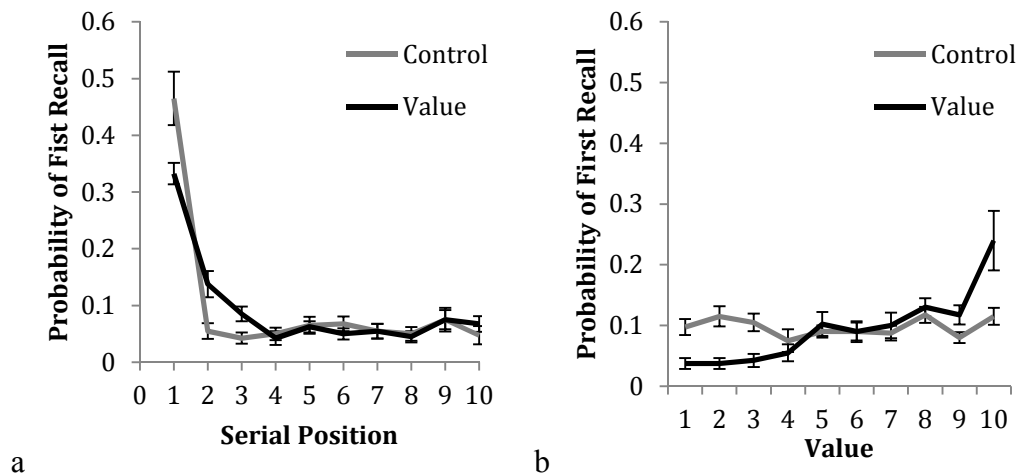
Lag conditional response probabilities (Figure 4a) for both forward and backward transitions were a function of presentation lag for both conditions, with forward transitions being more likely than backward transitions ($p = .006$). Additionally, transitions of lag +1 and -1 were more likely than transitions of any other lag ($p < .001$ for all comparisons). While value did not affect the conditional response probabilities for the control condition it did for the value condition (Figure 4b). Participants in the value condition exhibited overall lag-v conditional response probabilities that were marginally stronger in the forward direction ($p = .068$). Regarding their backward transition, participants in the value conditions were significantly more likely to show a -1 lag-v and

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-2 lag-v transitions compared to negative transitions 3,4, and 5 ($p < .05$ for all comparisons).

Figure 4. a. Lag-conditional response probabilities. b. Lag-v conditional response probabilities.

a   b
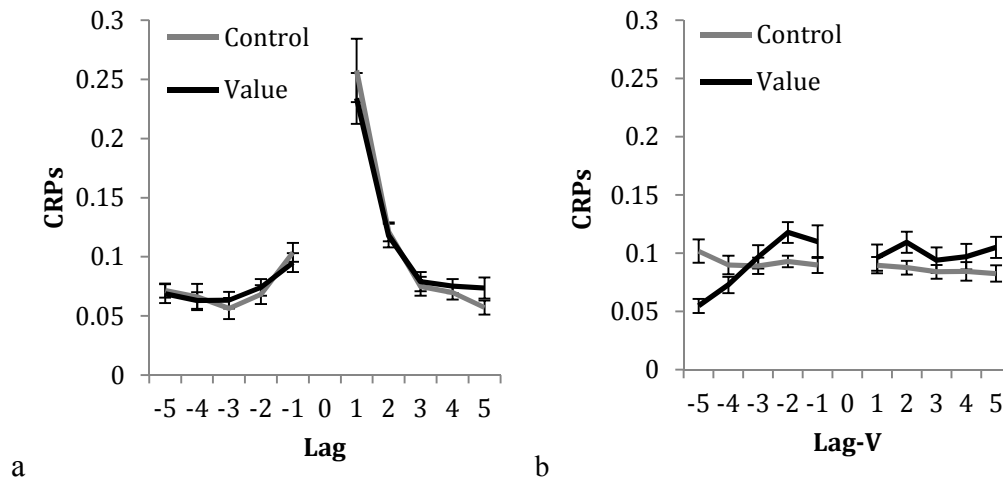
Delayed Free Recall – Recall Termination Measures

Termination responses were measured based on time-to-last response, exit latency, and total time spent searching (Table 1). Time-to-last response, the time from the beginning of the recall period to the last retrieved item, was roughly equal for the two conditions. Participants in both conditions spent approximately 22.5s until their last retrieved item. Exit latency, the time between the last retrieved item and the termination decision or termination of the recall period, was statistically equal for the two conditions although arithmetically bigger for the control condition. More specifically, participants in the control conditions spent approximately 17s between the last retrieved item and recall termination, while participants in the value condition spent approximately 12s. Lastly, total time spent searching was roughly equal for the two conditions, with participants in

the control condition spending approximately 40s total, while participants in the value

condition spending approximately 35s total.

Table 1. Time-to-Last response, exit latency and total-time-spent searching

measures for the delayed free recall as a function of condition. All measures are in

seconds.

Mean Search Termination Measures (sec)			
Condition	Time-to-last (SE)	Exit Latency (SE)	Total-Time-Spent Searching (SE)
Control	22.9 (1.5)	17.1 (2.2)	40.0 (3.4)
Value	22.6 (1.7)	12.6 (1.4)	35.2 (2.9)

Final Free Recall – Retrieval Measures

Participants recalled roughly 16.5% of the items during the final free recall. As

expected, total recall was not statistically different for the two conditions. Participants in

the control condition recalled an average of 31.7 items (15.8%), while participants in the

value condition recalled and average of 34.9 items (17.4%). As expected, the majority of

the participants began their recall with an item from the most recently presented list. In

terms of list probability of first recall for the final free recall we found no main effect of

condition, a main effect of list position, $F(19, 741) = 4.992$, $p < .001$, partial $\eta^2 = .113$,

and no interaction between the two variables. Participants began their final recall with an

item from list 20 significantly more often than with an item from any other list ($p < .016$

for all comparisons). 42.5% of the participants (17 participants) began their final recall

with an item from list 20. 45% of the participants (18 participants) began their recall with

an item from any other list. Lastly, 12.5% (5 participants) began their final recall with an extra-list intrusion, meaning a word that did not exist in any of the lists.

In terms of probability of recall as a function of serial position we found no main effect of condition, a main effect of serial position, $F(9, 342) = 9.268$, $p < .001$, partial η^2 = .196 and no interaction. This indicated that participants in both conditions tended to recall more items that they studied in primacy positions (Figure 5a). More specifically, pair-wise comparisons demonstrated that items that were studied in serial position "1" were significantly more likely to be recalled than items studied in any other serial position. ($p < .005$ for all comparisons). Additionally, items that were studied in serial position "2" were more likely to be recalled than items that were studied in serial positions 4,5,7,8,9, and 10 ($p < .043$ for all comparisons). On the contrary, and unlike what we expected, probability of recall was not a function of value (Figure 5b). Our results indicated no main effect of condition, no main effect of value and no interaction between condition and value. Therefore, value did not have an effect on probability of recall during the final free recall phase for either conditions.

Figure 5. a. Probability of recall during the final free recall as a function of serial position. b. Probability of recall during the final free recall as a function of value.
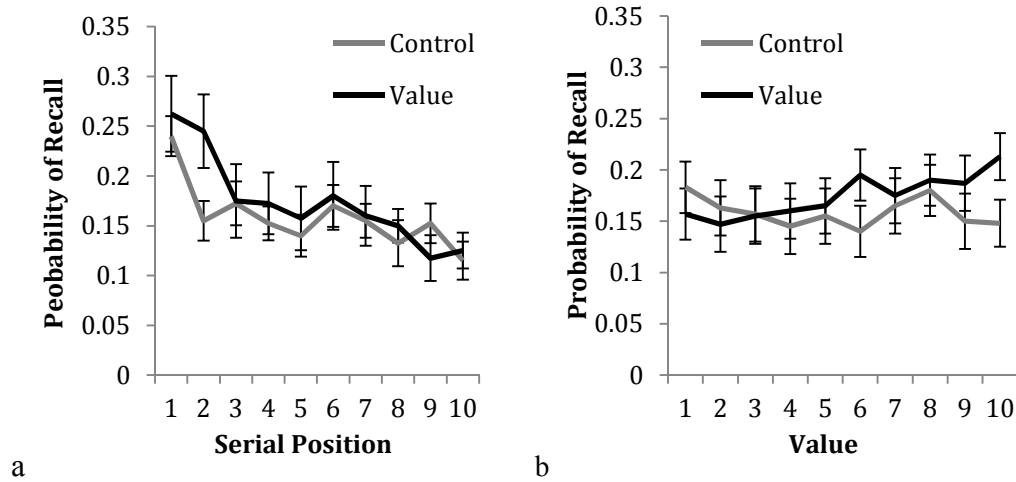
In regards to probability of first recall as a function of serial position (Figure 6a) we found no main effect of condition, a main effect of serial position $F(9, 342) = 2.24$, $p < .02$, partial $\eta^2 = .056$, and no interaction. More specifically, participants of both conditions were more likely to begin their final free recall with an item that they studied in a primacy position. Participants were significantly more likely to begin their final recall with an item that the studied in serial position "1" than items they studied in serial positions 4,7,8,9 ($p < .033$ for all comparisons). Probability of first recall was not affected by value (Figure 6b). Our results indicated no main effect of condition, no main effect of value and no interaction between condition and value. Therefore, unlike what we expected, participants did not tend to begin their final free recall with more high-value.

Figure 6. a. Probability of first recall during the final free recall as a function of serial position. b. Probability of first recall during the final free recall as a function of value.

a   b
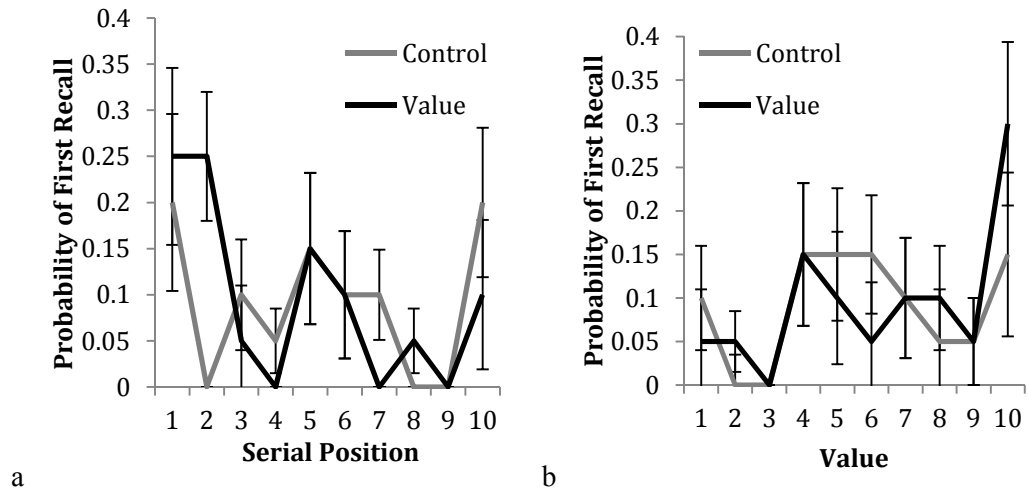
We also examined the list lag conditional response probabilities for the two

conditions during the final free recall. We expected that participants in both conditions

would be more likely to transition to a list that is of close proximity to the current list.

This did not seem to be in the case as participants tended to transition to any list lag

regardless of its proximity to the current list (Figure 7).

Figure 7. List-lag conditional response probabilities.
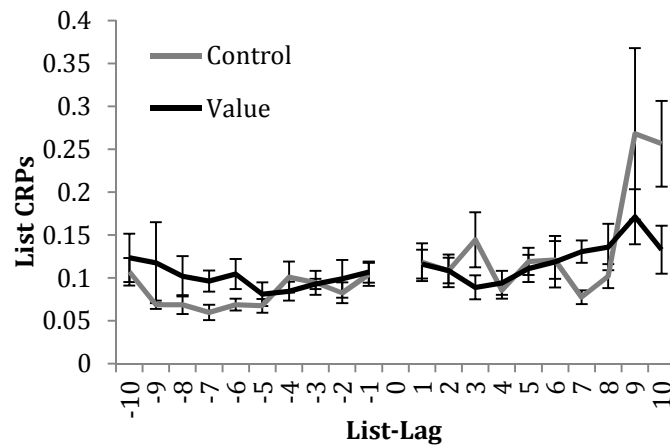
Final Free Recall – Recall Termination Measures

Termination responses were measured in terms of time-to-last response, exit

latency, and total time spent searching (Table 2). Time-to-last response, the time from the

beginning of the recall period to the last retrieved item, was statistically equal for the two conditions. Specifically, participants in the control group recalled their last item on average at 218s (3.6m), while participants in the value condition recalled their last item at approximately 243s (4m). Exit latency, the time between the last retrieved item and the termination decision, was statistically equal for the two conditions. Specifically, participants in the control condition spent roughly 27s between the last recalled item and recall termination, while participants in the value condition spend roughly 20s between the last recalled item and recall termination. Lastly, total-time-spent searching was roughly identical for the two conditions, with participants in the control group spending a total of 4.1m searching compared to participants in the value condition that spent a total of 4.4m.

Table 2. Time-to-Last response, exit latency and total-time-spent searching measures for the final free recall as a function of condition. All measures are in seconds.

Mean Search Termination Measures (sec)			
Condition	Time-to-last (SE)	Exit Latency (SE)	Total-Time-Spent Searching (SE)
Control	218.7 (14.7)	27.6 (4.5)	246.3 (14.9)
Value	243.7 (13.3)	20.2 (3.5)	263.9 (13.3)

Output Effects Based On Initial Free Recall

92% of the recalled items in final free recall were initially recalled during the delayed free recall. The two conditions differed significantly in the proportion of items that were recalled in the final free recall that were also initially recalled during the delayed free recall, $F(1, 38) = 5.263$, $p = .027$, partial $\eta^2 = 1.22$. 95% of the items recalled

by participants in the control condition during the final free recall were items that were also recalled during the delayed free recall. Only, 89% of the items recalled by participants in the value condition during the final free recall were items that were also recalled during the delayed free recall. The items that were not recalled during the final free recall but were recalled during the delayed free recall did not significantly differ in their average value or serial position between the two conditions.

Discussion

Experiment 1 investigated whether presenting participants with to-be-remembered items that vary in value, in the context of delayed free recall and final free recall paradigms, alters some of the widely accepted memory regularities observed in delayed free recall as well in several other memory paradigms. We aimed to achieve this by comparing the recall dynamics of delayed free recall and final free recall of a control and a value condition that were identical with the only difference being that the participants in the value condition were told that the numbers next to the study items denoted the importance of remembering that particular item later on.

Our results indicated that assigning differential value to the study items does not affect total recall during on either a delayed or final free recall task. For the delayed free recall, both probability of recall and probability of first recall indicated a main effect of serial position, a main effect of value and a significant interaction between condition and value. This indicated that while value did not take away the serial position effects it did affect both measures for participants in the value condition. On the contrary, for the final free recall we only found a serial position effect for both conditions, indicating that imbuing words with values does not affect subsequent memory. The lag conditional

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response probabilities were consistent with previous literature, while the lag-v

conditional response probabilities were relatively unaffected by value and hard to

interpret. Lastly, our results indicated that assigning differential value to the study items

does not affect the recall termination measures for either the delayed or the final free

recall.

The take home message for Experiment 1 is that, similar to what we predicted,

value had an effect on several of the recall dynamic measures, the most clear of which

were probability of recall as a function of serial position and probability of first recall.

However, inconsistent with our predictions, value did not take away the effects of serial

position that have been studied for well over half a century. In fact, the two variables

appear to be acting together. The simplest explanation for the results of Experiment 1 is

that regardless of the fact that we are introducing a variable as critical as value, serial

position effects are universal and remain even after the task has attempted to orient

participants to a new dimension, namely value.

An alternative explanation has to do with the degree to which participants are able

to associate each item with its value. For instance, the current 2 s presentation rates might

be too fast to allow participants to associate each study item with its value, especially

considering the fact that the values appear in random orders. To solve this problem, in

Experiment 2 we introduced an ascending and a descending condition where the order of

the presentation of the values was ascending and descending respectively. We believed

that this heuristic would allow participants to associate the items with their values easier

while maintaining the same presentation rate. Additionally, we believed that this order of

presentation manipulation would allow us to make more concrete predictions in terms of

the effects of value on the several free recall measures.

Chapter 3

EXPERIMENT 2: OVERVIEW

The purpose of Experiment 1 was to investigate whether adding values to the study items of the lists of a delayed free recall paradigm would, in any way, modify some of the widely accepted memory regularities observed in delayed free recall paradigms as well as several other memory paradigms. The purpose of Experiment 2 was to attempt to manipulate these memory regularities in a more clear and specific way. To achieve this goal, we manipulated the order of the value-presentation within each list. In Experiment 1, the values within each list were assigned in a random order. In Experiment 2, we included two more conditions. In one condition the values appeared in an ascending arithmetical order (1 to 10), while in another condition the values appeared in a descending arithmetical order (10 to 1). We believe that this trivial manipulation would allow us to make more concrete predictions for how recall dynamics are sensitive to information value.

Participants And Design

Sixty Participants were recruited from the Arizona State University participant pool and were randomly assigned to one of the three conditions (random, ascending, descending), so that we ended up with 20 participants in each condition. Participants received course credit for their participation. Each participant was tested individually in laboratory sessions lasting approximately one hour. Participants performed two practice lists with letters and 20 lists of 10 words. Words were 200 nouns selected from the Toronto word pool (Friendly, Franklin, Hoffman & Rubin, 1982).

Procedure

The procedure for Experiment 2 was identical to that of Experiment 1 with the following difference. The order of the values within each list for the random condition was random just like it was in the value condition of Experiment 1. However, the order of the values was in lockstep with the input position in an ascending manner for the ascending condition and descending for the descending condition. Therefore, Experiment 2 consisted of three conditions: a random condition, which was identical to the value condition from Experiment 1, an ascending condition, in which the values appeared in an ascending order within each list, and a descending condition, in which the values appeared in a descending order within each list.

Results

The results will be divided in two sections: one section devoted to the delayed free recall and a second section devoted the final free recall. Both sections will cover retrieval and termination decisions associated with each task.

Delayed Free Recall – Retrieval Measures

Participants recalled roughly 54% of the presented items. Total recall did not differ significantly among conditions. Participants in the ascending condition recalled an average of 114.4 items (57.2%), participants in the descending condition recalled an average of 107.2 items (53.6%) and participants in the random condition recalled approximately 105.8 items (52.9%).

In regards to probability of recall, our results demonstrated no main effect of condition, a main effect of serial position, $F(9, 513) = 12.542$, $p < .001$, partial $\eta^2 = .18$, and an interaction, $F(18, 513) = 22.437$, $p < .001$, partial $\eta^2 = .44$. Specifically,

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probability of recall for the random and the descending condition demonstrated a strong primacy effect, while probability of recall for the ascending condition demonstrated a strong recency effect (Figure 8a). This is notable because recency effects are not usually observed in delayed free recall paradigms.

The omnibus ANOVA was significant for serial positions 1,2,3,4,7,8,9, and 10 ($p < .001$ for all comparisons). For the sake of length we will report the comparisons for serial positions 1,2,3,8,9, and 10. The ascending and descending conditions differed significantly for all 6 of those comparisons ($p < .001$ for all comparisons). Participants in the ascending condition recalled significantly more items from serial positions 8,9, and 10 and significantly fewer items from serial positions 1,2, and 3 compared to participants in the descending condition. This demonstrated a recency effect for the ascending condition and a primacy effect for the descending condition which was expected considering the fact that higher-value items come in recency positions for that the ascending condition and in primacy positions for the descending condition.

The ascending and random conditions differed significantly for items from serial position 2,8,9 and 10 ($p < .05$ for the 4 comparisons) and marginally for items from serial positions 1 and 3 ($p < .084$ for the two comparisons). More specifically participants in the ascending condition were more likely to recall items from the last three serial positions and less likely to recall items from the first three serial positions compared to participants in the random condition. This was again expected because the last three serial positions for the ascending condition included the three highest-value items while the first three serial positions contained the three lowest-value items.

The descending and random conditions differed significantly for items from serial positions 1,3,8 ($p < .05$ for all three comparisons). Participants in the descending condition were significantly more likely to recall items from serial positions 1 and 3 and less likely to recall items from serial position 8. Although not as strong as with the ascending condition, this effect was again expected considering the fact that the high-value items come in the first three serial positions for the descending condition.

The above results are evidence of our hypothesis that value would guide probability of recall across serial position (Figure 8b). In fact, for probability of recall in terms of value we found no main effect of condition, a main effect of value, $F(9, 513) = 69.143$, $p < .001$, partial $\eta^2 = .548$, and an interaction between condition and value, $F(18, 513) = 2.487$, $p = .001$, partial $\eta^2 = .08$. The omnibus ANOVA was significant for values 1 and 10 ($p < .02$ for both comparison). Participants in the ascending condition were more likely to recall an item of value "1" ($p = .021$) and less likely to recall an item of value "10" ($p = .035$) compared to participants in the descending condition. While not expected, it becomes clear that primacy is increasing the proportion of lower-value items recalled by participants in the ascending condition while increasing the proportion of higher-value items recalled by participants in the descending condition. Participants in the ascending condition were also more likely to recall an item of value "1" ($p = .013$) compared to participants in the random condition, which again demonstrates the fact that primacy is increasing the proportion of items of value "1" being recalled by the participants in the ascending condition. Participants in the descending condition were only marginally more likely to recall a word of value "10" compared to participants in the random condition, probably due to an additive effect of primacy and value for the items

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presented at the beginning of the list that are also the highest-value items. Note in the

graphs that probability of recall as a function of serial position is identical to probability

of recall as a function of value for the ascending condition, while it is the mirror image

for the descending condition.

Figure 8. a. Probability of recall as a function of serial position. b. Probability of

recall as a function of value.

a   b
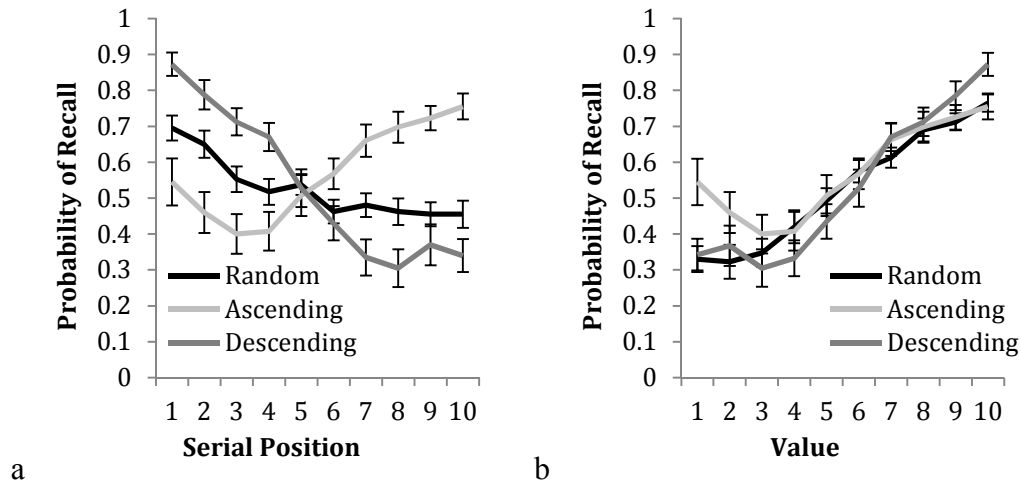
For probability of first recall in terms of serial position, we found no main effect

of condition, a main effect of serial position, $F(9, 513) = 51.46, p < .001$, partial $\eta^2 =$

$=.474$, and an interaction between condition and serial position, $F(18, 513) = 14.203, p <.$

001, partial $\eta^2 = .333$ (Figure 9a). The omnibus ANOVA was significant for serial

positions 1,2,3,5,6,7,8,9, and 10 ($p < .025$ for all comparisons). For the sake of length we

will report the comparisons for serial positions 1,2,3,8,9, and 10. Participants in the

ascending condition were significantly less likely to begin their recall with an item of

serial position 1 and 3, significantly more likely to begin their recall with an item of serial

position 8 and 9 ($p < .03$ for all comparisons) and marginally more likely to begin their

recall with an item of serial position 10 ($p = .072$) compared to participants in the

descending condition. This demonstrates that, due to the fact that higher-value items came at the end of each study list, participants in the ascending condition were more likely to begin their recall with a recency item since those items were of higher value. Recency is not usually seen in probability of first recall in delayed free recall so this is a novel finding. Additionally, participants in the ascending condition are significantly less likely to begin their recall with an item of serial position 2 and 3 ($p < .02$) and marginally less likely to begin their recall with an item of serial position 1 ($p = .058$) compared to the random condition. This was again expected and explained by the fact that primacy items in the ascending condition have the lowest values so participants are less likely to begin recall with those low-value items. Lastly, participants in the descending condition are more likely to begin their recall with an item of serial position 1 compared to participants in the random condition. This was expected considering that the highest-value item is always presented in serial position 1 for the participants in the descending condition.

The above results regarding probability of first recall are consistent with our hypothesis that value would guide probability of first recall (Figure 9b). In fact, we found no main effect of condition, a main effect of value, $F(9, 513) = 42.821$, $p < .001$, partial $\eta^2 = .42$, and a significant interaction, $F(8, 513) = 17.4$, $p < 001$, partial $\eta^2 = .379$. The omnibus ANOVA was significant for serial positions 1,5,6,7,9, and 10. For the sake of length we will report the comparisons for serial positions 1,9, and 10. Seemingly due to primacy, participants in the ascending condition are significantly more likely to begin their recall with an item of value 1 ($p = .01$) compared to participants in the descending condition. Additionally, due to the fact that recency effects are usually non-existent in delayed free recall, participants in the ascending condition are a lot less likely to begin

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their recall with an item of value 10 ($p < .001$). These results suggest that even though value guides probability of first recall serial position might still be playing a role in probability of first recall. Additionally, and for similar reasons, participants in the ascending condition are significantly more likely to begin their recall with an item of value 1 ($p = .007$) and significantly less likely to begin their recall with an item of 9 or 10 ($p < .025$), compared to the random condition. Lastly, participants in the descending condition were significantly less likely to begin their recall with an item of value 9 ($p = .018$) and significantly more likely to begin their recall with an item of value 10 ($p < .001$) compared with participants in the random condition. Our results seem to be suggesting that both serial position and value are contributing to probability of first recall. Note in the graphs that probability of first recall as a function of serial position is identical to probability of first recall as a function of value for the ascending condition, while it is the mirror image for the descending condition.

Figure 9. a. Probability of first recall as a function of serial position. b. Probability of first recall as a function of value.

a   b

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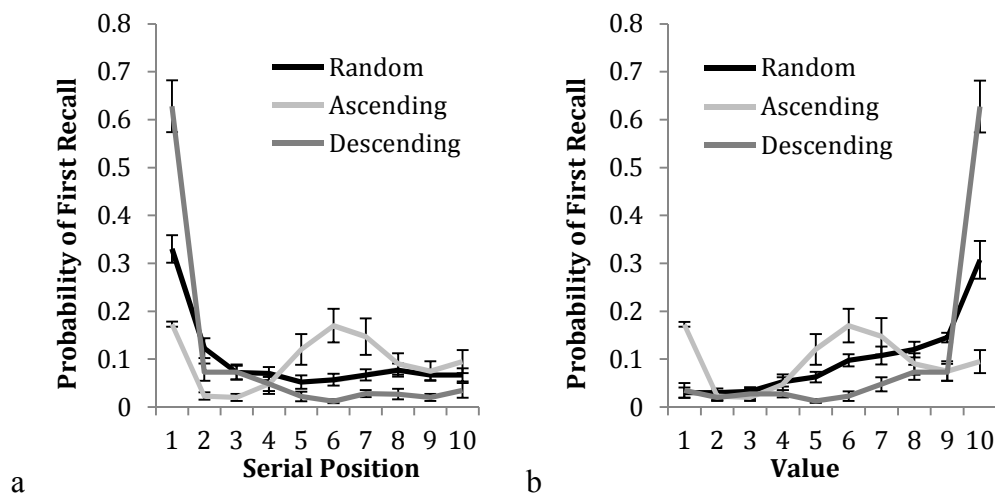
Conditional response probabilities were both a function of lag (Figure 10a) and a function of value lag (lag-v) (Figure 10b). The lag conditional response probabilities for the random condition were similar to what one might expect to see in the literature. Forward transitions of lag were stronger than backward transitions for all three conditions ($p < .01$ for all). Additionally, +1 and -1 lag transitions were significantly more likely in all three conditions, which is consistent with previous research ($p < .003$ for all). It therefore appears that presenting value in lock step with temporal context increases +1 transitions for both the ascending and the descending conditions. Conditional response probabilities were also a function of value. As expected backward lag-v transitions were significantly more likely, but only for the descending condition ($p < .001$). In fact, participants in the ascending and random conditions were significantly more likely to transition forward ($p < .04$ for both). Transitions of +1 lag-v were significantly more likely for participants in the ascending condition ($p < .001$) compared with any other lag-v transition, while transitions of -1 lag-v were significantly more likely for participants in the descending condition compared to any other lag-v transitions.

Figure 10. a. Lag-conditional response probabilities. b. Lag-v conditional response probabilities.
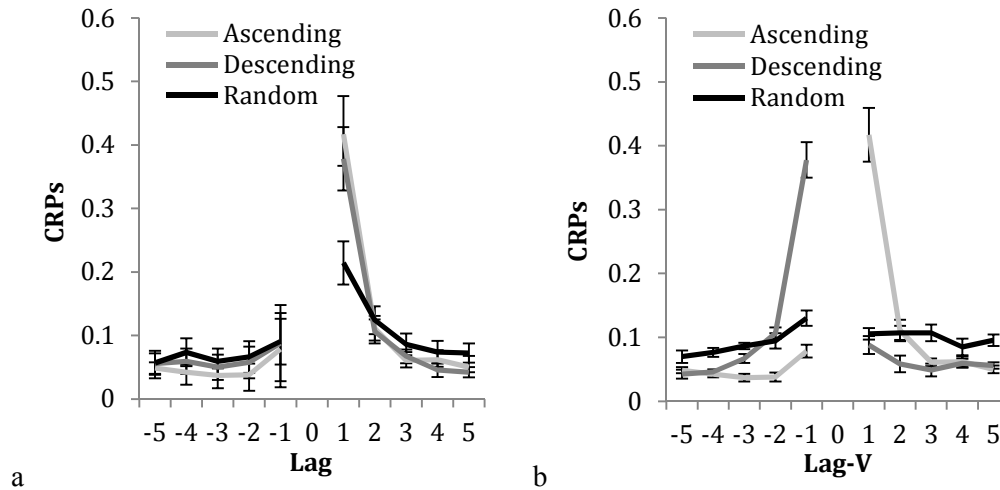
a   b

Delayed Free Recall – Recall Termination Measures

Termination responses were measures in terms of time-to-last response, exit latency, and total time spent searching (Table 3). Time-to-last response, the time from the beginning of the recall period to the last retrieved item, did not differ among the three conditions. Participants in the ascending condition recalled their last item at approximately 26s, participants in the descending condition recalled their last item at approximately 30s and participants in the random condition recalled their last item at approximately 32s. Exit latency, the time between the last retrieved item and the termination decision or the end of the recall period did not differ among the three conditions. Participants in the ascending condition spent approximately 7s between their last recalled item and recall termination, while participants in the descending and random condition spent approximately 6.2s and 5.7s respectively. Lastly, total time spent searching did not differ among the conditions. Participants in the ascending conditions spent a total of approximately 34s, while participants in the descending and random condition spent a total of approximately 36s and 38s respectively.

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Table 3. Time-to-Last response, exit latency and total-time-spent searching measures for the delayed free recall as a function of condition. All measures are in seconds.

	Mean Search Termination Measures (sec)		
Condition	Time-to-last (SE)	Exit Latency (SE)	Total-Time-Spent Searching (SE)
Ascending	26.5 (3.5)	7.5 (1.0)	34.0 (3.1)
Descending	30.2 (3.3)	6.2 (0.7)	36.4 (3.0)
Random	32.2 (3.9)	5.7 (0.7)	37.9 (3.6)

Final Free Recall – Retrieval Measures

Participants recalled roughly 15.5% of the words during the final free recall. Specifically, participants in the ascending condition recalled an average of 29.05 item (14.5%), participants in the descending condition recalled an average of 33.8 item (16.9%), and participants in the random condition recalled an average of 30.2 item (15.1%). Total final recall did not differ among the conditions. However, although not significant in either case, we are seeing an arithmetically opposite pattern between delayed free recall and final free recall. During delayed free recall participants in the ascending condition recalled arithmetically more item than participants in both of the other conditions while in the final free recall participants in the ascending condition recalled arithmetically less item than participants in both of the other two conditions.

As expected, the majority of the participants began their recall with an item from the more recently presented list. In terms of list probability of first recall for the final free recall we found no main effect of condition, a main effect of list position, $F(19, 1083)=$

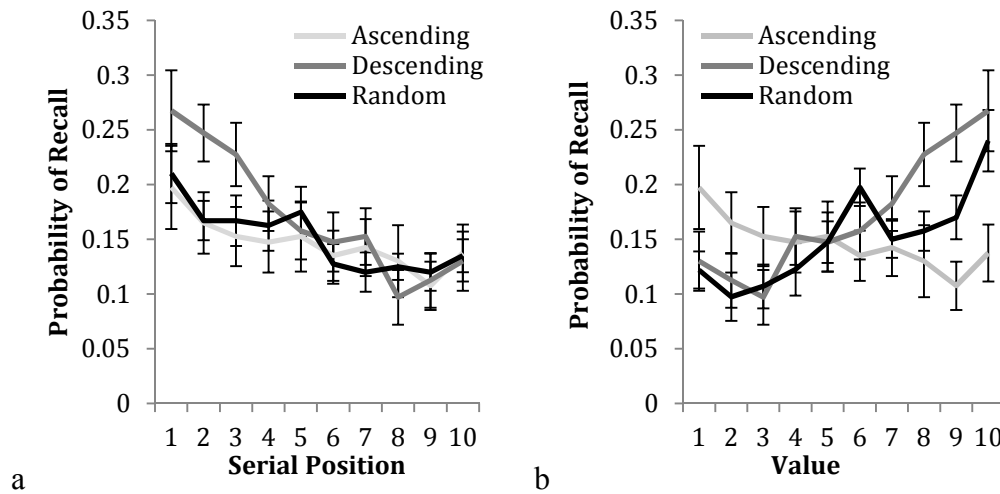8.692, $p < .001$, partial $\eta^2 = .132$, and no interaction between the two variables. Participants began their final recall with an item from list 20 significantly more often that with an item from any other list ($p < .004$ for all comparisons). 43.3% of the participants (26 participants) began their final recall with an item from list 20. 46.6% of the participants (28 participants) began their recall with an item from any other list. Lastly, 10% (6 participants) began their final recall with an extra-list intrusion, meaning an item that did not exist in any of the lists.

In terms of probability of recall as a function of serial position we found no main effect of condition, a main effect of serial position, $F(9, 513) = 13.679$, $p < .001$, partial $\eta^2 = .194$, and an interaction, $F(18, 513) = 1.794$, $p = .023$, partial $\eta^2 = .059$ (Figure 11a). An omnibus ANOVA test indicated that the three conditions differed significantly only for items coming from a serial position of 2 ($p = .036$). Post-hoc tests indicated that during the final free recall participants in the descending condition recalled a marginally higher number of items coming from a serial position of 2 compared to the other two conditions ($p < .82$ for both comparisons) that did not differ from each other.

Probability of recall was also a function of value (Figure 11b). We found no main effect of condition, a main effect of value, $F(9, 513) = 7.822$, $p < .001$, partial $\eta^2 = .09$, and a significant interaction between value and condition, $F(18, 513) = 6.095$, $p < .001$, partial $\eta^2 = 06$. The omnibus ANOVA test indicated that the three conditions differed significantly for items of value 8,9, and 10 ($p < .04$ for all comparison). Post-hoc comparisons indicated that during the final free recall participants in the descending condition recalled more items of value 8,9, and10 than participants in the ascending condition ($p < .045$ for all comparisons). This could be explained by the fact that primacy

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might be allowing participants in the descending condition to recall more high-value items.

Figure 11. a. Probability of recall as a function of serial position. b. Probability of recall as a function of value.

a   b

Probability of first recall during the final free recall was affected by serial position (Figure 12a). We found no main effect of condition, a main effect of serial position, $F(9, 513) = 2.046$, $p = .033$, partial $\eta^2 = .035$, and no interaction between condition and serial position. Participants in all three conditions were significantly more likely to begin their recall with an item they studied in serial position 1 compared to an item they studied in a serial position of 2,8,9, and 10 and marginally more likely to begin their recall with an item of serial position 1 compared to an item of serial position of 3 and 6. Essentially, participants of all three conditions were more likely to begin their final free recall with an item that they studied in a primacy position and particularly in serial position 1.

Probability of first recall in the final free recall was also affected by value (Figure 12b). We found no main effect of condition, a main effect of value, $F(9, 513) = 2.761$, $p < .005$, partial $\eta^2 = .046$, and no interaction between condition and value. Participants of

all three conditions were significantly more likely to begin their final free recall with an item of value 10 compared to an item with a value of 1,2,3,4,5, and 9 and also marginally more likely to begin their recall with an item of value 10 than an item of value 8. Essentially, participants in all three conditions were significantly more likely to begin their recall with an item of value 10 than an item of lower value.

Figure 12. a. Probability of first recall as a function of serial position. b. Probability of first recall as a function of value.

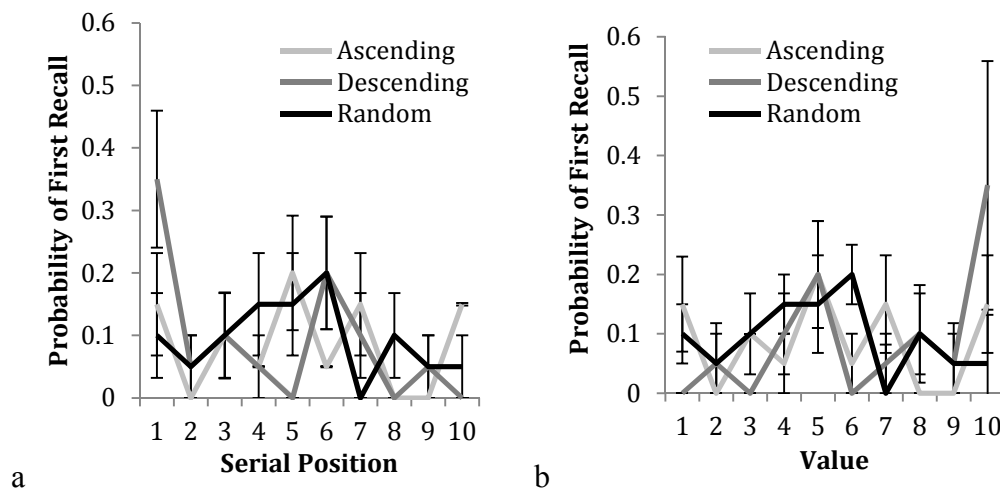a   b

We also examined the list lag conditional response probabilities for the two conditions during the final free recall. We expected that participants in both conditions would be more likely to transition to a list that is of close proximity to the current list. This did not seem to be the case as participants tended to transition to any list lag regardless of its proximity to the current list (Figure 13).

Figure 13. List-lag conditional response probabilities.
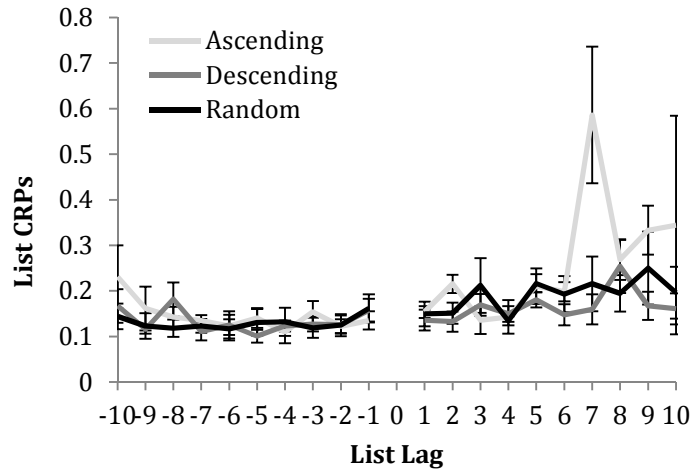
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Final Free Recall – Recall Termination Measures

Termination responses were measures in terms of time-to-last response, exit latency, and total time spent searching (Table 4). Time-to-last response, the time from the beginning of the recall period to the last retrieved item, did not differ among the three conditions. Participants in the ascending condition recalled their last word at approximately 208s, participants in the descending condition recalled their last word at approximately 236s and participants in the random condition recalled their last word at approximately 228s. Exit latency, the time between the last retrieved item and the termination decision or the end of the recall period did not differ among the three conditions. Participants in the ascending condition spent approximately 24s between their last recalled word and recall termination, participants in the descending spent approximately 31s and participants in the random condition spent approximately 29s. Lastly, total time spent searching did not differ among the three conditions. Participants in the ascending conditions spent a total of approximately 233s, while participants in the descending and random condition spent a total of approximately 267s and 257s respectively.

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Table 4. Time-to-Last response, exit latency and total-time-spent searching measures for the final free recall as a function of condition. All measures are in seconds.

	Mean Search Termination Measures (sec)		
Condition	Time-to-last (SE)	Exit Latency (SE)	Total-Time-Spent Searching (SE)
Ascending	208.4 (18.2)	24.6 (4.9)	233.0 (19.4)
Descending	236.2 (22.8)	31.3 (10.3)	267.5 (13.8)
Random	228.8 (21.5)	29.0 (11.1)	257.8 (13.7)

Output Effects Based On Initial Free Recall

94.3% of the recalled items in final free recall were initially recalled during the delayed free recall. An omnibus ANOVA demonstrated that the three conditions differed significantly in the proportion of items that were recalled in the final free recall that were also initially recalled during the delayed free recall, $F(2, 57)= 12.278$, $p < .001$, partial η^2 = .301. Post-hoc comparisons demonstrated that the proportion of items that were recalled during final free recall and were also initially recalled during delayed free recall differed between the ascending condition ($p < .008$ for both comparisons) and both of the other two conditions but did not differ between the descending and the random condition. 88.4% of the items recalled by participants in the ascending condition during the final free recall were items that were recalled during the delayed free recall. 95.4% of the items recalled by participants in the descending condition during the final free recall were recalled during the delayed free recall. 99.18% of the items recalled by participants in the random condition during the final free recall were recalled during the delayed free recall. The items that were not recalled during the delayed free recall but were recalled during

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the final free recall differed significantly in serial position, $F(1, 23) = 10.46$ $p < .005$, partial $\eta^2 = .313$, between the ascending and descending conditions. Participants in the ascending condition recalled more new items of earlier serial position compared to participants in the descending condition. The aforementioned analysis excluded the random condition because there was only one instance where a participant in the random condition recalled an item in the final free recall that he had not recalled during the delayed free recall. Due to the lack of enough observations (17 for the ascending condition and 8 for the descending condition) we will not attempt to explain this effect any further.

Discussion

Experiment 2 investigated whether presenting participants with to-be-remembered items that vary in value, in the context of delayed and final free recall paradigms, alters some of the widely accepted memory regularities. More specifically, by comparing an ascending, a descending condition and a random condition, we aimed to investigate whether value-presentation order might facilitate recall as well as modify recall dynamics in a different and more predictable manner than those of Experiment 1.

Again our results demonstrated that assigning differential value to the study items and manipulating the order of the presentation of the values does not affect total recall during either the delayed or the final free recall. For the delayed free recall, both probability of recall and probability of first recall indicated a main effect of serial position, a main effect of value as well as significant interactions of both serial position and value with condition. This indicated that the order of presentation of the values alters the serial position effects that are usually seen in the literature and also modifies the value

effects that we found in Experiment 1. These results were identical for the final free recall with the only exception that probability of first recall demonstrated only a main effect of value. The lag conditional response probabilities were consistent with previous literature. However, value and its order of presentation had a clear effect on the lag-v conditional response probabilities, where the descending condition exhibited stronger backward transitions, while the other two conditions exhibited stronger forward transitions. Lastly, our results indicated that assigning differential value to the study items and manipulating the order of the presentation of the values does not affect the recall termination measures for either the delayed or the final free recall.

Collectively, our results suggest that due to the fact that high-value items appear in primacy positions for the descending condition, participants in that condition are more likely to begin their recall with a high-value item and then transition to lower-value items. On the other hand, due to the values appearing in an increasing order for the ascending condition, participants in that condition are more likely to begin their recall with a low-value item and then transition to higher-value items. The random condition is simply replicating the results of the value condition from Experiment 1.

The take home message from Experiment 2 is that value had an effect on several of the recall dynamic measures. The order of presentation of the values also played an important role in Experiment 2. One of our most interesting results is the fact that the ascending condition is exhibiting a strong recency effect for both probability of recall and probability of first recall, neither of which are usually seen in the literature. In fact, orienting participants to the dimension of value has taken away the primacy effects for the ascending condition. These results make it obvious that participants are sensitive to

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the dimension of value and that the order of presentation of the value affects the way that participants organize their memory around that dimension. An important limitation of this particular experiment is the absence of control conditions for the ascending and descending conditions. It is possible that a heuristic as strong as numbers would affect a control condition that was not oriented to the value dimension. We intend to perform follow-up studies to test this possibility.

Chapter 4

GENERAL DISCUSSION

In the present investigation we developed two experiments, using a slightly altered delayed free recall paradigm, to investigate how and whether value modifies the dynamics of memory organization and memory search. In Experiment 1, we compared the dynamics of delayed and final free recall between a control and a value condition, where the only difference was that participants in the value condition were told that the numbers next to the study items denoted the importance of remembering each particular item during recall. In Experiment 2, we aimed to facilitate and strengthen the association between the items and the values. Experiment 2 consisted of a random condition, which was identical to the value condition of Experiment 1 and an ascending and descending condition, where value was in lockstep with the serial position in an ascending and a descending manner respectively.

Our results from both experiments demonstrated that both serial position and value had an effect on practically all measures of recall dynamics and particularly in the delayed free recall. Specifically, value interacted with condition in both Experiment 1 and Experiment 2 for the delayed free recall, in terms of probability of recall and probability of first recall. In Experiment 1, participants in the value condition recalled more high than low-value items and were also more likely to begin their recall with higher-value items compared to the control condition. In Experiment 2, participants of all three conditions were more likely to recall a high-value item, however, participants in the ascending conditions were less likely to do so compared to participants in the other two conditions. A similar pattern of results was found for probability of first recall where participants in

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the ascending condition were more likely to begin their recall with a lower-value item compared to participants of the descending and random condition. Additionally, in Experiment 2, the value lag conditional response probabilities exhibited stronger backward transitions for the descending condition, although the ascending and random condition exhibited stronger forward transitions. The serial position effects observed in our two experiments are similar to those observed in the literature, as we found primacy effects for probability of recall and probability of first recall for all conditions in both experiments, with the exception of a strong recency effect for the ascending condition in Experiment 2.

Overall, participants were sensitive to value and they were successful in remembering higher-value items, usually at the expense of lower-value items. However, unlike what we had hypothesized, the majority of the typically observed serial position effects remained, with the exception of the primacy effect for the ascending condition in Experiment 2. Our results suggested that both serial position and value had an effect on the recall dynamics in both experiments.

Current theories of memory account for primacy effect in one of two ways. Some argue that early list items have more opportunities for rehearsal in short-term memory and thus have a greater chance of being processed into long-term memory resulting to primacy (Rundus, 1971; Anderson, Bothell, Lebiere, & Matessa, 1998). Others argue that primacy results from the fact that items that come at the beginning of a list have less or no interference compared to items that come at the end of a list (Wixted and Ebbesen, 1991). Our results have important implications in terms of memory theory and theory development. Even though the introduction of a new dimension, namely value, did not

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allow us to completely take away the serial position effects, it produced some unusual effects particularly in Experiment 2. Specifically, the presence of value and the order of value-presentation in the ascending condition in Experiment 2 did not simply take the primacy effect away but it created a strong recency effect for both probability of recall and probability of first recall. Neither a rehearsal or an interference account could explain our results suggesting that that current theories of memory require updating that takes the importance of information into account.

Our results have some interesting implications also in terms of theory of why important information is remembered better than less important information. Specifically, we can refute the hypothesis that rehearsal is the driving force for this apparent selectivity for higher-value information. According to Laming's algorithm (Laming, 1999), if rehearsal was the mechanism by which important information is remembered better, then participants in the ascending condition in Experiment 2 should be remembering more low than high-value items as a result of the fact that they have more time to rehearse those low-value items because they appear at the beginning of each study list. However, our results indicated that participants in the ascending condition are recalling more high than low-value items, exhibiting a recency effect, even though those high-value items appear at the end of the study list and thus participants have less time to rehearse them.

One could argue that participants in the ascending condition simply ignore the low-value items and rehearse the high-value items instead. However, the distractor task is intended to not allow for rehearsal. Therefore the most recently presented (high-value) items should almost never be rehearsed and as a result almost never be recalled. This is clearly not the case. Importantly, participants in the ascending condition remembered

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more low-value items compared to the other two condition, potentially due to primacy and rehearsal. Therefore rehearsal is indeed having an effect on probability of recall. However, participants in the ascending condition are still remembering more high than low-value items, suggesting that rehearsal is not the driving force for more important information being remembered better.

Recently Ariel and Castel (2014) proposed and tested two non-exclusive hypothesis for why participants are successful in better remembering important information, namely the differential resource allocation hypothesis and the information reduction hypothesis. According to the former, participants attempt to encode both high and low-value items but they allocate more attention to the high-value items. On the other hand, according to the information reduction hypothesis participants attempt to entirely avoid and ignore low-value items during study. We believe that our results provide support for the differential resource allocation hypothesis.

We propose that the fact that participants in the ascending condition are recalling more low-value items than participants in the other two conditions is evidence for the fact that participants are not simply ignoring the low-value items. Our results fail to find support for the information reduction hypothesis. If this was the case, and considering the fact that participants are aware that the values will be presented in ascending order for all lists, participants should have always ignored the first 4-5 items and simply study the last 5 items that also happened to be the highest-value items.

In summary, our results illustrated that participants attempted to encode items in all trials. It appears that participants allocated attention to the low-value items but increased this allocation for the high-value items. It is possible that depending on the task

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conditions participants develop a distinct agenda for how to encode the information. Therefore, there is a possibility that participants in the value condition of Experiment 1 and the descending and random conditions of Experiment 2 are actually attempting to entirely ignore the low-value items. However, until we have further proof that that is the case we are assuming that participants in all three conditions are using similar strategies to encode the information and maximize their points. Additionally, even if participants in the descending and random conditions are using different strategies they are still recalling a relatively high percentage of low-value items. Therefore the differential resource allocation hypothesis appears to be the best explanation of why participants are successful at selectively remembering higher-value information. Future studied could examine this by suggesting different strategies to the participants before the beginning of the experiment. Additionally, future research could better test the differential resource allocation hypothesis by manipulating depth of encoding for high compared to low-value items. Lastly, future research ought to have participants assign values to the study items before study, as subjective and objective assignment of values might give rise to differential value effects.

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