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## The Effect of Future Oriented Tasks vs Incidental Orienting Task on Item-to-Item Associations

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### **Abstract**

Working memory (WM) is involved in temporary processing and maintenance of a limited amount of information. WM serves as an access-way to long-term memory (LTM). Individuals encode information into LTM best when the amount of information processed does not exceed the capacity limit of WM. Different strategies, like processing information in terms of future planning, improve verbal LTM performance, however, it is unclear if this results from increased efficiency in WM. This study aims to investigate how processing instructions manipulated at encoding alter associative memory binding as a function of WM capacity. Participants completed a computerized verbal WM word association task with lists of 3, 6, and 9 words. Processing instructions were manipulated between participants. The WM word association task was followed by a surprise recognition test to measure LTM and then a self-report questionnaire regarding memory strategy use. Results replicated past research and revealed a significant associative binding benefit for the within capacity 3 word list length across conditions. There was no difference as a function of processing instructions; however, the means were in the predicted direction of supporting a benefit of future planning instructions on improving associative memory binding and potentially increased capacity. Evaluation of the questionnaires suggested that participants used different encoding strategies when given incidental instructions (semantic strategies) versus planning instructions (relevance strategies). Most participants reported using semantics and familiarity strategies during the recognition task. Design limitations, potential implications and future directions are discussed.

FUTURE V INCEDENTAL PROCESSING

MONTCLAIR STATE UNIVERSITY

The Effect of Future Oriented Tasks vs Incidental Orienting Task on Item-to-Item

Associations

by

Victoria Winters

A Master's Thesis Submitted to the Faculty of

Montclair State University

In Partial Fulfillment of the Requirements

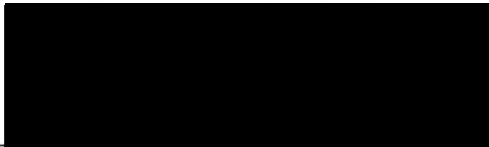
For the Degree of

Masters in General Psychology


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FUTURE V INCIDENTAL PROCESSING

/ THE EFFECT OF FUTURE ORIENTED TASKS VS INCIDENTAL ORIENTING  
TASKS ON ITEM-TO-ITEM ASSOCIATIONS /

A THESIS

Submitted in partial fulfillment of the requirements

For the degree of Masters in General Psychology

by

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Montclair, NJ

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iii

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**Table of Contents**

**Abstract**..... i  
 Copyright © 2017 by Victoria Winters. All rights reserved..... iv  
 Acknowledgements..... v  
 Table of Contents..... vi  
 List of Figures..... vii  
 The Effect of Future Oriented Tasks vs Incidental Orienting Tasks on Item-to Item  
 Associations..... 1  
     Working Memory..... 2  
         Embedded process models. .... 3  
     Processing and Memory..... 4  
         Levels of Processing. .... 4  
**Future-oriented processing**..... 6  
     WM Capacity & Associative Memory ..... 10  
     Current Research..... 11  
         Hypotheses..... 11  
 Methods..... 12  
     Participants..... 12  
     Design ..... 13  
     Procedure ..... 13  
         Phase one: Word list with orienting task. .... 14  
         Phase two: Word pairing recognition probe task ..... 15  
         Phase three: Questionnaires. .... 16  
 Results..... 16  
     Recognition Proportion Correct..... 17  
     Recognition Response Times..... 18  
     Questionnaires..... 18  
 Discussion..... 20  
     Recognition Proportion Correct..... 20  
     Recognition Response Times..... 22  
     Surveys..... 23  
     Limitations ..... 24  
     Future Directions ..... 28  
     Conclusion ..... 29  
 References..... 30  
 Appendix..... 40

**List of Tables**

*Table 1.* Total number of missed trials as a function of between participant condition (N=198). ..... 32

*Table 2.* Number of encoding trials missed per trial (N=198). *Table 2.* Number of encoding trials missed per trial (N=198). ..... 33

**List of Tables**

*Figure 1.* Sample 9 word list length presentation in Phase I (A) and word probe trial in Phase II (B). ..... 34

*Figure 2.* Illustration of the serial position impact on word lists. .... 35

*Figure 3.* Proportion correct during the list-membership recognition probe task (n= 180). Error bars represent one standard error. .... 36

*Figure 4.* Mean associative response times in milliseconds during the probe task, (n=180). Error bars represent one standard error. .... 37

*Figure 5.* Percentage of reported strategies used to select a word in the encoding phase of the experiment, N=199. .... 38

*Figure 6.* Percentage of reported strategies used during the probe phase of the experiment, N=199. .... 39



## FUTURE V INCEDENTAL PROCESSING

### **The Effect of Future Oriented Tasks vs Incidental Orienting Tasks on Item-to Item**

#### **Associations**

A large portion of past research has demonstrated a robust effect of processing instructions on improving long-term memory (LTM) ( Craik & Lockhart, 1972; Mazuryk & Lockhart, 1974; Rose, Myerson, Roediger, & Hale, 2010). There is inconsistent evidence about how processing instructions impact working memory (WM). Some research suggests that WM and LTM are both significantly enhanced by depth of processing (Loaiza, McCabe, Youngblood, Rose, & Myerson, 2011; Mazuryk & Lockhart, 1974), whereas other research suggests only minimal enhancement of WM (Rose et al., 2010). Understanding how new information is transferred into LTM may result in novel treatments for individuals with memory disorders, and lead to a greater understanding of learning strategies that may improve cognitive ability and specifically memory.

Although active processing of information currently interests psychologists, many researchers commonly describe memory as an act of recalling past events (Baddeley, 2012; Baddeley & Hitch, 1974; Craik & Lockhart, 1972; Sandry, 2013). Therefore, a large body of research has examined the amount of information that individuals can retain, the accuracy of one's recollections, how much information can be stored and for how long, and how this information is biologically stored in the brain (Cowan, Donnell, & Saults, 2013; Cowan et al., 2005; Klein, 2013; Miller, 1956; Oberauer, 2002). However, some recent research has adopted an alternative functional approach to understanding memory and shifted the focus of research to understanding memory as a

## FUTURE V INCEDENTAL PROCESSING

system that has evolved to help people plan for the future, rather than to remember the past (Klein, 2013).

### **Working Memory**

WM refers to the control, regulation, and maintenance of information that is processed at any given time with capacity limitations (Baddeley, 2000; Cowan, 2010; Cowan et al., 2005). In an early model of WM, researchers suggested that there were modality specific systems that process different types of information. The visuospatial sketchpad processes visual and spatial information and the phonological loop processes articulatory and verbal information. These separate components are subsystems of the central executive, which is dedicated to processing decisions and sending information to the correct subsystem (Baddeley & Hitch, 1974). Some of the evidence favoring the multi-component model of WM came from neurological patients as well as dual-task studies that provided converging evidence that these subsystems operated separately (Baddeley, 2000). There have been successive revisions to the multicomponent model, for example, the episodic buffer, a subsystem thought to integrate temporary information, was eventually added to the model in order to account for discrepant findings (Baddeley, 2000). While extremely influential in WM research, treatment of the episodic buffer is vague with respect to how information was transferred between WM and LTM (Cowan, 2011). Alternate models of memory do not assume WM operates as distinct subsystems but instead these models assume memory is composed of interacting layers or embedded processes and the level of accessibility to the contents of memory can be understood in terms of the amount of attention directed at internal memory representations (Cowan, 2001; Oberauer, 2002).

## FUTURE V INCEDENTAL PROCESSING

**Embedded process models.** WM holds information in a temporarily heightened state of availability (Logie & Cowan, 2015). Each embedded system holds information in a higher level of accessibility than information stored in LTM. Information that a person is actively paying attention to is more activated and available in WM (Cowan, 1993; Cowan et al., 2005). Alternate embedded processing models have been proposed to understand the structure of WM. Each model puts forward possible subsystems of different capacities which all hold a limited amount of information in varying levels of activation for short periods of time (Cowan, 1988, 1993, 2010; Cowan et al., 2005; Cowan, Scott Saults, & Elliott, 2002; Oberauer, 2002).

These two major embedded processing models of memory make similar assumptions about WM. In the original embedded process model, information of any modality is most accessible when it is available in the focus of attention. The focus of attention is limited, as it holds only what is immediately accessible for online processing, to be used at that moment (Cowan, 2000, 2001, 2010). According to this model, the focus of attention reflects the information that is easily accessible from conscious awareness and the focus of attention is capacity limited in that it can hold only three or four separate pieces of information. All other information is assumed to be maintained in a stimulated portion of LTM, called activated LTM. Information in activated LTM can be brought into the focus of attention more easily than information available in the non-activated portion of LTM (Cowan, 2000, 2001, 2011).

In a related but alternate embedded process model, the focus of attention is further subdivided into two regions. In this model, the focus of attention can only attend to one item at a time (Oberauer, 2002). The additional embedded component, the region of

## FUTURE V INCEDENTAL PROCESSING

direct access can hold about three items in a less activated state than the focus of attention, but more accessible than activated LTM. Items in the region of direct access can more easily shift into the focus of attention than information from LTM (Oberauer, 2002). This memory model has more flexibility in design, but still provides evidence of higher activation for no more than four items at a time. Both Cowan's and Oberauer's models agree that WM has a capacity limit of about four pieces of information, although they disagree on the terminology and activation level of the storage states.

### **Processing and Memory**

**Levels of Processing.** Early memory models, such as the multistore model (Atkinson & Shiffrin, 1968), tried to explain memory as an information storage system. Some researchers criticized such storage-focused models for not clearly explaining whether the limitations of memory result from *processing* capacity or *storage* capacity ( Craik & Lockhart, 1972). Therefore researchers began to examine the processing capacity rather than storage capacity (Baddeley & Hitch, 1974; Craik & Lockhart, 1972). Processing capacity suggests that there is a limit to how much information a person can actively encode at a given time, whereas storage capacity suggests that boundaries of memory are the result of a limit to the amount of information that can be stored and maintained (Craik & Lockhart, 1972). Research investigating processing suggested that memories are encoded based on their depth, or degree of cognitive and semantic analysis required to process information. Information that has greater depth creates a memory trace that can be strengthened with further elaboration or enrichment. Deeper processing allows for more items to be recalled than shallow processing, suggesting that storage

## FUTURE V INCEDENTAL PROCESSING

capacity could be altered based on how information is processed ( Craik & Lockhart, 1972). This view was labeled levels of processing.

The levels of processing approach suggests that the function of memory for an organism is not only to extract meaning from environmental stimuli, but to store the product of deeper analysis for future use. Therefore the creation of memories is not just to store accounts of experiences, but to encode aspects of the experiences that can be used in future situations. It is possible to directly manipulate the level of processing a participant employs while doing a task by using instructions such as to repeat a word (shallow processing) or to use a word contextually, in a sentence (deep processing). The more demanding task, putting a word in context, encourages processing the word with more depth. Understanding the meaning or context often leads to better delayed recall, suggesting that processing information impacts how well information is encoded into LTM (Craik & Lockhart, 1972).

Past research has produced inconsistent evidence regarding how levels of processing instructions affect WM and LTM. Deep processing leads to better LTM performance in both recall and recognition tasks following a delay compared to information processed shallowly, or rehearsal (Mazuryk & Lockhart, 1974). However, more recent research suggests that levels of processing does not impact activated information in WM, but that WM retrieves meaningful information from LTM after a short delay (Rose et al., 2010). In a recall and recognition task, depth of processing had a minimal effect on immediate WM recall, yet depth of processing led to greater performance on delayed LTM tests with the same items. Additionally, results showed that longer lists of eight words actually led to better recall than four word lists in the semantic

## FUTURE V INCEDENTAL PROCESSING

conditions, suggesting that depth of meaning leads to storing a greater number of items (Rose et al., 2010).

Alternate recent research reported that the effect of levels of processing was the same across both WM and LTM (Loaiza et al., 2011). Here, participants were given a reading span task that asked them to recall words that were presented within both shallow and deep oriented sentences followed by a two minute distractor task. Participants performed better on immediate and delayed recall tasks involving deeper items (Loaiza et al., 2011). The superior performance on reading memory tasks when given deep processing tasks on both immediate and delayed recall indicates that deep processing tasks are more effective than shallow processing tasks both in WM and LTM retrieval (Loaiza et al., 2011). Deeper levels of processing may provide stronger representations that can be retrieved from WM and LTM into the focus of attention. This could indicate that deeper processing leads to more available retrieval from than information that has been shallowly processed (Loaiza et al., 2011).

**Future-oriented processing.** While much research focuses on the structure of memory (Atkinson & Shiffrin, 1968), where memory is located in the brain (Eriksson, Vogel, Lansner, Bergstrom, & Nyberg, 2015), or what storage state memory is held in (Cowan, 2001, 2010, 2011; Oberauer, 2002), there is also interest in examining memory from the perspective of understanding the purpose of memory. While the structure of memory describes its design, psychologists should also focus on how those aspects contribute to the function of the memory system (Klein, 2013). Traditionally, research has examined what the system of memory is capable of recalling or recognizing with less consideration regarding the purpose of the system. This is partially due to the thinking

## FUTURE V INCEDENTAL PROCESSING

that understanding structure will explain function (Nairne, 2005). By overlooking function, researchers may have missed an important and informative frame of reference that explains why different structures exist in the way that they do (Klein, Cosmides, Tooby, & Chance, 2002). Initially, functional approaches to memory investigated a connection to evolutionary explanations for why certain information was maintained in the memory system. One functional perspective is that memory systems developed over the course of humans' evolutionary history to help organisms adapt their responses to problems regularly faced by the organism (Nairne, 2005). The ability to use memory in the service of future situations may be one of the selection pressures that gave rise to human memory as it operates today.

To explain the function of memory, Klein (2013) suggested that "memory has been designed by natural selection not to relive the past, but rather to anticipate and plan for future contingencies" (p. 222). This suggests that the focus of memory should not be on the structures of stored knowledge, but instead, research should be focused on understanding the *use* of memory. According to this approach, memories are created from past experiences in order to anticipate future events and inform action decision-making. In order for an organism to adapt to new circumstances based on past experiences, the organism must be able to retrieve previously acquired information and direct that information in a way that is relevant for current and future possible situations (Klein, 2013; Klein, Robertson, & Delton, 2010; Nairne, 2005). Therefore, memory should be seen as a future oriented system rather than the retrospective view that defines memory as a storage system for past experiences. This view promotes a shift in design and interpretation of memory paradigms in research. As discussed previously, WM maintains

## FUTURE V INCEDENTAL PROCESSING

information in an easily accessible state for brief periods of time. The purposeful use of temporarily held information depends on the goal of the task, the structure of the task, and the context in which the task is performed (Eriksson et al., 2015). This concept of active and flexible ‘working’ memory could be explained as prospective use of information for current and future goal-directed behavior. This constantly adjusting aspect of WM allows humans to act beyond the present moment (Eriksson et al., 2015).

In fact, the different types of memory seem to be atemporal when examined closely. Semantic and procedural memories exist without reference to an earlier time. Rather, procedural memories exist to deal with current or future contingencies and semantic memories can be seen as directing behavior to meet environmental demands (Klein, 2013). Episodic memory appears to have a more past-focused temporality, however from a future-oriented perspective, episodic memory enhances our ability to act effectively by imagining ourselves in future scenarios based on past outcomes (Klein, 2013). For example, a recent study found that participants performed better than a control group on a prospective memory task if they had mentally simulated the order of events necessary for the task the day before. This indicates that mentally simulating future information does improve future performance (Neroni, Gamboz, & Brandimonte, 2014).

***Survival vs planning future orientated processing.*** Evidence illustrates that orienting tasks requiring either survival decisions or planning decisions (both future oriented processing) may enhance retrieval of information more than traditional deep processing tasks (Klein, 2013; Klein, Robertson, & Delton, 2011; Sandry, 2013). Earlier research focused on survival as the driving factor in improved recall and recognition due to possible evolutionary reasons, for example, remembering information relevant to



## FUTURE V INCEDENTAL PROCESSING

survival would have a fitness advantage (Klein et al., 2010, 2011; Nairne & Pandeirada, 2011; Nairne, Thompson, & Pandeirada, 2007). On closer examination, planning conditions led to superior recall compared to functional survival oriented processing instructions, (Nairne et al., 2007) as well as other traditionally deep levels of processing conditions in recall tasks about a future-oriented scenario (Klein et al., 2010). This indicates that a survival scenario led to improved performance simply because it encouraged future planning during encoding, not because of the survival component (Klein et al., 2010). Additional research in this area corroborates this proposal because alternate fitness-relevant scenarios were not beneficial to memory (Sandry, Trafimow, Marks, & Rice, 2013). The planning component of survival processing instructions might be a better explanation for the memory advantage and one that is still congruent with a functional approach.

Additional research investigated the benefit of planning instructions on a WM task. Participants in planning conditions performed better on recognition tasks compared to control conditions in both immediate (WM) and delayed memory (LTM) trials. For example, response times for a WM task were shorter in a future-oriented planning condition when the list length was within the capacity of WM, suggesting future-oriented processing instructions lead to more efficient WM processing (Sandry, 2013). These studies indicate that processing information on the basis of future-oriented planning instructions improves both LTM (Klein et al., 2010) and WM efficiency (Sandry, 2013). This research suggests that information processing in WM is improved when participants are given a future oriented planning task and that WM is sensitive to processing

## FUTURE V INCEDENTAL PROCESSING

instructions, particularly when the to-be-processed information is within the capacity of WM.

### **WM Capacity & Associative Memory**

In addition to understanding the structure and function of memory, there is also an interest in how information from the limited capacity system of WM binds to LTM. Recently, researchers investigated how WM capacity is related to forming new associations in memory. Researchers manipulated the amount of information that participants were presented with and tested whether participants would be able to form new associations if the amount of information was outside of the capacity limit of WM (Cowan et al., 2013). Capacity was manipulated using lists composed of 3 words, 6 words, or 9 words. Participants were asked to make an incidental judgment, in this case, choosing which word is most interesting. The words in each list were randomly chosen by a computer, there were no obvious associations between words in any given list. The processing task required participants to choose one word as most interesting in order to deter participants from making meaningful connections between words. After completing selections for 12 lists of each list length of words, participants were given a surprise recognition task in which they were presented with two words and asked to indicate whether the two words came from the same list. The authors hypothesized that participants would perform better on this task when the amount of incidentally encoded information was within the capacity of WM, that is, when only 3 words were processed at a time. The findings of this study illustrated that participants did perform above chance accuracy when identifying words drawn from the same 3 word list. Performance was not significantly different between the beyond capacity 6 and 9 word lists, where

## FUTURE V INCEDENTAL PROCESSING

performance was close to chance (Cowan et al., 2013). This evidence supports the limited capacity view of WM and provides further evidence that the focus of attention cannot form associations when the capacity limit is exceeded. This is because participants performed significantly better on the 3 word list length recognition than either the 6 or 9 word list lengths, implying that list lengths longer than 3 items exceeds the capacity of WM.

### **Current Research**

Currently, it is unclear how future-oriented processing instructions impact the formation of novel associations in WM. Given the benefits of future-oriented processing on WM, it is likely that the limitations on WM capacity could be expanded. In the present experiment, we replicate the basic design of Cowan et al. (2013) and manipulate processing instructions (Klein et al., 2010; Sandry, 2013) to determine how future-oriented processing in WM impacts associative memory formation in LTM. All participants were presented with an incidental encoding task using lists of 3, 6, or 9 words and assigned to one of two conditions: choosing the most interesting word (incidental orientation; (Cowan et al., 2013) or choosing the word that would be most useful for planning a future party (planning orientation; Klein et al., 2010; Sandry, 2013). Following the encoding task, participants were presented with a surprise recognition task and asked to indicate whether two words were originally presented together. We aimed to test the following hypotheses regarding both WM and LTM.

**Hypotheses.** First, we expect to replicate past work and demonstrate higher accuracy of recognition for item-to-item associations for smaller list lengths that are

## FUTURE V INCEDENTAL PROCESSING

within the capacity of WM (3 word list; Cowan et al., 2013). Having examined past research, we made the following additional hypotheses.

***Future-Orientation of Memory.*** If the future-oriented processing instructions improve the efficiency of WM processing, then participants assigned to the future-oriented planning condition will demonstrate higher accuracy on the surprise LTM recognition task overall. On the basis of past research, different outcomes with respect to the list length might support different assumptions about WM. Specifically, if WM is a static resource, the benefit of future-oriented processing instructions will be limited to the 3-item list (within a stable capacity). If WM is a flexible resource, the benefit of future-oriented processing instructions may extend to larger list lengths, that is, it is possible that any processing benefit that is observed in the 3-item list would extend to the 6 or 9 item list.

## Methods

### Participants

In this experiment, 199 undergraduates (150 female, 48 male) from Montclair State University participated for partial course credit. The average age was 20.03 ( $SD=3.54$ ). We estimated our sample on the basis of prior research (Cowan et al., 2013) and doubled that sample size because the present study aims to replicate those procedures while also including a second between participants condition. A software algorithm randomly assigned participants to the interesting condition ( $n=97$ ) or the future planning condition ( $n=101$ ). One participant completed the experiment, however, their data was lost to computer error and their responses are not included in the main analysis, although they are included in the survey data.

## FUTURE V INCEDENTAL PROCESSING

### **Design**

This experiment replicates and builds on the procedures designed by Cowan et al. (2013) using a 2 x 3 mixed design assessing the impact of Processing Instructions (Interesting vs Planning) between participants and List Length (3, 6, or 9 Words) within participants on recognition memory for novel word pairs. Words were drawn from the same list used in Cowan et al. (2013). No particular effort was made to include words that were relevant to planning because past research has demonstrated that word-scenario congruency is not necessary to observe reliable effects (Nairne & Pandeirada, 2011; Sandry, 2013).

### **Procedure**

Participants were tested in individual rooms with an experimenter who monitored compliance to ensure participants read the words aloud. This aimed to ensure that the full lists were read before a selection was made. If the full list is not read, it cannot be known if all of the words entered W M. Participants were presented with a word list in black uppercase letters in single column on the computer screen. A white box surrounded each word with the remainder of the screen was black (Figure 1A). The words for the tasks were the same words used by (Cowan et al., 2013) and were selected from the MRC Psycholinguistic database (Fearnley, 1997). The words used were common, monosyllabic nouns with two to six letters. Words that were chosen had high scores in categories such as concreteness (591-670), imagery (459-667), and medium to high scores on familiarity (364-646). Each category is scored from 100 to 700. Additionally, they had a Kucera and Francis written frequency of 1-1207. A software algorithm randomly assigned the words to lists and recognition probe pairs.

## FUTURE V INCEDENTAL PROCESSING

**Phase one: Word list with orienting task.** The procedure was identical to (Cowan et al., 2013), however, processing instructions were manipulated between participants to be either incidental or future oriented processing instructions. Each participant was presented with 12 lists of each list-length of 3, 6, and 9 words, a total of 36 word-lists. A total of 216 words were presented to each participant. For each list, participants were asked to make a judgment about which word was most interesting or which word would be most useful when planning a party.

*Incidental processing instructions (Identification of most interesting word):* We would like you to select the word in the list that is most interesting by using the mouse to click on that word (Cowan et al., 2013).

*Functional Processing Instructions (Identification of most useful word for future planning):* We would like you to imagine you are planning a dinner party for the weekend. You plan to go to the store to purchase food. Since you are not sure of the guests' food preferences, you plan on purchasing a variety of different foods. We would like you to select the word in the list that is most relevant to planning for your party by using the mouse to click on that word (Klein et al., 2010; Sandry, 2013).

Word lists were presented vertically with one word per row centered on the computer screen (Figure 1A). Letters were 7 mm tall, baselines 27 mm apart, and were in all uppercase letters. Three-word lists were presented for 4.5 s, the six-word lists for 9.0 s, and the nine word lists for 13.5 s, allowing participants enough time to read each word aloud. Participants were instructed to use the mouse to click the word that they choose as most interesting or most useful, depending on their condition. Participants were not

## FUTURE V INCEDENTAL PROCESSING

informed of the surprise recognition task in the second phase to encourage the participants to focus attention on the words in the list in the context of their processing instructions, without intentional memorization. The computer software randomized the order of the words for each list presented to each participant. Participants were randomly assigned to the interesting condition or the planning condition by the computer program.

**Phase two: Word-pairing recognition probe task.**

Following completion of the first phase, participants were presented with a mask for 500 ms. Immediately following the mask, participants were given an unexpected memory task where two words were either drawn from the same or different list as in phase one. In each associative judgment recognition trial, participants were asked to judge if two words came from the same list or different lists (Figure 1B).

Participants were shown two probe words that came from the same or different lists presented in phase one. One word was above a point of fixation, and the other below. The words "NO" and "YES" were shown on left and right side (respectively) of the question "Same list?" (Figure 1B). Participants were asked to use the mouse to select "YES" or "NO" for each trial. The probe words were from the same serial position range of the list, regardless of if they were drawn from the same list or not. For example, both words would be drawn from serial positions 1-3, 4-6, or 7-9 (Figure 2). There could be no more than two words separating probe words selected from a list of 3 words. This was done to ensure that the same restrictions were used across all list lengths in order to prevent an effect due to serial position of words. That is, all words were selected with a separation of only 1 or 2 serial positions. This aimed to allow all word pairs selected to have been in the focus of attention at the same time.

## FUTURE V INCEDENTAL PROCESSING

In the recognition task, each word from phase one was presented in a pair once during phase two, for a total of 108 probe pair trials presented in a randomized order. For two thirds of the memory trials, the probe words came from the same list presented in phase one. Since fewer words were possible in the 3 word lists, this set up allowed for equal presentation of serial positions tested for same list versus different list trials. In other words, more words were not included from the 6 and 9 word lists simply because there were more words on those lists.

**Phase three: Questionnaires.** Participants were given a questionnaire after completing the second phase of the experiment. Questions centered on the strategies they used to complete phase one of the experiment, such as if words were chosen based on semantic qualities, how the words related to them personally, how the word would sound, how it looked or was spelled, which word stood out from others, or a combination of the above mentioned techniques. It also asked what strategies were used when asked to identify if two probe words were originally in the same list (Appendix). Other questions were included to expand understanding of the processes used during the two phases of the experiment.

### Results

Following Cowan et al. (2013)'s procedure, encoding data was inspected prior to analysis to identify missed responses, where a participant did not select a word in the initial trial. If a participant missed an encoding task trial, it could not be confirmed that the participant finished reading the list, and therefore it could not be confirmed that the words on the list made it into WM. Words from the *phase one* encoding task were used to populate the word probe pairs in *phase two*. Therefore, if words did not make it into WM



## FUTURE V INCEDENTAL PROCESSING

during encoding, the probe trial would not necessarily be measuring LTM. We removed LTM probe trials that included any words from missed encoding trials for participants who missed less than 4 encoding trials (Table 1). We operationalized the first three trials as familiarization trials for the participant to become acquainted with the task.

Participants who missed 4 or more encoding task trials were removed completely from analysis, as too many probe words had to be removed, and attention on the encoding trials could not be confirmed. Of the 101 participants in the planning condition and 97 participants in the interesting condition, a total of 14 participants in the planning condition ( $n=87$ ) and 4 participants in the interesting condition ( $n=93$ ) did not meet this criterion. Similarly to Cowan et al. (2013), this aimed to ensure that the probe task analysis was accurately measuring information that had entered WM. All analysis presented below are for the final sample of 180 participants.

### **Recognition Proportion Correct**

The effect of processing directions and list length on accuracy of the recognition task is displayed in Figure 3. There was a significant decrease in accuracy in the 6 and 9 word list lengths across both processing conditions (Figure 3). There was no significant effect due to processing directions; however the means were in the direction supporting a benefit of processing instructions for 3 and 6 item lists (Figure 3). A 2 X 3 mixed ANOVA was performed to examine proportion correct recognition across conditions and list lengths during the probe recognition task (Figure 3). The main effect of List Length was significant,  $F(2,356)=24.51$   $p<.001$ , replicating earlier work (Cowan et al., 2013). There was no main effect of Condition,  $F(1,178)=2.31$ ,  $p=.13$  and no interaction between List Length and Condition,  $F(2, 356)=.56$ ,  $p=.57$ .

## FUTURE V INCEDENTAL PROCESSING

### **Recognition Response Times**

To be thorough, we also investigated response time differences during the LTM task. It is possible that a stronger encoding strategy would lead to easier access to the contents of memory and be observed by shorter response times. The mean response times trend in a direction to support faster response time in the planning condition across all list lengths (Figure 4). A 2 X 3 mixed ANOVA was performed to examine the response times on the probe recognition task (Figure 4). There was no main effect of List Length,  $F(2,356)=2.38$   $p<.09$ . There was no main effect of Condition,  $F(1,178)=.54$ ,  $p=.46$ . There was no interaction between List Length and Condition,  $F(2,356)=.73$ ,  $p=.48$ .

### **Questionnaires**

While participants were removed when examining accuracy and response times, all participant data was included from the questionnaires ( $N=199$ ). All participants completed the experiment and answered the survey questions, even if they were not able to select words in the encoding phase due to the time constraints of the program. Cowan et al. (2013) reported interesting trends in responses, although the survey was not given to all of their participants. Therefore, the same survey questions were used with all participants to try to expand on previous findings. The questions of interest on the survey asked what strategies were used when selecting a word in the orienting task and what strategies were used when trying to remember word pairs. Other questions were included to confirm that participants read each question aloud or whether they selected words prior to completing any list. A coding system was created based on Cowan et al. (2013)'s reported questionnaire results, and was expanded to include categories appropriate for the planning category. Two independent coders rated each survey using a system to identify

## FUTURE V INCEDENTAL PROCESSING

any mentions of strategies used (such as spelling, esthetics, sound, semantics, relevance, salience, length, placement, familiarity, repetition, mismatched, unfamiliarity, 'gut'). The coders' findings were compared for interrater reliability and a third rater resolved disagreements. Strategies used by less than 10% of participants are not differentially reported.

Inter-rater reliability across coders was adequate ( $r=.90$ ) for strategies during the encoding task. In the interesting condition, the top three strategies used to select words reported by participants were semantic qualities of words, or how the words related to them personally (66%), salience, or how much a word stood out (28%), or how it sounded (13%). In the future planning condition, the top three strategies used to select words were relevance to the question (75%), semantics (11%), and salience (5%; Figure 5).

Inter-rater reliability across coders was not as high ( $r=.72$ ) for identifying strategies used during recognition of word pairs. In the interesting condition, the top four strategies used when identifying whether or not two probe words originally appeared in the same list were semantics (30%), familiarity of seeing or saying the words (27%), esthetics, how the words look or picturing the word/item (18%) and sound of the word (13%). In the future planning condition, the top three strategies used during the recognition phase were familiarity (21%), semantics (16%), sound (14%), and repetition of the word in their mind, remembering reading or saying the word (13%; Figure 6). Both conditions reported using semantics and familiarity the most frequently.

## FUTURE V INCEDENTAL PROCESSING

**Discussion**

The first goal of the experiment was to replicate past work and demonstrate higher accuracy for item-to-item associations for smaller list lengths that are within the capacity of WM (3 word list; Cowan et al., 2013). The next goal of this experiment was to examine if future-oriented planning instructions would improve the efficiency of WM processing. We hypothesized that participants assigned to the future-oriented planning condition would demonstrate higher accuracy on the surprise LTM recognition task, correctly identifying more word pairs than the interesting encoding condition in the 3 word list length, and potentially the 6 and 9 word list lengths, the later evidence for flexibility within WM. In sum, the goal was to investigate how future oriented planning instructions would influence associative binding in WM.

**Recognition Proportion Correct**

The main effect of List Length on probe accuracy was significant. This corroborates the findings of Cowan et al. (2013), the words in the 3 word list length led to improved accuracy compared to the 6 or 9 word list lengths. This supports the embedded processing models that suggests a WM capacity of three or four pieces of information (Cowan, 2000, 2001, 2010; Oberauer, 2002), but does not distinguish between levels of activation enough to confirm a limited focus of attention of four items or one item that could be used to differentiate between models.

In contrast to our hypothesis, there was no main effect of Condition on accuracy, and there was no interaction between List Length and Condition. The accuracy for both conditions and all three list lengths fell between .52 and .59 accuracy, with a mean overall accuracy of .54, illustrating that the average performance on this task was

## FUTURE V INCEDENTAL PROCESSING

relatively low overall. Similarly, Cowan et al. (2013) also found responses to be between .52 and .59. This may be due the difficulty of the task. The responses being around chance may indicate that many participants were guessing. Therefore, the instructions presented did not provide a strong enough processing manipulation to show a significant difference between conditions. While there was no difference between conditions, the means were in the predicted direction to support the hypothesis of a flexible WM capacity for future oriented planning instructions (Cowan et al., 2005; Oberauer, 2002).

One possible explanation for why there is less impact from the future orientated directions could have to do with the design of the experiment. Loaiza et al. (2011) suggested that reading words aloud creates a phonological cue, which may interfere with the semantic aspect of the task. Upon looking at the survey data, it was found that a number of participants reported 'repeating the words to see if they sounded like they had been originally read together', leading to 27% reporting using sound and 19% reporting using recognition in the recognition phase. While this was not something set out to be measured, future studies could expand on whether reading a word aloud interferes with other types of encoding.

When analyzing the proportion correct between conditions for this experiment, we tried to ensure that participants included in the analysis had actually read the words aloud during the first part of the procedure, which provides more confidence for the assumption that the words successfully entered WM. A researcher sat behind each participant to remind them to read the words, and to record deviation from this procedure. The data revealed that not all participants successfully made it through the list before making their selection. Additionally, some participants read the words but did not make a

## FUTURE V INCEDENTAL PROCESSING

choice in the allotted time, as evidenced by the high number of missed responses.

Analysis of the survey data reveals that many participants (14%) self-reported skimming or clicking the first word they found relevant/interesting prior to finishing each list. This indicates that they did not read every word on the list as expected. Following Cowan et al. (2013)'s procedure, we eliminated participants who missed enough word selection trials that were deemed to require removal of too many probe pairs in the second task. For the remaining participants, we removed probe trials that included words on a missed encoding trial to ensure that the probe words presented had actually been encoded in WM.

### **Recognition Response Times**

We examined associative recognition response times to see if a future oriented encoding strategy, a stronger strategy than incidental encoding, would lead to easier access to LTM and be observed by shorter response times. There was no main effect of List Length on Associative Response Times in the LTM probe task or for Condition. Nor was there an interaction between List Length and Condition. This is likely because response times on this task reflect access to information already stored in LTM. Again, due to the fact that the average accuracy was slightly above chance, there is the possibility that some participants were merely guessing during this phase of the experiment. It is possible that a different experimental task could improve upon the design used to further examine if LTM recognition time could be improved when information is encoded in a future oriented scenario. For example, a task where the encoding context was reinstated during retrieval may reveal a speed benefit for accessing representations stored in LTM.

## FUTURE V INCEDENTAL PROCESSING

### Surveys

Overall, there were larger differences between conditions in participant responses regarding how they selected words from each list than strategies used when asked to recognize probe pairs. This was expected, as their processing instructions for selection differed. Further, these qualitative differences suggest that participants did try and apply the processing strategy during the encoding task. The most frequent response for the interesting condition was semantics (66%) followed by salience (28%). These results support the efficacy of the processing instruction manipulations, as the task asked them to choose the most interesting word, which resulted in choosing something due to personal interest or if something stood out to the individual participant. Cowan et al. (2013) also found a large number of participants based judgements on semantics (41%). The most frequent response for the planning condition was relevance to a dinner event (75%), which again shows the effect of the instructions requesting a selection that would be most relevant to a dinner party (Figure 5). Research indicates that participants that use encoding strategies perform better on WM and verbal tasks (McNamara & Scott, 2001). Participants who reported use of some form of semantic strategy (e.g. relating to self, story formation, mental imagery) outperformed participants who used rehearsal or no strategy (McNamara & Scott, 2001). For the current experiment, this could suggest that participants who reported using semantics or relevance would therefore both have better recognition performance due to engaging the encoding directions efficiently. Future research should examine if participants who self-report utilization of task specific encoding strategies perform better at the recognition portion of the task. For such an

## FUTURE V INCEDENTAL PROCESSING

investigation, the survey questions should be rewritten to provide more concise and comparable results, such as the questionnaire given by McNamara and Scott (2001).

When asked what strategies were used to identify if two words came from the same original list in the probe task, participants had a larger spread of responses, and there were no strong trends based on condition. Both conditions reported using semantics (interesting =30%, planning = 16%) and familiarity (interesting= 27%, planning = 21%) the most (Figure 6).

### **Limitations**

This experiment had limitations that may have impacted the findings. Some of these limitations could be resolved in future studies. Two core studies were used to design the current study, Cowan et al. (2013) and Sandry (2013). Since the aim of this study was to expand upon their findings, effort was purposefully made to keep as many aspects the same as the original studies as possible. By doing so, a few flaws arose.

First, there was an imbalance between the length and complexity of the interesting directions used by Cowan et al. (2013) and the planning directions used first by Klein et al. (2010) and then subsequently Sandry (2013). Ideally, both conditions would have had instructions that were of equal length and complexity. However, since we know that the instructions used by Cowan et al. (2013) , Klein et al. (2010) and Sandry (2013) led to significant results in their respective studies, we kept the instructions the same. The rationale for this was also to increase the size of the effect between the conditions by pitting a weak processing strategy (incidental encoding) against a strong processing strategy (future-oriented processing).



## FUTURE V INCEDENTAL PROCESSING

Second, the time allotted to read the lists of 3, 6, and 9 words may have been too short for future oriented decisions. The amount of time was chosen by Cowan et al. (2013) in order to ensure enough time to read the list, without giving excess time in order to attempt to prevent allowing repetition. As mentioned previously, 14 participants in the planning condition and 4 participants in the interesting condition were removed due to missing more than 4 encoding trials. More trials were missed in the planning condition (249 missed trials, 6.78%) compared to the interesting condition (86 missed trials, 2.46%; Table 1). It is possible that the planning task required more comparative thinking, which may have slowed decision time. Therefore, the restricted display time may have limited participant's ability to make a selection in time. In order to truly make a decision for this planning task, one may have to go back and forth between items to decide which is the most relevant to the situation. This relative decision making process between 3 to 9 list items may have led to longer processing time than some other future planning tasks have found.

Third, a large number (32.32%) of participants missed the first trial (Table 2), even though they were told that the lists would appear as soon as they hit the spacebar. It seems likely that participants were not expecting the words to appear and disappear as quickly as they did, thus increasing the number of missed encoding trials, and subsequently the number of probe trials that needed to be removed. In the future, practice trials should be added so that participants can adjust to the time allotted for reading and selection.

Fourth, the experiment used a between-subject design, as did Sandry (2013). While this does reduce the possibility of guessing the full aim of the experiment, it led to

## FUTURE V INCEDENTAL PROCESSING

a greater possibility of participant differences in WM ability to interfere with results. This is less ideal for performing precise statistical tests because it invites between subject variability. However, a large sample size was used to try to balance out the limitations of between-subject experiments. If WM ability of each participant was kept constant, it may be more likely to see a difference between encoding directions. This can be achieved through use of a within subject design.

One additional limitation in this experiment was a floor effect, illustrated by the low overall accuracy. The difficult nature of the probe word pair identification task made accuracy around chance (.54). While the 3 word list lengths led to significantly higher recall than the 6 or 9 word list lengths, it is impossible to tell if the effect would have been stronger between conditions if the task itself led to higher initial accuracy. If the task was easier, the encoding manipulation may have shown a larger difference between conditions. Another possibility is that the 6 item list length may have too greatly exceeded WM capacity, which is theorized to be 3 to 4 items (Cowan, 2000, 2001, 2011; Oberauer, 2002). If additional list lengths of 4 and 5 items were included, it might have led to a clearer evaluation of the flexibility hypothesis. An easier task paired with smaller list lengths may lead to a better test of the effect that encoding strategies have on associative binding within WM.

Next, the survey used was adapted from Cowan et al. (2013). The Cowan et al. (2013) study did not use the survey continuously due to a change in research staff, but stated that they still were able to notice trends in processing so this experiment aimed to collect full survey data. In order to remain consistent with comparisons to this earlier research we opted to reuse the same survey questions. However, in some instances, the

## FUTURE V INCEDENTAL PROCESSING

questions should have been rewritten to provide more concise and comparable results. For example, the final question asked about which words and pairs were easiest and hardest to remember. This question confused some participants, which led to only certain parts of the question being answered. Although some of the questions led to vague answers, the key questions for this experiment regarding how participants decided on the word they selected from the initial list and how they tried to recall the word lists were answered clearly enough for the raters to come to consensus on responses.

Finally, based on the discussion of results of Cowan et al. (2013), an additional question should also be added to see if participants compared all words on one list at the same time or if they chose a word early in the list and compared that word to the later list items. For example, in a short list, items could be chunked, or mentally imagined at the same time, but this would not be possible with longer lists. In longer lists, it is possible that the first two items might be compared, and the selected word would be carried to compare to the rest of the list. For example, a participant to compare the first two words, *mouse* to *beef* and choose *mouse*, which in turn may also be more interesting than the third word, *sponge*. *Mouse* may again be more interesting than the fourth word, *bag*, however that means that *bag* was never directly compared to the second word (*beef*) or the third word (*sponge*). If participants used this 'carry over' method, it is possible that there may never have been a comparison between all items on the longer list, since certain words were dismissed after the initial comparison between the first items. Theoretically, this could suggest that not all words on the longer lists had the opportunity to be in the WM at the same time in order to form associations.

## FUTURE V INCEDENTAL PROCESSING

### **Future Directions**

Although this experiment did not find results that fully supported the theory that future oriented tasks lead to increased capacity and efficiency of WM and recognition from LTM, the data did trend in support of this flexibility hypothesis. In further research, the role of future oriented encoding should be paired with an easier task to remove the possibility of a floor effect distorting data between list lengths. An additional alteration could be to include 4 and 5 word list lengths to decrease the difference between conditions. With an easier task and more list lengths manipulated, it may be possible to see a greater impact of future oriented instructions versus incidental instructions.

Additionally, the time constraints of the task should be reconsidered to allow for more decision making time in more complex conditions. In such an experiment, it is possible that a shorter LTM response time may be found. This would support increased efficiency with future oriented processing tasks. Future research should also utilize within subjects design to decrease between participant variability.

Future research in this field could help identify whether WM is a static or flexible resource, thus determining if there is a fixed WM capacity or if capacity depends on task demands. If future oriented memory tasks can be shown to expand the limits of focus of attention, it may suggest that future oriented memory tasks may also create a stronger memory trace in LTM. All of this information could extend research into optimizing WM capacity and binding to LTM. This might be applicable both treatments of memory disorders and development of learning strategies.

## FUTURE V INCEDENTAL PROCESSING

### **Conclusion**

This research study replicated the results of Cowan et al. (2013), suggesting that binding within WM is limited to 3 items. While the future oriented condition did not yield statistically significant results, the means were in the predicted direction to support the hypothesis of improved associative memory binding and increased capacity when given planning instructions. Refinements to the current paradigm in future work may support a benefit of processing instructions adjusting the information processing limitations related to WM capacity. This line of research should continue in order to improve cognitive learning strategies regarding memory, and potentially result in new ways to identify and treat memory disorders.

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## FUTURE V INCEDENTAL PROCESSING

<u>Number of Trials Missed</u>	<u>Interesting Condition</u>	<u>Planning Condition</u>
1	33	30
2	12	23
3	4	15
4	1	3
5	0	4
6	1	0
7	1	1
8	0	1
9	0	0
10	0	2
11	0	1
12	0	0
13	0	0
14	0	1
15	0	0
16	0	0
17	0	0
18	0	2

*Table 1.* Total number of missed trials as a function of between participant condition (N=198).



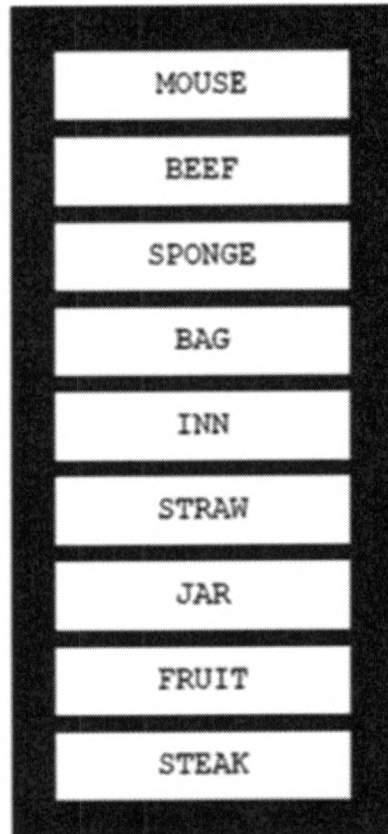
## FUTURE V INCEDENTAL PROCESSING

Encoding Trial Number	Interesting Trials Missed	Planning Trials Missed
1	21	43
2	8	23
3	2	17
4	4	7
5	1	8
6	2	12
7	2	7
8	3	4
9	1	3
10	0	6
11	1	3
12	2	1
13	2	3
14	1	5
15	0	5
16	0	5
17	1	4
18	2	2
19	0	7
20	4	3
21	1	4
22	6	7
23	2	4
24	2	8
25	2	5
26	1	6
27	0	5
28	3	7
29	1	5
30	1	4
31	2	6
32	3	5
33	0	4
34	1	4
35	1	4
36	3	3
<b>Total Trials Missed</b>	<b>86</b>	<b>249</b>

*Table 2.* Number of encoding trials missed per trial (N=198). *Table 2.* Number of encoding trials missed per trial (N=198).

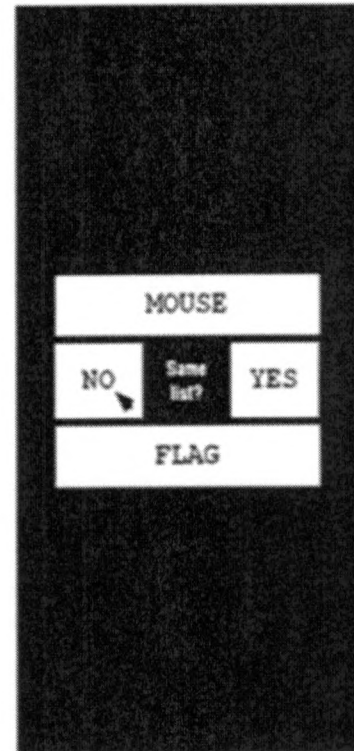
## FUTURE V INCEDENTAL PROCESSING

A. **Word-List Trial:**  
Click on the most interesting word.



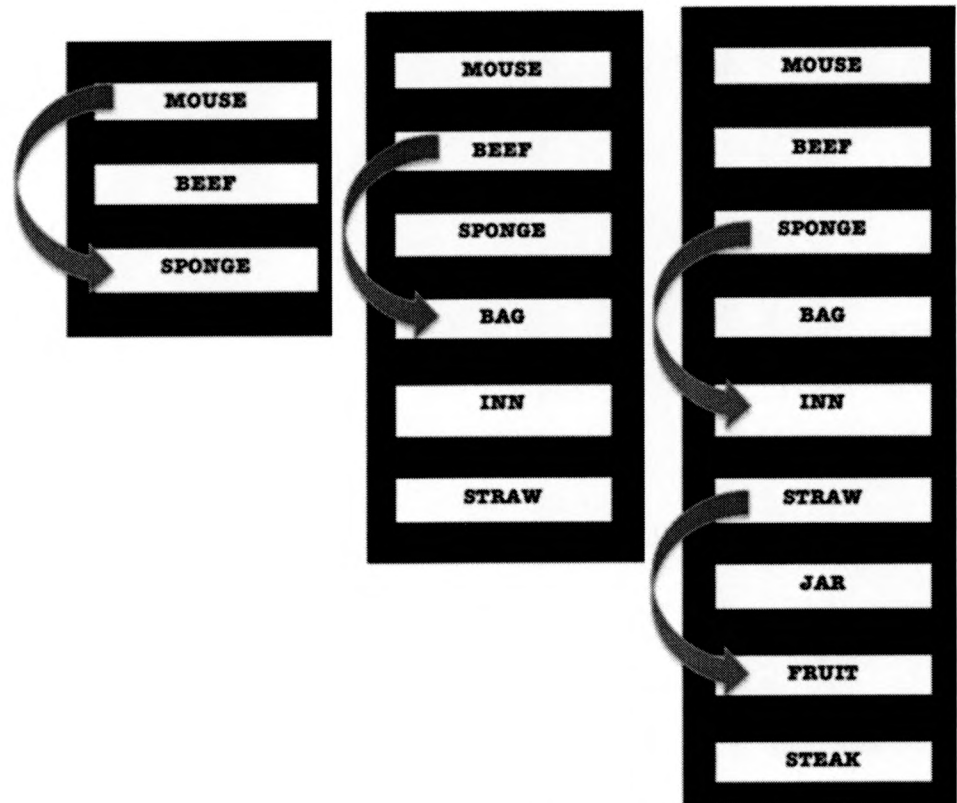
B.

**Word-Probe Trial:**  
Were the two words  
from the same list?



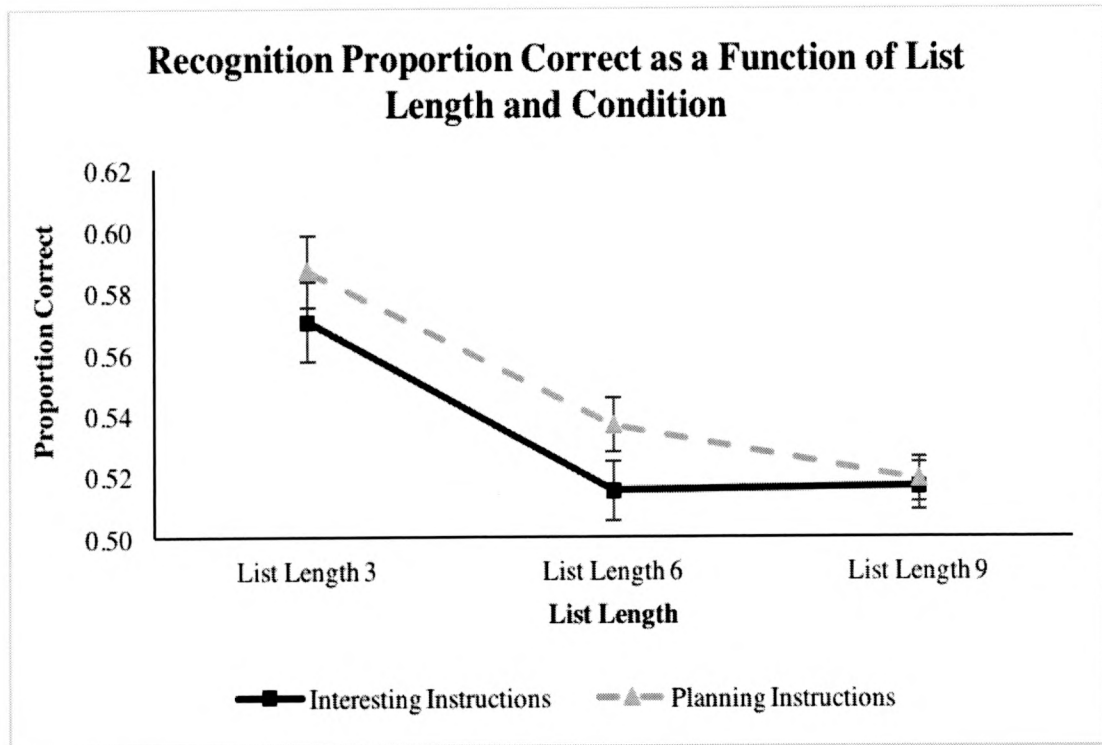
*Figure 1.* Sample 9 word list length presentation in Phase I (A) and word probe trial in Phase II (B).

## FUTURE V INCEDENTAL PROCESSING



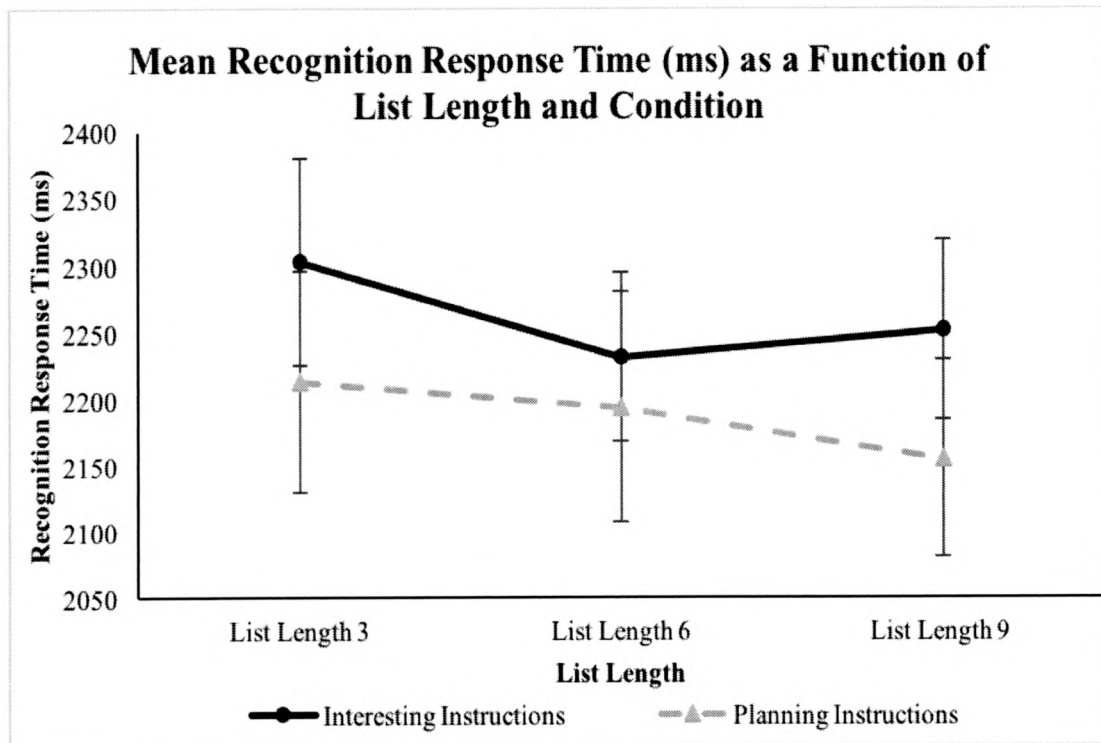
*Figure 2.* Illustration of the serial position impact on word lists.

## FUTURE V INCEDENTAL PROCESSING



*Figure 3.* Proportion correct during the list-membership recognition probe task ( $n=180$ ). Error bars represent one standard error.

## FUTURE V INCEDENTAL PROCESSING



*Figure 4.* Mean associative response times in milliseconds during the probe task, (n=180). Error bars represent one standard error.

## FUTURE V INCEDENTAL PROCESSING

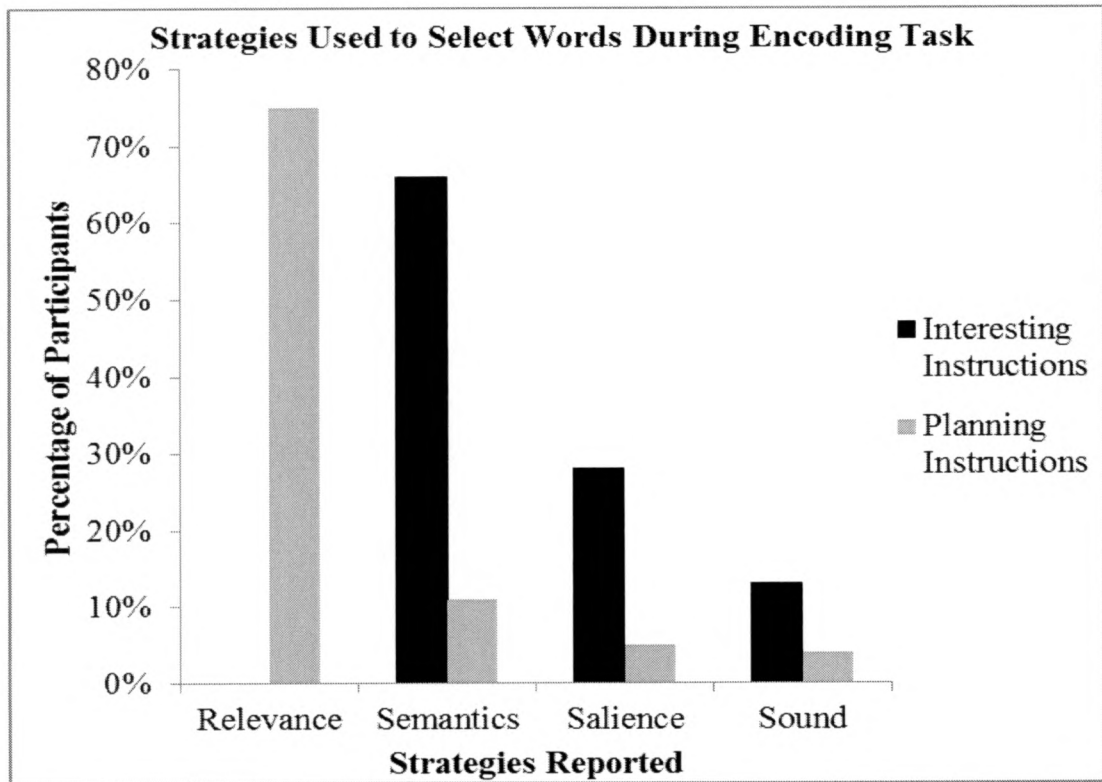
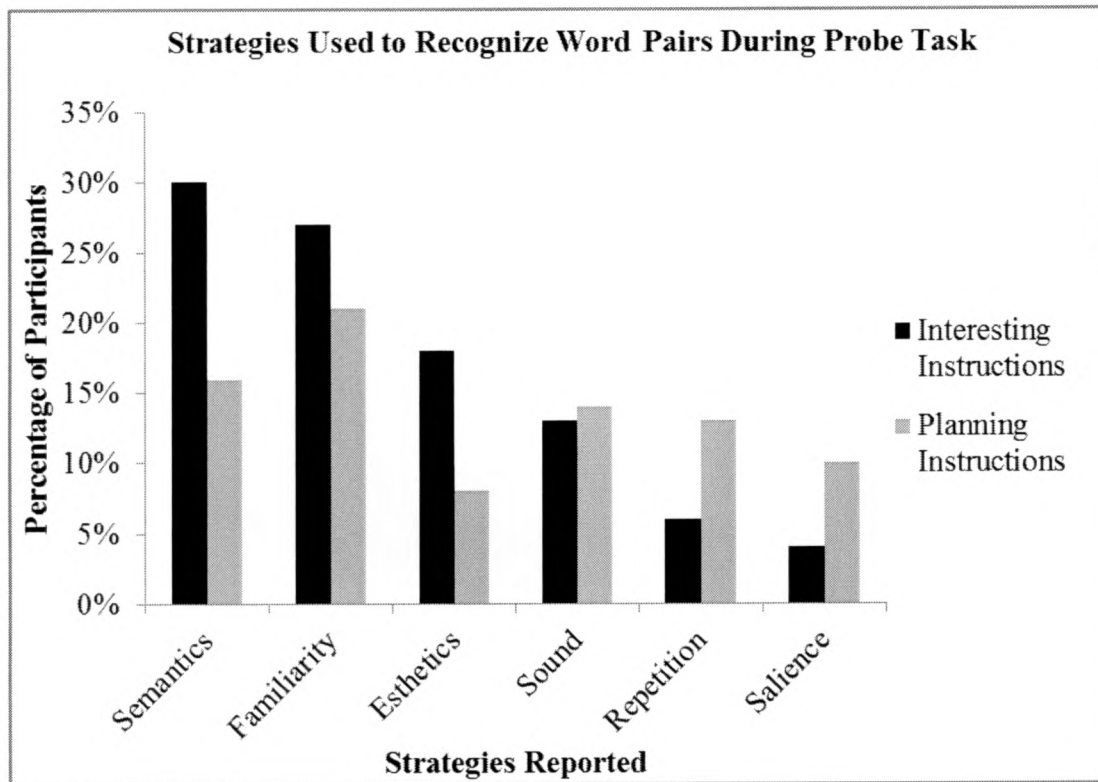


Figure 5. Percentage of reported strategies used to select a word in the encoding phase of the experiment, N=199.

## FUTURE V INCEDENTAL PROCESSING



*Figure 6.* Percentage of reported strategies used during the probe phase of the experiment, N=199.

**Appendix**

**Please answer these questions to the best of your ability.**

1. Please write the *Experiment Number* that is displayed on the computer in the box below.

2. What strategies did you use in your mind to help decide which word to choose from each list?
3. Later on, what strategies did you use in your mind to help remember the word pairings when asked to do so?
4. Did you read ALL the words on every trial or did you skim over some?
5. How loudly did you read the words?
6. Did you expect to be asked to recall the words?
7. What kinds of words were easiest and hardest to remember? What pairings were easiest or hardest?