View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by University of Waterloo's Institutional Repository

Interfering with episodic memory for words and pictures to uncover their representational codes

by

Melissa Meade

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Arts

in

Psychology

Waterloo, Ontario, Canada, 2015

© Melissa Meade 2015

Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

The work presented in Chapter 2 of this thesis has been accepted for publication in the journal Memory. This work is referenced as follows:

Meade, M. E. & Fernandes, M. A. (in press). The role of semantically related distractors during encoding and retrieval of words in long-term memory. *Memory.* (MEM-OP 14-188.R2)

Abstract

In this thesis, a divided attention paradigm was used to infer the representational codes used by words and pictures in long-term memory. Semantically categorized lists of words (Expt. 1) or pictures (Expt. 2, 3, 4, and 5) were studied or retrieved while simultaneously making size judgments to another set of distractor words (Expt. 1 and 2) or pictures (Expt. 3, 4, and 5) presented concurrently. We manipulated (within-subjects) the semantic relatedness and visual similarity (Expt. 4 and 5) of distractor to target item. Recognition accuracy for words was poorer when distractors were semantically related to target items. Recognition accuracy for pictures was equivalent with semantically related and unrelated distractors, but poorer when picture distractors were both semantically related and visually similar to the target item. These findings suggest that long-term episodic memory for words and pictures both require access to semantically-based representations, but that picture memory also requires access to visuo-spatial representations for optimal performance.

Acknowledgements

I would like to thank my supervisor, Myra Fernandes, for her support, guidance, and much appreciated encouragement throughout this process. As well, I want to thank my readers, Mike Dixon and Colin MacLeod,

I also want to thank my family for being so understanding and enthusiastically supportive. Finally, I want to thank Michael Klein for all of the advice, long conversations about this research, candy eating binges, and emotional support throughout this process.

Table of Contents

List of Figures

List of Tables

Chapter 1

Overview of experiments

In this thesis we used the divided attention (DA) technique to infer the cognitive resources and codes used to represent words and pictures in long-term episodic memory. In Experiment 1, we examined the influence of DA on recognition memory for words, when the concurrent task was semantically related or unrelated to the to-be-recognized target words. Participants were asked either to study or to retrieve a target list of categorized words while simultaneously making semantic decisions (i.e., size judgments) to another set of words heard concurrently. We manipulated semantic relatedness of distractor to target words, and whether DA occurred during the encoding phase or the retrieval phase of memory. Recognition accuracy was significantly diminished relative to full attention (FA), following DA conditions at encoding, regardless of semantic relatedness of distractors to study words. However, response times (RTs) were slower under DA with related (DA-R) compared to unrelated (DA-U) distractors. Similarly, under DA at retrieval, recognition RTs were slower in the DA related condition where distractors were semantically related than in the DA unrelated condition where distractors were unrelated to target words. Unlike the effect from DA at encoding, recognition accuracy was significantly worse under DA at retrieval in the DA related condition where the distractors were semantically related compared to the DA unrelated condition where they were unrelated to the target words. These results suggest that availability of general attentional resources is critical for successful encoding, as interference effects were similarly large regardless of the semantic relatedness of distracting items. In contrast, successful retrieval, at least for words, is particularly reliant on access to a semantic code, making it more sensitive to disruption from semantically related than unrelated distractors under DA conditions.

In Experiment 2, we examined whether episodic retrieval of pictures (like the words in Experiment 1) was differentially disrupted by semantically related distracting information. Accordingly, the target study and test materials for the memory task were presented as pictures (colour photographs of common objects) rather than as words. The goal was to determine whether retrieval of pictures, like words, would be disrupted more by semantically related than unrelated distractors. As in Experiment 1, recognition accuracy was worse and RTs were slower under both DA relative to FA conditions. Unlike that experiment, however, recognition memory for pictures under DA at retrieval in the DA related and DA unrelated conditions did not differ. When these data were analyzed together with those from Experiment 1, a significant material type (words, pictures) x condition (DA-R, DA-U) interaction emerged, such that semantically related word distractors were found to interfere more with memory for words than with memory for pictures.

In Experiment 3, we investigated whether interference with episodic memory of pictures depended on the modality of presentation of the distracting information. We hypothesized that the lack of an effect of semantic relatedness in Experiment 2 might have been because pictures have a dual representation (i.e. both semantic and visuo-spatial). As such, we changed the distractors to pictures so as to disrupt access to the visual-spatial code of the target pictures. Experiment 3 results showed, surprisingly, that despite presenting distractors as pictures, we did not find differential interference for distractors that were semantically related relative to when distracting pictures were from semantically unrelated categories.

In Experiment 4, we examined whether distractors that were visually similar (but not semantically related) to the target memory pictures would lead to greater impairment in retrieval than semantically related distractors. Results revealed no differences in memory performance when distractor pictures were either visually similar (but not semantically related), semantically related (but not visually similar), or unrelated to the picture in the target memory task. These results imply that visual similarity of distractors alone does not lead to differentially greater impairment in retrieval of pictures.

In Experiment 5, we assessed whether distractors that were both semantically and visually similar to the target memory pictures would produce larger interference with memory for target pictures. Within the DA related condition, we presented picture distractors that were from the same semantic category, as well as matched to be visually similar to the pictures in the target memory task in terms of shape, size, color, and features. Unlike in Experiments 3 and 4, the DA related condition now led to significantly greater memory interference than a DA unrelated condition in which distractors were both semantically unrelated and visually dissimilar.

Overall, this series of experiments indicates that memory for words is particularly susceptible to interference from semantically related distractors during retrieval, suggesting that representation of words in memory is based primarily on semantic codes. Memory for pictures, in contrast, was only differentially disrupted when distracting items had both semantic and visuo-perceptual overlap with the target pictures. These findings suggest that long-term episodic memory for words and pictures both require access to semantically-based representations, but that picture memory also requires access to visuo-spatial representations for optimal performance. Overall, this thesis provides evidence that the semantic meaning of words and pictures is used to store and retrieve these items in long-term memory, and that visual properties are additionally critical for memory of pictures.

The influence of semantic relatedness on memory for words

When attempting to retrieve information from long-term memory, we often believe that suggestions or hints will help us to remember. For example, without a grocery list, your shopping partner may believe it to be helpful to suggest items that are potentially needed (carrots, potatoes, peppers, etc.) in an effort to help you retrieve the target item (onions), though it is unclear whether these hints are helping or hurting memory. Semantic priming literature predicts facilitation during retrieval, if one is cued with words that are semantically related to those which need to be recalled (Meyer & Schvaneveldt, 1971). However, it is possible that hearing the word 'carrot' would lead to interference with your episodic memory for the word 'celery' because the two items compete for similar representational space. Semantic relatedness of target and distracting items could thus lead to greater interference with retrieval from long term memory.

Such a finding has been documented wherein recall from long-term memory is worse for semantically similar words within a list (Baddeley, 1966). Further, free recall has been found to be impaired by the presence of semantically related relative to unrelated information at encoding (Fernandes, Craik, Bialystok, & Kreuger, 2007; Marsh et al., 2008) and at retrieval (Marsh, Hughes, & Jones, 2008). Given these two disparate perspectives, we sought to clarify the degree to which long-term episodic memory would be negatively affected by concurrently presented items that are extralist (i.e. heard concurrently during encoding, or during a retrieval attempt), or whether memory would be facilitated, as predicted by studies of semantic priming.

To assess the influence of semantically related and unrelated information on episodic memory, we can use a divided attention (DA) paradigm in which we manipulate the relatedness of words in a distractor task to those in the focal memory task. A DA, or dual-task, paradigm consists of a memory task in which each item is encoded or retrieved while concurrent responses are required to a secondary 'distractor' task. If the type of processing required in the distractor task disrupts access to the representational code used to encode or store information in long-term memory, then subsequent memory for those items will be impaired relative to a condition in which encoding and retrieval take place without any distracting task (Fernandes & Moscovitch, 2000).

With regard to what effects distractors might have when present at encoding and retrieval, previous work demonstrates that while encoding seems to be generally disrupted by DA regardless of the type of distracting task, retrieval is more selectively disrupted by some distracting tasks but not others (Fernandes & Moscovitch, 2000; 2002; 2003). For example, using a DA paradigm, Fernandes and Moscovitch (2000) found greater interference in recall of words when the distracting task during retrieval involved the same material or representational system; interference with memory for words was larger when the distracting task was word- compared to digit-based. When DA was present during encoding, they found that memory accuracy was overall worse than full attention, with no differences in magnitude of interference depending on the type of distractor task. They concluded that encoding is dependent on availability/ability to recruit general attentional resources, whereas retrieval success required access to the underlying representational code of the memory traces. A DA paradigm was used in all of the experiments in this thesis to infer the representational code required for words (Chapter 2) and then for pictures (Chapter 3) in long-term memory.

The idea that semantic relatedness of cues could enhance processing is supported by findings from the semantic priming literature. Semantic priming is the decreased response time observed in responding to a target word that is semantically related to a prime, relative to an unrelated prime (Meyer & Schvaneveldt, 1971). Research shows that the simultaneous presentation of two semantically related words leads to faster response times on a lexical decision task (Fischler, 1977). As well, primes preceding target words that require a yes/no recognition decision speed responses to the targets when they are semantically related (Neely, Schmidt, & Roediger, 1983). The results from such studies suggest that we are faster to process, identify, and respond to words when preceded and/or accompanied by other semantically related words. Given this, one might predict that presenting information that is semantically related versus unrelated to that which one is trying to encode or retrieve would facilitate long-term memory.

However, the mere presence of semantically related words, even if extralist and unattended, has been shown to hinder memory performance on an immediate serial recall test (Neely & LeCompte, 1999). Marsh, Hughes, and Jones (2008; 2009) assessed the effect of auditory distraction on free recall of visually-presented semantically categorized lists of words.

They showed that unattended distractors that were semantically related compared to unrelated to the to-be-remembered words increased intrusions on an immediate free recall test and, as others have also shown, reduced veridical recall of target items (Marsh, Beaman, Hughes, & Jones, 2012; Marsh, Sorqvist, Hodgetts, Beaman, & Jones, 2015). Specifically, meaningful irrelevant speech disrupted free recall more than non-meaningful speech, and this effect was amplified when the irrelevant speech was semantically related to the to-be remembered information (Marsh et al., 2009). In Chapter 2, our goal is to determine whether semantically related distractors will improve or impair memory performance, relative to unrelated distractors.

Words vs. Pictures in episodic memory

In this thesis, we additionally sought to determine whether words and pictures require access to similar kinds of codes or representations to serve long-term memory. The findings from Experiment 1 suggest that access to a semantic representation is crucial for retrieval of words from episodic memory. The goal in the next set of experiments was to determine whether retrieval of pictures also depended on access to semantic representations, or whether memory for pictures might instead require access to different or additional representations than that required for words.

Previous researchers have suggested that visual information is stored in long-term memory differently than words, by way of a distinct visual representational code (Paivio, 1971; 1986;1991; Nelson, 1976; Stock, Roder, Burke, Bien, & Rosler, 2009). Neuroimaging data collected by Stock et al. (2009) lend evidence to the idea that information is stored in long-term memory by a code-specific representation involving sensory processing regions of the cortex.

Specifically, they found that identification of words from long-term memory that had been encoded with associated visual objects led to greater activation of visual sensory areas than was the case for words encoded with tactile/haptic associations. These findings indicate that pictorial information is likely to rely on a visual representational code in long-term memory. It is not clear, however, to what extent such a visual representational code is necessary for retrieval of pictorial information, and whether it is more or less important than a semantic or verbal code for memory of pictures.

The much reproduced finding that pictures are remembered significantly better than words (i.e. the picture-superiority effect or PSE, see Kirkpatrick,1894; Calkins,1898; Paivio, 1991) has been explained by the dual-code theory (Paivio, 1971; 1986), which posits that words are coded in memory verbally, whereas pictures are coded both verbally and visually. The additional visual code that pictures acquire over words is thought to enhance memory due to code-redundancy, such that there are a greater number of codes, or traces. Others (Nelson, 1976) have argued that both words and pictures are coded visually, but that the visual sensory code is qualitatively superior for pictures.

Regardless of the specific mechanism responsible for the PSE, pictures do indeed uniquely engage visual processing regions of the brain in comparison to words. Vaidya, Zhao, Desmond, and Gabrieli (2002) scanned participants in fMRI during both encoding and retrieval, and demonstrated that regions differentially involved in studying pictures relative to words were subsequently reactivated during a recognition test in which all items were presented as words. That regions were differentially activated, specifically the fusiform and inferior temporal gyri, during test for words that had been encoded as pictures relative to those that had been encoded as words suggests that the distinct visual code enjoyed by pictures benefits their subsequent retrieval.

In Chapter 3, we aimed to determine whether long-term memory for pictures and words was reliant on the same type of representational code (Experiment 2), and whether a visuo-spatial representational code was crucial for accessing pictures in memory (Experiments 3, 4, and 5). Our overall goal in this thesis was to infer the representational code relied upon for encoding of words and retrieval of words and pictures in episodic memory, by measuring the magnitude of interference experienced under DA conditions. Identifying these will refine our knowledge of how words and pictures are represented in the service of long-term memory.

Chapter 2 (Meade & Fernandes, in press)

The goal in Chapter 2 was to highlight shortcomings and alternative explanations for past work, while also investigating the effects of DA at both encoding and retrieval of words. The influence on long-term memory for words of having semantically related information present in a concurrently performed distracting task has previously been studied. Findings indicate that a distracting task containing speech that is semantically related to to-be-remembered words hinders their retrieval to a greater extent than does unrelated speech (Marsh et al. 2008; 2009). However, this past work was conducted using an unattended speech paradigm, which could pose potential problems in regard to the conclusions drawn from the findings, as outlined below.

The unattended speech paradigm has been used in studies investigating the influence of semantically related information on memory for categorized word lists. In this paradigm, participants are told that all auditory background speech is irrelevant and should be ignored while studying and recalling a list of categorized words for a memory task. Despite the irrelevant, unattended speech, recall was impaired to a significantly greater extent when the speech was semantically related, compared to unrelated, to the memory task (Marsh et al., 2008; 2009). However, a drawback of this paradigm is that participants were asked to simply ignore the distractors, and this may be more easily accomplished when the words are unrelated rather than related. That is, it is possible that related words had been primed due to the categorized nature of the study lists and therefore were more likely to quickly enter attentional/conscious awareness relative to unrelated words (Treisman, 1960; Smith, Bentin, & Spalek, 2001). In this case, related distractor words could be producing more interference simply due to the fact that they were better able to capture attention compared to the unrelated words. In the current line of experiments, we circumvented this issue by using a divided attention paradigm which required overt responding to both the target and the distracting stimuli. In this way, we could better ensure that both the related as well as the unrelated distractors entered conscious awareness.

Alternative explanations for the effect of semantic relatedness on memory for words

Marsh et al. (2008) discounted the idea that attentional capture could account for differences that they found in memorial output during free recall from related compared to unrelated distracting speech. They reasoned that their reported effect of semantic relatedness on free recall arose only when instructions emphasized free recall by category rather than by serial order, and this runs counter to what would be expected from an attentional capture account wherein the recall instructions should not influence interference. This is because attentional capture should occur without awareness or intent and should therefore occur independent of the demands of specific retrieval tests.

The Marsh et al. (2008) findings could, however, alternatively be explained by the contingent capture hypothesis (Folk, Remington, & Johnston, 1992) which posits that attentional capture is contingent on the congruency between the properties of a distractor and attentional control settings. Marsh et al. (2008) have suggested that a rehearsal encoding strategy is likely to be used for better remembering the order of items in serial recall, whereas the encoding of semantic information is more probable for a free recall task. If we consider this claim within the framework of the contingent capture hypothesis, it could be argued that the attentional control settings (i.e., the filter through which search occurs) in Marsh et al. (2008)'s serial recall task were incongruent with the property of the distractor expected to cause interference (semantic relatedness). As such, rehearsal of order for a serial recall task would lead to a lower likelihood that semantic features of the distractors would capture attention; because less attention was being paid to semantic features of distracting information, interference would be reduced compared to that observed when instructions for free recall emphasized recall by category. With the possibility that contingent capture can explain previously observed semantic interference effects (Marsh et al., 2008), we aimed to remove attentional capture as a potential explanation for their findings by using a divided attention (DA) paradigm. A DA paradigm, in which participants must overtly attend and respond to each distractor item, addresses this alternative explanation by specifying the allocation of attention. If participants must respond, and therefore attend, to all target and distracting items, there may no longer be the potential for some distractors (semantically related) to attract relatively more attention than others (semantically unrelated).

The influence of semantic relatedness on memory has indeed already been investigated using such a DA paradigm by Fernandes, Craik, Bialystok, and Kreuger (2007), producing findings that coincide with those of Marsh et al. (2008). Fernandes et al. (2007) demonstrated that when participants were asked to study lists of semantically categorized words while concurrently completing a distracting task with auditorily-presented words, subsequent free recall was worse when the distractors were semantically related than unrelated to the study list. The findings from Fernandes and colleagues (2007) thus suggest that semantic interference occurs in long-term memory and that this effect cannot be explained by attentional or contingent capture accounts.

The influence of semantic relatedness of distractors on recognition memory

Although both Fernandes et al. (2007) and Marsh et al. (2008) found relatively greater interference in the form of intrusions from semantically related distracting information, they both used a free recall task, where distractor words were presented during encoding, but not during retrieval. In this chapter, we chose to expand on these initial findings by examining the effect of semantic relatedness of distractors, *using a recognition rather than free recall test* of memory, and to contrast these effects when distractors are present at encoding versus retrieval. We expect different outcomes with a recognition test compared to a recall test as the former is relatively easier because generation of responses is not required. Since the words for recognition are provided and simply require a yes/no response, we might instead expect to find facilitation as is found in studies of semantic priming effects which involve lexical decisions to presented words. The mechanism by which we would expect semantic priming to occur in our DA paradigm would be akin to explanations put forth in distributed connectionist network models in which activation of shared features among related items automatically primes each of those items (Masson, 1995; Plaut, 1995; see also Stolz, Besner, & Carr, 2005).

By implementing a recognition test, we can exclude the possibility that internal-external source monitoring error might occur because the generation of potential responses is not required during recognition. That is, Marsh et al. (2008) found a greater increase in intrusions during recall when unattended speech was semantically related than when it was unrelated to target words, and suggested that this increase stemmed from both internal-external and external-external errors in source monitoring. An internal-external error refers to when semantically related items are internally generated by the participant and are then mistakenly believed to have come from the study list. An external-external error arises when participants recall distractor words and believe them to have been on the study list. Marsh et al. (2008) suggest that there is a greater chance of source monitoring errors when distractors are presented at encoding because they are presented closer, temporally, to presentation of the study list items, and therefore more likely to be 'bound' with the source information for the study list words.

As well, if auditory distractors and visual memory task items are presented in their respective modalities (as in the experiments conducted for this thesis), with explicit instructions that only the visual items are involved in the memory task, the likelihood of external-external source monitoring errors is greatly reduced. While a participant could potentially believe a visual word to be a previously presented auditory word, this is highly unlikely, specifically when attention is divided at retrieval and they are instructed to indicate which items they had seen previously in the study phase. Furthermore, during free recall, the participant can control how attention is allocated to the retrieval and the distractor tasks, switching back and forth between tasks as necessary (retrieving words between presentations of distractors; Wammes & Fernandes, in preparation). However, during recognition, when the words and distractors are presented simultaneously, such task switching is minimized, making it more possible for distractors to influence memory retrieval. Thus, the use of a recognition test is an important contribution in being able to determine the effect of semantically related information during retrieval, free of the influence of attentional capture.

Experiment 1

In this experiment, different groups of participants were asked either to encode or to retrieve a visually-presented target list of categorized words while simultaneously making semantic decisions (i.e., size judgments) to another set of words heard concurrently. We manipulated semantic relatedness of distractor to target words (within-subjects), and whether distraction occurred during the encoding or retrieval phase of memory (between-subjects). Each participant completed a full attention (FA) condition in which study and recognition took place without any distraction, and two different DA conditions in which they had to make size decisions to words depicting items that were either related (DA-R) or unrelated (DA-U) to the study list. In this chapter, we aimed to better specify the effect of semantically related distracting words on long-term memory by determining whether facilitation or interference would occur when these are present during encoding or during retrieval of the target words.

Method

Participants. Forty-eight undergraduate students at the University of Waterloo volunteered to participate in the study for course credit. Of the 48 participants, 24 (M_{age} = 19.88, SD = 1.63; 4 male and 20 female) were randomly assigned to the DA at encoding group, and 24 (M_{age} = 20.23, SD = 4.60; 8 male and 16 female) to the DA at retrieval group. All participants scored above 30% on the Mill Hill Vocabulary Scale indicating proficiency in the English language (see description below). Individuals who did not have English as a first language or who had been diagnosed with depression or anxiety disorders were excluded from signing up to participate.

Materials. Fifty related words from each of three different semantic categories were selected for the experiment, along with a set of 60 unrelated words. The semantic categories for the related words were *birds*, *musical instruments*, and *fruits/vegetables*. Word frequency and word length did not differ significantly across category lists: *birds* ($M_{freq} = 5.24$, $M_{length} = 6.38$), *musical instruments* ($M_{freq} = 4.82$, $M_{length} = 6.78$), *fruits/vegetables* ($M_{freq} = 5.30$, $M_{length} = 6.56$), and the unrelated words ($M_{freq} = 5.83$, $M_{length} = 5.92$); frequency: $F\ (3, 206) = 0.06$, $MSE = 3.15$, $p = 0.98$, and length: $F\ (3, 206) = 0.39$, $MSE = 1.42$, $p = 0.76$. Word relatedness was estimated by Latent Semantic Analysis (LSA; via http://lsa.colorado.edu) using a matrix cosine comparison to contrast the meaning within each 50-word list. A one-way ANOVA including only the related word lists revealed that there were no significant differences in the matrix comparison for the lists of *birds* ($M_{LSA} = 0.23$), *musical instruments* ($M_{LSA} = 0.22$), and *fruits/vegetables* ($M_{LSA} = 0.21$), $F\ (2, 139) = 0.51$, $MSE = .004$, $p = .60$. Importantly, when the unrelated word list was included, a one-way ANOVA indicated a significant effect, $F\ (3, 198) = 40.30$, $MSE = .22$, $p < .001$, such that the LSA score for the unrelated word list was significantly lower than that for the *birds*, $p < 0.001$, *musical instruments*, $p < 0.001$, and *fruits/vegetables*, $p < 0.001$, lists. Thus, as planned, words in the unrelated list were significantly less related to each other than were the words in *birds*, *musical instruments*, and *fruits/vegetables* lists.

All auditorily-presented words used for the distraction tasks were spoken by an English male voice using an open source text-to-speech application on ispeech.org and recorded into a .wav file using Audacity®, an open source audio editor and recorder. All visually-presented words used in the study and recognition tasks were presented visually in size 24 point Courier font, in black text on a white screen. All experimental stimuli were presented using E-prime (E-prime (v.2.2 software, Psychology Software Tools Inc., Pittsburgh, PA).

The original form of the Mill Hill Vocabulary Scale (MHV) (Raven, Court, & Raven, 1977) consists of 88 words divided into two sets (set A and set B) of 44 words. Participants were given set B in which the words are presented in a multiple-choice style format with instructions to "darken the circle next to the word that means the same as the word in heavy type above the group." If participants responded correctly to at least 30% of the items, they were considered fluent in the English language (Raven, Court, & Raven, 1977). The average Mill Hill scores from participants in the DA Encoding and DA Retrieval groups were 53% and 50%, respectively, indicating that participants were proficient in speaking and understanding English.

Procedure. Participants were tested individually. They first completed a consent form with questions about demographic information (age, gender, and years of formal education). After completing set B of the Mill Hill Vocabulary Scale, they completed the experiment on a computer. Participants were randomly assigned to either the DA Encoding group, in which divided attention took place during the encoding phase, or the DA Retrieval group, in which divided attention took place during the retrieval phase. Each participant took part in each of three memory conditions (FA, DA-related, DA-unrelated), counterbalanced across participants. The three lists of categorized words, *birds*, *musical instruments,* and *fruits/vegetables*, were pseudo-randomly assigned to each memory condition such that each category list had an equal chance of being used in each of the three memory conditions.

Memory conditions each began with a study phase in which 20 words were randomly selected from one of the 50-item semantic category lists and presented at a rate of 3 s per word, preceded by a 500 ms fixation cross. The study words in a given condition were always from the same category, and therefore semantically related, and the study phase was always followed by a short filler task (counting backwards by threes for 30 s) to reduce recency effects in memory. Following each study phase and filler task, a recognition test ensued in which 10 of the 20 studied words were intermixed with 10 new lures from the same category list; words were again presented at a rate of 3 s per word, preceded by a 500 ms fixation cross. Participants responded 'new' or 'old' for each word by pressing ‘n’ or ‘b’ on a QWERTY keyboard.

For those in the DA Encoding group, encoding was done either under FA or each of two different DA conditions, and recognition was always performed under full attention. For those in the DA Retrieval group, encoding was always done under full attention, and recognition was done either under FA, or each of two different DA conditions. In the DA conditions participants heard words on each trial that were either semantically related or unrelated to the words for the memory test. For those in the DA Encoding group, a distracting word was presented auditorily through the speakers at the exact same time as each word from the study list appeared on the monitor. For those in the DA Retrieval group, a distracting word was heard at the exact same time as each word appeared on the screen for the recognition test.

In the DA conditions, participants made a size decision to the auditorily-presented distracting word on each trial, by verbally indicating whether it depicted an object that was physically larger or smaller than the size of the computer monitor (i.e., response would either be ‘larger’ or ‘smaller’); responses were recorded by the experimenter using a keypress. This distracting task was to be performed within 3 s, concurrently during encoding or retrieval (depending on the group), after which time the next trial began regardless of whether a response was made. Participants were told to divide attention equally between the concurrent tasks while making responses as quickly and accurately as possible. In the related condition, the auditory distractor words came from the same category list as the studied words. In the unrelated condition, the auditory distractor words came from the unrelated word list.

In summary, for those in the DA Encoding group, the DA conditions required them to study words while also making verbal responses to distracting words. For those in the DA Retrieval group, the DA conditions required them to make keypress responses for the recognition task while concurrently making verbal responses to distracting words. In the related condition, the distracting words were taken from the same category (and therefore semantically related to) the memory task words; in the unrelated condition, the distractor words were unrelated to the memory task words and to each other. While this represents a difference in response demands for those in the DA Encoding compared to the DA Retrieval group, our key comparison of interest was whether the semantic relatedness of the auditory distracting words influenced the *magnitude* of memory interference on the recognition test.

A baseline measure of performance on the size decision task was also completed by each participant. The words used for this task were from the unrelated word list and were not presented elsewhere in the study. Administration of this baseline measure was completed either before or after the three conditions (DA -R, DA-U, or FA) for separate halves of the participants.

Results

Memory Performance. For each participant in the study, recognition performance was assessed using signal detection analysis (see Table 1) to calculate detection sensitivity (d prime, or *d'*, Macmillan & Creelman, 1991). A *d'* value of zero means that the participant is unable to distinguish studied words from new words presented on the recognition test. High positive values reflect good discrimination. We also calculated response bias (C; Snodgrass & Corwin, 1988), which provides an estimate of the participant's tendency to respond "old" and "new" in each condition, where larger values indicate a more conservative response bias tendency to respond "new" more often than "old" and smaller values indicate a liberal bias tendency to respond "old" more often than "new".

A 2 (Group: DA Encoding, DA Retrieval) x 3 (Condition: FA, DA-R, DA-U) mixed ANOVA was conducted using *d'* as the dependent variable, with Group as the between-subjects factor and Condition as the within-subjects factor. There was a main effect of Condition, F (2, 92) = 34.12, MSE = 23.73, $p < .001$, and a Condition X Group interaction, F (2, 92) = 4.50, MSE = 3.13, p = 0.01, η^2 = 0.09, η^2 = 0.43, but no main effect of Group, F (2, 92) = 0.06, MSE = 0.07, p = .82, η^2 = 0.001.

For the DA Encoding group, there was a main effect of Condition, F (2, 46) = 27.76, MSE = 19.71, $p < 0.001$, η^2 = 0.54. Simple effects contrasts revealed that *d'* was significantly lower in the related and unrelated conditions compared to FA (F (1, 23) = 53.84, MSE = 61.97, $p < 0.001$, η^2 = 0.70, and F (1, 23) = 27.73, MSE = 56.13, $p < 0.001$, η^2 = 0.55, respectively). In the related condition, *d'* did not differ significantly from that in the unrelated condition, F (1, 23) = 0.13, MSE = 0.15, p = 0.72, η^2 = 0.01, indicating that the magnitude of memory impairment under DA at encoding did not vary depending on the semantic relatedness of words in the distracting task.

For the DA Retrieval group, there was a main effect of Condition, F (2, 46) = 10.50, MSE = 7.15, $p < 0.001$, $\eta^2 = 0.31$. Simple effects contrasts revealed that *d'* was significantly worse in the related condition compared to the FA condition, F (1, 23) = 19.87, MSE = 28.55, $p < 0.001$, $\eta^2 = 0.46$. Memory performance in the unrelated condition did not differ significantly from that in the FA condition, F (1, 23) = 3.31, MSE = 6.19, $p = 0.08$, $\eta^2 = 0.13$. Unlike the effect of DA at encoding, *d'* in the related was significantly lower than in the unrelated condition, F (1, 23) = 10.50, MSE = 8.15, $p < 0.001$, $\eta^2 = 0.46$, indicating that processing semantically related, relative to unrelated, words in a distracting task differentially impaired memory during retrieval.

A second 2 (Group: DA Encoding, DA Retrieval) x 3 (Condition: FA, DA-R, DA-U) mixed ANOVA was conducted using C (response bias) as the dependent variable, with Group as the between-subjects factor and Condition as the within-subjects factor. This revealed a significant interaction, F (2, 94) = 7.33, MSE = 1.30, $p < 0.001$, $\eta^2 = 0.14$. To better understand the interaction, one-way repeated measures (Condition: FA, DA-R, DA-U) ANOVAs were run separately for the DA Encoding and DA Retrieval groups, revealing a main effect of Condition in the DA Encoding group, F (2, 46) = 15.56, MSE = 1.51, $p < 0.001$, $\eta^2 = 0.40$, but not in the DA Retrieval group, F (2, 46) = 1.91, MSE = 0.45, $p = 0.16$, $\eta^2 = 0.08$. For the DA Encoding group, simple effects contrasts further revealed that bias in the FA condition was lower than in the unrelated condition, F (1, 23) = 12.04, MSE = 2.75, $p = 0.002$, $\eta^2 = 0.34$, and in the related condition, F (1, 23) = 22.56, MSE = 5.77, $p < .001$, $\eta^2 = 0.50$, and that bias was lower in the unrelated condition compared to the related condition, F (1, 23) = 5.59, MSE = 0.55, p = 0.27, η^2 = 0.20. These results indicate that bias to classify items as “new” at retrieval was greatest when distractors were present during encoding and were semantically related.

Table 1. Experiment 1 Means and Standard Deviations for Memory Performance under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Distractors in the Encoding and Retrieval Groups.

	Distractors at Encoding			**Distractors at Retrieval**		
	FA	**DA-R**	**DA-U**	**FA**	**DA-R**	**DA-U**
Hit rate	0.86(*0.17*)	0.60(*0.20*)	0.68(*0.13*)	0.80(*0.16*)	0.64(0.*19*)	0.78(*0.17*)
False Alarm rate	0.10(*0.11*)	0.16(0.*14*)	0.22(0.*17*)	0.10(*0.13*)	0.20(0.*18*)	0.19(*0.16*)
Correct Rejection rate	0.89(*0.12*)	0.82(*0.16*)	0.77(*0.16*)	0.89(*0.15*)	0.60(0.*19*)	0.73(*0.19*)
Miss rate	0.14(*0.16*)	0.38(*0.21*)	0.30(0.*14*)	0.20(*0.16*)	0.18(*1.15*)	0.15(*0.15*)
d'	2.92(*1.17*)	1.31 (*0.58*)	1.39 (*0.88*)	2.45 (*0.90*)	1.36 (*0.78*)	1.94 (*1.14*)
C	-0.18(*0.40*)	0.31 (*0.45*)	0.16 (*0.40*)	0.07 (*0.50*)	0.23 (*0.49*)	-0.04 (*0.43*)

Memory Response Time. Median response time (RT) to make a correct recognition decision was recorded (See Table 2). A 2 (Group: DA Encoding, DA Retrieval) x 3 (Condition: FA, DA-R, DA-U) mixed ANOVA revealed a main effect of Group, F (2, 46) = 9.54, MSE = 62004409.48, p = 0.003, η^2 = 0.17, with slower RTs in the DA retrieval group (likely due to the need to make two overt responses under DA Retrieval) than in the DA encoding groups, a main effect of Condition, F (2, 92) = 31.34, MSE = 2617015.78, p < 0.001, η^2 = 0.41, and a significant Condition X Group interaction (2, 92) = 11.09, MSE = 925930.99, p < .001, η^2 = 0.19.

To better understand the interaction, we conducted one-way ANOVAs with Condition as a factor, separately for each Group. For the DA Encoding group there was a main effect of Condition, F (2, 46) = 6.14, MSE = 526720.72, p = 0.004, η^2 = .21. Simple effects contrasts revealed RTs were significantly slower in the related compared to the FA condition, F (1, 23) = 6.76, MSE = 1497750.84, p = 0.016, η^2 = 0.23, but not in the unrelated compared to the FA condition, F (1, 23) = 0.13, MSE = 4095.09, p = 0.72, η^2 = 0.006. As well, RTs were significantly slower in the related compared to the unrelated condition, F (1, 23) = 6.32, MSE = 1658478.38, p = 0.019, η^2 = 0.22.

For the DA Retrieval group, there was also a main effect of Condition, F (2, 46) = 37.13, MSE = 6032452.11, p < 0.001, η^2 = 0.62. Simple effects contrasts revealed that RTs were significantly slower in the related and unrelated conditions compared to the FA conditions (F (1, 23) = 64.08, MSE = 11220337.50, p < 0.001, η^2 = 0.74, and F (1, 23) = 35.13, MSE = 6104450.67, p < 0.001, η^2 = 0.60, respectively). As with the DA Encoding group, RTs were significantly slower in the related compared to the unrelated condition, $F(1, 23) = 5.58$, $MSE = 772568.17$, $p = 0.027$, $\eta^2 = 0.20$.

Table 2. Experiment 1 Mean Response Time and Standard Deviation for Hits During Recognition Under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Distractors in the Encoding and Retrieval Groups.

Group and Condition	**Distractor Location**	
	Encoding	**Retrieval**
FA	936 (*225.09*)	855 (*167.25*)
DA-R	1185 (*552.46*)	1498 (*404.37*)
DA-U	922 (*175.20*)	1351 (*380.46*)

Distractor Task Performance. Distractor task accuracy was measured as the percentage of correctly classified items on the size decision task, in baseline and in the DA related and unrelated conditions (See Table 3). A 2 (Group: DA Encoding, DA Retrieval) x 3 (Condition: Baseline, DA-R, DA-U) mixed ANOVA revealed a main effect of Condition, F (2, 92) = 32.94, MSE = .46, p<.001, η^2 = .42. Simple effects contrasts revealed that distractor task accuracy was significantly worse in the DA related condition compared to baseline, F (1, 23) = 47.01, MSE = 1.65, p < .001, and worse in the DA unrelated condition compared to baseline condition, F (1, 23) = 4.27, MSE = .07, p = .04. Accuracy in the DA related was also significantly worse than that in the DA unrelated condition, F (1, 23) = 30.47, MSE = 1.05, p < .001. There was also a main effect of Group, F (2, 92) = 6.84, MSE = .08, p = .01, such that distractor task performance was worse overall in the DA retrieval group. We did not find a Condition X Group interaction, F (2, 92) = 1.74, MSE = .02, p = .18.

Table 3. Experiment 1 Mean Percentage Correct and Standard Deviations to Make Size Decisions to Distracting Task Words During a Full Attention Baseline, and Under Divided Attention Conditions When Words were Related (DA-R) or Unrelated (DA-U) to those in the Target Memory Task, in the Encoding and Retrieval Groups.

Group and Condition	**Distractor Location**	
	Encoding	**Retrieval**
Baseline	0.91 (*0.06*)	0.90 (*0.09*)
DA-R	0.76 (*0.13*)	0.67 (*0.18*)
DA-U	0.88 (*0.06*)	0.85 (*0.12*)

Discussion of Experiment 1

The purpose of this experiment was to determine whether memory performance was interfered with or facilitated by a concurrent task involving information semantically related versus unrelated to that in the target memory task. We examined the influence of both semantically related and unrelated distractors on recognition memory performance when those distractors were presented at either encoding or retrieval. Recognition accuracy was significantly diminished by DA at encoding, relative to FA, regardless of relatedness of distractors to study words. Recognition RTs were, however, preferentially slowed by related compared to unrelated distractors. Under DA at retrieval, RTs were also slower relative to FA, and when distractors were semantically related rather than unrelated to target words. Unlike the effect from DA at encoding, recognition accuracy was worse under DA at retrieval when the distractors were related compared to unrelated to the target words.

Our findings coincide with those which used the unattended speech paradigm to demonstrate that presenting to-be-ignored auditory words during retrieval produces more intrusions on free recall when they are semantically related than unrelated (Marsh et al., 2008; 2009). As outlined in the introduction Chapter 2, a drawback of the unattended speech paradigm is that participants are asked simply to ignore the distractors, and this may be more easily accomplished when the words are unrelated rather than related. As such, the locus of any effect of semantic relatedness is unclear because, in a selective attention paradigm (Treisman, 1960), related distractor words could be producing more interference simply due to the fact that they are better able to capture attention compared to the unrelated words.

Alternatively, interference could also occur only when the attentional control settings or search set are congruent rather than incongruent with a relevant feature of the distractor items. As suggested by the contingent capture hypothesis (Folk, Remington, & Wright, 1994), attentional capture is contingent on the congruency between the properties of a distractor and attentional control settings; it could be argued that the attentional control settings (i.e., the filter through which search occurs) in the Marsh et al. (2008) serial recall task were incongruent with the property of the distractor expected to cause interference (semantic relatedness). One of the major differences between the current experiment and these previous ones lies in our use of the DA paradigm, in which participants must overtly attend and respond to each distractor item. We observed larger interference in the related than in the unrelated condition in DA at retrieval. Our findings paralleled those of Marsh and colleagues (2008) using an unattended speech paradigm, indicating that differences in attentional or contingent capture of extralist distractor words cannot account for the disruptive effect of semantic relatedness on retrieval from long-term memory.

One other major difference between the unattended speech paradigm and the current experiment is the use of free recall and recognition, respectively. The relevant explanation put forth to account for impaired memory performance in free recall paradigms is that of a source-monitoring error (Marsh et al., 2008; Fernandes et al., 2007; and Marsh et al., 2015 who also incorporate a working memory capacity account). Specifically, Marsh et al. (2008) suggested that an internal-external source-monitoring error occurs when semantically related items are internally generated and then believed to have come from an external source. Such an account is unlikely to be able to explain our findings, as participants were not required to generate responses. As well, an external-external source monitoring error wherein participants have difficulty remembering whether a word was seen or heard (and thus whether it was for study or not), is insufficient to explain the current findings given that participants know that the test words are presented in their original modality and responses do not need to be generated. Further, if visual items were being misattributed to the auditory source, we would expect to see a greater bias to reject old items in the DA Retrieval group. However, after conducting the signal detection analysis, we found no differences in bias (criterion C) across the three conditions (Full attention, DA related, and DA unrelated). Any differences in bias in the DA Encoding group had no apparent effect on memory performance as we did not find differences between DA related and DA unrelated when assessing *d'*. Overall, source-monitoring errors do not readily explain our findings.

Retrieving information involves the process of discriminating between relevant and irrelevant information stored in memory. Often, relevant information needs to be selected from among a series of related possibilities. This is likely to be particularly problematic when the irrelevant possibilities are not only temporally or contextually appropriate (as in the case of memory under DA unrelated) but also overlap semantically with the target or targets (as is the case of memory under DA related). Results commonly found in the well-known Deese–Roediger–McDermott (DRM) paradigm demonstrate the effect of semantic similarity on memory. In a common variant of the DRM paradigm, a list of semantically related words (banana, apricot, peach) is auditorily presented for study; here, participants are highly likely to recall study list words and semantically related, but non-presented, 'lures' (apple) (Deese, 1959b;

Roediger & McDermott, 1995). Although the false recalls in a DRM paradigm can be thought of as reflecting of a successful system of comprehension and encoding of information, they also illustrate the sometimes negative effects that result from the way that our memory operates. The high rate of intrusions of critical lures during recall in the DRM paradigm is similar to the higher intrusion rate of distractors in a related compared to unrelated condition on tests of immediate serial and free recall under semantic distraction conditions (e.g., Beaman, 2004; Marsh et al., 2008; 2009), and the poorer accuracy shown here on a recognition test of memory.

Why semantic interference in memory for words?

Inconsistent with findings from priming-based effects on recognition that would suggest facilitation, we did not find that semantically related information improved memory performance or speeded response times (Neely et al., 1983). Neely and colleagues (1983) found facilitation during long-term memory recognition when a related prime preceded a target in an old/new recognition task. It is likely that we instead found interference because the distractor word did not precede the target (as in Neely et al., 1983), but was presented simultaneously. Neely et al. (1983) explain their findings of facilitation using spreading activation theories (e.g., Anderson, 1983; Collins & Loftus, 1975), stating that activation of a prime word spreads and activates semantically related words, thus facilitating their retrieval during recognition. Since our distractors did not precede the recognition words, a spreading of activation could not occur to induce facilitation. Fischler (1977), however, found that when two semantically related words are presented simultaneously, responses to a lexical decision task were faster relative to when those words were unrelated. This difference in pattern of effects highlights that the influence of semantically related information differs depending on whether a lexical or semantic decision is employed and whether long-term memory is being accessed. The fact that we found interference when words were related and presented simultaneously during retrieval ultimately indicates that semantically related information does not facilitate processing required for retrieval, but rather hinders the process.

Fernandes and Moscovitch (2000) concluded that distractors present at retrieval interfere with memory accuracy when they hinder access to the underlying representational code of the memory traces. Our findings can be taken as evidence that the representational code required during retrieval from long-term memory is semantically based. In future work, it would be interesting to investigate whether the semantic interference effect that we found is still present when the secondary task does not require semantic processing of the distractor (such as judging the loudness of a word). It could be the case that by not engaging in overt semantic processing of the distractor, the semantically related distractor is not able to interfere with memory for the target words. However, it is also possible that the effect would remain given the finding that even when not directing attention to the irrelevant distracting information, semantically related distractors interfered more with memory than unrelated distractors (Marsh et al., 2008).

Encoding vs. retrieval asymmetry

Fernandes et al. (2007) found that related distractors produced greater interference only when presented during encoding, and not during retrieval, whereas we found greater interference from related distractors during retrieval but not during encoding. It is possible that by using a recognition test here rather than a free recall test as in Fernandes et al. (2007), we were better able to divide attention during retrieval and find the differential effects of distractors because each test word for recognition was presented simultaneously with a distractor. In contrast, during free recall, participants are able to control how they allocate attention to the retrieval and the distractor task, making it possible to switch back and forth between tasks as necessary (i.e., retrieving words between presentations of distractors; Wammes & Fernandes, in preparation). During our recognition task, words and distractors were presented simultaneously, minimizing the opportunity for such task switching. That we found no difference in memory accuracy when semantically related compared to unrelated distractors were present during encoding is actually in line with many traditional studies of divided attention (Baddeley, Lewis, Eldridge, & Thompson, 1984; Craik et al., 1996; and Fernandes & Moscovitch, 2000), which show that any distracting tasks during encoding have large reliable effects on memory performance.

Although memory accuracy showed no effect of semantic relatedness under DA at encoding, we did find that response time to make correct recognition decisions was longer in the DA related than in the DA unrelated conditions for both the DA Encoding and DA Retrieval groups. Such longer RTs in the DA Encoding group may reflect that the memory trace was made less distinctive by the presence of the semantically related relative to unrelated distractors during encoding. The longer RTs in the DA Retrieval group may reflect increased difficulty in accessing or reactivating target words when related distractors require simultaneous processing during retrieval.

Implications and extensions of findings

Our finding of an effect of semantic relatedness of distractors on retrieval of words can be understood within a parallel distributed processing (PDP) framework (McClelland, Rumelhart, & Hinton, 1986) and a semantic network extension to the framework originally put forth by Rumelhart (1990). The PDP semantic network model posits that semantically related items have overlapping patterns of activation among units representing a variety of features common to the items. The framework states that activity among the units is adjusted or updated to reduce the discrepancy between the current state of activation and the specific pattern which represents the target item (McClelland, 1994). In the case that two separate items are activated at once, two distinct patterns of activation for two unrelated items can be easily reached. However, when two semantically related items that have overlapping patterns of activation co-occur, their updating processes might interfere with one another. Specifically, if the items 'robin' and 'canary' are both present, units representing 'is a bird', 'has wings and feathers', and 'can fly' are all activated. Conflict could result from the features that are shared between the two items if the two updating processes attempt to shift activation in different ways (such as on a property that differs slightly between the two). The interference found in our results, when two semantically related items are simultaneously presented, could potentially be a result of this sort of conflict.

Conclusion

In this chapter, we have shown that a distracting task at encoding, regardless of its semantic relatedness to the target words, interferes with later memory compared to when encoding takes place under full attention. Unlike the effect from DA at encoding, our experiment showed that recognition accuracy was worse under DA at retrieval when the distractors were related compared to unrelated to the target words. Overall, our results suggest that availability of general attentional resources is critical for successful encoding, whereas successful retrieval is particularly reliant on access to a semantic code, making it sensitive to related distractors under DA conditions.

Chapter 3

In the previous chapter, we demonstrated that retrieval of words from long-term episodic memory was impaired by semantically related, relative to unrelated, distractors. In Chapter 3, we aimed to determine whether memory retrieval for pictures would be similarly affected by the semantic relatedness of information in a distracting task.

Given that, in the previous chapter, DA at encoding did not result in differential interference depending on the semantic relatedness of the distracting information, in the next set of experiments we confined our examination to only the effects of DA at retrieval. To this end, in Experiment 2, we used the same paradigm as in DA at Retrieval in Experiment 1, but presented pictures instead of words for study and test. We directly compared our findings in Experiment 2 to those from DA at Retrieval in Experiment 1, allowing us to compare, statistically, the influence of semantically related distractors on episodic retrieval of words to pictures. Following this, in subsequent experiments we will change the distractors from auditorily- presented words to visually-presented pictures. Our goal in these later experiments is to determine the influence of different kinds of picture distractors on memory for pictures.

Exploring the representational code used to retrieve words vs. pictures from long-term memory

In this thesis, we ultimately aimed to investigate similarities and differences in the codes used to represent words and pictures in episodic memory. In finding that retrieval of words was disrupted to a greater extent when distractors were semantically related relative to unrelated, we inferred that representation of words for episodic memory requires access to a semantic code.

Our goal in Chapter 3 was to determine whether retrieval of pictures, like words, is primarily dependent on access to a semantic code, or if retrieval of pictures are instead more dependent on access to visuospatial codes.

We could expect, based on our findings with memory for words, that retrieval of pictures should also be differentially disrupted when there is competition from a distracting task for a similar semantic code (i.e., from semantically related distractor words). Previous researchers have suggested that words and pictures share common semantic representations, based on findings that these stimuli semantically prime one another in naming tasks (Carr, McCauley, Sperber, & Parmelee, 1982); such findings suggest that pictures are stored semantically, just like words. Indeed, according to the dual-code theory (Pavio, 1971, 1986) pictures are coded, in part, verbally. Given that a verbal code for a common object is simply a word, and in Experiment 1 we demonstrate that memory for words requires access to a semantic representational code, we can assume that a verbal code of a picture should, like words, be susceptible to interference from semantic relatedness. However, pictorial stimuli are also coded visually according to the dual-code theory.

There is evidence to indicate that visuospatial distracting tasks interfere, to a greater extent than verbal ones, with memory for pictures (Fernandes & Guild, 2009; Pellegrino, Seigel, & Dhawan, 1976; Burton & Bruning, 1982). Such a result suggests that access to a visual code is more important for retrieval of pictures. In the following experiments we investigated the influence of semantically related and/or visually similar distractors on memory for pictures. We sought to be able to specify the type of code(s) that are necessary to represent pictures in long term memory.

The experiments presented in Chapter 3 of this thesis investigate the extent to which distractors that are semantically and/or visually related to memory task pictures impair retrieval. From this, we can infer the representational codes that are critical for picture memory, and better understand how pictures are remembered from long-term memory.

Overview of experiments in Chapter 3

In Experiment 2, we replicated the DA at retrieval portion of Experiment 1 from the previous chapter, using picture stimuli for the memory task rather than words. We wanted to compare memory performance for picture stimuli (Experiment 2), to performance for word stimuli in the DA retrieval group from Experiment 1 in the previous chapter. Our goal here was to establish whether there were differences in how words and pictures are stored in long-term memory. We expected, contrary to our finding with memory for word stimuli, that when we examined memory for pictures, we would not find differential memory performance between DA conditions with semantically-related relative to -unrelated distractors. We reasoned that the auditory distractor words from Experiment 1 would only interfere with the verbal code, leaving the visual code available to support retrieval of the to-be-remembered pictures from memory.

Given our prediction that auditory word distractors would not interfere with memory for pictures when the visual code remains acessible, the subsequent experiments aimed to determine whether we would find interference when the modality of presentation of the distractors changed from being auditorily-presented to visually-presented. We examined the effect on memory from semantically related picture distractors (Experiment 3), from visually similar picture distractors (Experiment 4), and from semantically related and visually similar distractors (Experiment 5). As in Chapter 1, we investigated the influence of these various distractor types on target memory performance, as defined by *d'*, as well as response time (RT) differences between distractor types.

We also recorded RT to make a recognition decision to the target pictures. . Given that memory for pictures is usually highly accurate (Standing, 1973), it is possible that we may not find impairment in target recognition accuracy, but will instead find interference only on the more sensitive RT measure. In this thesis, we discuss the memory results and their implications following each experiment, but save the discussion of RT data for the General Discussion section, as we found no significant differences in RT between DA conditions.

Experiment 2

After having demonstrated in Experiment 1 of the previous chapter that semantically related distractors interfere with memory for words, we next wanted to determine whether memory for pictures would be similarly susceptible to influence from semantic information. According to the sensory-semantic model of picture and word encoding (Nelson, Reed, & McEvoy, 1977), pictures have direct access to semantic information, by-passing verbal labeling, whereas words are first processed verbally/phonetically before semantic processing occurs. As well, it has been proposed that words and pictures share semantic representations (Carr et al., 1982). It could therefore be expected that memory for pictures could be highly susceptible to the influence of semantically-related distracting information. However, beyond the proposed likelihood that memory for pictures will activate semantic information, the sensory-semantic model also posits that pictures have a 'superior' visual sensory code than words. This is similar to the dual-code theory proposed by Paivio (1971, 1986), which credits the picture superiority effect to the visual code that pictures possess over words. Thus, words and pictures may have considerable overlap in the way that they are represented in memory, although it is also likely that pictures have a qualitatively distinct visual representation setting them apart from words.

Predictions regarding the representation of pictures in memory

We know from neuro-imaging studies that processing pictures leads to patterns of activation in visual sensory regions, distinct from action evoked by word stimuli (Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996; Kohler, Moscovitch, Winocur, & McIntosh, 2000) and that some of these regions are reactivated during retrieval of items studied as pictures (Vaidya et al., 2002). The evidence from neuro-imaging studies demonstrates that pictures do engage visual processing that is distinct from word processing, potentially revealing the visual code in action. If pictures are coded both visually and verbally, auditory distractors should only disrupt access to the verbal code, leaving the visual code available to access during retrieval. As such, we might expect to find in the current experiment that semantically related distractors do not impair retrieval of pictures more than unrelated distractors.

Indeed, past work assessing the influence of visual and verbal interference tasks on long-term memory for pictures and words has illustrated that verbal processing interferes with recall of pictures to a lesser extent than it interferes with recall of words (Pellegrino, Seigel, & Dhawan, 1976; Burton & Bruning, 1982). Similarly, Fernandes and Guild (2009) demonstrated in a DA paradigm that a visuospatial distracting task during retrieval interfered with memory for spatial patterns more than a phonological ditstracting task, and that the reverse was true for memory for words. The findings from Fernandes and Guild (2009) and Pellegrino, Seigel, and Dhawan, 1982) suggest that successful access to a visual code is even more important than access to a verbal code for retrieval of visuospatial information from long-term memory. As such, we predicted that, in comparison to retrieval of words from memory, retrieval of pictures would not be differentially disrupted by semantically related auditory distractors.

In Experiment 2, we used the same experimental design as in Experiment 1, but all word stimuli in the memory task were replaced with pictures. If words and pictures are coded similarly in long-term memory, we should find that semantically related distractors interfere with retrieval of memory for pictures, as we have found in memory for words. If we instead find that memory for pictures is not differentially impaired by semantically related distractors, it would indicate that pictures and words are uniquely coded in long-term memory.

Method

Participants. Twenty-four undergraduate (M age = 19.63, SD = 1.69; 6 male and 18 female) students at the University of Waterloo volunteered to participate in the study for course credit. All participants scored above 30% on the Mill Hill Vocabulary Scale indicating proficiency in the English language. Individuals who did not indicate having English as a first language or had been diagnosed with depression or anxiety disorders were excluded from signing up.

Materials. The picture stimuli were selected by replacing each word from the word lists used in Experiment 1 in Chapter 2 with a pictorial version of that item. For each word in the three 50-word categorized lists, a non-copyrighted color photograph of the object that the word represents was acquired from various online sources. Each picture was edited so that it contained a white background and was resized to 150 x 150 pixels. See Figure 1 for example picture stimuli.

Figure 1. Examples of items from each of the three categorized sets: *birds*, *musical instruments*, and *fruits/vegetables*.

Procedure. The procedure was identical to that used in Experiment 1 outlined in Chapter 2 of this thesis, with the exception that the memory task items were pictures rather than visually presented words.

Results

Memory Performance. Recognition performance was assessed using signal detection analysis to determine detection sensitivity (*d'*) (see Table 4 for means). A one-way ANOVA with Condition (FA, DA-R, and DA-U) as a factor was performed on the detection sensitivity data. No main effect of detection sensitivity was found, F (2, 46) = 0.59, MSE = 0.32, p = 0.56, η^2 = 0.03, indicating that retrieval of memory for pictures was not impaired by the presence of auditory distractors.

Of key interest was the difference in memory performance when the memory task stimuli were changed from words to pictures. As such, we analyzed the data from this experiment together with the data from the DA retrieval portion of Experiment 1 (memory for words rather than pictures). A 2 (Material: Word, Picture) x 3 (Condition: FA, DA-R, DA-U) mixed ANOVA was performed on detection sensitivity data. There was a main effect of Condition, F (2, 92) = 7.63, MSE = 3.58, $p < 0.001$, η^2 = 0.14, but no main effect of Material, F (2, 46) = 0.17, MSE = 0.17, p = .68, η^2 = 0.004. There was also a Condition x Material interaction, F (2, 92) = 4.23, MSE = 1.98, p = 0.008, η^2 = 0.08. As reported previously in chapter 2, when the to-be-remembered material was words, semantically related distractors led to significantly worse memory performance than did unrelated distractors. When the to-be-remembered material was pictures, the semantic relatedness of the distracting information did not influence memory performance. Thus, the significant Condition x Material interaction indicates that while semantically related auditory distractors differentially interfered with retrieval of words from episodic memory, the same pattern of interference was not found with memory for pictures.

Table 4. Means and Standard Deviations for Memory Performance under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Distractors for Memory for Words (Experiment 1) and Pictures (Experiment 2).

	Distractors at Retrieval		
	FA	**DA-R**	**DA-U**
Words			
Hit rate	0.80(*0.16*)	0.64(0.*19*)	0.78(*0.17*)
False Alarm rate	0.10(*0.13*)	0.20(0.*18*)	0.19(*0.16*)
Correct Rejection rate	0.89(*0.15*)	0.60(0.*19*)	0.73(*0.19*)
Miss rate	0.20(*0.16*)	0.18(*1.15*)	0.15(*0.15*)
d’	2.26(*0.66*)	1.32(*0.67*)	1.75(*0.84*)
Pictures			
Hit rate	0.82(*1.76*)	0.84(*1.21*)	0.84(*1.53*)
False Alarm rate	0.25(*2.15*)	0.24(*1.86*)	0.20(*1.50*)
Correct Rejection rate	0.71(*2.22*)	0.68(*2.22*)	0.80(*1.37*)
Miss rate	0.12(*1.40*)	0.11(*0.85*)	0.13(*1.42*)
d’	1.98(*0.88*)	1.84(*0.80*)	1.75(*0.98*)

Memory Response Time. Median response time (RT) to make a correct recognition decision was recorded (See Table 5). A one-way ANOVA on RT, with Condition as a factor, revealed a main effect of Condition, F (1, 46) = 518.36, MSE = 12966961.03, $p < .001$, $\eta^2 = .96$. Simple effects contrasts revealed that RTs were significantly slower in the DA related and DA unrelated conditions compared to the FA condition, (F (1, 23) = 996.63, MSE = 44549662.59, $p < .001$, $\eta^2 = .98$, and F (1, 23) = 831.86, MSE = 32263087.59, $p < .001$, $\eta^2 = .97$, respectively). As well, RTs were significantly slower in the DA related compared to the DA unrelated condition, F (1, 23) = 14.85, MSE = 989016.00, $p = .001$, $\eta^2 = .39$, indicating that, as was found with memory for words in Chapter 2, it took longer to respond when distractors were semantically related relative to unrelated to the to-be-remembered pictures.

As with memory performance, we wanted to compare recognition RTs between retrieval of words and pictures, again comparing the data from the current experiment to Experiment 1. A 2 (Material: Word, Picture) x 3 (Condition: FA, DA-R, DA-U) mixed ANOVA revealed a main effect of Condition, F (2, 92) = 267.34, MSE = 14202518.36, $p < .001$, $\eta^2 = .85$, a main effect of Material, F (1, 92) = 49.55, MSE = 2567722.99, $p < .001$, $\eta^2 = .52$, and a Condition x Material interaction, F (1, 92) = 33.52, MSE = 1780668.73, $p < .001$, $\eta^2 = .42$.

As reported previously in chapter 2, when the to-be-remembered material was words, semantically related distractors led to significantly longer RTs than did unrelated distractors. Similarly, when the to-be-remembered material was pictures, the presence of semantically related distractors led to significantly longer RTs than did unrelated distractors. What is likely driving the Condition x Material interaction is that making a memory response to pictures took significantly longer than it did to words, F (1, 46) = 61.72, MSE = 11257290.38, $p < .001$, η^2 = .57.

Table 5. Mean Response Time and Standard Deviation for Hits During Recognition Under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Distractors in Memory for Words (Experiment 1) and Pictures (Experiment 2).

Condition	**Response Time for Hits**	
	Words	**Pictures**
FA	863 (*167.24*)	881 (*167.62*)
DA-R	1546 (*455.95*)	2243 (*210.12*)
DA-U	1367 (*402.07*)	2040 (*231.69*)

Distractor Task Performance

Distractor task accuracy was measured as the percentage of correctly classified items on the size decision task, in the baseline and in the two DA conditions (See Table 6) when the memory task material was pictures. A one-way ANOVA on distractor task accuracy revealed a main effect of Condition, F (1, 46) = 35.95, MSE = .39, p < .001, η^2 = .61. Simple effects contrasts revealed that distractor task accuracy was significantly worse in the DA related condition compared to baseline, F (1, 23) = 86.30, MSE = 1.51, p < .001, η^2 = .79, and also worse in the DA unrelated condition compared to baseline condition, F (1, 23) = 10.41, MSE = .21, p = .004. Accuracy in the DA related condition was also significantly worse than in the DA unrelated condition, F (1, 23) = 22.11, MSE = 0.60, p < .001, η^2 = .49.

Table 6. Mean Percentage Correct and Standard Deviations to Make Size Decisions to Distracting Task Words during a Full Attention Baseline, and Under Divided Attention Conditions When Words are Related (DA-R) or Unrelated (DA-U) to both Words (from Experiment 1) and Pictures (from Experiment 2) in the Target Memory Task.

Condition	**Percentage Correct**	
	Words	**Pictures**
Baseline	0.90(*0.09*)	0.93(*0.07*)
DA-R	0.67(*0.18*)	0.68(*0.14*)
DA-U	0.85(*0.12*)	0.84(*0.13*)

Discussion

In Experiment 2, we examined memory retrieval performance for a set of pictures, completed under DA at retrieval with a concurrent task involving auditory presentation of either semantically related or unrelated words during retrieval. We found no differential memory performance when recognition of pictures was performed under DA concurrently with either distractor task. Comparing the current findings from Experiment 2 to those from Experiment 1, we found a significant Material X Condition interaction, indicating that semantically related, relative to unrelated, distractors impaired retrieval of words but not pictures from long-term memory. These results suggest that words and pictures are stored differently in episodic memory as the type of distracting information that differentially disrupts memory for words under DA at retrieval does not also differentially disrupt memory for pictures.

Considering Dual-Code theory (Paivio, 1971), which suggests that representations of pictures are based on both a verbal and a visual code in long-term memory, it is likely that we did not find interference with memory for pictures because we did not disrupt access to the visual code. Findings from Fernandes and Guild (2009) demonstrate that visuospatial processing is required in the retrieval of visuospatial information. Related findings from Pellegrino and colleagues (1976) demonstrated that completing a task requiring visual processing (visual search task) impaired recall of pictures (common objects) to a greater extent than did a verbal processing task (counting backwards). These studies suggest that access to a visual representational code is important for memory of both novel visuospatial information and pictures of common items. The latter finding is important with respect to the current experiment as it indicates that even when visual information is highly verbalizable, and thus more memorable (Silverberg & Buchanan, 2005), access to a visual code is still paramount for retrieval of pictures.

Further, neuro-imaging research suggests that recognition of words which had been encoded as pictures, compared to those encoded as words, results in activation in visual processing areas including the left ventrolateral extrastriate cortex, inferior temporal gyrus, and junction of the middle occipital and middle temporal gyri (Vaidya, Zhao, Desmond, & Gabrieli, 2002). Given that visual processing is engaged during retrieval of pictures from memory, it is possible that our auditory word distractors disrupted access to a verbal/semantic code but left the visual code fully intact for participants to rely upon for memory for pictures. Thus, in Experiment 3, we aimed to disrupt (via our DA manipulation) both the verbal/semantic AND the visual representations that may be required to store and retrieve pictures in episodic memory.

Experiment 3

In Experiment 3, distractors were changed from auditorily-presented words to visually-presented pictures. We expected that the distractors would now interfere with visual representations required for retrieval of pictures from memory, based on previous work demonstrating that visuospatial distracting tasks impair memory for visuospatial information (Fernandes & Guild, 2009; Pellegrino, Seigel, & Dhawan, 1976; Burton & Bruning, 1982). Further, we expected to find greater impairment in memory performance when distractors were semantically related compared to unrelated to the memory task pictures. If pictures are coded both verbally and visually (Paivio, 1971, 1986), and we disrupt access to the visual code by presenting distractors which also require access to visual representations, then reliance on the verbal code should increase. We expected then, based on Experiment 1, that semantically related distractors should impair access to this code. Therefore, we predicted that semantically related picture distractors should impair access to both the visual and the verbal code to a greater extent than semantically unrelated pictures. Such a finding would provide evidence that pictures are stored in long-term memory by way of both a visual code and a verbal/semantic code.

Methods

Participants. A total of 20 undergraduate students (M age=19.33, SD = 1.09; 5 male and 15 female) at the University of Waterloo volunteered to participate in the study for course credit. All participants scored above 30% on the Mill Hill Vocabulary Scale indicating proficiency in the English language. Individuals who did not indicate having English as a first language or had been diagnosed with depression or anxiety disorders were excluded from signing up.

Materials. The stimuli were the same as in the previous experiment with the exception that non-copyrighted color photographs of 20 objects in the unrelated list were also acquired. All pictures were edited so that each contained a white background and was resized to 150 x 150 pixels.

Procedure. The procedure was identical to the previous experiment, which contained a full attention (FA) condition and two divided attention conditions (related and unrelated), with minor changes regarding the distracting task. Here, in DA conditions, participants made a size decision to a distractor picture, instead of an auditorily presented word, concurrently with each trial in the picture recognition phase. The picture in the distracting task was presented on the screen alongside the picture for the recognition memory task. For each trial, pictures that were part of the recognition task were denoted with a black bar underneath each (to differentiate them from the pictures requiring the distracting task decision). These pictures were each presented for 3 s. In the DA conditions, the distracting task pictures were presented simultaneously with the memory task pictures, and were denoted with a black bar above each. See Figure 2 for a visual display of the paradigm. Each trial was preceded by a 500 ms fixation cross. As well, the memory task pictures were randomly presented on the left of the screen in 50% of trials so as to diminish strategic looking at only one side of the screen. Participants were told to divide attention equally between the concurrent tasks while making key-press responses as quickly and accurately as possible. In the related condition, the distractor pictures came from the same semantic category list as the studied pictures. In the unrelated condition, the distractor pictures came from the unrelated picture list.

A baseline measure of performance on the size decision task was also completed by each participant. The pictures used for this task were from the unrelated picture list and were not presented elsewhere in the study. Administration of this baseline measure was completed before the three experimental conditions for half of the participants or after the three conditions for the other half.

Figure 2. Example trial of DA at retrieval with picture stimuli. The picture with the black bar above (left) requires a distracting task decision, while the picture with black bar below (right) requires a recognition decision.

Results

Memory Performance. Recognition performance was assessed using signal detection analysis to calculate *d'* (see Table 7 for means). A one-way ANOVA on the *d'* data comparing the three conditions, revealed a main effect of Condition, F (2, 38) = 8.65, MSE = 5.32, p = 0.001, η^2 = 0.31. To better understand the main effect, simple effects contrasts were performed and revealed that detection sensitivity was significantly worse in the DA related and unrelated conditions compared to FA (F (1, 19) = 15.83, MSE = 17.17, p = 0.001, η^2 = 0.45, and F (1, 19) = 9.63, MSE = 14.63, p = 0.003, η^2 = 0.34, respectively). Detection sensitivity in the related condition was not significantly different than that in the unrelated condition, F (1, 19) = 0.09, MSE = 0.10, p = 0.76, η^2 = 0.005, indicating that processing semantically related, relative to unrelated, pictures in a distracting task during retrieval had no differential effect on memory performance.

Table 7. Experiment 3 Means and Standard Deviations for Memory Performance under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Picture Distractors During Retrieval.

	FA	**DA-R**	**DA-U**
Hit rate	0.90(0.*14*)	0.58(*0.22*)	0.64(0.*24*)
False Alarm rate	0.22(*0.15*)	0.19(*0.15*)	0.25(*0.17*)
Correct Rejection rate	0.79(*0.15*)	0.43(*0.20*)	0.55(*0.27*)
Miss rate	0.11(*0.14*)	0.13(*0.11*)	0.16(*0.11*)
d'	2.11(*0.85*)	1.19(*0.63*)	1.26(*0.66*)

Memory Response Time. Median response time (RT) to make a correct recognition decision was recorded (see Table 8). A one-way ANOVA revealed a main effect of Condition, F (2, 38) = 67.54, MSE = 7860841.35, $p < 0.001$, $\eta^2 = 0.78$. Simple effects contrasts revealed that RTs were significantly slower in the DA related and unrelated compared to FA conditions (F (1, 19) = 81.00, MSE = 23549925.31, $p < 0.001$, $\eta^2 = 0.81$, and F (1, 19) = 281.57, MSE = 23615077.81, $p < 0.001$, $\eta^2 = 0.94$, respectively). However, RTs were not significantly different in the related and unrelated conditions, F (1, 19) = .001, MSE = 45.00, $p < 0.001$, $\eta^2 < 0.001$, indicating that semantic relatedness of picture distractors had no effect on how long it took to make an 'old' response.

Table 8. Experiment 3 Mean Response Time and Standard Deviation for Hits During Recognition Under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Picture Distractors.

Condition	**Hits**
FA	911 (*153.81*)
DA-R	1996 (*458.77*)
DA-U	1998 (*342.27*)

Distractor Task Performance. Distractor task accuracy was measured as percentage of correctly classified items on the size decision task, in baseline and in the two DA conditions (See Table 9). A one-way ANOVA on distractor task accuracy revealed a main effect of Condition, F (2, 38) = 46.94, MSE = 0.85, $p < 0.001$, $\eta^2 = 0.71$. Simple effects contrasts revealed that distractor task accuracy was significantly worse in the related condition compared to baseline, F (1, 19) = 92.18, MSE = 3.36, $p < 0.001$, $\eta^2 = 0.83$, and worse in the unrelated condition compared to baseline, F (1, 19) = 29.13, MSE = 1.11, $p < 0.001$, $\eta^2 = 0.61$. Accuracy in the related conditon was also significantly worse than that in the unrelated condition, F (1, 19) = 18.11, MSE = 0.61, $p < 0.001$, $\eta^2 = 0.49$.

A Pearson correlation was computed to assess the relation between memory performance on the recognition task (d') and performance in the distractor task (percent correct). Collapsing across the two DA conditions, the analysis revealed a significant positive correlation between memory task performance and distractor task performance, $r(38) = 0.35$, $p = 0.03$. Looking within each condition separately, memory task and distractor task performance were significantly positively correlated in the unrelated condition, r (38) = 0.60, $p = 0.006$, but not in the related condition, $r(38) = 0.11$, $p = 0.64$. These correlations are not in a direction to suggest that there were systematic trade-offs in performance across the target and distracting task (if participants were trading off, then as memory performance increased, distractor task performance would be expected to decrease).

Table 9. Experiment 3 Mean Percentage Correct and Standard Deviations to Make Size Decisions to Distracting Task Pictures during a Full Attention Baseline, and Under Divided Attention Conditions When Pictures are Related (DA-R) or Unrelated (DA-U) to Those in the Target Memory Task.

Condition	**Percentage Correct**
Baseline	0.92(*0.08*)
DA-R	0.51(*0.19*)
DA-U	0.68(*0.19*)

Discussion

In Experiment 3, we divided attention during retrieval of pictures from episodic memory using picture distractors, whereas we had previously used auditory word distractors in Experiment 2. Unlike performance in Experiment 2, in this experiment both DA conditions disrupted memory for pictures relative to the FA condition. This finding is in line with our prediction that picture distractors would disrupt access to visual representations, as suggested by past work (Fernandes & Guild, 2009; Pellegrino, Seigel, & Dhawan, 1976; Burton & Bruning, 1982). Results suggest that when access to visuospatial representations is taxed by a visual distracting task, participants have difficulty accessing the visual code of the pictures stored in episodic memory. We had also expected to find worse memory performance when distractors were semantically related rather than unrelated to those in the target memory task. Contrary to predictions, memory performance was strikingly similar in the two DA conditions, demonstrating that semantically related, relative to unrelated, picture distractors do not differentially impair retrieval of pictures from episodic memory.

The relevance of visual information in memory for pictures

Previous work has demonstrated that novel objects varying in degrees of thickness, curvature, and tapering are confused more frequently in memory when they are more similar on these dimensions (Desmarais & Dixon, 2005; Desmarais, Dixon, & Roy, 2007). As well, participants are slower to respond to pictures of real-world objects from categories that contain items with high visual similarity (vegetables, animals, etc.) than categories of items with low visual similarity (tools, clothing, etc.). These past findings indicate that visual information, such as shape, is an important factor when retrieving visual information from memory, suggesting that picture distractors may only interfere with memory for pictures when they are visually similar. One explanation as to why we did not find differential impairment in memory performance across our two DA conditions, then, is that we did not manipulate visual similarity of the picture distractors to the pictures in the memory task; we manipulated only whether the picture distractors and targets were semantically related or not. For example, it may be that picture distractors only interfere with retrieval of target pictures when they are visually similar, overlapping in shape and features with the memory trace for the target picture, as suggested by findings from Desmarais and Dixon (2005).

In Experiment 3, distractor pictures were often visually dissimilar from memory task pictures on some trials; for example, a 'guitar' and a 'trumpet' are both members of the semantic category *musical instrument*, but have very different shapes (a guitar has a pear-shape, a trumpet is thin with a cone shape), different sizes (guitars are larger than trumpets), the types of features they consist of (guitars have strings, trumpets have tubes), and even colors (guitars are brown, trumpets are gold). As illustrated, while two items from a given category can be highly semantically related, they can also be quite visually dissimilar, with few overlapping visual attributes.

The overlap of visual and semantic similarity in common objects

While objects vary on a variety of dimensions within the visual domain, such as texture, color, size, and type and number of features, shape has been found to be particularly important (Gaissert & Wallraven, 2011). For example, when categorizing simple objects (in this case, seashells) into groups, shape was found to be the most important feature in determining which items are most similar, relative to features such as color, size, and texture (Gaissert & Wallraven, 2012). Shape is often related to the types of features that an object consists of (such as 'legs' or 'wings'), and objects that have similar features are often categorized together (such as 'robin' and 'sparrow'; Mervis & Rosch, 1981). One might think that distractors in the DA related condition would also be highly visually similar to the memory task pictures, since they share category membership (Mervis & Rosch, 1981; Rosch, 1978). However, as exemplified above, items from the same category can often be visually distinct (such as 'guitar' and 'trumpet'), making it unlikely that distractor pictures in Experiment 3 were visually similar to the memory task pictures on the majority of trials (in terms of shape, size, features, and color); this may be why the related condition did not result in greater interference with memory than did the unrelated condition.

To examine whether overlap in visual information of distractors to to-be-remembered targets influences memory performance, we conducted Experiment 4. One caveat in manipulating visual similarity is that visually similar items are generally also semantically related (Mervis & Rosch, 1981; Rosch, 1978), making it difficult to disentangle the influence of visual similarity and semantic relatedness. As such, for this experiment, we obtained stimuli (to be used in our distracting tasks) from Yee and Sedivy (2006) which contain sets of pictures that are visually similar but not semantically related, and different sets that are semantically related but not visually similar. We used these to manipulate semantic relatedness or visual similarity of distractor to target pictures, making it possible to observe the separate influence of visual similarity and semantic relatedness on memory for target pictures.

If episodic memory for pictures is based primarily on a visual representational code in long-term memory, we would expect to find greater impairment in retrieval when distractors are visually similar, than semantically related, to the to-be-remembered pictures. Alternatively, if pictures are coded dually, and rely on both visual and semantic codes, we might expect to find no differences in memory performance when the distractors are visually similar versus when they are semantically related to the target pictures.

Experiment 4

The goal of Experiment 4 was to determine whether visually similar but semantically unrelated distractors would impair retrieval of target pictures to a greater extent than when distractors were semantically related (but visually distinct). The procedure was identical to the previous experiments with the exception that there were four conditions instead of three. As in the prior experiments in this thesis, there was a FA condition; there were, however 3 different DA conditions, in which distractors were either visually similar but semantically unrelated (DA-V), semantically related but visually dissimilar (DA-S), or semantically unrelated and visually dissimilar (DA-U).

According to some researchers (Nelson, 1976; 1979), the picture superiority effect is a result of pictures having a qualitatively superior visual code relative to words, placing greater weight on the visual code in memory for pictures. Given this suggestion that pictures rely more on a visual code than a verbal one, we might expect that disruption of access to the visual code is sufficient to impair retrieval of pictures to a greater extent than disruption of a verbal code. As such, we should expect to find differentially greater impairment in memory for pictures in the DA-V condition, relative to DA-S and DA-U. However, under the dual-code theory (Paivio, 1971, 1986), we might expect that disrupting either the visual or the verbal code alone is not sufficient to lead to a greater magnitude of memory performance impairment. In this case, we should expect to find no difference in memory impairment between DA-V, DA-S, and DA-U conditions. If pictures rely on both visual and verbal codes in memory, then participants should be able to use whichever code is not being taxed in a given condition for successful retrieval of pictures (i.e., use the verbal code when access to the visual code is disrupted). In line with dual-code theory predictions, Pellegrino et al. (1976), observed greater impaired recall of pictures when a distracting task required both visual and auditory components than when a distracting task required visual processing alone. Similarly, evidence suggests that pictorial material is remembered significantly better when it is easy to describe verbally, indicating that the verbal code is also important for memory of pictures (Silverberg & Buchanan, 2005). Thus, we can expect to find, based on past work, that there will be no differential impairment between DA-V and DA-S.

By using a new set of stimuli that contain pairs of pictures which are visually similar and semantically unrelated, or semantically related and visually dissimilar, we can manipulate distractor to target picture relatedness/similarity in terms of either visual similarity or semantic relatedness. The goal in Experiment 4 was to determine whether visual similarity of distractors to target memory pictures would result in a greater magnitude of memory impairment than would semantic relatedness.

Participants. A total of 20 undergraduate students (M age = 18.70, SD = 1.30; 5 male and 15 female) at the University of Waterloo volunteered to participate in the study for course credit. All participants scored above 30% on the Mill Hill Vocabulary Scale indicating proficiency in the English language. Individuals who did not indicate having English as a first language or who had been diagnosed with depression or anxiety disorders were excluded from signing up.

Materials. Stimuli were acquired from Yee and Sedivy (2006), and were composed of images from a commercial clip art collection and from colored drawings (Rossion & Pourtois, 2001) based on the library of Snodgrass images (Snodgrass & Vanderwart, 1980) (see Figure 3 for examples of stimuli). The sets of pictures contained pairs that were either semantically related and visually dissimilar (e.g. 'glue' and 'tape'), visually similar and semantically unrelated (e.g. 'ball' and 'moon'), or both semantically unrelated and visually disimilar (e.g. 'pizza' and 'snake'). Pairs of images were controlled for the number of syllables and the frequency of the name of the items.

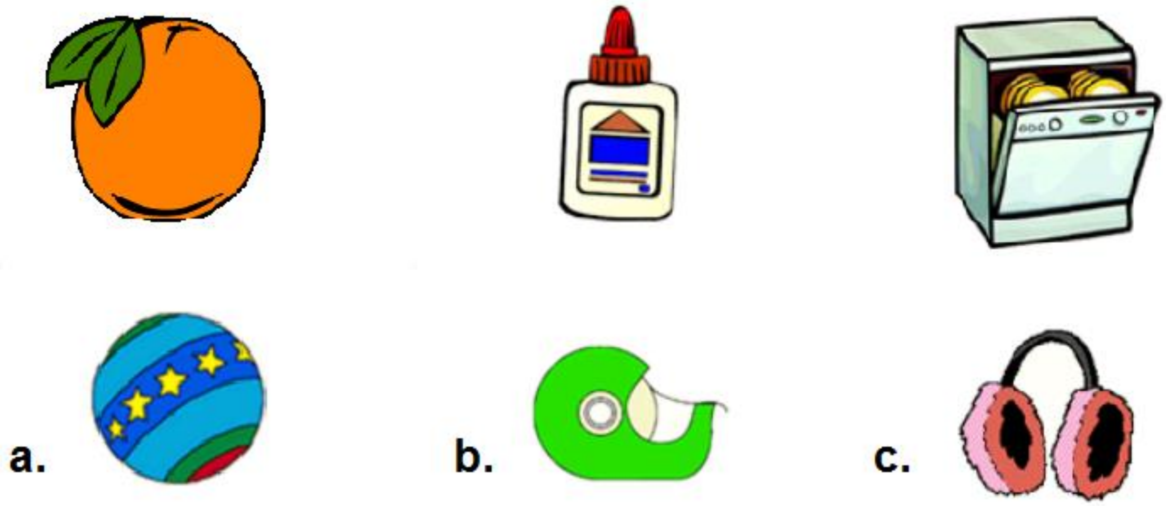

Figure 3. Stimuli used in Experiment 4 acquired from Yee and Sedivy (2006), with an example of a visually similar and semantically unrelated pair used in the DA-V condition (pair a), semantically related and visually dissimilar pair used in the DA-S condition (pair b), and visually dissimilar and semantically unrelated pair used in the DA-U condition (pair c).

Procedure. The procedure was identical to the previous experiments with the exception that there were four conditions instead of three. As in the prior experiments in this thesis, there was a FA condition, along with three conditions in which distractors were either visually similar and semantically unrelated (DA-V), semantically related and visually dissimilar (DA-S), or both semantically unrelated and visually dissimilar (DA-U). For each of the 4 conditions, each study phase contained 20 trials, and each recognition test phase contained 20 trials.

Results

Memory Performance. Recognition performance was assessed using signal detection analysis to calculate detection sensitivity (*d'*) (see Table 10 for means). A one-way ANOVA on the detection sensitivity data, comparing the four conditions, revealed a main effect of Condition, F (3, 57) = 4.38, MSE = 1.99, p = 0.008. To better understand the main effect, simple effects contrasts were performed and revealed that detection sensitivity was significantly worse in the DA-V, DA-S, and DA-U conditions compared to FA (F (1,19) = 11.33, MSE = 7.33, p = 0.003, F (1, 19) = 9.70, MSE = 9.89, p = 0.006, F (1, 19) = 12.71, MSE = 5.92, p = 0.002, respectively). No significant differences were found between the three DA conditions, indicating that visual similarity or semantic relatedness of distractors alone does not lead to differential impairment in retrieval of pictures compared to unrelated distractors.

Table 10. Experiment 4 Means and Standard Deviations for Memory Performance under Full Attention (FA), Divided Attention with Visually Related (DA-V), Divided Attention with Semantically Related Distractors (DA-S), and Divided Attention with Unrelated (DA-U) Picture Distractors During Retrieval.

	FA	**DA-V**	**DA-S**	**DA-U**
Hit rate	0.86(*0.14*)	0.75(*0.22*)	0.69(*0.23*)	0.72(0.25)
False Alarm rate	0.11(*0.05*)	0.18(*0.13*)	0.16(*0.18*)	0.14(0.25
Accuracy rate	0.75(*0.17*)	0.57(*0.24*)	0.53(*0.29*)	0.59(*0.25*)
d'	2.35(*0.60*)	1.74(*0.82*)	1.64(*1.80*)	1.80(*0.83*)

Memory Response Time. Median RT to make a correct recognition decision was recorded (See Table 11). A one-way ANOVA revealed a main effect of Condition, F (3, 57) = 35.20, MSE = 3719000.85, $p < 0.001$. Simple effects contrasts revealed that RTs were significantly slower in the three DA conditions compared to the FA condition (F (1, 19) = 60.93, MSE = 14183935.44, $p < 0.001$, F (1, 19) = 92.89, MSE = 16233637.44, $p < 0.001$, and F (1, 19) = 47.00, MSE = 14063196.27, $p < 0.001$, respectively). No other comparisons were significant, indicating that semantic relatedness and visual similarity of picture distractors had no effect on how long it took to make an 'old' response.

Table 11. Experiment 4 Mean Response Time and Standard Deviation for Hits During Recognition Under Full Attention (FA), Divided Attention with Visually Related (DA-V), Divided Attention with Semantically Related (DA-S, and Divided Attention with Unrelated (DA-U) Picture Distractors.

Condition	**Hits**
FA	865 (*190.59*)
DA-V	1707 (*396.82*)
DA-S	1767 (*336.10*)
DA-U	1703 (*452.22*)

Discussion

In Experiment 4, we found that memory performance was significantly worse, and response time was significantly slower, in all of the three DA conditions relative to FA. Further, we found no differences between distractor types, demonstrating that disrupting access to either the visual or the verbal code alone did not differentially impair retrieval of pictures. This finding is contrary to what would be expected if pictures are primarily based on visual representation in memory (Nelson, 1976; 1979), a perspective which would have predicted differentially greater impairment of memory in DA-V relative to DA-S. Instead, the results of this experiment are consistent with pictures being based on both visual and semantic representations, as suggested by the dual-code hypothesis (Paivio, 1971; 1986). By disrupting access to only one representational code at a time (visual or verbal), participants could then rely on access to the remaining representational code to retrieve pictures from memory.

If it is the case that memory for pictures relies on access to both a visual and a verbal code in long-term memory, then disrupting access to both of these should impair retrieval of pictures. That is, perhaps memory for pictures would be differentially disrupted only when the distracting task creates competition for BOTH visual AND semantic representations. We tested this hypothesis that by interrupting access to both visual and semantic representational codes participants would have no way to avoid interference in Experiment 5.

Experiment 5

In Experiment 5, we aimed to determine whether picture distractors that were both visually similar (in terms of shape, size, color, and features), and semantically related to those in the target memory task would impair memory performance to a greater extent than when distracting pictures were both semantically unrelated and visually dissimilar. To test this hypothesis, in Experiment 5, we created a DA condition in which we matched target memory pictures and distractor task pictures. In the DA related condition, distractors were selected to be from the same semantic category, as well as visually similar on dimensions such as shape, size, color, and type of features. These distractor pictures were selected based on a pilot study, to be visually similar to the memory task item on a given trial, based on similarity ratings across picture pairs on each of four dimensions: shape, size, color, and type of features. In the DA unrelated condition, distractors were both visually dissimilar and semantically unrelated (from different categories) to the pictures in the target memory task.

This prediction was based on the assumption that pictures are coded both verbally and visually (Paivio, 1971; 1986), and that by manipulating visual similarity and semantic relatedness of distractors, access to these codes would be disrupted, thus resulting in impaired retrieval from memory. In terms of a visual code, past work showed that pairs of novel objects which are more similar in shape are confused more often in memory (Desmarais & Dixon, 2005; Desmarais, Dixon, & Roy, 2007), and that real-world objects which are visually similar are responded to more slowly than more visually distinct objects (Lloyd-Jones & Humphries, 1997). In terms of a verbal code, Experiment 1 in this thesis demonstrated that names of objects are reliant on semantic representational codes. As such, we expected that by manipulating both visual similarity and semantic relatedness of distractor picture to target pictures in the DA related condition we would see worse memory performance than in the DA unrelated condition, in which distractors were visually dissimilar and semantically unrelated.

Method

Participants. A total of 24 undergraduate students (M age = 19.67, SD = 1.97; 12 male and 12 female) at the University of Waterloo volunteered to participate in the study for course credit. All participants scored above 30% on the Mill Hill Vocabulary Scale indicating proficiency in the English language. Individuals who did not indicate having English as a first language or had been diagnosed with depression or anxiety disorders were excluded from signing up.

Materials. All stimuli and materials were identical to Experiment 2, with the exceptions noted below.

In the DA related condition, the memory task and distractors pictures were selected to be matched on four dimensions: shape, size, color, and type of features, as well as being from the same semantic category. In a pilot study, six independent raters assessed the similarity of each of the visually similar "pairs" to be presented during the retrieval phase of the experiment; 20 pairs of memory task and distractor task pictures were selected from within each category, (*birds*, *musical instruments*, and *fruits/vegetables*). These raters were asked to rate on a 1-5 scale (where '1' indicated very dissimilar, and '5' indicated very similar), each of the four aforementioned dimensions for all 120 pairs of pictures (20 visually similar pairs and 20 random pairs from each of the 3 categories). We opted to compare the visually matched pairs of pictures to pairs of pictures randomly selected from within a category, as targets and distractors had randomly been selected in the DA related condition of Experiment 3. By doing so, we can later conclude that we successfully manipulated visual similarity of pictures, as random pairs of items from within a category were perceived (in this pilot study) to be far less visually similar than when pairs were purposefully matched. The visually similar pairs of pictures in the DA related condition were 32% more similar on all four dimensions than the randomly selected picture pairs in the DA unrelated condition (see Table 12 for average similarity ratings).

Table 12. Average Similarity Ratings (on a scale of 1 (low) to 5 (high)) for DA-R and DA-U Picture Pairs on Dimensions of *Shape*, *Size*, *Color*, and *Features* in the Pilot Study.

	DA-R	**DA-U**
Shape	3.96(*0.27*)	2.09(*0.16*)
Size	3.88(*0.25*)	2.28(*0.23*)
Color	3.31(*0.27*)	2.43(*1.32*)
Features	4.06(*0.19*)	2.39(*0.14*)
Overall	3.80(*0.25*)	2.18(*0.20*)

Procedure. The procedure was identical to the previous experiments, with the exception that memory task pictures and distractor pictures were no longer randomly selected for presentation from a given category, but were instead selected to be visually similar (as well as being semantically related) in the DA related condition. Specifically, each picture presented on the recognition task was matched to a specific distractor picture such that a given "pair" would always be presented together (for example, apple and peach, emu and ostrich, violin and fiddle).

Results

Memory Performance. Recognition performance was assessed using signal detection analysis to calculate detection sensitivity (*d'*) (see Table 13 for means). A one-way ANOVA on the detection sensitivity data comparing the three conditions, revealed a main effect of Condition, F (2, 46) = 14.76, MSE = 7.98, $p < .001$, $\eta^2 = .39$. To better understand the main effect, simple effects contrasts were performed, and revealed that detection sensitivity was significantly worse in the DA conditions compared to FA (F (1,23) = 31.52, MSE = 31.58, $p <$ .001, $\eta^2 = .58$, and F (1, 23) = 10.87, MSE = 10.67, $p = .003$, $\eta^2 = .32$, respectively). Importantly, detection sensitivity in the DA related condition was found to be significantly worse than in the DA unrelated condition, F (1, 23) = 4.32, $MSE < 5.33$, $p = .049$, $\eta^2 = .16$, indicating that distracting stimuli that were BOTH semantically related and visually similar, relative to unrelated, to the to-be-remembered picture stimuli differentially impaired memory performance.

Table 13. Experiment 5 Means and Standard Deviations for Memory Performance under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Picture Distractors During Retrieval.

	FA	**DA-R**	**DA-U**
Hit rate	0.90(*0.11*)	0.63(*0.22*)	0.78(*0.19*)
False Alarm rate	0.10(*0.14*)	0.19(*0.23*)	0.21(*0.24*)
Correct Rejection rate	0.90(*0.14*)	0.61(*0.26*)	0.68(*0.22*)
Miss rate	0.10(*0.12*)	0.23(*0.18*)	0.15(*0.17*)
Accuracy rate	0.80(*0.19*)	0.44(*0.29*)	0.56(*0.28*)
d'	2.53(0.72)	1.38(0.93)	1.86(0.84)

Memory Response Time. Median RT to make a correct recognition decision was recorded (see Table 14). A one-way ANOVA revealed a main effect of Condition, F (2, 46) = 302.16, MSE = 15541367.63, $p < 0.001$, $\eta^2 = 0.93$. Simple effects contrasts revealed that RTs were significantly slower in the DA conditions compared to the FA condition (F (1, 23) = 552.36, MSE = 49540576.76, $p < 0.001$, $\eta^2 = 0.96$, and F (1, 23) = 359.32, MSE = 43512147.51, $p < 0.001$, $\eta^2 = 0.94$, respectively). However, RTs were not significantly different in the two DA conditions, F (1, 23) = 2.00, MSE = 195481.50, $p = 0.17$, $\eta^2 = 0.08$, indicating that semantic relatedness of picture distractors had little of any effect on how long it took to make an 'old' response.

Table 14. Experiment 5 Mean Response Time and Standard Deviation for Hits During Recognition Under Full Attention (FA), Divided Attention with Related (DA-R) and Divided Attention with Unrelated (DA-U) Picture Distractors.

Condition	**Hits**
FA	891 (*194.14*)
DA-R	2328 (*326.15*)
DA-U	2238 (*347.97*)

Distractor Task Performance. Distractor task accuracy was measured as percentage of correctly classified items on the size decision task, in baseline and in the two DA conditions (See Table 14). A one-way ANOVA on distracter task accuracy revealed a main effect of Condition, F (2, 46) = 39.83, MSE = 0.85, $p < 0.001$, $\eta^2 = 0.63$. Simple effects contrasts revealed that distractor task accuracy was significantly worse in the DA related condition compared to baseline, F (1, 23) = 78.89, MSE = 3.41, $p < 0.001$, $\eta^2 = 0.77$, and also worse in the DA unrelated condition compared to baseline, F (1, 23) = 25.77, MSE = 0.86, $p < 0.001$, $\eta^2 = 0.53$. Accuracy in the DA related condition was also significantly worse than that in the DA unrelated condition, F (1, 23) = 16.29, MSE = 0.84, $p < 0.001$, $\eta^2 = 0.42$.

Table 15. Experiment 5 Mean Percentage Correct and Standard Deviations to Make Size Decisions to Distracting Task Pictures during a Full Attention Baseline, and Under Divided Attention Conditions When Pictures are Related (DA-R) or Unrelated (DA-U) to Those in the Target Memory Task.

Condition	**Percentage Correct**
Baseline	0.94 (*0.05*)
DA-R	0.56 (*0.21*)
DA-U	0.75 (*0.18*)

Discussion

In Experiment 5, we manipulated the presentation of memory task pictures and distractor pictures such that they were matched to be both semantically related and visually similar in the DA related condition, or visually dissimilar and semantically unrelated in the DA unrelated condition. As in Experiments 3 and 4, both DA conditions impaired memory performance relative to FA. Importantly in this experiment, however, we found that distractors that were both semantically related and visually similar, relative to unrelated/dissimilar to the to-be-remembered pictures, led to significantly worse memory performance for the to-be-remembered targets. That the DA related condition resulted in impaired retrieval of pictures relative to the DA unrelated condition is in line with previous work demonstrating that visually similar objects are confused more often in memory (Desmarais & Dixon, 2007). The findings from this experiment further demonstrate that episodic memory for pictures is interfered with by distractors that are BOTH semantically related and visually similar to the information that is being retrieved from long-term memory.

The results from this Experiment and Experiment 4 suggest that successful retrieval of pictures can occur with access to either visual or verbal representations; however, under DA, competition from a distracting task that contains both visual and verbal/semantic overlap with target images differentially disrupts retrieval.

Chapter 4

General Discussion

In this thesis, we used the DA technique to infer the cognitive resources and codes used to represent words and pictures in long-term episodic memory. Recognition accuracy for words was poor when distractors at retrieval were semantically related to target items. Recognition accuracy for pictures was equivalent between conditions with semantically related and unrelated distractors regardless of whether distractors were pictures or words, but poorer when picture distractors were semantically related as well as visually similar to the target item. These findings suggest that long-term episodic memory for words and pictures both require access to semantically-based representations, but that picture memory also requires access to visuo-spatial representations for optimal performance.

In Experiment 1, we demonstrated that semantically related compared to unrelated word distractors, presented concurrently during retrieval, differentially impaired retrieval of the words from long-term memory. In Experiment 2, we wanted to determine whether memory for pictures would similarly be susceptible to interference when attention was divided at retrieval. Unlike memory for words, DA at retrieval using distractors that were semantically related did not interfere with memory for pictures to a greater extent than did unrelated distractors. Further, changing from auditory distractors to picture distractors (in Experiment 3) did not result in any differences in memory performance between related and unrelated distractors. However, in Experiment 5, we found that when distractors were both semantically related and visually similar to the memory task pictures, memory was disrupted to a greater extent than when the distractors were unrelated/dissimilar (visually and semantically).

The findings presented in Chapter 3 are consistent with the Dual-Code theory as described by Paivio (1971), which posits that memory for pictures is superior to memory for words because pictures can be encoded both verbally and visually while words are only encoded verbally. If it were the case that pictures simply have a more distinctive visual code (Nelson, 1979) then we might expect to have found greater interference when distractors were visually similar relative to dissimilar in Experiment 4. However, we only found differentially greater impairment in retrieval when distractors were both visually similar and semantically related. This suggests that pictures are dependent on BOTH visual and semantic representations in episodic memory.

Performance on the distractor task

The use of a distractor task and DA paradigm is novel within the literature examining the influence of semantic relatedness on episodic memory for words and pictures. Previous work by Marsh, et al. (2008; 2009), used an unattended speech paradigm in which participants were not required to attend to distracting information while encoding and retrieving words from long-term memory, and for reasons outlined in Chapter 2, this may have influenced previous findings. Our use of a DA paradigm that required overt responses to each distracting task allowed us to ensure that participants were indeed attending to the distracting information (unlike in an unattended speech paradigm used in Marsh’s work).

When looking at accuracy in the distractor task, performance in all experiments was found to be worse in DA conditions compared to baseline, and always worse in DA related compared to DA unrelated conditions. The fact that memory and distractor task performance were both significantly worse when compared to full attention and baseline conditions, respectively, indicates that attention was successfully divided in our DA conditions (Fernandes & Moscovitch, 2000; 2002; 2003).

The influence of DA on response time to make recognition decisions to words and pictures

The response time analyses revealed that, in Experiment 1, the presence of semantically related distractors at encoding and retrieval slowed memory responses significantly more than did unrelated distractors when the memory task material was words. When looking at memory for pictures during DA at retrieval in Experiment 2, RTs were slowed to an even greater magnitude when verbal distractors were related relative to unrelated, though no such differences were found with pictures in Experiments 3 and 4.

The finding that responses were differentially slowed when auditory distractors were related to the memory task pictures (Experiment 2) is interesting given that no RT differences were found between distractor types when both memory task items and distractors were pictures (Experiment 2 and 3). We expected to find differentially slower RTs between semantically related and unrelated conditions when distractors were pictures.We had theorized, based on the dual-code theory (Paivio, 1971; 1986), that participants would need to rely on the verbal code to a greater extent when distractors were pictures, and thus should be more susceptible to interference from semantic relatedness. Specifically, visuospatial distractors should impair access to the visual code during retrieval (Fernandes & Guild, 2009; Pellegrino, Seigel, & Dhawan, 1976; Burton & Bruning, 1982), thus creating a greater reliance on the verbal code to retrieve pictures and therefore a greater opportunity for interference from semantically related information in accessing that verbal code. One reason for why we found slower RTs in DA conditions when distractors were auditory (Experiment 1 and 2), but not when they were pictures (Experiments 3, 4, and 5), might be because more diverse semantic information was activated when imagining the items presented auditorily. For example, imagining the size of a violin might involve visualizing someone playing a violin, or when you saw one last week in an orchestra, and these thoughts may be more likely to interfere with your memory for 'flute', than when a concrete picture of a violin is presented and you are able to focus solely on the physical characteristics of the object to make the size decision.

Additionally, it is notable that RTs were not differentially slowed in Experiment 5, since memory performance was significantly worse when distractors were both semantically related and visually similar to the memory task pictures. One explanation for this inconsistent pattern of findings in memory RT in Experiment 5 is that when memory task items were matched to be both semantically related and visually similar (in terms of size, among other dimensions), they would both elicit the same size decision required for the distractor task. As such, participants could quickly make their size judgment to the distracting item by assessing the size of both pictures on the screen (memory task picture and distractor), thereby saving time in differentiating the response particular to the distractor picture. In other words, it may have been faster to make a size decision in the DA-R condition when distractors were semantically and visually related because the two items were congruent in terms of size (i.e., “sparrow” and “swallow”), compared to DA-U in which they were incongruent (i.e., “sparrow” and “flamingo”).

Limitations and future directions

In this thesis, semantic relatedness was manipulated between conditions, such that in the DA related conditions, all distractors were related to the targets, and in the DA unrelated conditions, all distractors were unrelated to the targets. As a result, the DA conditions might be thought of as ‘pure’ lists, composed of either purely related trials or purely unrelated trials. This design arguably has less generalizability to understanding what types of information might disrupt retrieval in daily life, as a mixed design is more akin to the way that we naturally encounter information and attempt to remember things. In other words, a mixed-list design, in which some of the trials contain related distractors and some do not, might provide a better indicator of how semantically related information influences retrieval when we are not in a situation in which we are bombarded with an overwhelming amount of semantically related items. Importantly, it would also be of theoretical interest to determine whether semantic interference continues to occur in a mixed presentation, or whether we might alternatively see facilitation in such a context. When distractors are only occasionally related to the targets, they might act like primes as we see in semantic priming tasks (Meyer & Schvaneveldt, 1971). As discussed in Chapter 1, Neely et al. (1983) found speeding of recognition decisions on trials when cues (presented just prior to presentation of the target) were semantically related to the target, than when they were unrelated, suggesting that the presence of semantically related information can improve retrieval in some cases.

In the experiments in Chapter 3 of this thesis, we investigated the representational codes that are required for successful retrieval of pictures, finding that retrieval is only impaired when distractors are both visually similar and semantically related to target items. However, we do not know if the visual similarity of distractors must be presented in the visual modality, or if simply imagining an item that is visually similar to the target item would also lead to impaired memory performance. In Experiment 2 in Chapter 3, distractors in the DA conditions consisted of auditory distractors which were either semantically related or unrelated to the pictures in the memory task, but visual similarity of distractors to targets was not controlled as it was in Experiment 5. We hypothesized that we had found no difference in memory performance between DA conditions in Experiment 2 because we had not disrupted access to the visual representational code and therefore in all following experiments used picture distractors. Interestingly, we did not find differential interference in retrieval when picture distractors were semantically related relative to unrelated (Experiment 3), but only when visual similarity was manipulated as well (Expteriment 5). This could suggest that simply processing visual information might not disrupt access to what we have referred to as the 'visual' representational code.

Instead of being dependent on perceptual information, the visual representational code could potentially be reliant on conceptual information, regarding how an object looks. This would involve conceptual prototypes of objects based on past experience; what we imagine a particular object to look like. Future work could present auditory distractors of names of items that are both semantically related and visually similar to target memory task pictures, to determine if the presence of perceptual information is important in disrupting access to the 'visual' representational code. If semantically related and visually similar distractors lead to differentially greater memory impairment than unrelated/dissimilar distractors, this might suggest that the visual representational code is more conceptually based, involving prototypical information of what we know an object looks like based on memory and experience. Future explorations of what constitutes and interferes with the visual representational code can help us better understand how pictures are stored and retrieved from long-term memory.

One additional limitation to the work in this thesis is the simplistic perspective taken on what constitutes semantic relatedness, specifically across the visual and verbal modalities. Previous patient work has demonstrated a distinction between verbal semantics and visual semantics (Warrington & Crutch, 2010), the former referring to semantic information accessed through the verbal modality and the latter through the visual modality. Warrington and Crutch (2010) observed deficits in patient AZ on verbal tests of semantic knowledge while performance on visual tests of semantic knowledge remained intact. With regards to the work presented in this thesis, our conceptualization of 'semantics' is consistent with verbal semantics. Future work may benefit from further probing the distinction between verbal and visual semantic representational codes for words and pictures in long term memory.

Implications for real-world scenarios

Returning to our earlier example of shopping at the grocery store, we would suggest that thinking of, or hearing suggestions of, items that are semantically related to the target item that we are trying to retrieve can make it more difficult to remember. For example, having your shopping partner suggest red onions and bell peppers, should make it more difficult to remember that what you were intending to get was potatoes. However, this might not quite be the case with memory for visual information. As we have found in the experiments presented in this thesis, retrieval of pictures from memory requires access to both semantic and visual representational codes. When access to only one of these codes is disrupted, individuals can rely on the remaining code to retrieve information; disrupting access to the verbal semantic code leaves the visual code available for retrieval, and vice versa. As such, when standing in the produce section trying to remember what vegetables you need while looking around at the options, impairment of retrieval should be more likely to occur when observing items that are visually and semantically similar to the target item (e.g., looking at apples and trying to retrieve peaches) than those that are semantically similar but visually dissimilar (e.g., looking at apples when trying to retrieve grapes). Perhaps a better method for successfully remembering which items you need from the produce section would be to attempt to retrieve those items while away from the produce section.

Conclusion

In conclusion, this series of experiments indicates that memory for words is particularly susceptible to interference from semantically related distractors during retrieval, suggesting that representation of words in memory is based primarily on a verbal semantic code. Memory for pictures, in contrast, was only differentially disrupted when distracting items were presented that had both semantic and visuo-perceptual overlap with the target pictures. These findings suggest that long-term episodic memory for words and pictures both require access to semantically-based representations, but that picture memory also requires access to visuo-spatial representations for optimal performance. The work in this thesis implies that different stimuli are stored and retrieved in long-term memory using specific representational codes. In particular, we have demonstrated that words and pictures are both highly dependent on verbal semantic representational codes, and that visual attributes are additionally critical for memory for pictures.

References

Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior*, *22*(3), 261-295.

Baddeley, A. D. (1966). The influence of acoustic and semantic similarity on long-term memory for word sequences. *Quarterly Journal of Experimental Psychology, 18(4),* 302-309. doi:10.1080/14640746608400047

Baddeley, A. D., Lewis, V., Eldridge, M., & Thomson, N. (1984). Attention and retrieval from long-term memory. *Journal of Experimental Psychology: General, 113,* 518-540.

Beaman, C. P. (2004). The irrelevant sound phenomenon revisited: What role for working memory capacity? *Journal of Experimental Psychology: Learning, Memory and Cognition, 30,* 1106-1118.

Burton, J. K., & Bruning, R. H. (1982). Interference effects on the recall of pictures, printed words, and spoken words. *Contemporary Educational Psychology*, *7*(1), 61-69.

Calkins, M. W. (1898). Short studies in memory and in association from the Wellesley College Psychological Laboratory. *Psychological Review*, *5*(5), 451-462.

Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. M. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance*, *8*(6), 757-777.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*(6), 407-428.

Craik, F. I. M., Naveh-Benjamin, M., Ishaik, G., & Anderson, N. D. (2000). Divided attention during encoding and retrieval: Differential control effects*? Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1744-1749.

Deese, J. (1959a). Influence of inter-item associative strength upon immediate free recall. *Psychological Reports, 5*, 305-312.

Deese, J. (1959b). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58*, 17–22.

Desmarais, G., & Dixon, M. J. (2005). Understanding the structural determinants of object confusion in memory: An assessment of psychophysical approaches to estimating visual similarity. *Perception & Psychophysics, 67*(6), 980-996.

Desmarais, G., Dixon, M. J., & Roy, E. A. (2007). A role for action knowledge in visual object identification. *Memory & Cognition, 35*(7), 1712-1723.

Fischler, I. (1977). Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance, 3(1), 18-26*.

Fernandes, M. A., Craik, F., Bialystok, E., & Kreuger, S. (2007). Effects of bilingualism, aging, and semantic relatedness on memory under divided attention. *Canadian Journal of Experimental Psychology, 61*(2), 128-141.

Fernandes, M., & Guild, E. (2009). Process-specific interference effects during recognition of spatial patterns and words. *Canadian Journal of Experimental Psychology*, *63*(1), 24-32.

Fernandes, M. A., & Moscovitch, M. (2000). Divided attention and memory: Evidence of substantial interference effects at retrieval and encoding. *Journal of Experimental*

Psychology: General, *129*(2), 155-176.

Fernandes, M. A., & Moscovitch, M. (2002). Factors modulating the effect of divided attention during retrieval of words. *Memory & Cognition*, *30*(5), 731-744.

Fernandes, M. A., & Moscovitch, M. (2003). Interference effects from divided attention during retrieval in younger and older adults. *Psychology and Aging*,*18*(2), 219-230.

Folk, C. L., Remington, R. W., & Wright, J. H. (1994). The structure of attentional control: Contingent attentional capture by apparent motion, abrupt onset, and color. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(2), 317-329.

Gaissert, N., & Wallraven, C. (2012). Categorizing natural objects: A comparison of the visual and the haptic modalities. *Experimental Brain Research*, *216*(1), 123-134.

Kirkpatrick, E. A. (1894). An experimental study of memory. *Psychological Review*, *1*(6), 602-609.

Köhler, S., Moscovitch, M., Winocur, G., & McIntosh, A. R. (2000). Episodic encoding and recognition of pictures and words: Role of the human medial temporal lobes. *Acta Psychologica*, *105*(2), 159-179.

Lloyd-Jones, T. J., & Humphreys, G. W. (1997). Perceptual differentiation as a source of category effects in object processing: Evidence from naming and object decision. *Memory & Cognition*, *25*(1), 18-35.

Macmillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide.* New York: Cambridge University Press.

Marsh, J. E., Hughes, R. W. & Jones, D. M. (2008). Auditory distraction in semantic memory:

A process-based approach. *Journal of Memory and Language, 58(3),* 682-700.

Marsh, J. E., Hughes, R. W., Jones, D. M. (2009). Interference by process, not content, determines semantic auditory distraction. *Cognition, 110,* 23-38.

Marsh, J. E., Sörqvist, P., Hodgetts, H. M., Beaman, C. P., & Jones, D. M. (2015). Distraction control processes in free recall: Benefits and costs to performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41(1),* 118-133.

Marsh, J. E., Beaman, C. P., Hughes, R. W., & Jones, D. M. (2012). Inhibitory control in memory: Evidence for negative priming in free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(5), 1377-1388.

Masson, M. E. J. (1995). A distributed memory model of semantic priming**.** *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21(1*), *3-23*.

McClelland, J. L. (1994). The organization of memory: A parallel distributed processing perspective. *Revue Neurologique, 150*, 570- 579.

McClelland, J. L., Rumelhart, D. E., & Hinton, G. E. (1986). *The appeal of parallel distributed processing* (pp. 3-44). Cambridge, MA: MIT Press.

Mervis, C. B., & Rosch, E. (1981). Categorization of natural objects. *Annual Review of Psychology*, *32*(1), 89-115.

Meyer, D., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90(2),* 227-234.

Neely, J. H., Schmidt, S. R., & Roediger, H. L. (1983). Inhibition from related primes in recognition memory. *Journal of Experimental Psychology Learning Memory and Cognition*, *9(2)*, 196-211.

Nelson, D. L., Reed, V. S., & McEvoy, C. L. (1977). Learning to order pictures and words: A model of sensory and semantic encoding. *Journal of Experimental Psychology: human learning and memory*, *3*(5), 485-497.

Nelson, H. E. (1976). A modified card sorting test sensitive to frontal lobe defects. *Cortex*, *12*(4), 313-324.

Paivio, A. (1971). Imagery and language. *Imagery: Current Cognitive Approaches*, 7-32.

Paivio, A. (1986). Mental representations: A dual-coding approach. New York: Oxford University Press.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology*, *45*(3), 255-287.

Pellegrino, J. W., Siegel, A. W., & Dhawan, M. (1976). Differential distraction effects in short term and long-term retention of pictures and words. *Journal of Experimental Psychology: Human Learning and Memory*, *2*(5), 541-547.

Plaut, D. C. (1995). Semantic and associative priming in a distributed attractor network. In *Proceedings of the 17th annual conference of the cognitive science society* (Vol. 17, pp. 37-42).

Raven, J. C. (1977). Court JH, Raven J. *Manual for Raven's progressive matrices and vocabulary scales*.

Roediger, H.L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24(*4), 803–814.

Rossion, B., & Pourtois, G. (2001). Revisiting Snodgrass and Vanderwart's object database: Color and texture improve object recognition. *Journal of Vision*, *1*(3), 413.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), Cognition and categorization (pp. 27-48). Hillsdale, NJ: Erlbaum.

Rumelhart, D. E. (1990). Brain style computation: Learning and generalization. In: S.F. Zornetzer, J. L. Davis, and C. Lau (Eds.). (pp. 408-420). An introduction to neural and electronic networks. San Diego, CA: Academic Press.

Silverberg, N., & Buchanan, L. (2005). Verbal mediation and memory for novel figural designs: A dual interference study. *Brain and Cognition*, *57*(2), 198-209.

Smith, M. C., Bentin, S., & Spalek, T. M. (2001). Attention constraints of semantic activation during visual word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(5), 1289-1298.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*(1), 34-50.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*,*6*(2), 174-.

Standing, L. (1973). Learning 10000 pictures. *The Quarterly Journal of Experimental*

Psychology, *25*(2), 207-222.

Stock, O., Röder, B., Burke, M., Bien, S., & Rösler, F. (2009). Cortical activation patterns during long-term memory retrieval of visually or haptically encoded objects and locations. *Journal of Cognitive Neuroscience*, *21*(1), 58-82.

Stolz, J. A., Besner, D., & Carr, T. H. (2005). Implications of measures of reliability for theories of priming: Activity in semantic memory is inherently noisy and uncoordinated. *Visual Cognition*, *12*(2), 284-336.

Treisman, A. M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology*, *12*(4), 242-248.

Vaidya, C. J., Zhao, M., Desmond, J. E., & Gabrieli, J. D. (2002). Evidence for cortical encoding specificity in episodic memory: Memory-induced re-activation of picture processing areas. *Neuropsychologia*, *40*(12), 2136-2143.

Vandenberghe, R., Price, C., Wise, R., Josephs, O., & Frackowiak, R. S. (1996). Functional anatomy of a common semantic system for words and pictures. *Nature*, *383*(6597), 254-256.

Yee, E., & Sedivy, J. C. (2006). Eye movements to pictures reveal transient semantic activation during spoken word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(1), 1-14.

Warrington, E. K, & Crutch, S. J. (2010). A circumscribed refractory access disorder: A verbal semantic impairment sparing visual semantics. *Cognitive Neuropsychology*, *21*, 299-315.