The Influence of Study Context on Recollection: Cognitive, Neural, and Age-Related Processes

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Doctor of Philosophy
in
Psychology

Waterloo, Ontario, Canada, 2009

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

This thesis examines how the context in which an item is studied affects the phenomenological experience of the rememberer. Previous research has extensively studied how the match between study and test context affect subsequent memory performance; however, little work has attempted to examine how visual context information provided at study affects later recollection when that context information is not re-presented at retrieval. In particular, the quality of the memory retrieved may be enhanced when highly meaningful visual context information is provided at study. In each of seven experiments in the current thesis, participants studied words presented with context information high or low in meaningful content, and on a later recognition memory test made a Remember, Know, or New response to the words presented alone. Experiment 1 showed that participants had better overall memory, specifically recollection, for words studied with pictures of intact as opposed to scrambled faces. In Experiment 2, these results were replicated and recollection was shown to be higher for words studied with versus without pictures of faces. Experiment 3 showed that participants had higher memory performance, and recollection in particular, for words studied with upright compared to inverted faces. In Experiment 4, participants showed equivalent memory for words studied with novel or familiar faces. These results suggest that recollection benefits when visual context information high in meaningful content accompanies study words, and that this benefit is not related to the novelty of the context.

To further test the claim that participants engage in elaborative processes at study to bind item and context information, improving subsequent recollection, the subsequent set of experiments examined how normal, healthy aging affects participants’ ability to use context information provided at study to benefit subsequent recollection. Older adults have been shown to experience deficits both in memory for context and in recollection, suggesting that they might fail to use context effectively to increase recollection, in contrast to younger adults. Experiment 5 found that younger, but not older,

adults showed higher recollection for words studied with faces as compared to rectangles. To determine the type of cognitive processing required to obtain recollection benefits, and to examine whether instruction could alleviate age-related deficits, in Experiment 6, the type of processing engaged during the encoding of context-word pairs was manipulated. Younger and older adults studied words presented with a picture of a face under a surface feature or binding feature instruction condition. Both age groups showed higher recollection in the binding than surface instruction condition. Results suggest that older adults do not spontaneously engage in the processes required to boost recollection when visual context information is provided at study, although instructional manipulation during encoding lessens this deficit. This is in line with the Associative Deficit Hypothesis (Naveh-Benjamin, 2000), suggesting that older adults' recollection deficit involves a specific difficulty in binding item and context information.

The final experiment used functional Magnetic Resonance Imaging (fMRI) to examine the neural correlates of recollection, specifically testing the hypothesis that sensory-specific reactivation of context information occurs during item recollection. In Experiment 7, brain activation for Remember responses given to words studied with and without meaningful context information was compared. Behaviourally, 8 of the 14 participants showed a higher proportion of Remember responses to words studied with faces than scrambled faces, and 6 did not. Whole brain analysis showed that, for only those participants who showed higher memory performance for words studied with faces, activation in the fusiform gyrus and hippocampus was higher, and a region-of-interest analysis showed increased activation in the functionally-defined FFA (identified in a localizer task), for Remember responses given to words studied with faces compared to scrambled faces. A regression analysis additionally showed that activation in the fusiform gyrus increased as the relative recollection benefit for words studied with meaningful (face) compared to non-meaningful (scrambled face) context information increased across participants. Results suggest that encoding context can influence the pattern of recollection responses on a recognition task and that sensory-specific reactivation is related to behavioural performance. The findings of these experiments suggest that participants can use context information high in meaningful content at study to improve subsequent recollection and I suggest that this involves the use of elaborative processes at encoding that integrates item and meaningful contexts. Such recollection benefits can also be observed in older adults when they are provided experimental instructions to bind item and context at encoding. In addition, the brain regions used to process context information are reactivated at retrieval and, importantly, that this neural pattern determines whether a boost in recollection, from the encoding manipulation, is observed. Participants can thus use context information provided at study to boost subsequent recollection, and I suggest that this involves cognitive processes that bind item and context information at encoding and the reactivation of sensory-specific brain regions at retrieval.

Acknowledgements

I gratefully acknowledge Myra Fernandes with whom this project was designed and under whose guidance it was conducted. I thank my committee members Colin MacLeod and Jonathan Fugelsang, and the University of Waterloo Department of Psychology, Behavioural Neuroscience division, for their support on this project. I also thank my helpful lab-mates for their wonderful suggestions and the many research assistants for their help in collecting the data.

A big thank you to my mom and dad for always providing me with the support I needed and for always believing in me. I am especially thankful to Matthew for helping me stay grounded and focused, for making me laugh, and for making me hot chocolate during the long workdays and nights.

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Chapter 1
General Introduction

When we recognize objects in our environment, our memories often contain details of the episode in which we first encountered the item. At other times, our memories arise only as an unspecific sense that an item has been previously experienced. The difference between such memories is easily demonstrated by the example of seeing someone on the street whom you have met previously. Sometimes we can place where we first met the person whereas other times, despite knowing that the person is familiar to us, we cannot remember where we previously encountered them. This difference in subjective experience during retrieval has led some researchers to hypothesize that there are dual processes underlying recognition, representing qualitatively different types of memory (Gardiner, 1988; Yonelinas, 2002). This doctoral thesis explores how the context in which an item is studied affects the phenomenological experience of the rememberer.

The general introduction of this thesis is broken into four sections. It begins with an explanation of dual process theories of recognition memory, as well as a competing theory, followed by a description of the remember-know paradigm. The literature examining context effects on recognition memory is then reviewed. The final section outlines the rationale for the series of experiments that follow.

1.1 Dual Process Theories of Recognition Memory

Dual process theories of recognition memory propose that there are two processes underlying recognition, representing qualitatively different types of memory, known as recollection and familiarity (Gardiner, 1988; Yonelinas, 2002). Whereas recollection refers to the effortful retrieval of detailed contextual information about individual personal episodes, familiarity is thought of as an awareness of having previously encountered a given item or event, represented as memory strength.

Experimental evidence shows that manipulations performed at encoding and retrieval can produce different effects on the two processes (Yonelinas, 2002). For example, at encoding, divided attention, levels of processing, and generate-read manipulations produce greater effects on recollection than familiarity (Jacoby, 1991; Yonelinas, 2001). At retrieval, speeded responding conditions decrease recollection while leaving familiarity relatively constant (Yonelinas & Jacoby, 1994), whereas changes in modality on a verbal recognition test decrease familiarity, but not recollection (Gregg & Gardiner, 1994). These experimental manipulations have led researchers to suggest that whereas familiarity is a fast, relatively automatic process, recollection is a slower, more controlled retrieval process (Yonelinas, 2002).

1.1.1 Dual process and signal detection models

Several dual and signal detection models of recognition memory currently exist. Presently, the most popular model of dual process theories of recognition memory, proposed by Yonelinas (1994), is the dual-process signal-detection/high-threshold (DPSD) model. This model suggests that recollection is a high-threshold process, in that recollection either does or does not occur. If recollection is achieved, a high-confidence decision that the item has been experienced is made. If recollection fails, then a familiarity-based decision is made. Familiarity is modeled as a continuous variable regulated by an equal-variance detection model (see Figure 1). Signal detection models assume that both targets (studied items) and lures (unstudied items) contain a certain amount of evidence that the item was experienced previously (or memory strength). This evidence is further assumed to be normally distributed. As shown in Figure 1, the target and lure distributions contain equal variance.

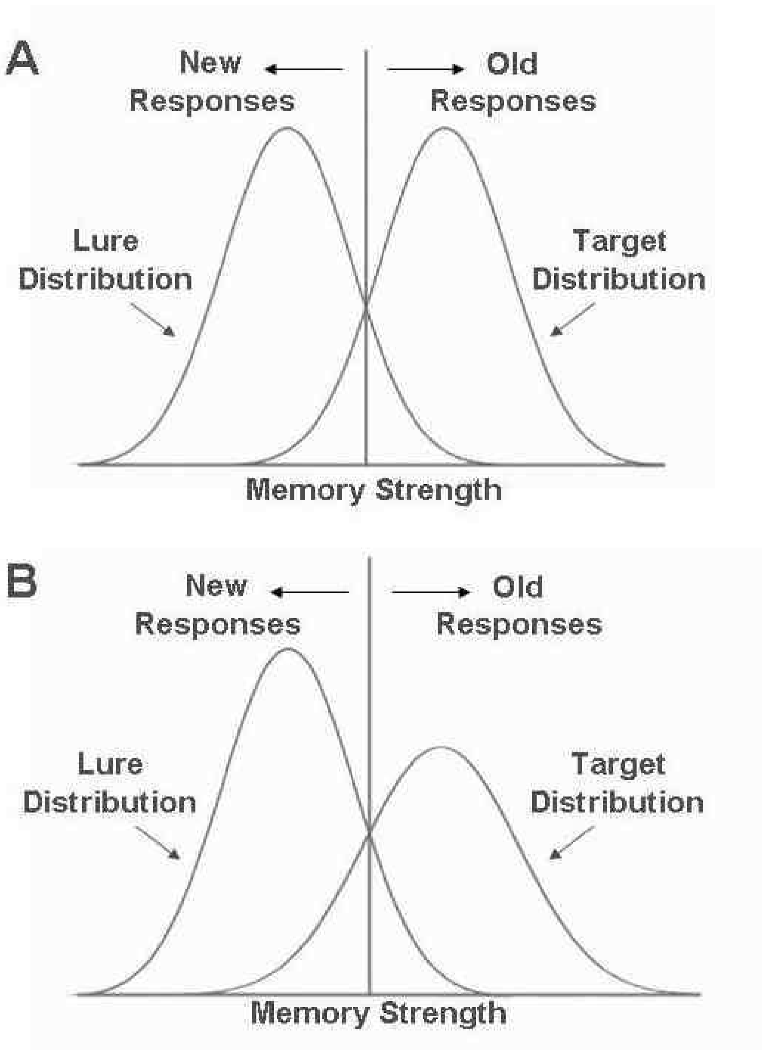

Figure 1. The equal-variance signal detection model (panel A), representing familiarity in the dual-process signal-detection (DPSD) model of recognition memoy, and the unequal-variance signal-detection (UVSD) model (panel B), representing both recollection and familiarity in the UVSD model of recognition memory. Modified from Wixted (2007).

Although the DPSD model has obtained support from both cognitive and neuropsychological studies, it has been challenged by the theoretically older unequal-variance signal-detection (UVSD) model (Wixted, 2007). The important distinction between these two models is that, whereas the DPSD model incorporates both a high-threshold process and equal-variance process, the UVSD model contains only one signal-detection process based on a continuously distributed memory strength variable. The UVSD model, shown in Figure 1, is similar to the equal-variance detection model described above, except that the variance of the lure distribution is smaller than that of the target distribution (in most models the target distribution is approximately 1.25 times that of the lure distribution; Ratcliff, Sheu, & Gronlund, 1992). The unequal variance is believed to represent the fact that targets can be considered lures that have memory strength added to them when experienced on a study list. In an equal variance model, each target would need to have the exact same amount of strength added to each item during study. In contrast, if the amount of strength added to the target items differ, then variability will be added to the target distribution, leading to an unequal variance model (Wixted, 2007).

Whether the DPSD or UVSD model can best account for recognition memory performance is currently under debate. In particular, the receiver operator characteristic (ROC) methodology has been used to compare the ability of these two models to fit recognition memory data. ROCs are generally obtained by asking participants to make confidence ratings as they make recognition decisions. The cumulative hit rate and false alarm rate for each confidence rating are then plotted against one another. The DPSD and UVSD models predict slightly different ROC curves. The UVSD predicts a curvilinear ROC curve (and a linear ROC when the hit and false alarm rates are converted to z-scores, or z-ROCs). The DPSD model also predicts a curvilinear ROC, however, the extent of the curve changes depending on the relative contribution of recollection and familiarity. Importantly, the DPSD model predicts curvilinear z-ROCs, with the extent of the curve increasing as recollection increases. The shape of the predicted z-ROC curve is thus an important point of divergence between these models (Parks & Yonelinas, 2007; Wixted, 2007).

The UVSD and DPSD models have been compared by fitting ROC curves derived from recognition memory studies to those predicted by the models. Heathcote (2003) showed that the

UVSD model produced a better fit of individual participant recognition memory data in 75% - 80% of the cases, although the DPSD model also produced a good fit to the data. Healy, Light, and Chung (2005) also showed that UVSD model produced a better fit of data from an associative recognition memory task in both younger and older adults than the DPSD model.

In a more recent examination, Rotello, Macmillan, Hicks, and Hautus (2006) tested signal-detection, DPSD, and a new variant, the Sum-difference Theory of Remembering And Knowing (STREAK) model. The STREAK model suggests that items differ in both specific and global strength and that increasing specific strength promotes higher confidence ratings and recollection responses, whereas increasing global strength promotes higher confidence ratings and know responses. Thus, in this model, high confidence familiarity and low confidence recollection responses can occur. This is in contrast to the method used to create DPSD ROC curves, in which high confidence responses are assumed to relate to recollection. This STREAK model produced a better fit to the data than the DPSD model; however, it still did not produce as good a fit as the signal-detection model. Starns and Ratcliff (2008) have recently confirmed these results, demonstrating that the UVSD model produces a better fit to recognition memory data than the STREAK model. Research thus suggests that the UVSD model may be a better predictor of recognition memory data than the DPSD model.

However, Parks and Yonelinas (2007) argue that, while both the UVSD and DPSD models produce relatively good fits to recognition data, the models are best tested in conditions in which recollection is high. This reflects the fact that the models produce more similar curves when the relative contribution of recollection is low. The two models should thus diverge the most on recognition memory tests that require recollection, or the retrieval of contextual detail. Yonelinas (1997) found that a task in which only recollection was involved (an associative recognition test) produced a curvlinear zROC, a finding that only the DPSD, and not the UVSD, model would predict. Such U-shaped z-ROC curves were subsequently found for a task in which participants had to recall the context in which the items were presented (Yonelinas, 1999), providing strong support for the DPSD model. Parks and Yonelinas (2007) additionally argue that studies investigating the neural correlates of recognition memory performance have supported the DPSD model. As discussed further below, separate brain regions have been shown to support recollection and familiarity (Bowles et al., 2007; Skinner & Fernandes, 2007; Yonelinas, Otten, Shaw, & Rugg, 2005), a prediction of DPSD, rather than UVSD model. However, some have argued that the methods used to obtain such results are problematic (see Dunn & Kirsner, 2003; Wais, Mickes, & Wixted, 2008).

This discussion shows that the debate on whether a UVSD and DPSD model best accounts for recognition memory data will not be resolved in the near future. In the current thesis I have chosen to examine recognition memory from a dual process perspective. I have chosen to work from this framework for two reasons. First, as described above, the literature shows that experimental manipulations produce different effects on recollection and familiarity, suggesting distinct cognitive processes. Second, as will be described more thoroughly in Chapter 4, the neuropsychological and neuroimaging literature suggest that recollection and familiarity are associated with distinct brain regions (Bowles et al., 2007; Skinner & Fernandes, 2007; Yonelinas et al., 2002). These findings indicate that a dual process theory of recognition memory can provide unique insights and memory performance at both cognitive and neural levels. The limitations of this approach will be discussed further in the general discussion.

1.2 The Remember-Know Paradigm

The remember-know paradigm was created by Tulving (1985) and subsequently developed by Gardiner and colleagues (Gardiner, 1988; Gardiner & Java, 1990; Gardiner, Ramponi & Richardson-Klavehn, 1998) to explore recollection and familiarity empirically. In this procedure, participants study a list of items and, during a recognition test, are asked to state that they 'Remember' an item if they can recall specific details (or contextual information) about the item from the study episode, that they 'Know' an item was on the study list if it is familiar, but lacks specific details from the study episode, or that the item is 'New' if they deem the item not to be from the study list. Participants generally have little difficulty distinguishing between Remember and Know responses once proper instructions are provided. Remember responses are believed to align with recollective memory processes, whereas Know responses support familiarity-based recognition (Yonelinas, 2001).

The retrieval of contextual information is required to experience a detail-rich memory known as a recollection (Yonelinas, 2002). By its operational definition, a Remember response relies on the retrieval of contextual detail. This detail may involve spatiotemporal information (where/when an item was presented), perceptual information (such as the colour in which an item was presented, or which of two speakers spoke an item), or information generated internally at the time of study (thoughts, feelings, or emotions). A ‘Remember’ response can be based on any one, or more, of these information types. Recollection can thus be thought of as being dependent on the binding of spatiotemporal, perceptual, and/or subjective features to item information at study, which enables the formation of complex memory traces, and the subsequent retrieval of item-context pairs. This notion is supported by work examining source memory. In these studies, source, or context, memory includes the spatiotemporal, physical features, cognitive operations, and emotional states that are associated with the presentation of an item during encoding. Such memory is often tested by asking participants to report the spatial location, colour, or voice in which an item was originally presented (Hashtroudi, Johnson, & Chrosniak, 1990). Research shows that participants are more likely to provide accurate source information for Remember responses than for Know responses (Dewhurst & Hitch, 1999; Perfect, Mayes, Downes, & VanEijk, 1996), and that encoding conditions that enhance source memory also selectively increase the rate of Remember, but not Know, responses (Conway & Dewhurst, 1995; Donaldson, MacKenzie, & Underhill, 1996).

A variety of manipulations have shown that 'Remember' and 'Know' responses can be dissociated. Some variables have large effects on Remember responses but produce small or no effects on Know responses. These include encoding the meaning or the features of stimuli (Gardiner, Java, & Richardson-Klavehn, 1996), generating or reading words (Gardiner, 1988), dividing attention at study (Gardiner & Parkin, 1990), changing the retention interval (Gardiner & Java, 1991; though also see Yonelinas, 2002, who demonstrates that retention interval can influence both recollection and familiarity), and administering the drug lorazepam as compared to a placebo (Curran, Gardiner, Java, & Allen, 1993). Other research has shown that changing the study-test modality has a larger effect on Know than on Remember responses (Gregg & Gardiner, 1994). Further studies show that some variables have opposite effects on Remember and Know responses. For example, when word and non-word stimuli are compared, increased Remember responses are observed for word stimuli and increased Know responses are observed for non-word stimuli (Gardiner & Java, 1990). In addition, whereas younger adults show increased Remember responses when compared to elderly adults, the elderly participants show increased Know responses when compared to young (Parkin & Walter, 1992). We have also shown that, while divided attention at retrieval generally increases Remember false alarms, divided attention conditions that overlap in the content with the retrieval task also decrease Know responses (Skinner & Fernandes, 2008). These studies support the notion that Remember and Know responses are distinct recognition processes.

There has, however, been considerable disagreement in the literature regarding whether the remember-know paradigm is process-pure, or measures separate psychological processes. For example, Rotello, Macmillan, Reeder, and Wong (2005) found that by altering the instructions of the remember-know task, participants changed their willingness to report a Remember response, and that recollection estimates from the remember-know paradigm did not converge with other measures. They suggested that dissociations shown in the remember-know paradigm may be the result of changes either in sensitivity (the general interpretation) or response bias. In addition, Wais et al. (2008) found that source recollection for Know responses was significantly above chance, indicating that Know responses are not devoid of contextual detail, a violation of the process-pure assumption. They suggested that the remember-know procedure probes degrees of recollection, rather than separate memory processes.

Despite these findings, there are several advantages to using the remember-know paradigm to estimate recollection and familiarity. First, participants are able to make accurate Remember and Know responses when given proper instructions, making the paradigm easy to administer in the laboratory. Second, the remember-know paradigm is an inclusive measure of recollection, as compared to the process dissociation procedure, in which recollection is limited by the particular context (e.g., word list) that the experimenter wants the participant to recall. Third, several studies show that estimates of recollection based on remember-know judgments are similar to those made by recognition confidence judgments, suggesting that remember-know responses do provide accurate measures of recollection and familiarity (Yonelinas & Parks, 2007). Finally, Remember and Know responses have been shown to have distinct neural correlates, indicating that remembering and knowing can be dissociated at the neural level (Skinner & Fernandes, 2007). In the current study, the remember-know paradigm was used under the assumption that Remember responses contain more contextual detail than Know responses, and that, by distinguishing between Remember and Know responses, we can gain a more accurate picture of how study context affects the subjective experience of the rememberer.

1.2.1 Obtaining estimates of recollection and familiarity with the remember-know paradigm.

The remember-know paradigm is often used to develop estimates of recollection and familiarity. The procedure with which one does so, however, depends on the model of recollection and familiarity that one chooses to endorse. There are three models that describe the possible relation between recollection- and familiarity-based memory processes: exclusivity, redundancy, and independence (see Figure 2). In the case of exclusivity, an item may be recollected or it may be familiar, but no one item can be both recollected and familiar at the same time (Knowlton & Squire, 1995; Richardson-Klavehn, Gardiner, & Java, 1996). The second model, redundancy, suggests that all items that are recognized are familiar, and that a subset of those items is also recollected (Joordens & Merikle, 1993). The final model, that of independence, suggests that an item may be either recollected or familiar, and that a subset are both recollected and familiar at the same time (Jacoby, 1991). While the current study did not aim to compare these different models, these assumptions influence the methods used to estimate recollection and familiarity.

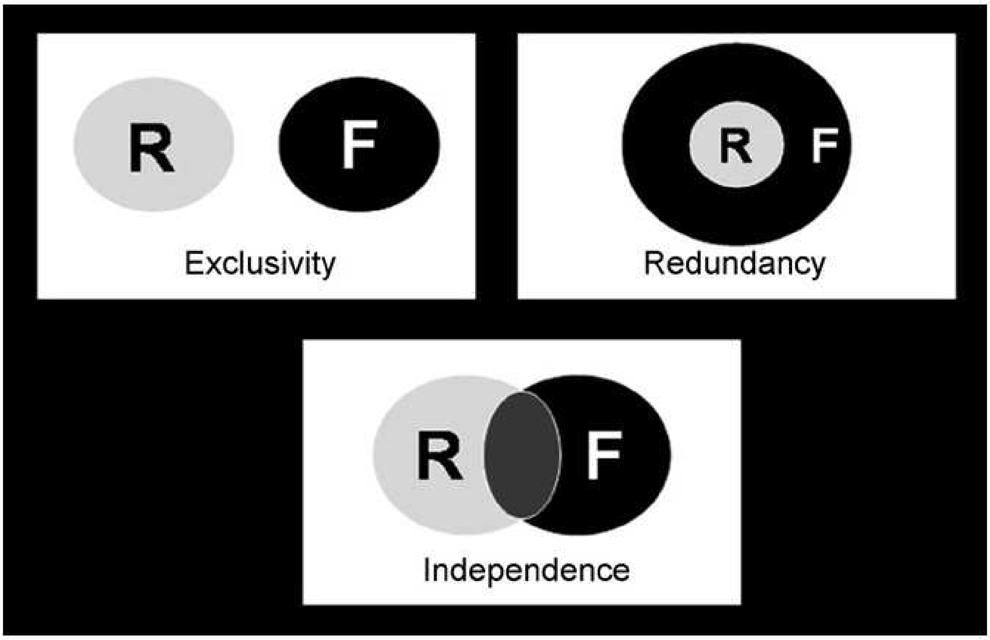

Figure 2. Visual depictions of three models of the relation between recollection and familiarity. R = recollection; F = familiarity. From Skinner & Fernandes (2007).

If one adopts an assumption of exclusivity, then one can calculate recollection and familiarity directly from estimates of Remember and Know responses. That is, if one believes that Remember responses accurately reflect the recollection process and Know responses accurately reflect the familiarity process, no estimate corrections are required (Richardson-Klavehn et al., 1996). If one adopts a model of redundancy or independence, however, corrections must be made to develop accurate estimates of familiarity since the proportion of Know responses will underestimate the value of familiarity.

With respect to redundancy, if all items that are recollected are also familiar, familiarity is estimated by combining both Remember (familiarity + recollection) and Know (familiarity) responses. Thus, familiarity is estimated as overall memory accuracy. In contrast, independence models state that only a subset of the items that are recollected is also familiar. Estimates of independent remember-know (IRK) familiarity are thus developed by dividing the number of Know responses by the opportunities available to make a Know response (i.e., 1 – recollection; see Yonelinas & Jacoby, 1995, for further details).

The method through which recollection and familiarity are estimated can alter the conclusions one makes about these processes. For example, Parkin and Walter (1992) showed that older adults made fewer Remember, but more Know, responses as compared to younger adult participants. If a model of exclusivity is adopted, this would lead to the conclusion that although recollection decreases with age, familiarity increases. However, when these estimates are converted using assumptions of independence, the results show lower recollection, but equal familiarity, in the older adults, suggesting that whereas recollection decreases with age, familiarity stays the same (Richardson-Klavehn et al., 1996).

Whether recollection and familiarity are best modeled using assumptions of exclusivity, redundancy, or independence is still under debate. It is not a goal of this thesis to compare different models of recollection and familiarity; rather, in the results sections overall recognition, Remember responses, Know responses, and IRK familiarity are all examined so that the effects of context on familiarity, regardless of the model, can be investigated.

1.3 Context Effects on Recognition Memory

As studied to date, context effects refer to the notion that the environment in which an item is encoded and retrieved can influence memory for that item. The study of such context effects has focused almost exclusively on whether reinstating study context at test benefits memory performance. Although multiple studies have shown that reinstating study context at retrieval benefits recall performance, tests of recognition memory show far more inconsistent effects (Bjork & Richardson-Klavehn, 1989; Smith, 1988). Whereas some research has shown that participants are better at identifying targets from distracters when items are tested in the same context as at study (Geiselman & Glenny, 1977; Smith, 1986), others have failed to find a recognition deficit when there is a change of context between study and test (Fernandez & Glenberg, 1985; Smith, Glenberg, & Bjork, 1978).

Macken, (2002) used a dual process approach to try to elucidate these effects. He used the remember-know paradigm to show that recollection accuracy for targets and distractors presented in previously studied contexts (same-context) was higher than for targets and distractors presented in new unstudied contexts (different-context), even when the 'different-context' targets were presented in a previously studied, but mismatching, context. Gruppuso, Lindsay, and Masson (2007) have subsequently extended these findings to face recognition. Macken (2002) suggested that context effects are found only when recognition is accompanied by conscious recollection due to the encoding and retrieval of context-specific associations. This interpretation, however, has been recently challenged by Hockley (2008) who found similar rates of recollection responses for studied items presented at retrieval along with their studied context, and for studied items presented with an 'old' but mismatching context.

Murnane, Phelps, and Malmberg (1999) have built upon earlier global matching models of memory to form what they call the item, associated context, and ensemble (ICE) model, to understand the role of context on recognition memory. ICE theory proposes that there are 3 types of information used to make recognition decisions: the item information, the context information, and ensemble information, which represents the integration of item and context information. According to the theory, presenting context information that is matched across study and test will increase both the hit rate and the false alarm rate. However, only when ensemble information is developed will the changes in hit rate outweigh the changes in false alarm rate, leading to an increase in discrimination. In an experiment, Murnane et al. showed that discrimination of items presented in same or different contexts at retrieval increased when the contexts were rich in meaning (pictures of scenes containing the target words in an appropriate location; for example, a word presented on a banner trailing an airplane), but did not differ for simple contexts (a combination of foreground colour, background colour, and screen location). They suggested that only the meaningful context information was integrated with the item information to form ensemble information, improving recognition performance.

In the current thesis, rather than measuring how the match between study and test context influences item memory performance, as in Macken's and Murnane et al.'s work, I examined how context information presented at study, but absent at retrieval, influences subsequent item recognition for target information. In the real world, the items we perceive and remember never occur in isolation, but are associated with other information, objects, thoughts, or emotions. This context information, present at encoding, may not always be present at retrieval. For example, a person trying to recall a grocery list may be in a totally different environment (e.g., the grocery store) than when the list was studied (e.g., their kitchen), or, in the case of eyewitness identification, people may be asked to recognize a photograph of an individual devoid of the context in which the individual was first encountered. Our daily lives are filled with situations in which context information present at study is not available at retrieval. This thesis asks whether we can successfully use context information at study to improve subsequent memory performance even when that context information is not present at retrieval.

Following from Murnane et al., I hypothesize that only when context information present at study is rich in meaningful content will participants be able to use elaborative processes to integrate item and context information to form ensemble information. Furthermore, I extend Murnane et al.'s ICE theory by suggesting that when participants develop ensemble information at study, the item will be bound to the contextual information and consequently will be retrieved preferentially through recollective memory processes. This rich and meaningful context information at study may increase subsequent item recollection, even when that context information is not present at retrieval. Increasing recollection is believed to benefit memory processing, since recollection provides a more vivid mnemonic experience, and memory errors (such as source decisions) can occur when relying on familiarity alone (Jacoby, 1991).

Providing context information high in meaningful content at study may help participants interpret material in a meaningful way. This may then facilitate the accessibility of the memory at retrieval. For example, in a standard levels-of-processing manipulation, participants are asked to perform either a 'shallow' (e.g., perceptual) or a 'deep' (e.g., semantic) task. Research shows that memory performance is higher for deeply as compared to shallowly encoded items (Craik & Lockhart, 1972) and that this benefit is greater for recollection than familiarity (Gardiner et al., 1996). Thus, when participants consider the meaning of items, recollection of the item improves. By providing meaningful context information at encoding, we may facilitate 'deep' (meaningful) processing of the item information, as participants associate the item and context information, or use the context information to initiate in elaborative processes. This line of reasoning suggests that participants will engage in more elaborative (deep) processing at encoding, without experimental instructions, by simply presenting items with meaningful context information. This would extend levels-of-processing theory to show that meaningful context information provided at study can benefit memory.

Few studies have directly examined whether providing context information at study, but absent at retrieval, influences later memory performance. In his Master's thesis, Gopie (2005) used a remember-know paradigm to compare memory performance for words studied with no context information, words studied with context information (a combination of word colour and location) without that context information reinstated at test, and words studied with context information with that context information reinstated at test. He found that, whereas overall memory performance did not differ for words studied with and without context information, the number of correct Remember responses was higher for words studied with additional context. Interestingly, memory performance for words studied with context information did not differ depending on whether that context information was reinstated at test. In addition, when participants were probed as to whether they could recall the colour and location of words studied with context information given Remember responses, participants showed chance performance. Gopie stated that the results support the notion that Remember responses are influenced by encoding manipulations that emphasize distinctive or salient aspects of stimuli (i.e., increasing the number of colour/location combinations increased distinctiveness of individual word stimuli). He additionally suggested that recollection does not increase when study context is reinstated at test (as proposed by Macken, 2002), but that recollection may be reduced when the study test contexts differ.

In a more recent study, Luo, Hendriks, and Craik (2007) asked participants to study a list of words visually, which were presented either alone or coupled with a sound related to that item (for example, the word 'door' was paired with the sound of a door shutting). In a later exclusion test, they found that younger adults were more likely to correctly reject previously presented words if they were presented with a related sound at study. Older adults, however, were unable to use the sound information to reduce their false alarms in the exclusion test. This work suggests that the younger adults were able to effectively integrate the word-sound pairings into a cohesive memory trace, and this allowed them to later use recollective processes to reject those items. The older adults, however, were unable to benefit from the additional context, possibly because they were unable to successfully bind, or associate, the item and context information in memory. Thus, whereas younger adults were shown to benefit from context information present at study but absent at retrieval, the older adults were not.

While Luo et al.'s work demonstrates that younger adults' memory performance can benefit when context information is presented at encoding, it did not specifically test whether qualitative differences in memories resulted from their manipulation at encoding. Gopie's (2005) and Luo et al.'s (2007) work also did not examine whether varying the level of meaningful content in context information provided at encoding affects recollection performance, as I have hypothesized from Murnane et al.'s (1999) work. In the current thesis, I address these limitations by using the remember-know procedure to obtain estimates of recollection and by directly manipulating the amount of meaningful content in the context information provided at encoding.

The current thesis also aims to investigate how age-related changes in cognitive processing affect context effects in recognition memory. Older adults show deficits in their ability to both recollect item information (Perfect, Williams, & Anderton-Brown, 1995; Prull, Dawes, Martin, Rosenberg, & Light, 2006) and to retrieve specific contextual information from previous events (Ferguson, Hashtroudi, & Johnson, 1992; Kausler & Puckett, 1981; Naveh-Benjamin & Craik, 1995). In line with these findings, Naveh-Benjamin (2000) has suggested that older adults have a specific deficit in forming associations between items, an item and its context, or two contextual features, known as the Associative Deficit Hypothesis (ADH). He has shown that age-related differences in memory performance are higher when participants are required to retrieve associations between an item and a context than when they are required to retrieve item information alone (Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004). Collectively, the research suggests that older adults do not adequately bind item and contextual information at study to develop context-rich memory traces that can later be retrieved by recollective memory processes. The results of Luo et al. (2007) additionally demonstrate that older adults' memory performance did not benefit when additional context information was presented at study. In this thesis, I further investigate how age-related changes in cognitive processing affect older adults' ability to use context information at study to benefit subsequent memory performance and aim to determine the source of this deficit.

Finally, in this thesis the neural correlates of recollection are investigated by using functional Magnetic Resonance Imaging. Previous research suggests that recollection and familiarity differ in the extent to which they recruit frontal, parietal, and medial-temporal brain regions (Skinner & Fernandes, 2007). Research also suggests that recollection, and not familiarity, involves the reactivation of brain regions originally used to process context information, known as sensory-specific reactivation (Wheeler & Buckner, 2004). The current thesis aims to identify the neural regions needed to retrieve specific context information, facilitating recollection, and specifically tests the hypothesis that sensory-specific reactivation is characteristic of recollection by comparing brain activation during the retrieval of item information studied with and without meaningful context information.

1.4 Overview of the Experiments

The purpose of this thesis is to determine more precisely how providing a contextual source at study but not at retrieval, influences subsequent item recollection. By examining cognitive, neural, and age-related processes, I hope to specify the processes that influence the development and reactivation of context-rich memories, and the underlying neural systems mediating contextual retrieval. In Chapter 2, I test how visual context information provided during encoding, and unrelated to the target study word, affects later recollection for the targets presented alone, using a remember-know paradigm. By exploring how different contexts similar in perceptual features but varying in meaningful content, as well as how the novelty of the context, influence subsequent item recollection, I hope to determine how the encoding of external context information changes the way in which item information is processed and subsequently remembered. In Chapter 3, I examine the effects of age on item-context binding and reactivation, using current theoretical models of aging to predict specific effects. I further consider how age-related changes in recognition can be alleviated by instructional manipulations. In Chapter 4, functional Magnetic Resonance Imaging (fMRI) technology is used to specify the brain regions involved in the reactivation of context information. These data are then used to elaborate upon neural models of retrieval. The data from all of these experiments are then brought into a unified framework in the general discussion.

Chapter 2

Effects of Study Context on Item Recollection

In this chapter, I examine how context information presented at study influences recognition memory performance. While there is a substantial literature examining how reinstating study context at test influences recognition memory, few studies have examined how providing context information at study but not at retrieval, influences recognition performance. Gopie (2005) found that, while overall memory performance did not differ for words studied with and without perceptual context information, Remember responses increased for words presented with context information at study. Luo et al. (2007) additionally found that younger adult participants were more likely to correctly reject previously presented words on an exclusion test if the words were presented with a related sound at study. This suggests that the participants were able to integrate the word-sound pairings into a cohesive memory trace (or ensemble information), which allowed them to subsequently use recollective memory processes to reject those items. However, Luo et al. (2007) did not examine the qualitative differences in memories that resulted from their manipulation at encoding. The remember-know paradigm allows participants to state such qualitative differences by reporting whether contextual detail accompanies their memory. In this chapter I extend the findings of Luo and colleagues by determining whether providing context during study alters the quality of memory, using a remember-know paradigm.

I also extend Gopie (2005) and Luo et al.'s (2007) work by examining how the *richness* of the contextual information present at study affects recollection and familiarity. Contextual information can vary across multiple dimensions which may affect participants' ability to use that information to improve later recollection. In particular, the level of meaning may influence the ability to integrate context and item information into a cohesive memory trace. Theorists suggest that participants intentionally engage in strategic processes during memory tasks that benefit their memory performance (Jennings & Jacoby, 1993). I hypothesize that the more meaningful the context, the greater the potential to use such intentional processes at encoding to successfully bind the item and context information into a distinctive/detailed memory.

There is an extensive literature demonstrating that processing the meaning of item information improves subsequent memory performance (Craik & Lockhart, 1972). For example, participants show better memory for words than for non-words, and this benefit has been noted specifically for Remember responses (Otten, Sveen, & Quayle, 2007). In addition, patients with selective semantic memory impairments show deficits on long-term verbal memory tasks, suggesting that memory relies on processing the meaning of incoming information (Warrington, 1975). Research using levels of processing manipulations also supports such findings: memory performance is higher for deeply (encode meaning) as compared to shallowly (encode surface features) encoded items (Craik & Tulving, 1975) and this benefit is greater for recollection than familiarity (Gardiner et al., 1996). Thus, when participants consider the meaning of items, recollection of the item improves.

We could, however, conceptualize that varying the level-of-processing simply changes the type of context information bound to item information: Deep processing encourages participants to bind subjective/meaningful contexts (thoughts, emotions, etc) to the item, whereas shallow processing promotes the binding of perceptual contexts (colour, font, etc). This interpretation suggests that having participants attach meaningful context information to an item at study will improve subsequent recollection. Support for this interpretation comes from work showing that when words are studied in the presence of a semantically related context word, item memory increases (Mayes, MacDonald, Donlan, Pears, & Meudell, 1992) and cued recall performance improves when word pairs are related in meaning (Nelson, McEvoy, & Schreiber, 1990). Murnane et al.’s work (1999) additionally suggests that only when visual context information is high in meaningful content do participants engage in the processes required to integrate item and context into ensemble information, improving recognition performance. It is currently unknown, however, whether participants use meaningful context information that is unrelated to the item to improve subsequent memory performance and recollection in particular.

2.1 Overview of Chapter 2

The experiments in this chapter examined how context information provided at study, and varying in meaningful content, influenced recognition memory performance in younger adult participants. In the first experiment, I investigated whether recollection benefits when words are presented with context information high in meaningful content at study. Participants had better overall memory, specifically recollection, for words studied with pictures of intact faces than scrambled faces, despite the fact that the two contexts were perceptually equivalent (similar luminance and contrast). This suggests that participants are able to use meaningful context information to improve subsequent memory performance, and recollection in particular.

In Experiment 2, I tested the notion that context information high in meaningful content produces a recollection benefit, rather than the alternative explanation that context information low in meaningful content produces a recollection deficit. Experiment 2 replicated the results of Experiment 1 and showed that recollection was higher for words studied with pictures of faces than when no image accompanied the study word. The results thus substantiate the claim that context information high in meaningful content provided at study can be used to benefit subsequent recollection. In Experiment 3, the visual context information was equated in both perceptual features and inter-item similarity. Participants showed higher memory performance, and recollection in particular, for words studied with upright compared to inverted faces. These results demonstrate that even when the same contexts are presented at study (faces), disrupting the amount of meaning that can be extracted from the context information (inverting the face) reduces subsequent item recollection.

Experiment 4 examined how the novelty of the context provided at study influenced later recollection. Previous research has shown that novel items are better remembered than familiar items (Tulving & Kroll, 1995). It is thus possible that the novelty of the context might affect subsequent item memory performance. Participants showed equivalent memory for words studied with novel or familiar faces, suggesting that the novelty factor of the context information does not change later recollection of target words. Taken together, the results of these experiments suggest that recollection benefits when visual context information high in meaningful content accompanies study words, and that this benefit is not related to the novelty of the context (Skinner & Fernandes, under review). I suggest that participants use elaborative processes to integrate item and meaningful contexts into ensemble information, improving subsequent item recollection.

2.2 Experiment 1

As suggested by Murnane et al. (1999), providing visual contexts rich in meaningful content at study may promote the use of elaborative processes that integrate item and context to form ensemble information. To test the hypothesis that recollection benefits when contexts with high, as compared to low, meaningful content are provided at study, I asked participants to study target words presented with pictures of intact or scrambled faces. I selected face stimuli for the meaningful context condition because these contain semantic complexity, and reasoned that participants could use these to develop context-rich memory traces. Research demonstrates that face perception involves multiple processes that identify invariant perceptual features (such as eye colour) and the changeable aspects of faces (such as expression), which are important social cues. Faces may be considered semantically complex visual information because, in addition to the visual analysis of faces, face processing is believed to involve cognitive functions that extract meaning from faces, such as the social relevance of face information (Haxby, Hoffman, & Gobbini, 2002). This hypothesis additionally follows from studies showing that participants are more likely to remember verbal descriptors if the information is paired at study with a photograph of a face than when paired with a name, (Kargopoulos, Bablekou, Gonida, & Kiosseoglou, 2003) schematic face, or geometric shape (Glenberg & Grimes, 1995). I used scrambled faces as my control trials since they contain similar luminance and contrast to the face images, but differ substantially in meaningful content. Controlling for perceptual features such as luminance and contrast is essential, given that research shows that both variables can affect perception and subsequent memory of an image (Harley, Dillon, & Loftus, 2004; Loftus, 1985). It is thus possible that relative differences in these variables, present in context information, similarly influence item memory.

Participants viewed words that were paired with a picture of either an intact face or a scrambled face and subsequently performed a one step remember-know memory test for the words presented alone (i.e., participants make either a Remember, Know, or New response to words, rather than give a Remember or Know response to words previously identified as old). By developing a scrambled version for each face stimulus, I was able to keep the luminance and contrast of the context image constant, and could thereby assure that these features were not an important factor determining which contexts improve later recollection of concurrently presented target words. I hypothesized that, despite equating for luminance and contrast levels of images, the rate of Remember responses would be higher for words studied with intact faces than for words studied with scrambled faces. Participants were expected to use the additional meaningful content information of the intact faces to develop ensembles, or associations, between the item and context, increasing Remember-based responding for the words. Know responses, and independence remember-know (IRK) measures of familiarity, which do not require retrieval of contextual details, were expected to be unaffected by the manipulation of context. Thus, only those memory responses that involve the retrieval of contextual detail were expected to be affected by context manipulations at study.

Method

Participants. Fifteen undergraduates (7 female) from the University of Waterloo received course credit or token monetary remuneration for participation in the study. The mean age and years of education of the participants were 20.00 (SD = 1.60) and 14.40 (SD = 1.50), respectively. All participants were fluent English speakers, and had normal or corrected-to-normal hearing and vision.

Materials. Two-hundred-twenty-five medium to high frequency words were chosen from Celex, a lexical database available on CD-ROM (Baayen, Piepenbrock, & Gulikers, 1995), for the three study-test cycles of the memory task. In each of these cycles, the study list was comprised of 50 words: 25 were paired with pictures of faces (face trials) and 25 were paired with pictures of scrambled faces (scrambled trials). A corresponding list was created for use in the subsequent recognition test, consisting of the 50 studied words plus 25 lures (words not presented in the study phase). Thus, across the three study-test cycles, 75 words were paired with pictures of faces, 75 with pictures of a scrambled faces, and 75 served as lures. Three different study-test list combinations were created such that each word was paired with either a picture of a face, a scrambled face, or served as a lure across lists, counterbalanced across participants. The order of presentation of the word lists for the three study-test cycles was also counterbalanced across participants. All test lists were equated on letter length (M = 6.31), and word frequency (M= 18.27 occurrences per million; Baayen et al., 1999). An additional 30-item word list was used in the practice session, with the same characteristics as the words in the experimental session.

Face stimuli were taken from the AR face database, which contains black and white photographs showing the frontal view of male and female faces (Martinez & Benavente, 1998). Seventy-five faces with neutral expressions, 38 male and 37 female, were randomly chosen to serve as the face stimuli. The face stimuli were randomly assigned to 25 words for each study list; thus, each study word was paired with a unique face. An additional 8 face stimuli were chosen to be used in the practice session. The scrambled faces were created in Matlab 7.06 software by randomizing the pixels of the 75 face images chosen from the database. Thus, for each face stimulus, there was a corresponding scrambled image. This randomization altered the spatial frequency of the images, while preserving the luminance and contrast (see Figure 3).

Procedure. Stimulus presentation and response recording were controlled by an IBM PC, using E-prime v.1.1 software (Psychology Software Tools Inc., Pittsburgh, PA). Participants were tested individually, and completed the experiment in approximately one hour. The experiment began with a short practice block consisting of 16 study trials, in which 8 face-word and 8 scrambled-word encoding trials were presented visually, in random order, using the same timings and procedure as in the experimental trials (described below). Subsequently, remember-know test response instructions were given (see below), and 15 recognition trials consisting of 4 words studied with faces, 4 words studied with scrambled faces, and 7 new words, presented in random order, were presented.

Following practice, participants completed the 3 study-test cycles. I used 3 study-test cycles in the design to increase the number of trials associated with each encoding trial-type (word paired with a face and word paired with a scrambled face), while lessening the memory demands of each individual recognition task. For each of the 3 study phases, a trial began with a picture of a face or a scrambled face appearing on the screen for 1000 ms centered in the upper half of the screen (screen coordinates: X = 324, Y = 180). A word presented in 28 point bold Arial font then appeared directly below the picture for 2000 ms (X = 324, Y = 379), after which both the picture and the word disappeared, followed by a 500 ms fixation cross presented centrally (see Figure 3). In each of the three study phases, 50 trials were presented (25 face-word and 25 scrambled-word), with trial type randomized. Within each study phase, the 25 scrambled images were the scrambled versions of the 25 face images presented in the face trials to control for differences in perceptual features (luminance and contrast) present in the context information provided at study. All stimuli were presented in a fully illuminated room on a 17 inch (43.18 cm) computer screen, and the viewing angles of the picture and word stimuli were approximately 16.6º and 5.7º respectively. Participants were asked to memorize the words for an upcoming memory test. To ensure that participants encoded the context (face or scrambled face) during study, participants were also asked to manually identify, for each study trial, the picture presented with each word as either a face or a scrambled face, by making a button press on a computer keyboard. Participants were not provided specific instructions on how to process the contextual stimuli. Each trial was 3.5 s in length (timings noted above), and participants were asked to make their classification response during this time.

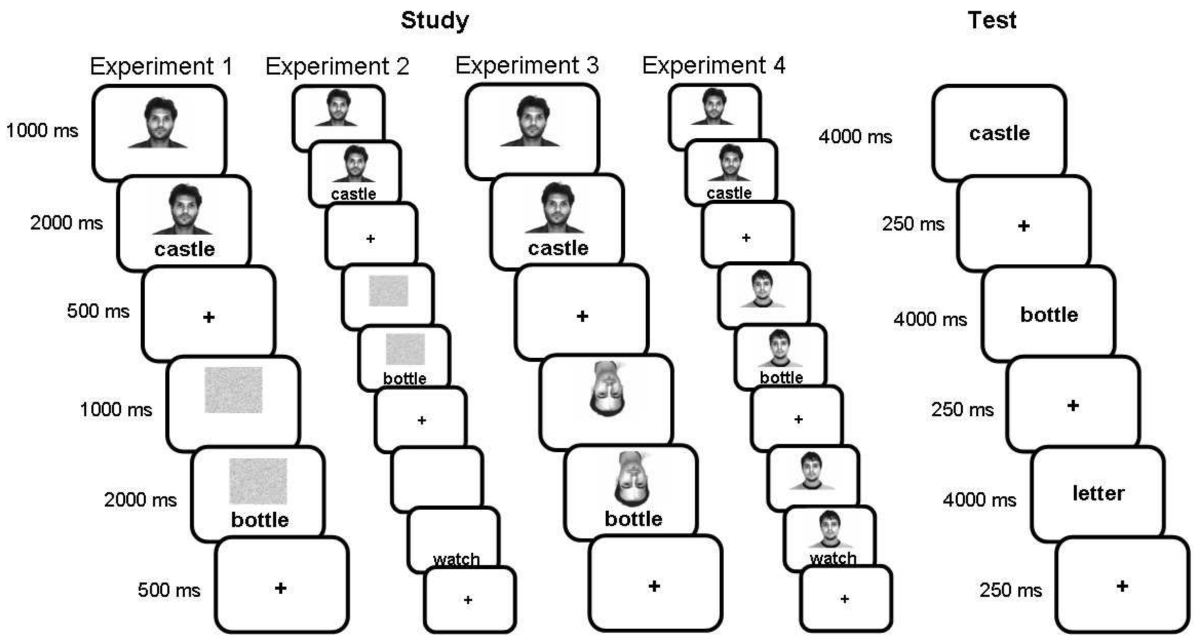

Figure 3. Sample study and test trials. In Experiment 1, words were presented together with pictures of intact or scrambled faces during study. In Experiment 2, words were studied with pictures of intact faces, scrambled faces, or no image. In Experiment 3, participants studied words presented with a picture of an upright or an inverted face. In Experiment 4, participants viewed either novel faces (above) or a familiar face (below). The familiar face was presented repeatedly during the study session. For all four experiments, on a subsequent remember/know recognition memory test, all words were presented alone.

Afterees for 30 seconds before beginning the remember-know recognition test. The test instructions for the remember-know task were as follows: Participants were told that they would see some words that were from the study list and other words that were not. If they believed the word was not from the study list, participants were instructed to respond ‘N’ for New by pressing the ‘3’ key on the numerical keypad of a standard computer keyboard. If they thought the word was from the study list, they had two options, ‘R’ or ‘K’. They were told to report ‘R’ for Remember by pressing the ‘1’ key if the word was ‘old’ and they could recall specific details associating that word with the study episode. They were given examples of such details: They may remember an image, thought, or feeling they had associated with the word during study, or the temporal order of the words. Participants were not explicitly told that they could base their ‘R’ responses on the picture presented with the word at study; however, if the participant asked, they were told they could use the picture, as well as the additional information already mentioned, to make an ‘R’ response. These contextual details meant they had a specific recollection of that word. If however, they believed the word to be ‘old’ but they did not recall a specific study detail associated with the word, they were asked to report ‘K’ for Know by pressing the ‘2’ key. To clarify the ‘K’ memory response, participants were also given the example of meeting someone on the street that they knew they had met before, but not being able to determine the specific instance in which they had met them. Participants were then asked if they understood the distinction between ‘R’ and ‘K’ responses and, after the practice session, participants were asked to give the details of the context accompanying an ‘R’ response to the experimenter, in order to ensure that they understood the difference between ‘R’ and ‘K’, and were not simply responding on the basis of response confidence.

During each of the ensuing test phases, 75 words (25 studied with faces, 25 studied with scrambled faces, and 25 lures) were presented in random order. The words were presented in the centre of the screen in the same font and size as at study. As described above, participants were asked to make a Remember, Know, or New response by pressing one of three buttons (1, 2, or 3 on the keyboard). The word remained on the screen for 4000 ms, followed by a fixation cross for 250 ms (see Figure 3). Participants could make their response anytime within the 4250 ms of each recognition trial. Each participant was told that four seconds should be enough time to make their response and that, if they did miss a word, they should not worry, and just try to complete the next trial. Participants were given a short break (approximately 2 minutes) between study-test cycles. The order of presentation of the word lists for the three study-test cycles was counterbalanced across participants.

Results and Discussion

All analyses use a significant value of $p \leq .05$.

Identification task performance. Data from the identification task, performed during the study phase, were analyzed using a repeated measures ANOVA. Mean accuracy (measured as hit rate – false alarm rate) on the identification task was .97 (SD = .04) for faces, and .97 (SD = .03) for scrambled faces, which did not differ significantly, $F(1, 14) = 2.15$. I also examined response time, although speed of responding was not emphasized during the identification task. The mean response time (RT) in milliseconds to correct responses was 1274.07 (SD = 618.63) for faces and 1142.09 (SD = 582.12) for scrambled faces, with significantly slower RT to identify faces than scrambled faces, $F(1, 14) = 19.60$, $MSE = 130654.92$.

Memory task performance. Table 1 shows the means for each memory measure and trial type, collapsed across the three recognition tests. Overall memory performance was analyzed using hit rate minus false alarm rate as the dependent measure (since false alarm rate was the same for both trial types), as well as d’. I then analyzed Remember accuracy, Know accuracy, and IRK familiarity separately. For each measure, data were first analyzed in separate 2 (Context: studied with a face or studied with a scrambled face) x 3 (Study-Test cycle) x 3 (List order) ANOVAs. Since the last two variables produced non-significant main effects and interactions for all analyses, data were collapsed across Study-Test cycle and List order.

Overall recognition accuracy was measured as number of hits out of 75 – number of false alarms out of 75, for each word type. There was a main effect of Context, with higher accuracy for the words studied with faces than with scrambled faces, $\underline{F}$ (1, 14) = 4.51, $\underline{MSE}$ = .03. There was a similar main of Context using d' as the dependent measure, $\underline{F}$ (1, 14) = 4.58, $\underline{MSE}$ = .23.

I then analyzed proportion of Remember responses (number of correct Remember responses out of 75 – number of false Remember responses out of 75) and proportion of Know responses (number of correct Know responses out of 75 – number of false Know responses out of 75) for each word type (see Figure 4). For Remember responses, there was a main effect of Context, with a higher proportion of Remember responses for words studied with faces than words studied with scrambled faces, $\underline{F}$ (1, 14) = 4.89, $\underline{MSE}$ = .04. There was no effect of Context on Know responses, $\underline{F}$ (1, 14) = .16, or on the IRK familiarity measure, $\underline{F}$ (1, 14) = .30. Retrospective power analyses performed on IRK familiarity showed that $\underline{d}$ = .29 and that, with a power estimate of .80, I would need to run 94 participants to obtain a significant effect of context on this measure; thus I am confident that the context manipulation had no significant effect on familiarity, though it did on recollection.

Although RT had not been emphasized at retrieval, I examined these data in two separate repeated measure ANOVAs for correct Remember and Know responses. There was no effect of Context for either Remember, $\underline{F}$ (1, 14) = .25, or Know, $\underline{F}$ (1, 14) = 1.96, responses, $\underline{ps} > .05$.

I also examined whether there was a correlation between RT on the identification task performed at encoding and later recollective memory performance, although the results should be treated with caution due to the small sample size. The correlations with face and scrambled face RT were non-significant, $\underline{r}$ = .30 and .22, respectively.

Table 1.

Experiments 1, 2, 3, and 4. Mean Memory Performance and Response Time in Milliseconds for Words Studied with Different Contexts.

	Experiment 1		Experiment 2			Experiment 3		Experiment 4	
Measure	Face	Scrambled	Face	Scrambled	No Image	Upright Face	Inverted Face	Novel Face	Repeated Face
Overall Hit Rate	.75 (.10)	.69 (.15)	.72 (.15)	.67 (.15)	.69 (.15)	.78 (.08)	.73 (.10)	.77 (.15)	.76 (.14)
Overall FA Rate	.13 (.13)	.13 (.13)	.12 (.10)	.12 (.10)	.12 (.10)	.20 (.15)	.20 (.15)	.13 (.13)	.13 (.13)
Remember Hit Rate	.48 (.20)	.41 (.22)	.54 (.22)	.44 (.24)	.47 (.24)	.60 (.12)	.51 (.17)	.57 (.23)	.56 (.22)
Remember FA Rate	.03 (.05)	.03 (.05)	.04 (.05)	.04 (.05)	.04 (.05)	.07 (.10)	.07 (.10)	.04 (.07)	.04 (.07)
Know Hit Rate	.27 (.14)	.28 (.17)	.19 (.11)	.22 (.11)	.22 (.13)	.17 (.07)	.21 (.11)	.20 (.11)	.20 (.12)
Know FA Rate	.09 (.10)	.09 (.10)	.09 (.07)	.09 (.07)	.09 (.07)	.12 (.05)	.12 (.05)	.09 (.08)	.09 (.08)
IRK Familiarity	.39 (.19)	.35 (.21)	.29 (.15)	.30 (.14)	.32 (.18)	.29 (.10)	.31 (.14)	.39 (.13)	.36 (.13)
d'	2.05 (.74)	1.87 (.85)	1.97 (.72)	1.76 (.70)	1.84 (.75)	1.71 (.45)	1.59 (.45)	2.15 (.53)	2.10 (.55)
RT Remember Responses	1353 (322)	1329 (341)	1110 (237)	1144 (255)	1168 (232)	1112 (159)	1147 (290)	1167 (258)	1201 (264)
RT Know Responses	1710 (493)	1632 (368)	1670 (398)	1716 (483)	1635 (476)	2016 (461)	1877 (436)	1759 (504)	1774 (520)

Note: FA = false alarm; Familiarity was calculated as F = K / (1-R); RT = response time in milliseconds; Standard deviations shown in parentheses.

The results of Experiment 1 showed that participants had better memory for words that were studied with pictures of intact faces than words studied with scrambled faces, and this effect was specific to Remember responses. This effect occurred regardless of the fact that these two types of context were matched for luminance and contrast. The results demonstrate that changing the amount of meaningful content in context information provided at study alters the subjective experience of the rememberer.

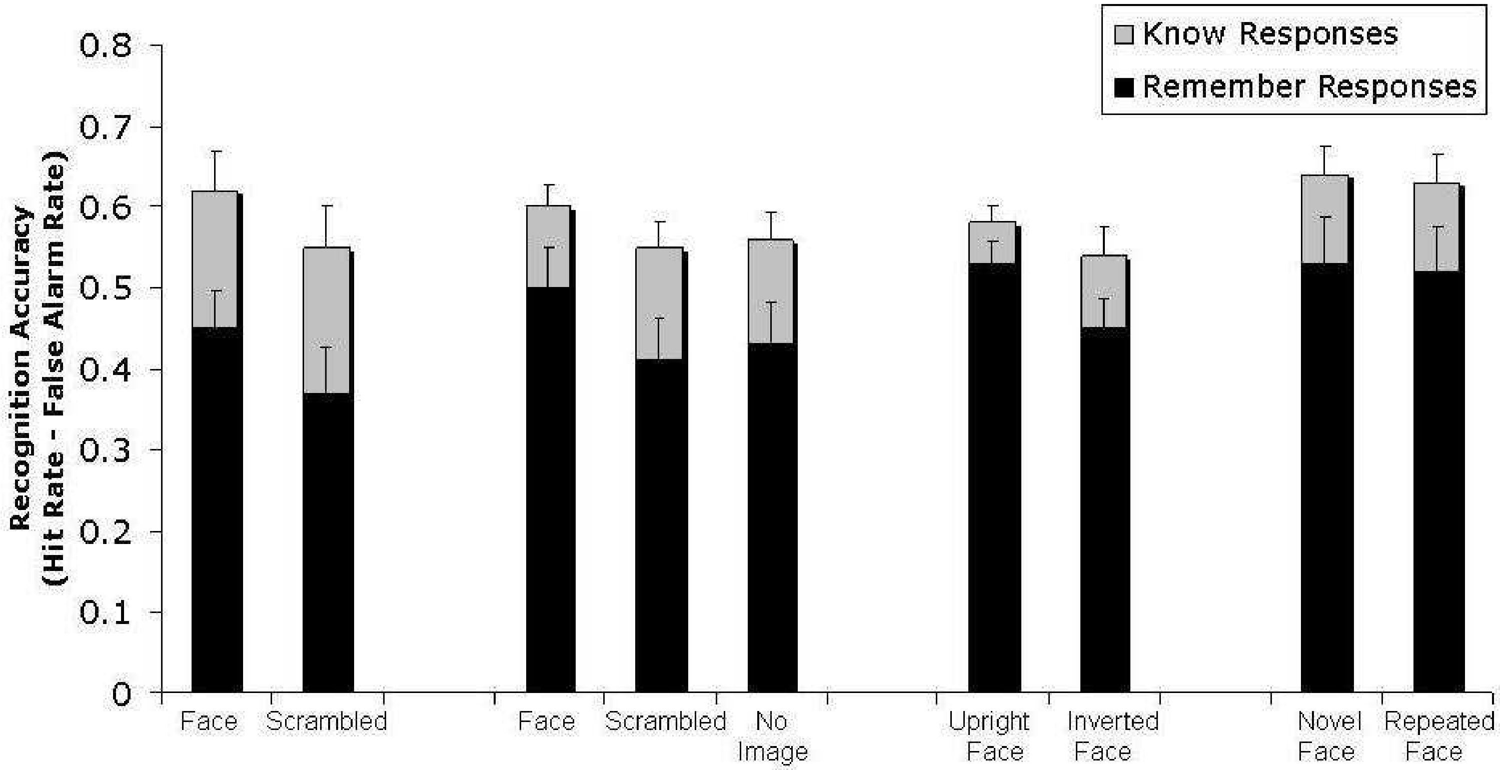

Figure 4. Mean recognition accuracy for words studied with different context in Experiments 1, 2, 3, and 4. Grey bars show Know accuracy and black bars show Remember accuracy, measured as hit rate – false alarm rate. Error bars show the standard error of the mean.

2.3 Experiment 2

Although the results of Experiment 1 are in line with the hypothesis that participants can use context information rich in meaningful content to create ensemble information, reflected in increased subsequent recollection, the study did not include a neutral baseline condition, limiting the theoretical interpretation of the results. That is, it is unknown whether providing intact faces as accompanying study context is boosting recollection, as compared to when no context information accompanies study words. It may be that in Experiment 1, presenting scrambled faces is impairing subsequent recollection for studied words, rather than the meaningful context (intact faces) boosting recollection. In Experiment 2, participants studied words with pictures of faces, scrambled faces, or no image, and subsequently performed a remember-know recognition test to the words presented alone, as in Experiment 1. I expected recollection to be higher for words studied with faces as compared to with scrambled faces and no image, whereas familiarity would be unaffected. Recollection and familiarity were expected to be equivalent for words studied with scrambled faces and no image.

<u>Method</u>

<u>Participants.</u> Eighteen undergraduates (10 female) from the University of Waterloo, naïve to the experiment, participated in the study for course credit or token monetary remuneration. The mean age of the participants was 20.83 (<u>SD</u> = 2.04) and years of education was 14.67 (<u>SD</u> = 0.91).

<u>Materials.</u> The face stimuli were the same as those used in Experiment 1, although only 60 face and 60 scrambled face images were required. Two-hundred-forty medium to high frequency words were chosen from Celex for the three study-test cycles. In each of these cycles, the study list was comprised of 60 words: 20 were paired with pictures of faces, 20 were paired with pictures of scrambled faces, and 20 were viewed with no image. A corresponding list was created for use in the subsequent recognition test, consisting of the 60 studied words plus 20 lures. Although this represents a disproportionate number of studied to unstudied words, this was done to ensure there was an

adequate sample of each response type while reducing the time required to complete each memory task. Three different study-test list combinations were created such that each word was paired with either a picture of a face, a scrambled face, or no image, counterbalanced across participants. The order of presentation of the word lists was also counterbalanced. All test lists were equated on letter length (M = 6.29) and word frequency (M= 23 occurrences per million). An additional 30-item word list was used in the practice session, with the same characteristics as the words in the experimental session.

Procedure. The experimental session followed the same procedures as Experiment 1. During the identification task, however, participants were instructed to identify the picture as either a face by pressing the '1' key, a scrambled face by pressing the '2' key, or no image by pressing the '3' key (see Figure 3). As in Experiment 1, within each study cycle, the 20 scrambled images were the scrambled versions of the 20 face images presented in the face trials. During the recognition test, the words again were presented alone and participants were asked to make a 'Remember', 'Know', or 'New' response.

Results and Discussion

All analyses were evaluated at the $p \leq .05$ level.

Identification task performance. Identification task performance was analyzed using a 3-way repeated measures ANOVA. Mean accuracy (hit rate – false alarm rate) on the identification task was .98 (SD = .02) for faces, .99 (SD = .01) for scrambled faces and .98 (SD = .02) for no image, which did not differ significantly, F (2, 34) = .98. Speed of responding was analyzed, although had not been emphasized during the identification task. The mean response time (RT) in milliseconds to correct responses was 1549.42 ms (SD = 466.81) for faces, 1432.45 ms (SD = 419.58) for scrambled faces, and 1977.48 ms (SD = 227.67) for no image, which differed significantly, F (2, 34) = 36.29, MSE = 141881.40. Simple effects tests showed that RT to identify no image was slower than to identify faces, F (1, 17) = 26.84, and scrambled faces, F (1, 17) = 49.06, and that RT to identify faces was slower than to identify scrambled faces, F (1, 17) = 18.82.

Memory task performance. Table 1 shows the means for each memory measure and trial type. Data were again analyzed separately using overall recognition, overall d’, Remember accuracy, Know accuracy, and IRK familiarity as dependent variables in separate 3 (Context: studied with an intact face, scrambled face, or with no image) x 3 (Study-Test cycle) x 3 (List order) ANOVA; since the latter two variables invariably produced non-significant main effects and interactions, the data were collapsed across these variables.

Overall recognition accuracy, measured as hit rate out of 60 – false alarm rate out of 60, showed a significant effect of Context, F (2, 34) = 3.49, MSE = .01, and simple effects tests showed that there was no difference in overall accuracy between the face and no image, F (1, 17) = 1.97, and the scrambled face and no image, F (1, 17) = 1.27, trials, but that accuracy was higher in the face than scrambled face trials, F (1, 17) = 8.01. Analysis of d' showed the same pattern of results (main effect of Context, F (2, 34) = 3.26.

Retrospective power analyses of overall memory performance showed that when the face and no image conditions were compared, d = .33 and that, with a power estimate of .80, we would need to run 72 participants to obtain a significant effect of context on overall recognition accuracy. A similar comparison of the scrambled face and no image condition showed that d = .27 and that, with a power estimate of .80, we would need to run 108 participants to obtain a significant effect of context on this measure.

I then analyzed proportion of Remember responses and proportion of Know responses for each word type, as in Experiment 1 (see Figure 4). There was a main effect of Context on Remember responses, F (2, 34) = 6.92, MSE = .04. Remember accuracy was higher for words studied with faces than with scrambled faces, F (1, 17) = 14.49, and than no image, F (1, 17) = 5.09. Remember accuracy did not differ between words studied with scrambled faces and no image, $F(1, 17) = 1.26$, $p > .05$. There was no effect of Context on Know responses, $F(2, 34) = 2.04$, or for IRK familiarity, $F(2, 34) = 0.67$. Retrospective power analyses performed on IRK familiarity showed that $d = .05$ when face and scrambled face trials were compared and $d = .19$ when face and no image trials were compared. With a power estimate of .80, I would need to run 3889 and 181 participants, respectively, to obtain a significant effect of context on IRK familiarity.

As in Experiment 1, I analyzed RT to correct Remember and Know responses in two separate repeated measure ANOVAs, although RT had not been emphasized at retrieval. There was no effect of Context on RT for Remember, $F(2, 34) = 1.09$, or Know, $F(2, 34) = 2.08$, responses.

I again examined whether there was a correlation between RT on the identification task performed at encoding and later recollective memory performance, though the results should be interpreted with caution due to the small sample size. The correlations between identification task performance and later Remember accuracy for face, scrambled face, and no image trials were non-significant, $r = -.04$, $-.17$, and $.03$, respectively.

The results substantiate my claim that meaningful context information provided at study can be used to benefit subsequent recollection. Recollection was higher for words studied with faces as compared to those studied without any context information. As in Experiment 1, memory performance was higher for words studied with faces as compared to scrambled faces, and this benefit was shown specifically in recollection. These results argue against the hypothesis that the scrambled face contexts impair recollection; rather, they support the alternative hypothesis that participants can use context information high in meaningful content at study to benefit memory. The argument here is that this context promotes integration of item and context into ensemble information, enabling subsequent recollection.

Although recollection was higher for words studied with faces as compared to no image, overall memory performance was not significantly different between the face and no image encoding trial types. Retrospective power analyses showed that, if the face and no image trial types do differ, the effect is small and a large sample would be required to obtain the effect. While this result poses difficulties if one adopts a single-process view of recollection (e.g., Wixted, 2007), my results do demonstrate that context information high in meaningful content benefited memory for those items in which participants reported a context-rich memory. Specifically, the results show that Remember accuracy was higher for words studied with faces as compared to no image. Adopting a dual-process perspective, this finding provides support for the interpretation that recollection increases when context information high in meaningful content is provided at study.

2.4 Experiment 3

Experiments 1 and 2 showed that participants have higher recollection of words studied with pictures of faces (highly meaningful visual contexts) than of scrambled faces (low meaningful visual contexts), or no accompanying context at study. It could be argued, however, that scrambled faces are less useful cues for word-context integration, not because they are lacking in meaning, but because they contain greater inter-item perceptual similarity. If it is difficult to distinguish different scrambled faces, this may make it harder to form specific, or distinctive, item-context associations. To test this possibility, in Experiment 3 I asked participants to study words presented with pictures of upright or inverted faces. Research has shown that inverting a picture of a face disrupts the normal holistic processing of the face information (Tanaka & Farah, 1993). In particular, inverted faces are believed to be processed more featurally. Consequently, this provides an appropriate control condition with which to test the context effect on recollection. By disrupting participants' ability to process the face using normal holistic-based processes, I should disrupt their ability to extract meaning from the face, and therefore, impair their ability to engage in the elaborative processes that bind the item and context into ensemble information, while leaving the visual features, and the inter-item similarity, equivalent across these trial types. This hypothesis suggests that providing context information high in meaningful content at study can help participants engage in intentional strategies at study, such as elaborative processing, that develop rich memory traces.

In this experiment, I expected memory performance to be higher for words studied with upright than inverted faces, since inverting the face should disrupt participants' ability to extract meaningful information from the face. Context information high in meaningful content should increase the development of ensemble information, reflected in increased recollection, or Remember accuracy, at retrieval. In contrast, Know responses, which do not require the retrieval of context information, were expected to be unaffected by the context manipulation at encoding.

Method

Participants. Fifteen undergraduates (8 female) from the University of Waterloo, naïve to the experiment, participated in the study for course credit or token monetary remuneration. The mean age and years of education of the participants were 19.78 (SD = 1.72) and 13.96 (SD = 1.28), respectively. All participants were fluent English speakers, and had normal or corrected-to-normal hearing and vision.

Materials. The word and face stimuli were the same as those used in Experiment 1. For the inverted face trials, the 75 faces used for the face-word pairs were rotated 180°. The pictures thus consisted of 75 upright faces and 75 inverted faces (see Figure 3).

Procedure. The experimental session followed the same procedures as Experiment 1. During the identification task, however, participants were instructed to identify the picture as either an upright face, by pressing the '1' key, or an inverted face, by pressing the '2' key. During the recognition test, the words again were presented alone, and participants were asked to make a 'Remember', 'Know', or 'New' response, as in Experiment 1.

Results and Discussion

All analyses were evaluated at the p ≤ .05 level.

Identification task performance. Identification task performance was analyzed using a 2-way repeated measures ANOVA. Mean accuracy (hit rate – false alarm rate) on the identification task was .95 (SD = .05) for upright faces and .96 (SD = .05) for inverted faces, which did not differ significantly, F (1, 14) = 2.08. Speed of responding was analyzed, though it had not been emphasized during the identification task. The mean response time (RT) in milliseconds to correct responses was 947.71 ms (SD = 305.12) for upright faces and 882.07 ms (SD = 313.35) for inverted faces, which differed significantly, F (1, 14) = 7.25, MSE = 32317.85.

Memory task performance. Table 1 shows the means for each memory measure and trial type. As in Experiments 1 and 2, all measures were first analyzed in a 2 (Context: studied with an upright or inverted face) x 3 (Study-Test cycle) x 3 (List order) ANOVA, although data were collapsed across the latter two variables as they consistently produced non-significant main effects and interactions. Overall recognition accuracy (measured as hit rate – false alarm rate) showed a significant effect of Context, with higher accuracy for words studied with upright than with inverted faces, F (1, 14) = 6.38, MSE = .02, though the effect using d' as the dependent measure did not reach significance, F (1, 14) = 2.26, $p > .05$.

I then analyzed proportion of Remember responses and proportion of Know responses for each word type, as in Experiments 1 and 2 (see Figure 4). There was a main effect of Context for Remember responses, with a higher proportion of Remember responses for words studied with upright than inverted faces, F (1, 14) = 4.97, MSE = .06. There was no effect of Context for Know responses, F (1, 14) = 1.89, or for IRK familiarity, F (1, 14) = 1.1. Retrospective power analyses performed on IRK familiarity showed that d = .09 and, with a power estimate of .80, I would need to run 1502.67 participants to obtain a significant effect.

As in Experiment 1, I analyzed RT to correct Remember and Know responses in two separate repeated measure ANOVAs, although RT was not emphasized at retrieval. There was no effect of Context on RT for Remember responses, $\underline{F}$ (1, 14) = .49, although participants were faster to make Know responses for words studied with inverted than upright faces, $\underline{F}$ (1, 14) = 17.56, $\underline{MSE}$ = 145766.40.

I again examined whether there was a correlation between RT on the identification task performed at encoding and later recollective memory performance. The correlations between identification task performance and later Remember accuracy for upright and inverted faces were non-significant, $\underline{r}$ = -.18 and -.07, respectively, although the results should be interpreted with caution due to the small sample size.

These results show that memory performance, and recollection in particular, benefits when words are presented with pictures of upright, as compared to inverted, faces, suggesting that recollection increases when items are presented with a context high in meaningful content, despite controlling for inter-item perceptual similarity and changes in visual information. In particular, this study demonstrates that even when the same face contexts are provided at study, item recollection suffers when participants' ability to process the face holistically is disrupted. This provides further evidence that the level of meaningful content in context information is an important factor that influences subsequent recollection.

2.5 Experiment 4

In the final experiment of this chapter, I examined how changing the novelty of the context presented at study influenced later recollection. The novelty encoding hypothesis suggests that encoding consists of two steps: a novelty assessment, followed by higher level encoding operations (Tulving & Kroll, 1995). Novel items are given preference for higher level encoding operations, which increases subsequent memory performance. In support of this hypothesis, research shows that when participants are familiarized with a subset of words before the study session, they show lower recognition for those words than for words presented solely during the study phase (Tulving & Kroll, 1995). Although some researchers have suggested that such novelty effects are based in recollection (Dobbins, Kroll, Yonelinas, & Liu, 1998; Rajaram, 1998), other research suggests that novelty effects act on both recollection and familiarity (Kishiyama & Yonelinas, 2003).

In our previous experiments, each word was paired with a unique face in the high meaningful context trials. Since the scrambled face and inverted face trials of Experiments 1, 2, and 3 contained lower meaningful content, they may have been perceived as more similar (or familiar) than the face images. The novelty, or uniqueness, of the intact face contexts may have promoted increased processing of the word-context pair as an integrated unit, influencing subsequent recollection. It is thus possible that context information high in meaningful content will improve memory performance only if it is novel (or unique), and this is the basis of our effects in Experiments 1, 2, and 3. Alternatively, participants may be able to use novel and familiar context information to develop equally unique associations between item and context pairs, since the word is always novel, and thus so too is the word-context association that is developed. More specifically, it may be novel associations created by the participant, rather than novel contexts per se, which benefit subsequent recollection. Examining whether it is the novelty (or uniqueness) of the accompanying context information presented across trials that leads to the boost in recollection for the target word can help pinpoint what aspect of context information, at study, enhances recollection.

Participants studied words that were presented with either a ‘novel face’ (as in the face trials of Experiments 1, 2, & 3) or a ‘repeated face’ (which replaced the scrambled/inverted face trials in Experiments 1, 2, & 3). To this end, participants were exposed to a face that was repeatedly presented as the ‘context’ during the practice session. This repeated face was then used for the ‘repeated-context’ trial types during the experimental trials. As in the other experiments, following study, participants performed a memory test for the words presented alone. If the novelty of the context accompanying the word during study enhances word-context integration, recollection should be higher for words studied with unique faces (novel-context trials) as compared to words studied with the repeated face (repeated-context trials). Alternatively, if participants are able to similarly use novel and repeated context information to create integrated ensemble information (or memory traces), recollection should not differ across the two trial types.

Method

Participants. Fifteen undergraduates (8 female) from the University of Waterloo, naïve to the experiment, received course credit or token monetary remuneration for participation in the study. The mean age and years of education of the participants were 20.47 (SD = 1.96) and 14.53 (SD = 1.13), respectively. All participants were fluent English speakers, and had normal or corrected-to-normal hearing and vision.

Materials. The word and face stimuli were the same as those used in Experiments 1, 2, and 3, except that instead of using the scrambled or inverted faces, an additional face stimulus from the AR face database (hereafter referred to as the ‘repeated face’) was chosen for the ‘repeated-context’ trial type. Hence, of the 50 study words in each study-test cycle, 25 were paired with a unique picture of a face (novel-context trials), and 25 were paired with the ‘repeated face’ (repeated-context trials). The repeated face was kept constant across the three study-test cycles, as this was believed to best replicate the ‘scrambled face’ trials of Experiment 1 and 2 (in which a highly similar image was repeatedly presented across trials and memory tasks). The recognition test materials were the same as in Experiments 1 and 3: 75 test words (across the three study-test cycles) initially studied with unique faces, 75 studied with the ‘repeated face’, and 75 new words (see Figure 3).

Procedure. The procedure was similar to Experiments 1, 2, and 3. Participants began with a practice session followed by the three study-test cycles, with the same timings, fonts, orientations, and sizes as in the previous experiments. The study/identification task was changed for this experiment; for the identification task, they were told to press the ‘1’ key if they saw a picture of a unique face or the ‘2’ key if the saw a picture of the repeated face (prior to practice, participants were shown a picture of what was to be known as the ‘repeated face’ which, following the practice trials, became a familiar face to participants relative to the unique face trials). Participants then gave 'Remember', 'Know' or 'New' judgments to the word presented alone during the corresponding recognition memory tests, as in Experiment 1, 2, and 3.

Results and Discussion

All analyses were evaluated at the $\underline{p} \leq .05$ level.

Identification task performance. Data from the identification task were analyzed using a 2-way repeated measures ANOVA. Mean accuracy (hit rate – false alarm rate) on the identification task was .95 (SD = .04) for the novel and .95 (SD = .04) for the repeated faces, which did not differ significantly, $\underline{F}$ (1, 14) = 0.32. The mean response time (RT) in milliseconds to correct responses was 1789 (SD = 458) for the novel and 1729 (SD = 526) for the repeated face trial types, which also did not differ significantly, $\underline{F}$ (1, 14) = 4.01.

Memory task performance. The means for each memory measure and trial type are shown in Table 1. Analyses for all response types were again conducted initially as 2 (Context: studied with a novel face or the repeated face) x 3 (Study-Test cycle) x 3 (List order) ANOVAs. The latter two variables consistently produced non-significant main effects and interactions for all measures, so data were collapsed across these factors. The main effect of Context on overall recognition accuracy (hit rate – false alarm rate) and overall d' were not significant, $\underline{F}$ (1, 14) = .46 and .74, respectively.

I then examined proportion of Remember responses and proportion of Know responses for each word type, as in Experiments 1, 2, and 3 (see Figure 4). There was no effect of Context on Remember, $\underline{F}$ (1, 14) = .39, or Know, $\underline{F}$ (1, 14) = .00, responses, nor on IRK familiarity, $\underline{F}$ (1, 14) =

.53. I performed retrospective power analyses on both Remember accuracy and IRK familiarity measures. This analysis showed that $\underline{d}$ = .16 for Remember accuracy and .18 for IRK familiarity, indicating that, with a power estimate of .80, I would need to run 284 and 221 participants to obtain a significant effect of context, respectively.

RT for Remember and Know responses were then analyzed in two separate ANOVAs, although RT was not emphasized at retrieval. There was no effect of Context for either Remember, $\underline{F}$ (1, 14) = .73, or Know, $\underline{F}$ (1, 14) = .08, responses, $\underline{ps}$ > .05.

The results indicate that the novelty of the context provided at study did not differentially affect later overall recognition or recollection of target words, suggesting that novel contexts do not enhance word-context integration. The findings support the alternative hypothesis that familiar contexts do not impair subsequent recollection since the word-context association (or ensemble) is always novel. I discuss the implications of this finding further in the general discussion.

2.6 General Discussion of Chapter 2 Experiments

I examined how visual context information provided during encoding, and unrelated to the target study word, affected later recollection for words presented alone. This study is novel in that it focused on how additional meaningful context present at study, but absent at retrieval, influenced later recollection of target information. In four experiments, I showed that recollection was consistently higher when words were studied with context information high in meaningful content (faces) as compared to contexts that were similar in perceptual features but lower in meaningful content (scrambled face or inverted face), and that this effect reflects a boost in recollection compared to when words are presented without any additional visual context information. Furthermore, I showed that this effect was not due to differences in the novelty of context information across trials. I discuss each of these points in turn.

Experiments 1-3 tested the hypothesis that target words studied with accompanying context high in meaningful content would benefit later recollection of targets, compared to when the context contained similar perceptual features (luminance, contrast, and inter-item perceptual similarity) but was lower in meaningful content. This hypothesis follows from Murnane et al.'s (1999) ICE theory, in that I suggest it is only when context information present at study is rich in meaningful content that participants integrate item and context information into a cohesive memory trace. I additionally extend this theory by suggesting that when participants develop such ensemble information at study, the item will be bound to the contextual information and thus retrieved preferentially through recollective memory processes. In support of this, I found that participants had higher overall memory for words studied with pictures of faces relative to words studied with scrambled faces or inverted faces, and that this effect was specific to words given Remember responses. This finding replicates that of Luo et al. (2007), showing that the provision of additional context information at study can improve later recollection. Experiments 1, 2 and 3 extend this work by demonstrating that a) changing the amount of meaning that can be extracted from visual context information changes the quality of the memory retrieved, b) this effect reflects a boost in recollection, relative to when no visual context is presented at study, and c) the boost to recollection reflects differences in the meaning, rather than changes in the perceptual characteristics or the inter-item similarity of the context presented at study. Importantly, whereas past research has focused on context reinstatement effects, showing somewhat contradictory results on how context information influences recognition memory performance (Bjork & Richardson-Klavehn, 1989; Macken, 2002: Murnane et al., 1999; Smith, 1988), my paradigm shows that one does not need to re-present the context at retrieval to observe enhanced recollection.

Experiment 2 provides a critical contribution to the theoretical interpretation of the findings. The results substantiate the claim that providing contexts high in meaningful content at study boosts recollection and, furthermore, that the provision of context information gives participants an opportunity to use elaborative processing to integrate item-context pairs into cohesive memory traces, as compared to a no-context condition. In addition, Experiment 3 showed that even when the same contexts are presented at study (faces), disrupting the amount of meaning that can be extracted from the context information (inverting the face) reduces subsequent item recollection. That this occurred without any specific experimental instructions to bind the item and context information at study suggests that participants use strategies that integrate the item and context into ensemble information spontaneously.

I suggest that participants use a strategic process during encoding in which meaningful context information aids in developing rich memory traces for target information. Other research converges on this notion, showing that encoding the meaning of item information improves memory performance (Gardiner et al., 1996); however, I extend this to the encoding of meaningful context information. The work shows that providing participants a meaningful framework in which to process item information, through the provision of external context information, changes the way in which item information is processed and subsequently remembered. Specifically, I suggest that participants engage in controlled encoding processes that promote the binding of item and context information into a distinctive/detailed memory trace. This is supported by theories proposing that participants use strategic elaborative processes at encoding to support binding processes (Shing, Werkle-Bergner, Li, & Lindenbrger, 2008) and that recollection is due to the retrieval of elaborated memory traces (Macken & Hampson, 1993). In addition, Murnane et al. (1999) suggest that "context information that is relatively rich in meaningful content should be more easily integrated into an ensemble through a process of item elaboration" (p. 408). With respect to the current study, I propose that face contexts, which are high in meaningful context, are more easily elaborated upon during study scrambled face contexts, which are low in meaningful content. Participants are thus able to elaborate a link, or an association, between faces and words, which promotes the binding of item-context information, or the development of ensemble information, accounting for the boost in recollection.

Support for this hypothesis comes from post-experiment questioning, performed in Experiment 2, which suggests that the participants were developing stories or making subjective judgments to link the word to the face during study to improve their later memory performance. In this experiment, participants were asked to describe the strategies they used to remember the words on the task. Over 60% reported that they used the pictures of faces to help them remember the words; some of these participants reported directly associating the words and the face, whereas others stated that they used the faces to help increase the personal relevance of the word. For example, one person reported that they used the faces that reminded them of their family and friends to make a story about the word. In addition, many of those participants reported that they found it easier to use such strategies to remember the words studied with faces as compared to the words studied with scrambled faces.

Of note, in Experiments 1, 2, and 3, participants were consistently slower in identifying pictures of faces as compared to scrambled and inverted faces. While these results should be interpreted with caution, as RT was not emphasized at encoding, they do lend support to the possibility that participants spend more time examining the faces, or engaging in some other process at encoding, that leads to subsequent recollection benefits for words studied with faces. If this were true, one would expect that RT for face identification at encoding would be positively correlated with subsequent recollection performance; I did not find this was the case in any of the experiments. However, these correlational analyses may be misleading due to the small sample size. Further studies should continue to examine whether RT differences at encoding can lead to important insights into the processes at encoding that support recollection benefits of context information.

The results of this study are similar to that of Gopie (2005) in that Remember responses were found to increase for words studied with additional context information. However, in our study we also found an increase in overall recognition when words were studied with information high versus low in meaningful content, whereas Gopie (2005) found that overall recognition performance did not differ for words studied with and without context information. This difference may reflect variation in the context manipulation used in the two studies. Whereas we compared memory performance for words studied with context information high and low in meaningful content, Gopie compared memory performance for words studied with and without additional perceptual context information (word colour and screen location). The perceptual context information used in Gopie's study is not very high in meaningful content. Murnane et al. (1999) suggested that ensemble formation is a function of the meaningful content in the context information. It is possible that, whereas Gopie's manipulation increased the distinctiveness of the stimuli, increasing recollection but leaving overall recognition unchanged, my manipulation increased item-context integration, increasing both overall recognition and recollection performance. The results suggest that the meaningful content of the contextual stimuli is an important factor in predicting future memory performance.

In Experiment 4, I showed that the novelty of the context information did not differentially affect recollection of target information. I suggest that this finding reflects the fact that, even though a familiar face was presented in the repeated-context trials, the target study word was different on each trial. Since the target word information always varied in both the novel-context and repeated-context trials, participants had the possibility to forge unique ensemble information (or associations) between the word and picture information, regardless of whether the picture itself was novel or repeated. Hockley (2008) showed similar results, demonstrating that reinstatement effects on memory performance did not differ when novel or repeated contexts were presented at study. He argued that these findings pose a problem for interpretations suggesting that context reinstatement effects in recognition memory are the result of specific item-context associations formed at study (as proposed by Macken, 2002), since it should be more difficult to retrieve associations for repeated contexts. This hypothesis follows from evidence of associative interference and of the fan effect, in which response time and/or error rate on a memory task increases when multiple items are associated with a single concept. However, in our experiments, and in Hockley (2008), the contexts were images, rather than word or sentence stimuli generally used in tests of associative interference, suggesting that this may be an important variable. For example, it may be that images more easily allow the formation of unique ensemble information than do words. In line with this, we have suggested that, in the present experiments, participants created a new piece of information, an ensemble, when associating item and context information at study. As an ensemble is a unique piece of information (or association) developed for each item-context pair, it is possible that the effects of associative interference are reduced when an ensemble is developed. Another possibility is that the repeated face became increasingly distinctive through repetition. For example, by becoming more familiar with the face, participants may have been able to assign more meaning, or a more distinctive identity, to the face (e.g., it is the female face with the nice smile again), which countered the decrease in the novelty of this context information. Such possibilities will need to be tested in the future.

I have suggested that when context information high in meaningful content is provided at study, participants engage in elaborative processes that support the development of ensemble information. This follows from Murnane et al.'s (1999) hypothesis that participants can more easily use elaborative processes to integrate item and context information at study when context information is high in meaningful content. While the studies in this chapter show that memory performance, and recollection in particular, is higher for words studied with context information high versus low in meaningful content, they have not directly shown that highly meaningful context information promotes item-context integration, failing to rule out other potential explanations of the data. In particular, it is possible that the data reported here is related to distinctiveness effects of memory (see Hunt & Worthen, 2006 for an extensive report on how item distinctiveness influences memory).

In a study similar to the experiments reported here, Israel and Schacter (1997) examined whether providing context information at study could reduce false memories in the Deese/Roediger and McDermott (DRM) task. In the DRM task, participants often false alarm to a non-studied item (e.g., sleep) because it is highly related to the list of study words (e.g., bed, pillow, etc). Israel and Schacter found that false alarms on this task were reduced when the words were studied with pictorial representations. They suggested that words studied with pictures were more distinctive than studying the words alone and that participants used a 'distinctiveness heuristic' at test to improve memory performance (Schacter, Israel, & Racine, 1999), correctly rejecting non-studied items because they failed to recollect distinctive features (i.e., picture information) at retrieval. These results have been subsequently replicated (Gallo, Weiss, & Schacter, 2004; Schacter et al., 1999). While these studies consistently show that false alarms of non-studied related words are reduced at test when distinctive pictorial information is provided at study, unlike the current study, they fail to show consistent changes in the hit rate.

MacLeod, Gopie, Hourihan, Neary, and Ozubko (in press) have additionally examined how distinctiveness affects memory performance in what they call the production effect. They demonstrated that memory performance is higher for words that are spoken aloud during study as compared to words read silently. They suggest that, when words are spoken aloud at study, participants develop more distinctive records of the words, which are used at test to help them discriminate studied from non-studied items. MacLeod et al. go on to suggest that this phenomenon is in a member of a class of encoding variables that improve memory by increasing the distinctiveness of studied items, including the generation effect (producing a word from a cue leads to better memory than simply reading the word) and the enactment effect (performing an action leads to better memory than reading the instruction). Two features of this class of encoding manipulations support this interpretation: The effects are more consistently found in within-participant mixed-list designs and they are found on explicit, but not implicit, tests (MacLeod et al., in press).

With respect to the current study, it may be argued that words studied with context information high in meaningful content become more distinctive. That is, at test, participants expect to recall more distinctive information for words studied with context information high, as compared to low, in meaningful content. The distinctive information provided at study (the face) is used heuristically at test to help participants discriminate studied from non-studied items. Thus, whereas I have argued that participants use elaborative processes at study to integrate the item and context information, developing unique ensemble information and increasing recollection, this hypothesis suggests the item-context associations at study produce more distinctive memory traces, which are used heuristically at test to improve subsequent memory performance.

The notion that face contexts are used to make item information more distinctive, resulting in improved memory performance, is not necessarily exclusive from the interpretation that face contexts are used to elaborate upon to-be-remembered information at study to develop cohesive, rich memory traces. Elaboration at study surely works to make the item information distinctive and, in order for face information to make item information appear more distinctive at retrieval, some binding between the face and item information must occur at study. The difference between these hypotheses may thus be related to the extent that elaboration is used to make item information distinctive: An ensemble/distinctiveness-account likely requires richer elaborations at study than the more heuristic-based distinctiveness-account offered above.

To help elucidate this issue, I will refer to what Schmidt (1991) calls distinctive processing. In this class of distinctiveness, "different processes evoked by different tasks or materials are thought to lead to memory traces varying in distinctiveness" (p. 532). Examples of distinctive processes are the levels-of-processing effect and concreteness effect. I suggest that the manipulation found in the current study is a form of distinctive processing. That is, by providing the face contexts at study, participants engage in a different type of processing (i.e., binding/developing associations between item and context), which enhances the distinctiveness/memorability of the item though the formation of rich memory traces. Schmidt (1991) noted that this class of distinctiveness is the only form of distinctiveness to show consistent effects in both within- and between-participant designs. In contrast, the production effect (MacLeod et al., in press), generation effect (Begg & Snider, 1987), and enactment effect (Engelkamp & Dehn, 2000) have all been shown to work predominantly in within-participant, mixed-lists, rather than between-participant designs (though the distinctiveness heuristic has been shown to work in between- and not within-participant designs; see Dodson & Schacter, 2001 for a description and explanation of this phenomenon). MacLeod et al. (in press) suggest that this occurs because distinctiveness is relative to the context in which an item occurs (for example, words said aloud are only distinctive if there are some words that are read silently). Examining whether the effects found in the current study can be found in a between-participant design may thus lead to important insights regarding the basis of this effect: If the recollection benefits found in this study occur because the face-word pairs are distinctive <u>relative to</u> the scrambled face-word pairs (as in the production, generation, and enactment effects), the effect should be consistently found in within-, but not between-participant designs. However, if participants use the face context provided at study to engage in a different from of processing at study (i.e., engage in more elaborative processes that integrate the item and context information), recollection benefits should be consistently found in both within- and between-participant designs.

However, as mentioned previously, these interpretations are not necessarily mutually exclusive, but rather relate to the extent to which participants are believed to engage in elaborative processes that integrate the item and context at study. Whereas some participants may engage in a rather low level of binding, in which words studied with face contexts become distinctive relative to words studied with scrambled face contexts, it is possible that other participants engage in a deeper level of binding through which ensembles are formed. Thus, it may be too simplistic to suggest that one can 'test' these two alternatives by 'pinning them' against one another in a between-participant design. Rather, a more sophisticated approach may be to ask participants to state what information they are basing their Remember responses on. By asking people to report the context information through which they make a Remember response, one can gain insight into the extent to which participants have used elaborative processes to integrate the item and context information at study.

The experiments in this chapter have begun to delineate the characteristics of context information that can be used to improve subsequent item recollection. In particular, they suggest that context information, unrelated to the target item and absent at retrieval, can improve memory, specifically recollection, if it is meaningful to the participant. Future studies can determine more specifically what types of context information promote maximal integration of item and context information, and later item recollection. For example, whether different types of objects have different effects on recollection remains to be determined. Do images of faces produce larger benefits to subsequent recollection than do images of dogs (or other animal faces) or geometric figures? There may also be specific context effects based on individual differences. For example, one might expect that dog experts would be better able to integrate visual images of different dog breeds with item information than non-experts, since they would be able to extract more meaning from the context, affecting subsequent recollection. Another possibility is that the personal relevance, or affective valence of the context, will influence subsequent recollection of target information. Thus, while I have provided evidence that provision of meaningful context information benefits recollection, this paradigm can be used in future studies to examine conditions which best promote item-context integration.

One limitation of the current study, however, is that although I have shown that changing the type of visual context information provided at study (high or low in meaningful content) influences memory performance, I have not specified the processes required to obtain recollection benefits when context information is provided at encoding. Specifically, the hypothesis that participants use controlled processes at encoding to bind item-context pairs, and that this is more easily accomplished with context information high in meaningful content, has not been explicitly tested. If controlled processes are required to integrate item and context information, one would expect that limiting the amount of processing time at encoding (i.e., reducing the time in which face-word pairs are presented at study) would impair item-context binding and thus, reduce recollection benefits when meaningful context information is provided at study. One would similarly expect that dividing participants' attention during encoding would disrupt participants' ability to engage in the controlled processes required to promote item-context binding. Such hypotheses should be tested in future work.

Another method that can be used to test the hypothesis that controlled processes at encoding are required to obtain recollection benefits is to examine how the normal aging process affects participants' ability to obtain recollection benefits, examined in Chapter 3. Since older adults are believed to have deficits in controlled processes (Craik & Byrd, 1982), older adults should show less of a benefit, or possibly no recollection benefit, when context information high in meaningful content is provided at study, if such controlled processes are required to integrate item and context into ensemble information. I also examine how changing the cognitive operations performed on the context, rather than changes in the context presented at study, influence subsequent recollection. These experiments begin to address questions of how item-context binding occur, rather than focusing on which contexts best promote item-context binding.

A second limitation of this thesis thus far is that I have currently placed the majority of the focus on controlled processes at encoding. However, it is also possible that participants are required to use controlled processes at retrieval to obtain recollection benefits from context information provided at study. Research shows that the successful retrieval of information often involves the deliberate use of controlled processes, such as the initiation and implementation of search strategies or complex decision making (Glisky, Rubin, & Davidson, 2001; Moscovitch, 1994). In addition, Glisky et al. (2001) suggest that active retrieval processes may be particularly required when source information is poorly encoded. Theorists propose that recollection involves more processing time at retrieval than familiarity, required to retrieve source information and engage in additional search and post-monitoring processes (Yonelinas, 2002). It is therefore possible that the context benefits reported in this thesis require such controlled processes at retrieval. Such possibilities could be tested by limiting the time participants have to make a response, or by dividing attention, at test.

It is also important to begin replicating these findings using other experimental paradigms to determine whether the effects extend beyond remember-know recognition tests. Examining how recollection is affected by varying the meaningful content in context information provided at study using the process dissociation procedure (PDP) or receiver operating characteristic (ROC) paradigms would provide important extensions to this work. First, they could provide converging evidence that the effect is specific to recollection. Second, it is possible that, in the current study, participants engaged in binding strategies because the remember-know paradigm was used at test (i.e., participants tried to develop context-rich memories to report a Remember response). Examining how context information provided at study affects recollection in PDP or ROC paradigms could test whether participants spontaneously engage in these strategies regardless of the test demands, or whether the strategies used at encoding depend on the retrieval task.

In summary, I have shown that participants can use meaningful visual context information, present only at encoding, to develop rich memory traces enhancing later recollection of target words, and that this benefit is not related to the novelty of the context. These results are in line with current memory models hypothesizing that item and context information can be bound into ensembles, and additionally suggest that this leads to a specific benefit in recollection responses.

Chapter 3

Age-related Changes in the use of Study Context to Increase Recollection

In this chapter, I examine how healthy aging affects participants' ability to use context information high in meaningful content to improve subsequent item recollection. Memory difficulties are a persistent and common complaint among older adults. However, research shows that not all memory processes are equally disrupted by advancing age. For example, older adults show relatively preserved performance on tests of non-declarative (Light & Singh, 1987) and semantic (Park, Polk, Mikels, Taylor, & Marshuetz, 2001) memory, although performance on short-term or episodic memory tasks often shows a decline with advancing age (Park et al., 2001). Further variation is found within the episodic memory domain. For example, episodic memory tests that provide a retrieval cue, such as recognition or cued-recall tests, show smaller age-related deficits than tests that do not provide external cues, such as free recall (Craik, 1986).

Of great interest to memory researchers is that recollection appears to be more adversely affected by normal aging than is familiarity. Older adults show a marked decline in their ability to recollect past events, but generally show small or no change in familiarity responses (Perfect et al., 1995; Prull et al., 2006). This finding suggests that memory deficits associated with normal aging specifically affect processes involved in the encoding and/or retrieval of contextual details of past events. This notion is supported by studies that have examined source memory. These studies show that older adults have difficulty remembering the context in which an item was presented (Ferguson et al., 1992; Kausler & Puckett, 1981; Naveh-Benjamin & Craik, 1995), and that there are larger age deficits in memory when participants are asked to remember source (context) information as compared to item (content) information (McIntyre & Craik, 1987; Spencer & Raz, 1995). Thus, it appears that not all memory processes are equally affected by normal aging; rather, there is a disproportionate decline in the processes involved in encoding and/or retrieving contextual details of past events. Craik (1986) has suggested that reduced cognitive resources in older adults results in a reduction in the spontaneous use of elaborative strategies at encoding and retrieval, which leads to age-related deficits in memory performance.

Another theoretical framework that can be used to explain these findings is the Associative Deficit Hypothesis (ADH; Naveh-Benjamin, 2000). This hypothesis suggests that older adults have a specific deficit in forming associations between items, an item and its context, or two contextual features. This theory is supported by work in which participants are asked to study associated information (such as face-name pairs) and are later given a recognition test on either the item information (the face or the name) or the association between the items (the face-name pair). These studies show that age-related differences in memory performance are higher when participants are required to retrieve associations between two items than when they are required to retrieve item information (Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004). I believe that this deficit contributes to the decreased tendency of older adults to produce recollective memory responses: Older adults do not adequately bind contextual information to the to-be-remembered item, preventing the formation of a context-rich memory trace that can later be retrieved by recollective memory processes.

In a previous study, Luo et al. (2007) found that younger adult participants were more likely to correctly reject previously presented words on an exclusion test if the words were presented with a related sound at study. Older adults, however, were unable to use the sound information to reduce their false alarms in the exclusion test. This work suggests that the younger adults were able to effectively integrate the word-sound pairings into a cohesive memory trace, and this allowed them to later use recollective processes to reject those items. The older adults, however, were unable to benefit from the additional context, possibly because they were unable to successfully bind, or associate, the item and context information in memory. In addition, Experiments 1-3 of this thesis, reported in Chapter 2, showed that younger adults can use context information high in meaningful context to boost subsequent item recollection. The current study (Skinner & Fernandes, in press) aimed to extend the findings of Luo et al. by investigating whether the normal aging process affects participants' ability to attain a recollection benefit when meaningful context information is provided at study, and how this affects the type of memory that is retrieved.

3.1 Overview of Experiments

The ADH suggests that older adults have specific difficulties binding item and context information into cohesive memory traces. This leads to the prediction that younger, but not older, adult participants can use context information provided at study to benefit subsequent memory performance. The extent to which contextual information benefits later memory performance, and recollection in particular, may also depend on one's ability to engage in self-initiated, controlled processing at encoding. Craik and Byrd (1982) hypothesized that, whereas younger adults readily engage in controlled, effortful encoding processes that support successful memory performance, normal aging is related to a failure to voluntarily engage in such beneficial processes. Consequently, whereas younger adults may spontaneously engage in the controlled processes required to link item and context at study to produce later recollection benefits, older adults may fail to engage in such processes.

Age differences in the use of context information to improve recollection may thus be conceptualized as a deficit in engaging in the beneficial cognitive operations that link item and context. I thus predicted that younger, but not older, adults would show higher recollection when context information high in meaningful content was provided at encoding. This possibility was tested in Experiment 5. As predicted, younger adults showed higher recollection when words were studied with pictures of faces, as compared to a picture of a rectangle, whereas older adults showed similar memory performance for the two word-context types. The results suggest that older adults were unable to engage in the controlled processes required to integrate item and context memory into ensemble information, preferentially retrieved through recollective memory processes.

If age-related deficits in the ability to use contextual information to boost subsequent recollection are related to the type of cognitive processes engaged at encoding, specific instructions provided at study might serve to compensate for such deficits. Studies that have examined how instructional manipulations at encoding influence later recollection (for items presented without context information), have shown that recollection increases in older adults when the instructions encourage elaborative processing. For example, Perfect et al. (1995) found that when younger and older adults studied words under deep relative to shallow encoding conditions the age difference in recollection was eliminated: Both age groups showed an equivalent increase in the number of correct Remember responses given to words studied under deep as compared to shallow encoding conditions. Lövdén, Rönnlund, and Nilsson (2002) similarly showed that participants of varying ages (35-90 years) gave more Remember responses to words studied under elaborative instructions as compared to an intentional study condition. However, the level of improvement was found to vary with age, with larger improvements in younger participants.

An additional question in my thesis, explored in Experiment 6, was whether instructional manipulations that encourage elaborative processing of the link between item and context at encoding would increase recollection benefits attained from contextual information provided at study, particularly in older adults. I show that recollection is higher when participants are instructed to associate the item and context information (e.g., does the face ‘match’ the target word?), as compared to when instructions focus on featural processing of the context (e.g., is the face male or female?) in both younger and older adults. This finding thus suggests that strategic, or elaborative processes, are needed to develop associations, or links, between item and context information at study, which enhance later recollection of target items.

3.2 Experiment 5

In this experiment, I examined how the richness of contextual information provided at study influenced later memory performance in younger and older adults. Participants studied words presented with either a picture of a face (high meaningful context condition) or a rectangle (low meaningful context condition), and the remember-know procedure was subsequently used to test recognition memory for the words presented alone. Since Experiments 1-3 demonstrated that younger adult participants can use face contexts to improve subsequent item recollection, I again selected face stimuli for the high meaningful context condition. In contrast, a picture of a rectangle was selected for the low meaningful context condition, as it provides relatively little unique context information that can be used to develop rich memory traces. I expected recollection to be higher for words studied with high, relative to low, meaningful context information in younger adults, since they should be able to effectively use the face context at study to develop distinctive memory traces. To the extent that this effect depends on one’s ability to engage in processes that bind contexts high in meaningful content provided at study to the words, and that older adults have an associative binding deficit (Naveh-Benjamin, 2000), older adults, in contrast, were expected to show similar levels of recollection across the two study trial types. Know responses, which do not require retrieval of any contextual details, were expected to be unaffected by the manipulation of context during encoding, and unaffected by aging.

Method

Participants. Thirty people took part in the experiment. Fifteen healthy undergraduate students from the University of Waterloo received course credit or token monetary remuneration and 15 older adults recruited from the Waterloo Research in Aging Pool (WRAP) at the University of

Waterloo received token monetary remuneration for participating in the study. The WRAP pool is a database of healthy seniors in the Kitchener-Waterloo area recruited by means of newspaper ads, flyers, and local television segments. The mean age was 19 years (SD = 1.44, range = 17-22) for the younger adults and 74 years (SD = 5.79, range = 64-82) for the older adults. All participants were fluent English speakers, and had normal or corrected-to-normal hearing and vision. The mean numbers of years of education were 13.73 (SD = 1.53) and 13.60 (SD = 1.30) for the younger and older adult groups respectively, which did not differ significantly. The National Adult Reading Test – Revised (NART-R) was also administered to allow an estimate of Full Scale IQ (FSIQ), based on number of errors in pronunciation during vocabulary reading (Blair & Spreen, 1989; Nelson, 1982). Younger and older adults had mean FSIQ estimates of 107.16 (SD = 6.56) and 116.36 (SD = 6.48) respectively, which differed significantly, $t(28) = 3.87$, $p = .001$. Older adults were also administered the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) to screen for gross neurological conditions. All had MMSE scores of greater than 27/30 (M = 29.27, SD = 0.88), indicating they were free from major cognitive and neurological impairments.

Materials. Stimuli for the memory tasks were medium to high frequency words chosen from Celex, a lexical database available on CD-ROM (Baayen et al., 1995). Two-hundred-twenty-five words were randomly chosen for use in three different study-test cycles. In each of these cycles, the study list was comprised of 50 words: 25 were paired with pictures of faces and 25 were paired with a white rectangle. A corresponding list was created for use in the subsequent recognition test, consisting of the 50 studied words plus 25 lures (words not presented in the study phase). Thus, across the three study-test cycles, 75 words were paired with pictures of faces, 75 with the picture of a white rectangle, and 75 served as lures. Three different study-test list combinations were created such that each word was paired with either a picture of a face, a rectangle, or served as a lure across lists, counterbalanced across participants. The order of presentation of the word lists for the three study-test cycles was also counterbalanced across participants. All test lists were equated on letter length (M = 6.31), and word frequency (M= 18.27 occurrences per million; Baayen et al., 1999). An additional 30-item word list was used in the practice session, with the same characteristics as the words in the experimental session.

Face stimuli were taken from the AR face database which contains black and white photographs showing the frontal view of male and female faces, approximately 25-40 years of age (Martinez & Benavente, 1998). Seventy-five faces with neutral expressions, 38 male and 37 female, were randomly chosen to serve as the face stimuli. The face stimuli were randomly assigned to 25 words for each study list; thus, all study words were paired with a unique face. An additional 8 face stimuli were chosen to be used in the practice session. The rectangle stimulus was created in Microsoft Paint by drawing the black outline of a box on a white background in the same dimensions as the face stimuli, which was 18 x 16 cm.

Procedure. Stimulus presentation and response recording were controlled by an IBM PC, using E-prime v.1.1 software (Psychology Software Tools Inc., Pittsburg, PA). Participants were tested individually, and completed the experiment in approximately one hour. All participants began by performing the NART - Revised and older adults were also administered the MMSE. Participants were then given a short practice block consisting of 16 study trials in which 8 face-word and 8 rectangle-word items were presented visually, in random order, using the same timings and procedure as in the experimental trials (described below). Subsequently, remember-know test response instructions were given (see below), and 15 recognition trials consisting of 4 words studied with faces, 4 words studied with rectangles, and 7 new words, presented in random order, were presented visually.

The test instructions for the remember-know task were as follows: Participants were told that they would see some words that were from the study list, and other words that were not. If they believed the word was not from the study list, participants were instructed to respond “N” for New by pressing the ‘3’ key on the numerical keypad of a standard computer keyboard. If they thought the word was from the study list, they had two options, “R” or “K”. They were told to report “R” for Remember by pressing the ‘1’ key if the word was ‘old’ and they could recall specific details associating that word with the study episode. They were given examples of such details: They may remember an image, thought, or feeling that they had associated with the word during study, or the temporal order of the words, or the like. These contextual details meant they had a specific recollection of that word. If however, they believed the word to be ‘old’ but they did not recall a specific study detail associated with the word, they were asked to report ‘K’ for Know by pressing the ‘2’ key. To clarify the “K” memory response, participants were also given the example of meeting someone on the street that they knew they had met before, but not being able to determine the specific instance in which they had met them. Participants were then asked if they understood the distinction between “R” and “K” responses and, after the practice session, participants were asked to give the details of the context accompanying a response to the experimenter, in order to ensure that they understood the difference between "R" and "K", and that they were not responding simply on the basis of response confidence.

Following practice, participants completed the three study-test cycles. I used 3 study-test cycles in the design to increase the number of trials associated with each encoding trial-type (word paired with face and word paired with rectangle), while lessening the memory demands of each individual recognition task. For each of the 3 study phases, a trial began with a picture of a face or a rectangle appearing on the screen for 1000 ms centered in the upper area of the screen (screen coordinates: X = 324, Y = 180). A word presented in 28 point bold Arial font then appeared directly below the picture for 2000 ms (X = 324, Y = 379), after which both the picture and the word disappeared, followed by a 500 ms fixation cross presented centrally. In each of the three study phases, 50 trials were presented (25 face-word and 25 rectangle-word), with trial type randomized. All stimuli were presented in a fully illuminated room on a 17 inch (43.18 cm) computer screen, and the viewing angles of the picture and word stimuli were approximately 16.6º and 5.7º respectively. Participants were asked to memorize the words for an upcoming memory test. To ensure that participants encoded the context (face or rectangle) during study, participants were also asked to manually identify, for each study trial, the picture presented with each word as either a face or rectangle, by making a button press. Participants were not provided specific instructions on how to process the contextual stimuli. Each trial lasted 3.5 s, and participants were asked to make their classification response during this time.

After each study phase, participants counted backwards by threes for 30 seconds. During the ensuing test phase, 75 words (25 studied with faces, 25 studied with rectangles, and 25 lures) were presented in a randomized order. The words were presented in the centre of the screen in the same font and size as at study. Participants were asked to make a Remember, Know, or New response by pressing one of three buttons (1, 2, or 3 on the keyboard). The word remained on the screen for 4000 ms, followed by a fixation cross for 250 ms. Participants could make their response anytime within the 4250 ms of each recognition trial. They were told that four seconds should be enough time to make their response and that, if they did miss a word, they should not worry, and just try to complete the next trial. Participants were given a short break (approximately 2 minutes) between each study-test cycles. The order of presentation of the word lists for the three study-test cycles was counterbalanced across participants.

Results

All analyses were evaluated at the $\underline{p} \leq .05$ level unless otherwise noted.

Identification task performance. Data from the identification task, performed during the study phase, were analyzed using a 2 (Context: face or rectangle) x 2 (Age group) ANOVA. Mean accuracy (measured as hit rate – false alarm rate) on the identification task in younger and older adults was .97 (SD = .02) and .92 (SD = .23) for faces, and .97 (SD = .02) and .98 (SD = .03) for rectangles, respectively. Although speed of responding had not been emphasized during the identification task, I nonetheless examined these data. The mean response time (RT) in milliseconds to correct responses in younger and older adults was 1133 ms (SD = 685) and 999 ms (SD = 492) for faces, and 1112 ms (SD = 706) and 992 ms (SD = 519) for rectangles, respectively. The main effects of Context and Age group, as well as the interaction, for accuracy and RT were non-significant (Fs < 1.0).

Memory task performance. Table 2 shows the means for each memory measure, trial type, and age group, collapsed across the three recognition tests. Overall memory performance was analyzed using hit rate minus false alarm rate as the dependent measure (since false alarm rate was the same for both trial types), as well as d'. For each measure, data were first analyzed in a 2 (Context: encoded with a face or encoded with a rectangle) x 2 (Age group) x 3 (Study-Test Cycle) x 3 (List order) ANOVA. Since the latter two variables produced non-significant main effects and interactions, data were collapsed across these variables and analyzed in a 2 x 2 ANOVA.

I analyzed recognition accuracy (measured as number of hits out of 25 – number of false alarms out of 25, for each word type) to determine whether there was an overall memory boost for words studied with faces as compared to rectangles. There was a main effect of Context, with higher accuracy for the words studied with faces than for the words studied with rectangles, F (1, 28) = 4.99, MSE = .01. The effect of Age group was also significant, F (1, 28) = 10.79, MSE = .21, with younger adults showing higher recognition accuracy than older adults. These effects were accompanied by a marginally significant Context x Age group interaction, F (1, 28) = 3.91, MSE = .10, p < .06. Planned comparisons showed that memory accuracy was higher for words studied with faces than words studied with rectangles in the younger adults, t (14) = 3.27, but that this was not true in the older adults, t (14) = 0.17. Analysis of d' also showed a main effect of context, F (1, 28) = 5.95, MSE = .17, a main effect of Age group, F (1, 28) = 14.75, MSE = 7.10, and a trend towards a significant Context x Age Group interaction, F (1, 28) = 3.21, MSE = .09, $p < .10$. As in the analysis of overall memory performance, planned comparisons showed that d' was higher for words studied with faces than words studied with rectangles in the younger adults, t (14) = 3.53, but that this was not true in the older adults, t (14) = 0.40.

I then analyzed accuracy of Remember (number of correct Remember responses out of 25 – number of false Remember responses out of 25, for each word type) and Know (number of correct Know responses out of 25 – number of false Know responses out of 25, for each word type) responses in two separate 2 (Context) x 2 (Age group) x 3 (Study-Test Cycle) x 3 (List order) ANOVAs. Since the latter two variables again produced non-significant main effects and interactions, data were collapsed across these variables and analyzed in a 2 x 2 ANOVA. For Remember responses, there was a main effect of Context, with higher accuracy for words studied with faces than words studied with rectangles, F (1, 28) = 9.18, MSE = .05 (see Figure 5). The main effect of Age group was not significant, F (1, 28) = 2.46. Importantly, there was a significant Context x Age group interaction, F (1, 28) = 8.98, MSE = .05. Planned comparisons showed that younger adults had higher Remember accuracy for words studied with faces as compared to words studied with rectangles, t (14) = 3.57, but that Remember accuracy did not vary with Context in the older adults, t (14) = 0.32. Retrospective power analysis showed that, for estimates of recollection in older adults, d = .01, and that with a power estimate of .80, I would need to run 106,003 older adults to obtain a significant effect of context on recollection.

Table 2.

Experiment 5. Mean Memory Performance and Response Time in Milliseconds for Words studied with Faces (Face) Versus Rectangles (Rectangle), in Younger and Older Adults.

	Face		Rectangle	
Measure	Younger Adults	Older Adults	Younger Adults	Older Adults
Overall Hit Rate	.80 (.14)	.70 (.15)	.70 (.16)	.70 (.14)
Overall FA Rate	.15 (.11)	.24 (.15)	.15 (.11)	.24 (.15)
Remember Hit Rate	.52 (.23)	.41 (.20)	.40 (.20)	.41 (.22)
Remember FA Rate	.02 (.02)	.07 (.08)	.02 (.02)	.07 (.08)
Know Hit Rate	.27 (.19)	.29 (.21)	.24 (.19)	.29 (.20)
Know FA Rate	.13 (.10)	.17 (.11)	13 (.10)	.17 (.11)
IRK Familiarity	.24 (.22)	.14 (.25)	.33 (.17)	.14 (.21)
d’	2.11 (.55)	1.35 (.51)	1.92 (.52)	1.32 (.44)
RT Remember Responses	1161 (166)	1650 (403)	1250 (207)	1656 (456)
RT Know Responses	1600 (429)	2013 (540)	1578 (390)	2003 (647)

Note: FA = false alarm; IRK Familiarity was calculated as F = K / (1-R); RT = response time in milliseconds; Standard deviation shown in parentheses.

For Know responses, there was no effect of Context, $F(1, 28) = 3.68$ or Age group $F(1, 28) = 1.24$, and no interaction, $F(1, 28) = 3.53$. I also calculated IRK familiarity, and again found no main effect of Context, $F(1, 28) = 2.61$, or Age group, $F(1, 28) = 3.68$, and no interaction $F(1, 28) = 2.56$. Retrospective power analyses were performed on IRK familiarity separately for both younger and older adults. They showed that d = .19 for younger and .01 for older adults and, with a power estimate of .80, I would need to run 220 younger and 15,235 older participants to obtain a significant effect of context.

Although RT was not emphasized at retrieval, I examined these data in two separate 2 (Context) x 2 (Age group) ANOVAs for correct Remember and Know responses. There was no effect of Context, nor did it interact with Age group for either Remember or Know responses. There was, however, a main effect of Age group for both Remember, F (1, 28) = 14.30, MSE = 2997859.18, and Know, F (1, 28) = 5.23, MSE = 2543973.99, responses, with slower response in older adults.

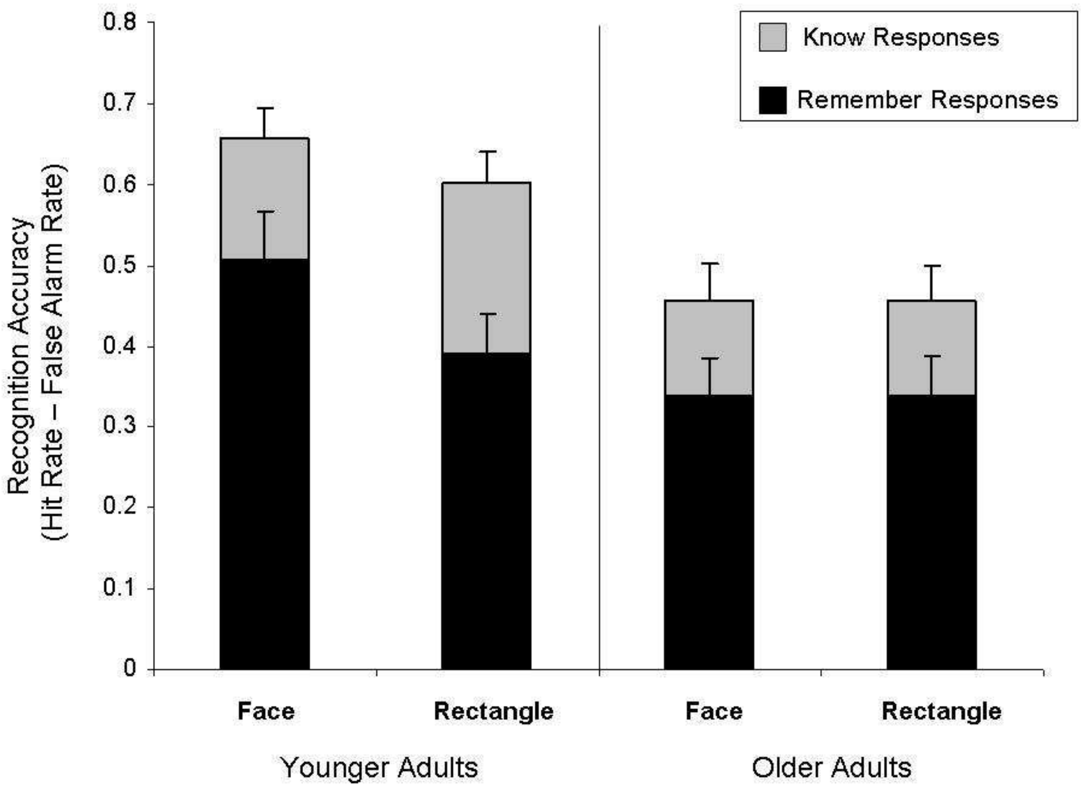

Figure 5. Mean recognition accuracy in Experiment 5, for words presented together with pictures of faces (Face) or with a rectangle (Rectangle) during study, in younger and older adults. Grey bars show Know accuracy and black bars show Remember accuracy, measured as hit rate - false alarm rate. Error bars show the standard error of the mean.

I also examined whether there was a correlation between RT on the identification task performed at encoding and later recollective memory performance, though, due to the small number of participants in each age group in this experiment, the data should be interpreted with caution. The correlations with face and rectangle RT were non-significant in younger adults ($\underline{r}$ = .15 and .30, respectively). In older adults, a significant correlation was found such that as RT to identify the stimulus at encoding as a face increased, so did later recollection of words initially paired with faces ($\underline{r}$ = .64). This similar correlation, with the rectangle identification RT and later recollection, was only marginally significant ($\underline{r}$ = .49, $\underline{p}$ < .08).

<u>Discussion</u>

This experiment examined whether providing meaningful context information during study of words improves later recollection of the words when presented alone at retrieval, and how age interacts with this effect. Younger adults showed better memory for words that were studied with pictures of faces (high meaningful context condition) than for words studied with rectangles (low meaningful context condition), and this effect was specific to Remember responses during later retrieval. This result shows that younger adults are more likely to recollect items that are presented with context information high in meaningful content at study. In contrast, older adults did not show an overall memory or recollection benefit for words initially encoded with faces compared to rectangles.

It could be suggested that the older adults did not show a recollection benefit in the high meaningful context, as compared to the low meaningful context, condition because they spent more time processing the face than rectangle stimuli during study. If more attention was given to the face than rectangle stimuli at study, memory for the words studied with faces would suffer. By this explanation, older adults were unable to benefit from the high meaningful context condition because they were distracted by the complex (face) stimuli during study. Although there is evidence that older adults are more likely to process task irrelevant stimuli (Lustig, Hasher, & Tonev, 2006), this does not appear to have been a factor in my experiment. My data show no age differences in accuracy or RT on the identification task (face/rectangle classification) performed during encoding. As well, the only significant correlation was between RT to classify a face during encoding and later recollection, in older adults only. This positive correlation is not in the direction to support the hypothesis that the face stimuli held the attention of older adults, and this produced lower subsequent recollection of the words paired with faces. Instead, longer RTs to classify face stimuli during encoding were associated with a higher, rather than a lower, proportion of accurate Remember responses. Although I acknowledge that response time was not emphasized in the identification task, this finding suggests that older adults' recollection benefits, rather than suffers, when additional processing time is devoted to the picture (face) stimuli. It is possible that this correlation represents the successful binding of face-word pairs during encoding in the older adult group, though this explanation is speculative.

Experiment 5 replicates, conceptually, the data of Luo et al. (2007), showing that provision of context at study can improve later recollective memory processes in younger, but not older, adults. Neither their experiment, nor this one, however, specifies the cognitive processes that are deficient in older adults, or examines whether there are ways of overcoming this age-related deficit. As outlined in the Introduction, I hypothesized that context information high in meaningful content allows younger adult participants to engage in controlled encoding processes that promote the binding of item and context information into a distinctive/detailed memory trace. Younger participants, unlike old, may be more likely to elaborate a link, or an association, between faces and words, which promotes the binding of item-context information, accounting for the boost in recollection. Support for this hypothesis comes from work showing that elaborative processing exclusively boosts Remember, and not Know, responses in younger adults (Gardiner et al., 1996). In addition, the post-experiment questioning from Experiment 2, reported in the General Discussion of Chapter 2, suggests that younger adult participants were developing stories or making subjective judgments to link the word to the face during study to improve their later memory performance.

This may explain why older adults did not show a memory boost when the face contexts were provided during study: They did not engage in elaboration of the face-word pairings, making binding of the context-word pairing less likely, and preventing subsequent recollection responses. Such a claim is in line with previous work showing that older adults do not voluntarily engage in elaborative processing during study (Craik & McDowd, 1987). In addition, to my surprise, the older adults appeared to perform the identification task at study faster than younger adults, although this difference did not reach significance. Given that the opposite effect would be predicted, as research shows a slowing in processing speed with age (Salthouse, 1996), this may show that younger and older adults approached the tasks with different strategies. For example, older adults may have made the identification task as soon as possible so they could focus attention on the study word, whereas the younger adults, who used the face contexts to improve subsequent recollection, may have been more likely to spread attention across the item-context pairs throughout the study task.

If differences in the ability to elaborate a link between item and context information at encoding are the source of the age-related deficit found in Experiment 5, providing specific instructions to engage in such processing may help to alleviate this deficit. My hypothesis is supported by other research showing that recollection is higher in older adults when instructions provided at study encourage deep, elaborative processing as compared to shallow (Perfect et al., 1995; Pierce, Sullivan, Schacter, & Budson, 2005) or intentional (Lövdén et al., 2002) encoding.

3.3 Experiment 6

In Experiment 6, I examined whether providing explicit instructions on how to encode the context presented during the study phase affected later recollection of words. In so doing, I aimed to determine a) what types of cognitive operations are required to promote recollection, and b) whether age deficits in the use of context information to boost subsequent recollection can be alleviated by providing explicit instructions to engage in elaborative processes at encoding.

In this experiment, another group of younger and older adults studied words that were paired with pictures of faces in two different study sessions. In each session, a different type of encoding instruction was given. In one, participants were asked to identify the gender of the face (surface feature condition). In the other, participants were asked to state whether the word ‘matched’ the face (binding feature condition). Participants were given examples of what might constitute a ‘match’ or a ‘mismatch’ response (for example, participants might state match if the word ‘juice’ was below a face that looked as though it would enjoy drinking juice or ‘mismatch’ if the word ‘frantic’ appeared below a face with a calm expression) and were told that their responses were purely subjective. These instructions were chosen because, whereas the binding feature condition encourages participants to develop a link or an association between the context and item information, the surface feature condition does not require such processing. Participants then made Remember, Know, or New decisions on the words presented alone, as in Experiment 5. If the ability to use rich contextual information to boost subsequent recollection depends on the extent to which a link or an association is developed between the item and context information, recollection of words studied with faces should be higher in the binding feature condition than in the surface feature condition. As well, if a difference in the ability to elaborate a link between item and context information at encoding is the source of the age-related deficit in recollection in Experiment 5, providing specific instructions to engage in such processing may help to alleviate this deficit in older adults. Thus, I expected that Remember accuracy would be higher in both younger and older adults for words studied with faces in the binding condition than in the surface feature instruction condition.

Method

Participants. Thirty-two people, naïve to the experiment, participated. Sixteen healthy undergraduate students from the University of Waterloo received course credit and 16 older adults recruited from the Waterloo Research in Aging Pool (WRAP) at the University of Waterloo received token monetary remuneration for participating in the study. The mean age was 21 (SD = 1.71, range = 18-24) for the younger adults and 73 (SD = 3.24, range = 69-80) for the older adults. All participants were fluent English speakers, and had normal or corrected-to-normal hearing and vision. The mean numbers of years of education were 14.69 (SD = 1.35) and 14.94 (SD = 1.48) for the younger and older adult groups respectively, which did not differ significantly. FSIQ was also determined by administering the NART-R. Younger and older adults had mean FSIQ estimates of 107.50 (SD = 8.55) and 120.07 (SD = 5.23) respectively, which differed significantly, t (30) = 5.02, p < .001. Older adults were also administered the MMSE to screen for gross neurological conditions, and all had MMSE scores of greater than 27/30 (M = 28.87, SD = 0.72), indicating that they were free from major cognitive and neurological impairments.

Materials. Word stimuli for the memory tasks were drawn from the same pool used for Experiment 5. For each of the two study-test cycles, the study list consisted of 45 words paired with pictures of faces. A corresponding list was created for use in the subsequent recognition test, consisting of the 45 studied words plus 45 lures. The word lists were counterbalanced such that each word list was studied with each of the instruction conditions across participants. The word lists were equated on letter length (M = 6.28) and word frequency (M = 17.64 occurrences per million; Baayen et al., 1999). An additional 36 words were used in the two practice sessions.

Face stimuli were chosen from the same database used for Experiment 1. Ninety faces with neutral expressions, 50 male and 40 female, were chosen, and randomly assigned to the 45 words from each study list (balancing for gender), with an additional 18 faces chosen to be used in the practice sessions.

Procedure. The procedure was similar to Experiment 5. Participants first performed the NART-R and older adults were also administered the MMSE. Participants then completed the first practice block and study-test session 1, followed by a second practice block and study-test session 2, with the order of study instructions counterbalanced across participants (Order factor). For each of the practice blocks, participants saw 9 face-word pairs, in random order, using the same timings and procedure as in the experimental trials (described below). Subsequently, remember-know test response instructions were given (as in Experiment 5), and for each practice block, 18 recognition trials consisting of the 9 study words and 9 new words, presented in random order, were presented.

For each study phase, a trial began with a picture of a face appearing above a word stimulus (same display, positions, viewing angles, and font as in Experiment 5) for 3000 ms, after which both the picture and the word disappeared, followed by a 500 ms fixation cross presented centrally. Participants were asked to memorize the words for an upcoming memory test. In addition, participants were instructed to make a decision on each face by making a button press. In the surface feature condition, participants were asked to identify whether the face was male or female. In the binding feature condition, participants were asked to state whether the face 'matched' the word. They were given examples of what a yes or no answer may be (for example, a face paired with the word 'juice' may or may not match the face if the person looked like they did or did not enjoy drinking juice). All participants were told that their responses were subjective, that there were no right or wrong answers, and that they could respond any time within the 3500 ms of each trial. In order to ensure that participants understood the instructions, they were asked to give an example of a response after the practice phase. The instruction conditions were counterbalanced across participants, such that half of the participants performed the surface feature, and half the binding feature, condition first.

After each study phase, participants counted backwards by threes for 30 seconds. During each test phase, the 45 study words and 45 lure words were presented alone in a randomized order, with the same presentation rate and display as in Experiment 5. Participants were asked to make a manual Remember, Know, or New key press response. Participants were given a short break (approximately 2 minutes) between the two study-test cycles.

Results

All analyses were evaluated at the $\underline{p} \leq .05$ level unless otherwise noted.

Study task performance. Mean accuracy (measured as hit rate – false alarm rate) on the surface feature study task for the younger and older adults was .98 (SD = .03) and .98 (SD = .03) respectively, and did not differ between age groups, $\underline{t}$ (30) = 0.67. The mean proportion of faces that were deemed to 'match' the word in the binding feature study task in the younger and older adults was .41 (SD = .23) and .40 (SD = .15) respectively, which also did not differ between groups, $\underline{t}$ (30) = 0.18. As in Experiment 5, although speed of responding had not been emphasized during the encoding task, I nonetheless examined these data in a 2 (Instruction: feature or binding) x 2 (Age group) ANOVA. The mean RT in milliseconds in younger and older adults was 1175 ms (SD = 325) and 1364 ms (SD = 315) for the surface feature condition, and 1576 ms (SD = 350) and 1969 ms (SD = 236) for the binding feature condition, respectively. The analysis showed a main effect of Instruction, $\underline{F}$ (1, 30) = 78.61, MSE = 405385.03, with longer RTs in the binding than in the surface feature condition, and a main effect of Group, $\underline{F}$ (1, 30) = 9.71, MSE = 1357429.88, with longer RTs in the older than younger adults. The interaction was not significant, $\underline{F}$ (1, 30) = 3.23.

Memory task performance. Table 3 shows the means for each memory measure, condition, and age group. In keeping with the previous experiments, overall memory performance was analyzed using hit rate minus false alarm rate as the dependent measure, as well as d', although false alarm rate now differed between the two conditions. Data were analyzed in a 2 (Instruction) x 2 (Age group) x 2 (Order) ANOVA, with the first variable within and the latter two variables between participants.

I analyzed recognition accuracy (measured as hit rate out of 45 – false alarm rate out of 45) to determine whether the binding feature instruction improved overall memory for words as compared to the surface feature instruction. There was a main effect of Instruction, with higher accuracy for the words studied under the binding feature than the surface feature instruction, $\underline{F}$ (1, 28) = 41.25, $\underline{MSE}$ = .31. There was no effect of Age group, $\underline{F}$ (1, 28) = 2.09. There was, however, an Instruction x Age group interaction, $\underline{F}$ (1, 28) = 5.48, $\underline{MSE}$ = .04, and planned comparisons showed that memory accuracy was higher for words studied under the binding than surface feature condition in both age groups (younger adult, $\underline{t}$ (15) = 6.03, older adults, $\underline{t}$ (15) = 2.11), although the size of the difference between these two conditions was larger in younger adults. I calculated a difference score such that memory accuracy in the surface condition was subtracted from the binding condition. The mean score was .19 (SD = .13) in younger and .09 (SD = .15) in older adults, which differed significantly, t (30) = 2.09. Analysis of d' showed a similar pattern of results.

The ANOVA also showed an Instruction x Order interaction, $\underline{F}$ (1, 28) = 9.02, $\underline{MSE}$ = .07. Post-hoc comparisons showed that participants in both task order 1 (surface feature followed by binding feature instruction condition) and task order 2 (binding feature followed by surface feature instruction condition) showed higher memory accuracy in the binding than surface feature condition, $\underline{t}$ (30) = 6.02, and $\underline{t}$ (30) = 2.41, respectively, although a calculation of difference scores (as above) showed that the effect was larger for those in task order 1. The mean difference score was .21 ($\underline{SD}$ = .14) for participants in task order 1 and .07 ($\underline{SD}$ = .12) for participants in task order 2, which differed significantly, $\underline{t}$ (30) = 2.90. There was no Order x Age group, or Instruction x Order x Age group interaction. A similar pattern of results was found when d' was analyzed.

I then analyzed accuracy of Remember (Remember hit rate – Remember false alarm rate) and Know (Know hit rate – Know false alarm rate) responses in two separate 2 (Instruction) x 2 (Age group) x 2 (Order) ANOVAs. For Remember responses, there was a main effect of Instruction, with higher Remember accuracy for words studied under the binding feature than surface feature instructions, $F_{(1, 28)} = 21.47$, $MSE = .40$ (see Figure 6). There was no effect of Age group, $F_{(1, 28)} = 0.76$ and no Instruction x Age group interaction, $F_{(1, 28)} = 1.40$.

Table 3

Experiment 6. Mean Memory Performance and Response Time in Milliseconds for Words Studied Under Binding Processing Instructions Versus Surface Feature Processing Instructions, in Younger and Older Adults.

	Binding		Feature	
Measure	Younger Adults	Older Adults	Younger Adults	Older Adults
Overall Hit Rate	.82 (.15)	.76 (.12)	.67 (.14)	.71 (.14)
Overall FA Rate	.12 (.09)	.19 (.14)	.16 (.12)	.23 (.17)
Remember Hit Rate	.64 (.22)	.61 (.17)	.44 (.19)	.51 (.14)
Remember FA Rate	.04 (.05)	.10 (.07)	.06 (.09)	.10 (.09)
Know Hit Rate	.19 (.17)	.15 (.13)	.23 (.15)	.20 (.13)
Know FA Rate	.09 (.07)	.09 (.14)	.11 (.12)	.12 (.09)
IRK Familiarity	.22 (.33)	.11 (.28)	.17 (.23)	.12 (.25)
d’	2.36 (.92)	1.80 (.68)	1.63 (.60)	1.57 (.72)
RT Remember Responses	1333 (303)	1474 (424)	1342 (289)	1389 (332)
RT Know Responses	2169 (498)	2147 (665)	2044 (491)	2233 (579)

Note: FA = false alarm; IRK Familiarity was calculated as F = K / (1-R); RT = response time in milliseconds; Standard deviations shown in parentheses.

The analysis for Remember accuracy also showed a significant Instruction x Order interaction, F (1, 28) = 10.23, MSE = .19, and post-hoc comparisons showed that although there was a significant effect of instruction in task order 1 (surface feature followed by binding feature instruction condition), $\underline{t}$ (15) = 4.85, this was not true for task order 2 (binding feature followed by surface feature instruction condition), $\underline{t}$ (15) = 1.15. There was no Order x Age group, $\underline{F}$ (1, 28) = 0.76, or Instruction x Order x Age group interaction, $\underline{F}$ (1, 28) = 0.07.

The analysis for Know responses showed no effect of Instruction, $\underline{F}$ (1, 28) = 0.54, Age group, $\underline{F}$ (1, 28) = 0.73, and no interactions. A similar pattern was found when I calculated IRK familiarity. Retrospective power analyses were performed on IRK familiarity separately in both younger and older adults. They showed that $\underline{d}$ = .20 for younger and .04 for older adults and, with a power estimate of .80, I would need to run 1,901 younger and 5,950 older participants to obtain a significant effect of context.

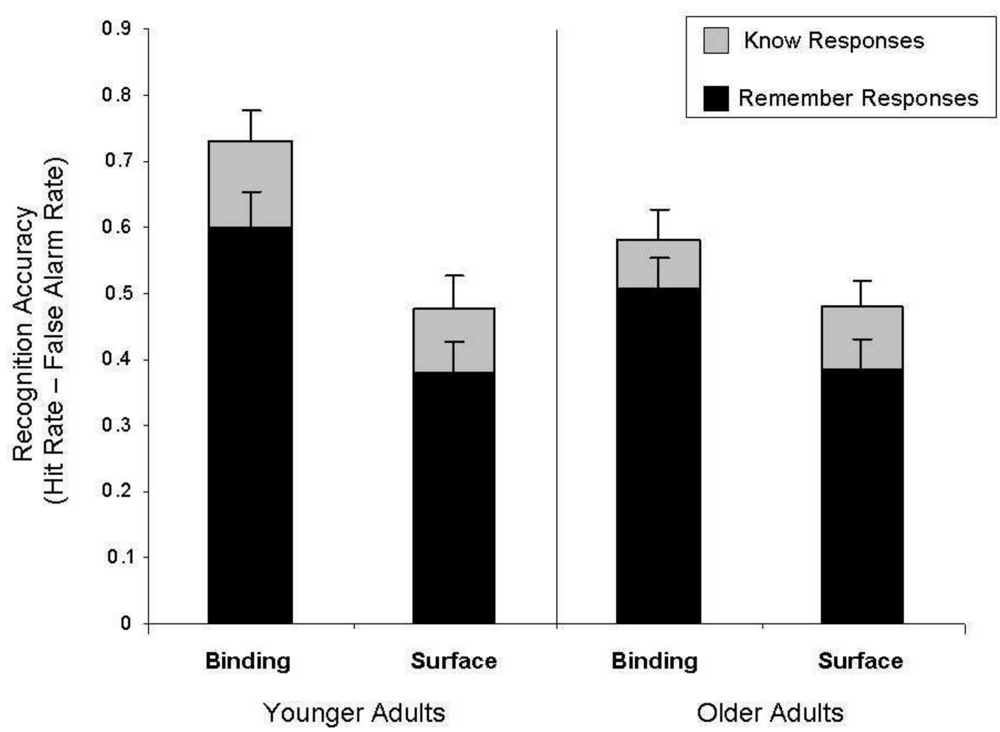

Figure 6. Mean recognition accuracy in Experiment 6, for words studied with faces under surface feature processing instructions (Surface) or binding feature processing instructions (Binding) in younger and older adults. Grey bars show Know accuracy and black bars show Remember accuracy, measured as hit rate - false alarm rate. Error bars show the standard error of the mean.

I again analyzed RT at retrieval for correct Remember and Know responses in a 2 x 2 x 2 ANOVA, although RT was not emphasized. For Remember responses, there was no effect of Instruction, $\underline{F}$ (1, 21) = .02, but there was a main effect of Age group, $\underline{F}$ (1, 21) = 5.09, $\underline{MSE}$ =607140.17, with responses slower in the older adult than younger adult group. There was also a main effect of Order, $\underline{F}$ (1, 21) = 7.05, $\underline{MSE}$ = 841092.27, with slower response times in participants in task order 1 than task order 2. None of the interactions were significant. The analysis for RT to Know responses did not show a main effect of Instruction, Age group, or Order, and there were no significant interactions.

Discussion

This experiment examined whether providing explicit instructions on how to encode context information during the study phase affected later recollection of words, and whether age deficits in the use of highly meaningful context information to boost subsequent recollection, found in Experiment 5, could be alleviated by providing explicit instructions to engage in elaborative processes at encoding. Both age groups showed an increase in overall memory in the binding relative to the surface feature condition, and this benefit was larger in the younger group. Critically, recollection increased when encoding instructions encouraged the binding of item and context information, and most importantly, this boost in recollection occurred in both younger and older adults. Thus, unlike in Experiment 5, older adults now showed a boost in recollection from a high meaningful context encoding condition.

I did find a task order interaction, however, such that participants who performed the binding feature condition first, then the surface feature condition, showed a smaller change in overall memory accuracy and Remember accuracy between the two instruction conditions. The finding suggests that once participants begin to use binding feature processing operations, it is difficult to switch to less elaborative surface feature operations. This finding is similar to that obtained in studies where participants are taught to use imagery or verbal mediators to link word pairs, which demonstrate that participants abandon ineffective rote rehearsal strategies as they adopt more effective imaginal and verbal mediation strategies (Paivio & Yuille, 1969). Importantly, the task order effect was found in both younger and older adults, suggesting that older adults continued to benefit from the provision of binding feature instructions across tests. This suggests that, once given the opportunity to engage in cognitive operations that encourage the binding of information, older adults (as well as young) will continue to do so, even when the task instructions do not explicitly require binding.

3.4 General Discussion of Chapter 3 Experiments

I examined whether providing a context high in meaningful content during study altered the quality of subsequent memory for words, using a remember-know paradigm. I was specifically interested in whether the level of meaning in the context information present at study affected recollection and familiarity-based memory, and whether normal aging interacted with these effects. In addition, I examined how providing instructions on how to process the context at study altered later recollection in younger and older adults. In Experiment 5, I found that younger, but not older, adults showed a recollection benefit when context high in meaningful content was provided at study. In Experiment 6, I found that this recollection benefit depended on the type of instructions given during encoding. Specifically, recollection was higher when participants were instructed to develop links or associations between the word and context information at encoding. Importantly, this was found in both younger and older adults, indicating that older adults can use context provided at study to improve later recollection, although they do not do so spontaneously. These results are discussed in turn.

Experiment 5 showed that younger adults had higher overall memory for words studied with pictures of faces relative to words studied with rectangles, and that this effect was specific to words that were given Remember responses. The finding demonstrates that recollective memory benefits when context high in meaningful content is provided at study. Older adults, however, did not show a recollection benefit when context information high in meaningful content was provided at study, suggesting that whereas younger adults spontaneously use contexts that are rich in meaning to boost subsequent recollection of target items, older adults do not.

This work both supports and extends the findings of Luo et al. (2007), who showed that recollective processes benefit when context is provided at study, but only in younger adults. The older adults in my sample were high-functioning, as indicated by their higher FSIQ estimate relative to younger adults, yet still showed relative deficits in recollection when highly meaningful context was provided during encoding. This suggests that the recollection deficit in normal aging cannot be due to differences in general intellectual capacity across age groups. Rather, the age difference in recollection appears to be related to a specific age-related deficit that affects the encoding and/or retrieval of rich contextual details.

Experiment 6 extended these findings by showing that older adults' recollection performance can benefit from context provided at study under some conditions. This was achieved by changing the instructions given during encoding. In both age groups, the binding feature condition led to an increase in the proportion of Remember responses relative to the surface feature condition. This finding suggests that recollection depends not on what context is presented at study per se, but on the cognitive operations performed on that context, with higher recollection resulting from conditions that promote associations between item and context information. In addition, the results show that older adults <u>can</u> use context provided at study to boost subsequent recollection, but that they do not do so spontaneously. This further suggests that older adults may be able to be trained to use context information to improve their later recollection. In line with this hypothesis, I found that the benefit to recollection in the binding compared to surface feature instruction condition was lower when participants performed the binding feature, rather than the surface feature, instruction first.

This suggests that once participants began to use an elaborative encoding strategy, they continued to use that strategy. Importantly, this was found in both younger and older adults, indicating that once older adults were taught an elaborative strategy, they continued to use this strategy of their own volition. This finding is in line with previous work showing that repetition-lag training programs can reduce recollection failures in older adults, and that such gains transfer to other tasks (Jennings, Webster, Kleykamp, &Dagenbach, 2005). As well, Bissig and Lustig (2007) recently showed that the usefulness of such training is dependent on the degree of elaborative encoding performed during study. Training older adults to develop associations between item and context information at encoding may thus improve memory performance and recollection in particular. Future research should examine whether training older adults to use binding or linking strategies at encoding can improve recollection performance on different tasks, and whether older adults can apply that strategy to novel tasks and environments.

Although I did find that instructions encouraging the association of item-context pairs boosted subsequent recollection in both younger and older adults, it should be noted that the manipulation did not eliminate age differences in recollection. As shown in Table 3, the binding feature instruction condition showed an age difference in Remember accuracy of approximately .10 (compared to an age difference of .17 in the high meaningful context (face) condition in Experiment 5; see Table 2). This suggests that although I was able to boost recollection in older adults by providing instructions that developed associations between item and context, I was not able to eliminate the associative deficit altogether. Recent work by Naveh-Benjamin, Brav, and Levy (2007) also suggests that instructional manipulations can alleviate, but not eliminate, age-related binding deficits. They examined whether instructional manipulations reduced the age-related associative deficit by having younger and older adults study word pairs under intentional encoding conditions, elaborative instructions at encoding, or elaborative instructions at encoding and at test. Although the associative deficit was reduced when participants were encouraged to use a verbal associating strategy at encoding, the deficit was not eliminated unless the verbal strategy was used at both encoding and retrieval. These results suggest that older adults may show even greater benefits in recollection performance if they are encouraged to reinstate the cognitive operations used at study to bind item and context information when they are retrieving item information, although future work is needed to test this hypothesis.

Although the current study focused on age-related deficits in the encoding of context information, the recent work by Naveh-Benjamin et al. (2007) suggests that the locus of the associative deficit is not solely at encoding, but involves retrieval as well. This claim stems from work showing that the successful retrieval of information often involves the deliberate use of controlled processes, such as the initiation and implementation of search strategies or complex decision making (Glisky et al., 2001; Moscovitch, 1994). In line with this, Glisky et al. (2001) suggested that active retrieval processes may be particularly required when source information is poorly encoded, such as when older adults are provided no instructional support at study. These studies suggest that age-related deficits in spontaneous use of context information to boost item recollection are likely related to reduced use of controlled processes at both encoding (i.e., elaboration) and retrieval (i.e., initiation of and recovery of source information).

There has been recent interest in determining whether an age-related reduction in attentional resources (Craik, 1986) is the mediating factor of the associative deficit observed by Naveh-Benjamin and colleagues (2000). Naveh-Benjamin, Guez, and Shulman (2004) had younger adults under full-attention, younger adults under divided-attention, and older adults under full attention study word pairs and perform subsequent item and associative recognition tests. They found that younger adults under divided attention had lower item and associative memory as compared to younger adults under full attention, whereas older adults showed only an associative deficit. This finding argues against the hypothesis that the associative deficit is mediated by reductions in attentional resources with age. Castel and Craik (2003) found similar results, in that, whereas younger adults under divided attention showed a decrease in hit rate, older adults showed an increase in false alarm rate on an associative recognition test (indicative of an associative deficit). However, Castel and Craik also showed that both divided attention and aging had greater effects on associative than item tests. They argue that this finding demonstrates that the associative deficit is not unique to aging.

An interesting extension to the work presented here would be to compare memory performance for words studied with meaningful context information in older adults and younger adults under divided attention. If older adults fail to show recollection benefits when meaningful context is provided at study because a reduction in attentional resources impairs their ability to engage in elaborative processes at study, younger adults under divided attention should show similar performance on this task as older adults under full attention conditions (i.e., similar memory performance when context information high and low in meaningful content is provided at study). However, if older adults fail to use study context to benefit recollection because of an associative deficit that is in addition to a reduction in attentional resources, older adults should show deficits on the task above that of the younger adults under divided attention conditions (i.e., divided attention conditions at study in younger adults participants will not eliminate recollection benefits when context information high in meaningful content is provided at study).

My findings contribute to recent interest in determining when older adults can (and cannot) use contextual information to improve their memory performance. My results showed that both younger and older adults can use context information to benefit subsequent recollection, but older adults do not spontaneously engage in these processes. Other work suggests there may be some situations in which older adults can spontaneously use contextual information to improve memory performance as well as younger adults. For example, age differences in source memory are eliminated when the context is affective in nature (Rahhal, May, & Hasher, 2002). More recently, May, Rahhal, Berry, and Leighton (2005) reported an age-related deficit when participants were asked to recall the perceptual (colour) or non-emotional conceptual details (luxury or economy) associated with a car at study, but there were no age deficits when asked to recall emotional details (safe or dangerous). It is therefore possible that older adults could spontaneously use affective contexts to increase later recollection, although further work is needed to determine whether this is true.

In summary, Experiment 5 showed that younger, but not older, adults showed a recollection benefit when a context high in meaningful content was provided at study. Experiment 6 showed that recollection was higher when participants were instructed to develop links or associations between the word and context information at encoding. Importantly, this was found in both younger and older adults, indicating that older adults can use context high in meaningful content provided at study to improve later recollection, although they do not do so spontaneously.

Chapter 4
Reactivation of Sensory-Specific Brain Regions during the Retrieval of Context Information

In this chapter, I examine how the provision of context information high in meaningful content at study affects the brain regions used to retrieve context information. The introduction begins with a discussion of neuroimaging as a technique to study memory processing and describes functional imaging findings relating to item and source memory retrieval. I then review findings from functional neuroimaging that have provided insights into the brain regions involved in recollection and familiarity, followed by an overview of the current study (Skinner et al., under review).

4.1 Functional Neuroimaging Findings of Memory Retrieval

Functional neuroimaging provides researchers the opportunity to examine the neural substrates of memory in the healthy brain, which has led to major discoveries regarding the brain regions involved in memory encoding and retrieval. While many earlier neuoimaging studies of memory used Positron Emission Tomography (PET) and block designs (e.g., Kapur et al., 1994; Schacter, Alpert, Savage, Rauch, & Alpert, 1996; Tulving, Kapur, Markowitsch, et al., 1994), more recent studies have employed event-related functional Magnetic Resonance Imaging (fMRI). This latter approach permits a more powerful examination of memory processes, as it allows researchers to estimate the hemodynamic responses for a single trial (Dobbins & Davachi, 2006). This is particularly important for memory research, in which the experimenter cannot predict the type of response (hit, false alarm, miss, correct rejection) that the participant will make for each item.

While neuropsychological studies of amnesic patients placed the focus of memory processing on the medial temporal lobe (MTL), early PET experiments of memory retrieval discovered prominent activations in the frontal lobes. For example, in an early PET study, Schacter et al. (1996)

showed that right hippocampal activity was higher when participants retrieved words from a test list in which there was a high level of recall, as compared to a low level of recall, but that right anterior prefrontal cortex (PFC) activity did not differ between conditions. This work suggested that while the medial temporal lobe sub-serves processes relating to the successful retrieval of the contents of memory, the right PFC sub-serves more general processes relating to retrieval. Indeed, comparisons of encoding and retrieval tasks showed that there is relatively greater activity in the left PFC during the encoding of information and relatively greater activity in the right PFC during the retrieval of information, a finding later termed HERA for hemispheric encoding-retrieval asymmetry (Nyberg, Cabeza, & Tulving, 1996: Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). Since frontal lobe patients were found to show subtle memory deficits only on tasks that depend on strategic control processes (Shimamura, Janowsky, & Squire, 1990), the finding that the right PFC was activated even during simple recognition tasks was quite surprising. Researchers have subsequently developed various theories regarding the role of the PFC at retrieval, including the participation in the establishment of retrieval mode (Lepage, Ghaffar, Nyberg, & Tulving, 2000; Tulving et al., 1994), retrieval effort (Schacter et al., 1996), monitoring and verification processes (Cabeza, Locantore, & Anderson, 2003; Henson, Shallice, & Dolan, 1999), or post-retrieval processing (Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996). Although these models posit different roles for the right PFC, what is common is that this region is implicated in control processes relating to retrieval, rather than in recovering the content of memories. This research shows that functional neuroimaging can provide unique insights into the neural correlates of memory retrieval.

Functional neuroimaging studies that have examined source memory retrieval can additionally help determine the brain regions involved in the retrieval of context information. Interestingly, these studies suggest that the left prefrontal cortex sub-serves processing relating to the retrieval of source information (Dobbins, Foley, Schacter, & Wagner, 2002; Nolde, Johnson, &

D'Esposito, 1998). For example, Rugg, Fletcher, Chua, and Dolan (1999) showed increased activation in the left anterior and inferior cortices when participants were required to judge which orienting task participants performed on the item at study, as compared to recognition memory. These findings converge with others suggesting that some control processes involved in memory retrieval rely on the left PFC (Dobbins & Wagner, 2005; Nolde et al., 1998).

Additional research suggests that source retrieval may rely on the hippocampus. In one study (Cansino, Maquet, Donlan, & Rugg, 2002), participants made natural/artificial judgments on common objects presented visually in one of four quadrants, and at retrieval performed a recognition and source memory test. Activation in the right hippocampal formation was higher when participants gave correct, as compared to incorrect, source memory judgments. Dobbins, Rice, Wagner, and Schacter (2003) additionally found that the hippocampus was recruited when participants were required to recover the encoding context at retrieval. However, other studies have failed to show differential activity in the hippocampus when source memory retrieval was compared to item memory retrieval (Fan, Snodgrass, & Bilder, 2003). In a more recent study, Tendolkar et al. (2008) manipulated the amount of source information retrieved. They showed that hippocampal activation was related to source retrieval generally (i.e., regardless of the amount of source information retrieved) and that a region of the posterior parahippocampus increased in activation as the amount of contextual information retrieved increased. These findings suggest that different regions of the medial temporal lobe may be involved in indexing different aspects of source retrieval.

4.2 Brain Regions Involved in Recollection and Familiarity

Insights into the brain regions involved in the retrieval of context information can also be gained by examining recollection and familiarity using fMRI. In a review of 12 studies that used event-related fMRI in conjunction with the 'remember-know', process dissociation procedure, or receiver operator characteristic memory paradigms, we showed that recollection and familiarity can be differentiated in four brain regions: the frontal lobes, the parietal lobes, the medial temporal lobes, and sensory-specific brain regions (Skinner & Fernandes, 2007). This was accomplished by identifying Brodmann Areas that showed intermediate and high levels of agreement (peak activation found for that Brodmann Area in ≥ 33% and 50% of the studies examined, respectively). Thus, while activation was found in many brain regions, we were able to specify the brain areas common to recollection and familiarity processing across studies. In the frontal lobes, whereas both recollection and familiarity were found to activate the right dorsolateral PFC, only recollection was associated with activity in anterior and superior frontal brain regions, suggesting that recollection involves additional control processes mediated by the frontal lobe. Additional lesion work supports this hypothesis, showing that patients with damage to the right inferior PFC show lower recollection estimates relative to controls (Levine et al., 1998; Levine, Freedman, Dawson, Black, & Stuss, 1999). In the parietal lobes, both recollection and familiarity were found to activate the precuneus, whereas recollection activated an additional region of the inferior parietal lobe. Vilberg and Rugg (2008) have additionally suggested that the inferior parietal lobe is preferentially involved in recollection. Skinner and Fernandes (2008) suggested that these frontal and parietal regions are part of a retrieval network, and that the strength of connections between these brain regions may help differentiate recollection- and familiarity-based memory retrieval.

With respect to the medial temporal lobes, multiple neuroimaging studies suggest that recollection is associated with hippocampal activation, whereas familiarity is associated with deactivation in the surrounding medial temporal lobe. For example, Montaldi et al. (2006) showed bilateral hippocampal activation when scenes that were recollected were compared to scenes given high confidence familiarity ratings, whereas activation in the perirhinal cortex decreased as memory confidence increased. A similar distinction between the hippocampus and rhinal cortex was found by Daselaar, Fleck, Dobbins, Madden, and Cabeza (2006). This dissociation is additionally supported by lesion work, demonstrating that whereas damage to the hippocampus impairs recollection while sparing familiarity, damage to the surrounding temporal lobe impairs familiarity while sparing recollection (Bowles et al., 2007; Yonelinas et al., 2002).

The final difference between recollection and familiarity found in our review was in sensory-specific brain regions. Sensory-specific reactivation refers to the finding that some of the cortical regions active during encoding are active again during retrieval, supporting neural models of memory suggesting that remembering episodes of one's past involves the reinstatement of the representations active during initial learning (Kahn, Davachi & Wagner, 2004; Nyberg, Habib, McIntosh, & Tulving, 2000; Nyberg et al., 2001; Owen, Milner, Petrides, & Evans, 1996; Wheeler & Buckner, 2003; Woodruff, Johnson, Uncapher, & Rugg, 2005). For example, Nyberg et al. (2000) used PET to show that the retrieval of words originally studied with sound information produced overlapping activation in the auditory cortex with that produced when the word-sound pairs were encoded. Subsequently, Wheeler and Buckner (2004) hypothesized that if it is recollection, and not familiarity, that involves the subsequent retrieval of contextual detail, only recollection should be associated with the reactivation of sensory-specific brain regions during a recognition test. In their study, participants studied words with accompanying related pictures (e.g., the word dog was presented visually along with a picture of a dog), and on a later scanned recognition test using event-related fMRI, made Remember, Know, or New responses to the words presented alone. They found that activity in a region of the left inferior temporal cortex, known to be activated during the perception of visual information based on a previous experiment (Maccotta & Buckner, 2002), was higher for Remember than Know responses. This finding has subsequently received support from Johnson and Rugg (2007), who showed that activation during Remember, as compared to Know, responses overlapped the brain regions used to originally encode the information.

In summary, past research suggests that recollection and familiarity differ to the extent in which they recruit frontal, parietal, medial-temporal, and sensory-specific brain regions. In particular, these data suggest that the retrieval of context information involves sensory-specific reactivation. In the current study, I build on these findings by examining how the provision of context information that differs in meaningful content at study affects later recollection for item information. This comparison can help identify the neural regions needed to retrieve specific context information, facilitating recollection, and can specifically test the hypothesis that sensory-specific reactivation is characteristic of recollection.

4.3 Overview of Chapter 4 Experiment

This chapter consists of an event-related fMRI experiment. I examined the neural correlates of recollection by investigating how meaningful visual context information present during encoding of target words influenced later recollection for the words presented alone at retrieval. To accomplish this, I compared brain activation for Remember responses given to words studied with and without meaningful context information. Participants first performed a localizer task, in which the fusiform face area (FFA) was identified. Participants then studied words presented with pictures of faces or scrambled faces, and on a subsequent scanned recognition test made ‘Remember’, ‘Know’, or ‘New’ responses to words presented alone. Behaviourally, 8 of the 14 participants showed a higher proportion of Remember responses to words studied with faces than scrambled faces, and 6 did not. Whole brain analysis showed that activation in the fusiform gyrus and hippocampus was higher, and a region-of-interest analysis showed increased activation in the functionally-defined FFA, for Remember responses given to words studied with faces compared to scrambled faces. When participants were divided into groups based on behavioural performance, this pattern was found only in those participants who showed higher recollection for words studied with faces. A regression analysis additionally showed that activation in the fusiform gyrus increased as the relative recollection benefit for words studied with meaningful (face) compared to non-meaningful (scrambled face) context information increased across participants. Results suggest that context-specific brain regions implicated during encoding are recruited during retrieval, and that the degree to which participants activate context-specific brain regions during retrieval is related to a behavioural benefit, in later recollection, for target information presented alone.

4.4 Experiment 7

The current study examined whether the brain regions mediating recollection vary with encoding context. The previous experiments of this thesis found that participants were better able to integrate item and context information into cohesive memory traces, retrieved preferentially through recollective memory processes, when the context information was high in meaningful content. This suggests that when participants recollect item information encoded with meaningful context information, they should reactivate the sensory-specific brain regions used to originally process that context information (as proposed by Wheeler & Buckner, 2004).

In the current study, we used this paradigm to examine whether the type of context information presented at study affects the brain regions sub-serving recollection. Whereas previous work has examined how sensory-specific reactivation of encoding context differs for Remember and Know responses, the current study compared activation for two different types of Remember responses: those given to items studied with visual context information either high or low in meaningful content. Such a comparison can identify the neural regions needed to retrieve specific context information, facilitating recollection. In addition, because the current study used faces as the context information, which consistently activates the fusiform gyrus bilaterally, known as the fusiform face area (FFA; Kanwisher, McDermott, & Chun, 1997; O'Craven & Kanwisher, 2000), I could define, a priori, the specific region of the brain that should be reactivated during recollection.

The current study was conducted in two phases. In phase I, a localizer task was used to identify the FFA in each participant, using a block design. To identify the FFA, activation during the viewing of faces was compared to that from the viewing of houses, as this contrast has been shown to isolate the FFA in other work (Yovel & Kanwisher, 2004). In phase II, participants studied words presented visually, accompanied by pictures of faces or pictures of scrambled faces on each trial (which was not scanned). Thus, I changed the meaning of the context information presented with the study word, while keeping the basic visual features (luminance and contrast) of the context constant, as in Experiments 1-2. The subsequent recognition test was scanned using event-related fMRI, in which the participants gave a Remember, Know, or New response to words presented alone.

To examine the neural regions recruited during recollection of these different word types, I contrasted activation for Remember responses given to words studied with faces as compared to words studied with scrambled faces. I hypothesized that the brain regions used to retrieve words studied with context information high (face) and low (scrambled face) in meaningful content would differ. Specifically, if the face context is bound to the target word, and retrieved through recollective memory processes, activation in the FFA during word recollection should be higher for words studied with faces than with scrambled faces.

I was additionally interested in whether activation in the fusiform gyrus was related to behavioural performance on the recognition memory task. I have hypothesized that when meaningful context information is provided at study, participants engage in elaborative processes that bind the item and context information in memory, improving subsequent recollection. Participants likely differ in their tendency to engage in such item-context binding at encoding, influencing subsequent recollection. It is thus possible that sensory-specific reactivation is related to the extent to which participants engage in the successful binding, and subsequent retrieval of, the word-face pairs. I hypothesized that activation in the fusiform gyrus would increase as the relative difference in recollection accuracy between words studied with intact faces compared to scrambled faces increased. This would provide evidence that sensory-specific reactivation is related to recollection accuracy.

Method

Participants

Fifteen normal healthy participants (8 female; 1 left-handed), from 19 to 29 years of age (mean age = 23.13, SD = 2.97), with a mean of 16.67 (SD = 1.84) years of education completed the study after giving informed consent. All procedures were approved by the ethics committee at the University of Waterloo and a joint ethics committee of the University of Toronto and Baycrest Centre for Geriatric Care. All participants spoke English fluently and were free from psychiatric or neurological disease.

Behavioural task materials

Face stimuli for the localizer task were taken from the AR face database, which contains black and white photographs showing the frontal view of male and female faces (Martinez & Benavente, 1998). House stimuli were 20 black and white pictures of houses (O'Craven, Downing, & Kanwisher, 1999). The face and house stimuli were matched for size (11 x 9 cm).

Two-hundred-twenty-five medium to high frequency words were chosen from Celex, a lexical database available on CD-ROM (Baayen et al., 1995), for the three study-test cycles of the memory task. For each cycle, the study list was comprised of 50 words: 25 were paired with pictures of faces (face trials) and 25 were paired with pictures of scrambled faces (scrambled trials). For the subsequent recognition test, a corresponding list was created, consisting of the 50 studied words plus 25 words not presented in the study phase (lures). Accordingly, across all three study–test cycles, 75 words were paired with pictures of faces, 75 with the picture of a scrambled face, and 75 served as lures. Three different study-test list combinations were created such that each word was paired with either a picture of a face, a scrambled face, or served as a lure across lists, counterbalanced across participants. The order of presentation of the word lists for the three study-test cycles was also counterbalanced across participants. All test lists were equated on letter length ($\underline{M}$ = 6.31), and word frequency ($\underline{M}$= 18.27 occurrences per million; Baayen et al., 1999). An additional 30-item word list was used in the practice session, with the same characteristics as the words in the experimental session.

Seventy-five faces with neutral expressions, 38 male and 37 female, were randomly chosen from the AR face database to serve as the face stimuli for the memory task. The face stimuli were randomly assigned to 25 words for each study list; thus, all study words were paired with a unique face. An additional 8 face stimuli were used in the practice session. The scrambled faces were created in Matlab 7.06 software by randomizing the pixels of the 75 face images chosen from the database. Thus, for each face stimulus, there was a corresponding scrambled image. This randomization altered the spatial frequency, and meaningful content, of the images, while preserving luminance and contrast.

Procedure

Stimulus presentation and response recording were controlled by an IBM PC, using E-prime v.1.1 software (Psychology Software Tools Inc., Pittsburgh, PA). Participants were tested individually, and completed the experiment in approximately two hours. The experiment began with a practice session, outside of the scanner, consisting of a block of the localizer and a block of the memory task, using the same timings and procedure as in the experimental trials. This was done to ensure that all participants understood the experimental tasks before entering the scanner. Participants first viewed 10 face and 10 house stimuli for the practice localizer task, followed by the practice study session, in which 16 study trials (8 face-word and 8 scrambled-word) were presented visually, in random order. Subsequently, ‘remember-know’ test response instructions were given and 15 recognition trials consisting of 4 words studied with faces, 4 words studied with scrambled faces, and 7 new words, were presented in random order.

The instructions for the remember-know test were as follows: Participants were told that they would see some words that were from the study list, and other words that were not. If they believed the word was not from the study list, participants were instructed to respond ‘N’ for New by pressing the ‘3’ key with their ring finger on a computer keypad. If they thought the word was from the study list, they had two options, ‘R’ or ‘K’. They were told to report ‘R’ for Remember by pressing the ‘1’ key with their index finger if the word was ‘old’ and they could recall specific details associating that word with the study episode. They were given examples of such details: They may remember an image, thought, or feeling they had associated with the word during study, or the temporal order of the words. These contextual details meant that they had a specific recollection of that word. If however, they believed the word to be ‘old’ but they did not recall a specific study detail associated with the word, they were asked to report ‘K’ for Know by pressing the ‘2’ key with their middle finger. To clarify the ‘K’ memory response, participants were also given the example of meeting someone on the street that they knew they had met before, but not being able to determine the specific instance in which they had met them. Participants were then asked if they understood the distinction between ‘R’ and ‘K’ responses and, after the practice session, participants were asked to give the details of the context accompanying an ‘R’ response to the experimenter, to ensure that they understood the difference between ‘R’ and ‘K’, and were not responding simply on the basis of response confidence.

Following practice, participants entered the scanner and the anatomical scan was obtained. For the subsequent localizer task, a block design was used. Participants viewed 19 blocks of 20 images; 10 blocks contained images of faces and 9 blocks contained images of houses, with blocks presented in alternating sequence. The image remained on the screen for 400 ms followed by a fixation cross presented for 600 ms, making each trial one second long. Participants were asked to press a key with their index finger on a standard button box if they viewed the same image twice in a row anytime within the one second trial (one-back task).

Participants then completed 3 study-test cycles. The study phase was not scanned. For each of the 3 study phases, a trial began with a picture of a face or a scrambled face appearing for 1000 ms centered in the upper half of the screen (screen coordinates: X = 324, Y = 180). A word presented in 28 point bold Arial font then appeared directly below the picture for 2000 ms (X = 324, Y = 379), after which time both the picture and the word disappeared, followed by a 500 ms fixation cross presented centrally. In each of the three study phases, 50 trials were presented (25 face-word and 25 scrambled-word), with trial type randomized. Within each study phase, the 25 scrambled images were the scrambled versions of the 25 face images presented in the face trials. Participants were asked to memorize the words for an upcoming memory test. To ensure that participants encoded the context (face or scrambled face) during study, participants were also asked to manually identify, for each study trial, the picture presented with each word as either a face or a scrambled face by making a button press using their index or middle finger on a button box. Participants used their dominant hand to make their response. Each trial was 3500 ms in length (timings noted above), and participants were asked to make their classification response during this time.

After each study phase, participants counted backwards by threes for 30 seconds before beginning the remember-know recognition test. The test phase of each study-test cycle was scanned using a fast event-related design. Each run consisted of 75 words (25 studied with faces, 25 studied with scrambled faces, and 25 lures) and 25 central fixation crosses presented in a pseudo-random order. During each non-fixation trial, the word was presented in the centre of the screen in the same font and size as at study. As described above, participants were asked to make a Remember, Know, or New response by pressing one of three buttons on a button box with their dominant hand. The word/fixation cross remained on the screen for 4000 ms, followed by a central fixation cross for 250 ms; thus, for the fixation trials, the fixation cross remained on the screen for 4250 ms. Participants could make their response anytime within the 4250 ms of each recognition trial.

fMRI data acquisition

Visual displays were presented on a screen which participants viewed using a mirror attached to the head coil. Headphones and foam pillows were used to dampen scanner noise and minimize head movement. Participants responded by pressing one of three buttons on a fORP bimanual 8-button fiber optic response box positioned under their dominant hand, which rested on the scanner bed (Current Designs Inc., Philadelphia, PA).

Data were acquired with a whole-body 3.0 Tesla MRI scanner (Siemens Tim Trio, Erlangen, Germany) with a standard head coil. Axial anatomical images were acquired using a 3-dimensional T1-weighted fast spoiled gradient echo image (TR = 2000ms; TE = 30ms; flip angle = 70 degrees; acquisition matrix = 256 x 192; FOV = 256mm; 160 axial images; slice thickness = 1mm). Functional imaging was performed to measure brain activation by means of the blood oxygenation level-dependent (BOLD) effect (Ogawa, Lee, Kay, & Tank, 1990). Functional scans for the localizer and memory tasks were acquired with a single-shot T2*-weighted pulse sequence with echo planar imaging (EPI) acquisition (TR = 2000ms; TE = 30ms; flip angle = 70 degrees; effective acquisition matrix = 64 x 64; FOV = 200mm; 28 slices; slice thickness = 5mm). One hundred and ninety five time points were collected for the localizer scan and 222 time points were collected for each retrieval scan. Images were aligned to the plane of the anterior and posterior commissure (AC-PC).

fMRI data analysis

Processing and analysis were performed using the Analysis of Functional Neuroimages (AFNI, version 2007_05_29_1644) software package (Cox & Hyde, 1997). The first 5 data points in all fMRI time series, corresponding to presentation of a blank screen in the paradigm, were omitted from analysis to ensure magnetization had reached steady state. For the event-related (memory retrieval) runs, between-slice timing differences caused by slice acquisition order were adjusted and time series were spatially co-registered to a reference scan to correct for head motion using a 3D Fourier transform interpolation, using a functional volume that minimized the amount of head motion to < 2 mm. One participant was removed from the behavioural and fMRI analysis due to excessive head motion (> 3mm). Localizer and memory retrieval data were then converted to units of percent change and the memory retrieval runs were concatenated using the 3dcalc and 3dTcat commands in AFNI.

Individual participant data were analyzed using the 3dDeconvolve program in AFNI. For the Localizer data, General Linear Tests (GLTs), using a block response function, were used to distinguish different regions of BOLD signal change for the FACE and HOUSE trials. The response was modeled with one regressor, with the HOUSE trials serving as the baseline. For the memory retrieval (event-related) runs, participant data were sorted into the following response types: 1) REM FACE: items studied with a face and correctly identified with a Remember response, 2) REM SCR: items studied with a scrambled face and correctly identified with a Remember response, 3) KNOW FACE: items studied with a face and correctly identified with a Know response, 4) KNOW SCR: items studied with a scrambled face and correctly identified with a Know response, and 5) FIX: baseline fixation crosses. GLTs were used to contrast the selected memory responses to baseline (FIX). New items given Remember and Know responses (false alarms), misses, and correct rejections were also identified, but were not used in the analyses. A tent function was used to model the data, with the function estimated at 7 time points. Events of interest were time-locked to the stimulus onset. Each participant's data were extracted and transformed into a common space based on the Talairach and Tournoux (1988) atlas, and spatial smoothing was performed using an isotropic Gaussian blur with a full width at half maximum (FWHM) of 6 mm to increase the signal-to-noise ratio. Original 3 x 3 x 5 mm voxels were resampled to 2 x 2 x 2 mm prior to group analysis.

Both whole-brain (exploratory) and Region-of-Interest (hypothesis-driven) analyses were performed on the averaged group data. For the whole-brain analysis, two voxel-wise, two-factor ANOVAs, using FIX as baseline, with Response Type (FACE and SCR) as a fixed factor and participants as a random factor, were conducted to compare activation for REM FACE to REM SCR, and KNOW FACE to KNOW SCR responses. I used the Talairach atlas (Talairach & Tournoux, 1988) in AFNI and the automated Talairach Daemon (Lancaster et al., 2000) to define Brodmann Areas for the regions of activation identified by the analyses.

For the Region-of-Interest (ROI) analysis, data obtained from the localizer task were used to define the fusiform face area (FFA). Thus, this analysis uses a functional localizer, or fROI, approach (as in Saxe, Brett & Kanwisher, 2006). The localizer data were first analyzed using a voxel-by-voxel t-test, using the activation during HOUSE trials as a baseline, to distinguish the brain regions in which percentage change in activation for FACE trials was significantly different than zero. These maps were averaged across participants, and the FFA was defined by identifying the 100 most significant voxels active in either the left or right fusiform gyrus using the 3dmerge program in AFNI. I then performed two repeated measure ANOVAs on the data. First I compared the mean activation in the FFA for REM FACE and REM SCR responses, extracted for each participant using the 3dROIstats program in AFNI. I then performed a similar analysis for KNOW FACE and KNOW SCR responses.

A regression analysis was additionally performed to identify regions of activation in the REM FACE > REM SCR contrast that correlated significantly with behavioural performance on the recognition memory task. For the analysis, memory performance was measured as a difference score: Remember accuracy for words studied with faces minus Remember accuracy for words studied with scrambled faces. This difference score shows the relative recollection advantage (or disadvantage) for words studied with faces as compared to scrambled faces, for each participant. The 3dRegAna program in AFNI was used for this analysis.

Results

Behavioural Data

There was considerable variability in memory performance across the sample, with approximately half showing higher memory accuracy for words studied with faces as compared to scrambled faces and half showing the opposite effect (see below). This behavioural variability led to a null effect of context on behavioural performance; however, I took advantage of this variability to examine whether differences in brain activation were related to differences in memory performance within the sample. Whole-brain, region-of-interest, and regression analyses were first performed with the Overall Group data (all 14 participants). Participants were subsequently divided into two groups: one that showed higher accuracy for words studied with faces than words studied with scrambled faces (Group F, n = 8) and one that did not show this behavioural effect (Group S, n = 6). Group F assignment was based on numerical differences in remember accuracy for word studied with faces and scrambled faces (face > scrambled), as opposed to significant differences. Whole-brain and region-of-interest analyses were then performed on Group F and Group S data.

Localizer task performance. Behavioural data from the localizer task for the Overall Group were analyzed using a repeated measure ANOVA. Mean accuracy (measured as hit rate – false alarm rate) on the one-back localizer task was .88 (SD = .11) for faces and .81 (SD = .20) for houses, which did not differ significantly, $F(1, 13) = 1.83$, $p > .05$.

Behavioural data from the localizer task were then analyzed using a 2 (Image) x 2 (Group: F or S) ANOVA, with Image as a within- and Group as a between-participant factor. Mean accuracy (measured as hit rate – false alarm rate) for Groups F and S, respectively, on the one-back localizer task was .87 (SD = .11) and .88 (SD = .11) for faces and .87 (SD = .13) and .74 (SD = .27) for houses. There was no effect of Image or Group, and no interaction, Fs (1, 12) < 2, ps > .05.

Identification task performance. The mean accuracy and response time (RT) for correct responses on the identification task, performed during the study phase (see Table 4), were first analyzed for the Overall Group in a repeated measures ANOVA. Identification accuracy for pictures of faces and scrambled faces did not differ, F (1, 13) = 0.32, $p > .05$, though RT to correct identification was slower for pictures of faces than scrambled faces, F (1, 13) = 11.64, $p < .05$.

When participants were broken into Group F and Group S, the mean accuracy and RT for correct responses on the identification task were analyzed using 2 (Context) x 2 (Group) ANOVAs. There was no effect of Context, or Group, and no interaction, Fs (1, 12) < 2.5, ps > .05 on identification accuracy. The RT analysis showed no effect of Group, F (1, 12) = .57, and no interaction, F (1, 12) = .06, but did show a main effect of Context, F (1, 12) = 10.35, $p < .01$, with slower identification RT for pictures of faces.

Memory task performance. Data from the recognition memory task for the Overall Group were first analyzed in a 2 (Word context: studied with a face or scrambled face) x 3 (Study-Test cycle) x 3 (List order) ANOVA; because the last two variables produced non-significant main effects and interactions, data were collapsed across Study-Test cycle and List order. Table 4 shows the means for each memory measure and trial type, collapsed across the three recognition tests. Overall recognition accuracy was measured as number of hits out of 75 – number of false alarms out of 75, for each word type. The effect of Word context was not significant, F (1, 13) = 0.75 $p > .05$.

I then analyzed proportion of Remember responses (number of correct Remember responses out of 75 – number of false Remember responses out of 75) and proportion of Know responses (number of correct Know responses out of 75 – number of false Know responses out of 75) for each word type. There was no effect of Word context for Remember, F (1, 13) = 0.01, or Know, F (1, 13)

= 1.75, responses, nor for independent remember-know (IRK) measures of familiarity, $\underline{F}$ (1, 13) = .2.90, $\underline{ps}$ > .05. Comparisons of RT showed no effect of Context for either Remember, $\underline{F}$ (1, 13) = 3.67, or Know, $\underline{F}$ (1, 13) = .46, responses, $\underline{ps}$ > .05.

Similar analyses were performed on the data with participants divided into Group F and Group S in a 2 (Context: studied with a face or studied with a scrambled face) x 2 (Group: F or S) ANOVA, with Context as a within- and Group as a between-participant variable. There was no effect of Context on overall accuracy, $\underline{F}$ (1, 12) = .07, or Group, $\underline{F}$ (1, 12) = .41, $\underline{ps}$ > .05, but there was a significant interaction, $\underline{F}$ (1, 12) = 7.87, $\underline{MSE}$ = .05, $\underline{p}$ < .05. Paired t-tests showed that whereas recognition accuracy did not vary with context in Group F, $\underline{t}$ (7) = 1.62, Group S showed higher recognition accuracy for words studied with scrambled faces as compared to faces, $\underline{t}$ (5) = 9.09, $\underline{p}$ < .05. Analysis of d' showed a similar pattern of effects.

I then analyzed the proportion of Remember responses (number of correct Remember responses out of 75 minus number of false Remember responses out of 75), for each Group and Context type. There was no effect of Context, $\underline{F}$ (1, 12) = .68, or Group, $\underline{F}$ (1, 12) = .23, $\underline{p}$s > .05, but a significant interaction, $\underline{F}$ (1, 12) = 5.71, $\underline{MSE}$ = .06, $\underline{p}$ < .05. Paired t-tests showed that Group F had higher Remember accuracy for words studied with faces as compared to scrambled faces, $\underline{t}$ (8) = 2.72, whereas Group S showed the opposite effect, $\underline{t}$ (5) = 3.93, $\underline{p}$s < .05.

A similar analysis for Know responses showed no effect of Context, $\underline{F}$ (1, 12) = .68, no effect of Group, $\underline{F}$ (1, 12) = .23, and no interaction, $\underline{F}$ (1, 12) ps > .05. A similar pattern was found for IRK familiarity. A retrospective power analysis performed on IRK familiarity in Groups F showed that $\underline{d}$ = .04, and that, with a power estimate of .80, I would need to run 5345 participants to obtain a significant effect of context.

Table 4.

Experiment 7. Mean Performance on the Identification Task at Encoding and Mean Memory Performance and Response Time in Milliseconds for Words Studied with Different Contexts for the Overall Group, Group F, and Group S.

	Overall Group		Group F		Group S	
Measure	Face	Scrambled	Face	Scrambled	Face	Scrambled
Identification Accuracy	.94 (.05)	.94 (.03)	.95 (.03)	.94 (.05)	.92 (.07)	.95 (.03)
Identification RT	1322 (577)	1227 (583)	1427 (671)	1326 (668)	1180 (437)	1093 (472)
Overall Hit Rate	.64 (.11)	.66 (.13)	.66 (.12)	.61 (.12)	.61 (.11)	.74 (.10)
Overall FA Rate	.18 (.11)	.18 (.11)	.14 (.10)	.14 (.10)	.23 (.12)	.23 (.12)
Remember Hit Rate	.37 (.14)	.36 (.12)	.43 (.15)	.35 (.13)	.28 (.09)	.39 (.08)
Remember FA Rate	.02 (.02)	.02 (.02)	.01 (.02)	.01 (.02)	.03 (.03)	.03 (.03)
Know Hit Rate	.27 (.10)	.30 (.10)	.23 (.11)	.27 (.11)	.33 (.07)	.35 (.04)
Know FA Rate	.16 (.10)	.16 (.10)	.13 (.09)	.13 (.09)	.20 (.10)	.20 (.10)
IRK Familiarity	.26 (.14)	.31 (.15)	.27 (.13)	.27 (.12)	.25 (.15)	.37 (.17)
d'	1.57 (.71)	1.64 (.68)	1.75 (.50)	1.59 (.53)	1.32 (.92)	1.70 (.89)
RT Remember Responses	1478 (209)	2011 (1558)	1507 (235)	1603 (276)	1483 (177)	1552 (222)
RT Know Responses	1867 (317)	1902 (338)	1915 (345)	1955 (370)	1892 (232)	1925 (244)

Note: FA = false alarm; Familiarity was calculated as F = K / (1-R); RT = response time in milliseconds; Standard deviations shown in parentheses.

Although RT was not emphasized at retrieval, I examined these data in two separate repeated measure ANOVAs for correct Remember and Know responses. There was no effect of Context or Group and no interaction for either Remember or Know responses, ps > .05. A median split analysis showed a similar pattern of results.

fMRI Data for Recognition Memory

Overall Group whole brain analysis. Using a significance threshold of $p < .001$ and a cluster size of 5 or more contiguous voxels, direct comparisons of REM FACE and REM SCR conditions for the Overall Group data showed that Remember responses given to words studied with faces were associated with increased activity in the left precentral, right posterior cingulate, left postcentral, right middle temporal, left superior temporal, left middle occipital, bilateral cuneus, thalamic, and left cerebellar gyri (See Table 5). Importantly, the analysis also showed increased activation for REM FACE than REM SCR responses in the right hippocampus and parahippocampal gyrus, and critically, in the left fusiform gyrus (see Figure 7). A Monte Carlo simulation was completed using the Alphasim program in AFNI to determine the false positive discovery rate (α) of this fusiform activation. The analysis performed at $p < .001$ showed a high false positive rate ($\alpha > .50$) for this region; however, when the threshold was lowered to $p < .005$, a similar analysis showed that the activation in this region was associated with a false positive rate of $\alpha < .005$. This region of the fusiform gyrus (x, y, z = -36, -39, -11) is similar to the region identified as the Group FFA in the localizer analysis (x, y, z = -40, -46, -12; see below). The analysis did not identify any regions of increased activation for REM SCR as compared to REM FACE responses.

As in most remember-know tests in young adults, participants endorsed more items as remembered than known; thus the analyses for Know responses should be interpreted with caution. The General Linear Model (GLM) analysis comparing activation during KNOW FACE and KNOW

SCR responses did not show significant activation in the fusiform gyrus. This was true even when the threshold was lowered to $p < .01$.

Table 5.

Coordinates and t-statistics of brain regions showing differences in activation for REM FACE responses compared to REM SCR responses for the Overall Group.

Brain Region (BA)	Coordinates			t-statistic
	x	y	z	
REM FACE > REM SCR				
Left precentral (6)	-44	-4	47	4.32
Right posterior cingulate (30)	20	-62	7	4.35
Right hippocampus	31	-11	-15	4.68
Right parahippocampus	14	-3	-15	4.38
Left postcentral (1)	-34	-33	67	4.42
Left fusiform (37)	-36	-39	-11	4.27
Right middle temporal (37)	40	-55	-1	4.75
Left superior temporal (41)	-44	-40	12	4.43
Left superior temporal (38)	-48	7	-14	4.68
Left middle occipital (19)	-29	-89	9	4.75
Left middle occipital (37)	-39	-67	2	4.61
Left Cuneus (17)	-18	-75	7	4.50
Right Cuneus (18)	6	-81	14	4.42
Left Thalamus	-27	-29	1	4.46
Left Cerebellum	-9	-58	-2	4.76
Left Cerebellum	-35	-62	-45	4.47
Left Cerebellum	-24	-79	-16	4.33

Note: The Talairch coordinates represent the peak for the given region; for the t-statistic positive values represent greater activation for REM FACE than REM SCR; BA = Brodmann's Area according to the atlas of Talairach and Tournoux (1988).

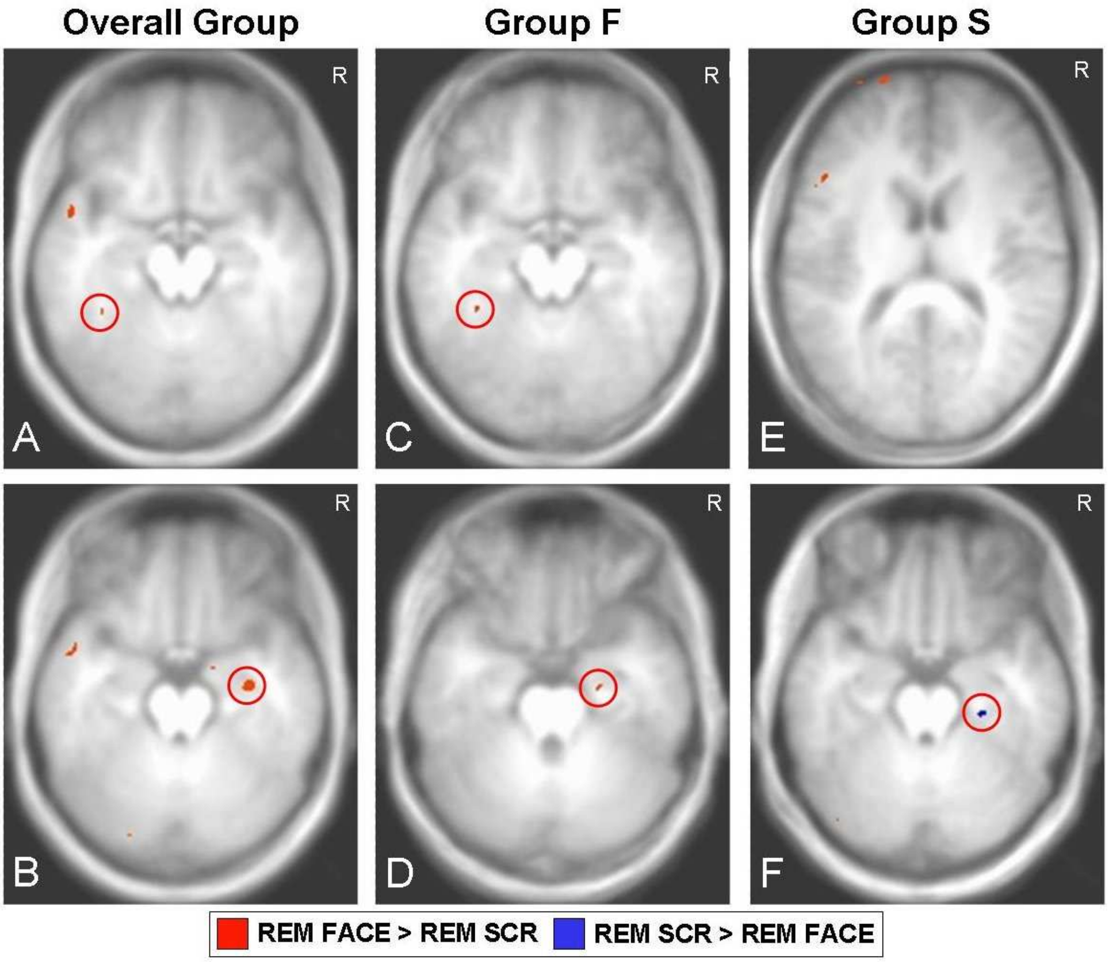

Figure 7. Brain areas with differences in activity for Remember responses given to words studied with faces and words studied with scrambled faces for the Overall Group, Group F, and Group S on averaged anatomical scans. Areas in orange represent regions with higher activity for REM FACE than REM SCR responses; areas in blue represent regions with higher activity for REM SCR than REM FACE responses. (A) An axial slice for the Overall Group at z = -11 mm from the AC-PC line showing increased fusiform activity, $p < .001$; (B) An axial slice for the Overall Group at z = -15 mm showing increased hippocampal activity, $p < .001$; (C) An axial slice for Group F at z = -11 mm showing increased fusiform activity, $p < .002$; (D) An axial slice for Group F at z = -15 mm showing increased hippocampal activity, $p < .002$; (E) An axial slice for Group S at z = 16 mm showing increased frontal activity, $p < .002$; (F) An axial slice for Group S at z = -16 mm showing increased parahippocampal activity, $p < .002$.

Overall Group region-of-interest analysis. Analysis of the Overall Group localizer data identified a region in the left fusiform gyrus (peak region of activation (x, y, z) = -40, -46, -12) as the Overall Group FFA. A repeated measures ANOVA with Word context as the within-participant variable showed that, for the group analysis, percent signal change was higher in the Group FFA for REM FACE than REM SCR responses, F (1, 13) = 14.02, MSE = 2.08, p < .005 (see Figure 8). There was no difference in activation in the FFA for the KNOW FACE (M = .51, SD = .65) versus KNOW SCR (M = .36, SD = .51) contrast, F (1, 13) = .44, p > .05.

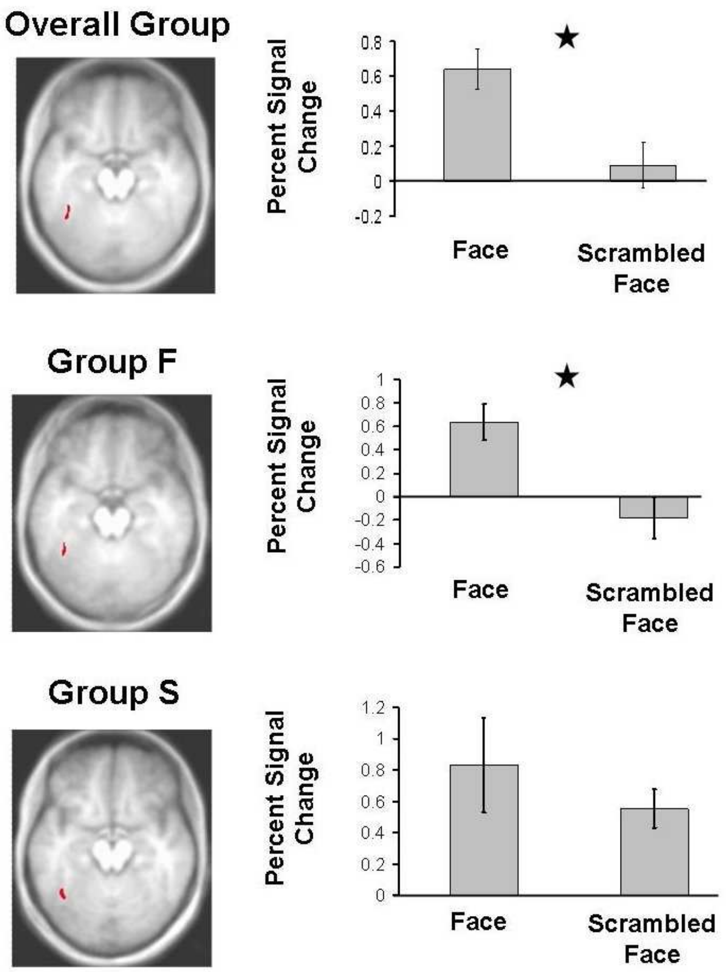

Figure 8. Functionally defined FFA, identified in the localizer task, and percent signal change in the FFA for Remember responses given to words studied with pictures of faces or scrambled faces in the Overall Group (top) Group F (middle) and Group S (bottom). Peak regions of activation in the FFA for the Overall Group, Groups F, and Group S were (x, y, z) = -40, -46, -12, (x, y, z) = -39, -45, -13 and (x, y, z) = -40, -52, -11, respectively, and are presented on averaged anatomical scans.

Overall Group regression analysis. A regression analysis was used to identify regions for which level of activation across participants in the REM FACE > REM SCR contrast correlated significantly with behavioural performance on the recognition task, as measured by the difference in Remember accuracy for words studied with faces as compared to scrambled faces. We used a threshold of $p < .005$ and a cluster size of 5 or more contiguous voxels. The regions identified in the analysis were bilateral middle frontal gyri, left medial and inferior frontal gyri, bilateral superior and left middle temporal gyri, the right cerebellar gyrus, and importantly, the right and left fusiform gyrus (see Table 6 & Figure 9). A Monte Carlo simulation showed that, although the false positive rate for the region in the left fusiform gyrus was high ($\alpha > .50$), the activation in the right fusiform gyrus was associated with an extremely low false positive discovery rate of $\alpha < .005$.

Table 6.

Coordinates and t-statistics of brain regions showing increased activation across participants in the RFACE > RSCR contrast as the recollection benefit for words studied with faces increased.

Brain Region (BA)	Coordinates			t-statistic
	x	y	z	
Right middle frontal (11)	37	47	-9	3.71
Left middle frontal (11)	-28	30	-17	3.59
Left medial frontal (11)	-9	27	-12	3.75
Left inferior frontal (47)	-27	18	-18	3.62
Left inferior frontal (44)	-52	10	17	3.73
Right fusiform (37)	36	-45	-10	4.31
Left fusiform (37)	-45	-38	-13	3.73
Right superior temporal (38)	31	13	-31	3.96
Right superior temporal (38)	50	6	-20	3.68
Left superior temporal (38)	-53	2	-7	3.93
Left superior temporal (42)	-67	-25	8	4.14
Left middle temporal (21)	-55	-33	-2	3.83
Right cerebellum	3	-72	-42	3.57

Note: The Talairch coordinates represent the peak for the given region; for the t-statistic positive values represent greater activation for the REM FACE > REM SCR contrast with increasing behavioural performance (see methods); BA = Brodmann's Area according to the atlas of Talairach and Tournoux (1988).

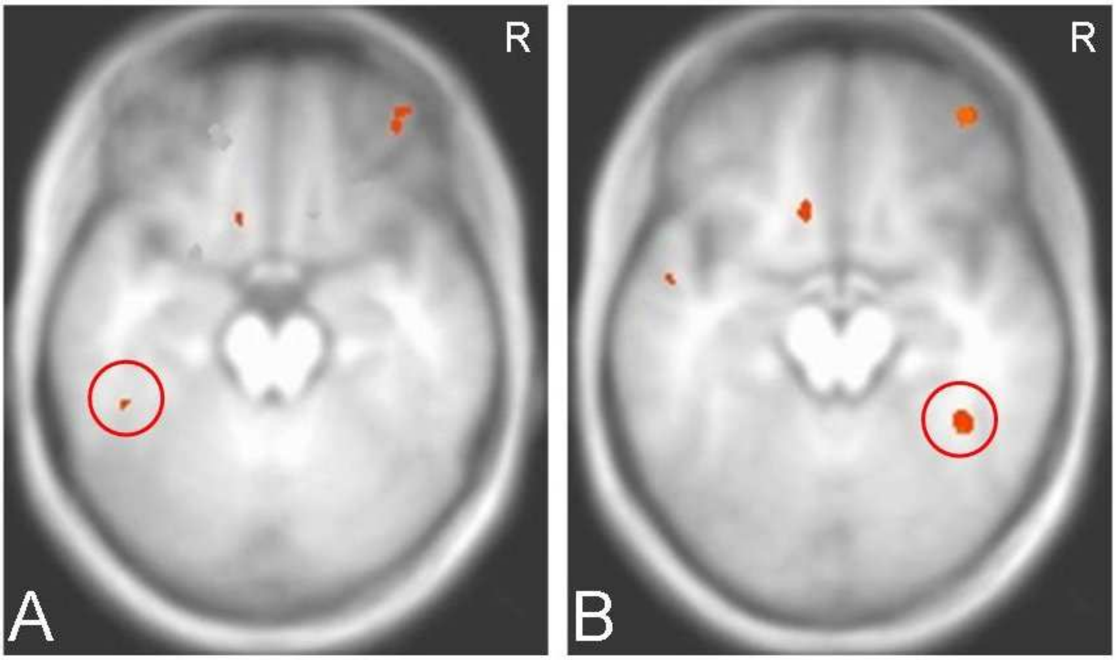

Figure 9. Brain areas that increased in activation in the REM FACE > REM SCR contrast as the recollection benefit for words studied with faces increased across participants on averaged anatomical scans. Areas in orange represent significantly positive correlations, $p < .005$. (A) An axial slice at z = -14 from the AC-PC line showing increased left fusiform activity; (B) An axial slice at z = -10 from the AC-PC line showing increased right fusiform activity.

Group F whole-brain analysis. For the Group F and Group S analyses, the significance threshold was reduced to $p < .002$ and a cluster size of 5 or more contiguous voxels, since the behavioural split reduced the number of participants in each analysis. Direct comparisons of REM FACE and REM SCR responses showed significant activation for REM FACE as compared to REM SCR responses in bilateral posterior cingulate, left inferior parietal, right middle temporal, bilateral superior temporal, left middle occipital, left cuneus, right precuneus, and left thalamic gyri (see Table 7). Bilateral parahippocampal activation was also identified with one region crossing the borders of the right parahippocampus and the hippocampus (see Figure 7). Critically, I found higher activation for REM FACE as compared to REM SCR responses in the left fusiform gyrus (x, y, z = -34, -37, -

12), close to the region identified as the FFA in the Group F localizer analysis (see below). The only area of activation higher for REM SCR than REM FACE responses was the middle frontal gyrus.

The General Linear Model (GLM) analysis comparing activation during KNOW FACE and KNOW SCR responses did not show significant activation in the fusiform gyrus.

Table 7.

Experiment 7. Coordinates and t-statistics of brain regions showing differences in activation for REM FACE responses compared to REM SCR responses for Group F.

Brain Region (BA)	Coordinates			t-statistic
	x	y	z	
REM FACE > REM SCR				
Left posterior cingulate (30)	-9	-62	12	5.83
Right posterior cingulate (31)	19	-61	15	5.90
Left parahippocampal	-14	-44	1	5.23
Right hippocampal/ parahippocampal	20	-12	-19	5.18
Right parahippocampal	9	-41	3	5.77
Left inferior parietal (40)	-58	-41	22	5.40
Left fusiform (37)	-34	-37	-12	5.08
Right middle temporal (21)	52	-29	-7	5.47
Left superior temporal (41)	-42	-30	4	5.56
Left superior temporal (38)	-40	11	-20	6.06
Left superior temporal (42)	-62	-28	16	5.43
Right superior temporal (22)	56	6	3	5.69
Right superior temporal (38)	55	2	-6	5.41
Left middle occipital (37)	-38	-67	2	5.76
Left middle occipital (19)	-31	-83	5	5.31
Right precuneus (31)	12	-71	29	5.12
Left cuneus (18)	-18	-75	22	5.00
Left cuneus (18)	13	-80	20	5.37
Left thalamus	-27	-30	2	5.75
REM SCR > REM FACE				
Left middle frontal (6)	-28	7	41	-5.46

Note: The Talairch coordinates represent the peak for the given region; for the t-statistic, positive values represent greater activation for REM FACE than REM SCR and negative values represent greater activation for REM SCR than REM FACE responses; BA = Brodmann's Area according to the atlas of Talairach and Tournoux (1988).

Group F region-of-interest analysis. Analysis of Group F localizer data identified a region in the left fusiform gyrus (peak region of activation (x, y, z) = -39, -45, -13), as the region most highly activated in the FACE - HOUSE contrast, $p < .0001$. I called this functionally defined region the Group F FFA. A repeated measures ANOVA with Context as the within-participant variable showed that percent signal change was higher in the FFA for REM FACE than for REM SCR responses, $F(1, 7) = 12.77$, $MSE = 2.65$, $p < .01$ (see Figure 8). A similar analysis of Know responses showed there was no difference in activation for KNOW FACE ($M = .41$, $SD = .60$) and KNOW SCR ($M = .42$, $SD = .65$) responses, $F(1, 7) = 0.00$, $p > .05$.

Group S whole-brain analysis. I applied the same significance threshold of $p < .002$ and a cluster size of 5 or more contiguous voxels as in the Group F analyses. Group S showed increased activation for REM FACE than REM SCR responses in the left inferior and middle frontal, bilateral superior frontal, bilateral precentral, right posterior cingulate, left middle temporal, right inferior and left middle occipital, and bilateral cerebellar gyri (see Table 8). Unlike Group F, no difference in activation was found in the fusiform gyrus or in the medial temporal lobe for this contrast. There was one area showing activation higher for REM SCR than REM FACE responses in the right parahippocampus (see Figure 7). Even when I lowered the threshold to $p < .01$, there was still no evidence of differential fusiform activation. As in Group F, the GLM analysis comparing activation during KNOW FACE and KNOW SCR responses did not show significant activation in the fusiform gyrus.

Table 8.

Experiment 7. Coordinates and t-statistics of brain regions showing differences in activation for REM FACE responses compared to REM SCR responses for Group S.

Brain Region (BA)	Coordinates			t-statistic
	x	y	z	
REM FACE > REM SCR				
Left inferior frontal (45)	-45	22	15	7.33
Left medial frontal (6)	-5	5	61	8.83
Left superior frontal (9)	-10	58	26	8.16
Left superior frontal (10)	-19	66	16	7.15
Left precentral (6)	-30	-2	32	6.43
Right precentral (6)	31	-8	34	8.59
Left cingulate (31)	-19	-38	29	7.54
Right posterior cingulate (30)	31	-75	5	7.50
Left middle temporal (37)	-41	-59	-2	7.61
Left middle temporal (21)	-47	4	-18	7.03
Right inferior occipital (19)	41	-78	-5	7.60
Left middle occipital (18)	-28	-93	1	6.77
Left cerebellum	-40	-71	-15	7.34
Left cerebellum	-32	-62	-38	6.41
Left cerebellum	-2	-48	-44	6.91
Right cerebellum	33	-40	-20	7.19
REM SCR > REM FACE				
Right parahippocampal	24	-23	-16	-8.08

Note: The Talairch coordinates represent the peak for the given region; for the t-statistic, positive values represent greater activation for REM FACE than REM SCR and negative values represent greater activation for REM SCR than REM FACE responses; BA = Brodmann's Area according to the atlas of Talairach and Tournoux (1988).

Group S region-of-interest analysis. The Group S localizer data identified a region in the left fusiform gyrus as the area most highly active for the FACE - HOUSE contrast (peak region of activation (x, y, z) = -40, -52, -11, $p < .0001$). I called this the Group S FFA.

Unlike Group F, the repeated measures ANOVA for Group S failed to show a difference in activation in the FFA for REM FACE compared to REM SCR responses, $F(1, 5) = 0.59$ (see Figure 8). Similar to Group F, however, the KNOW FACE – KNOW SCR contrast showed no difference in activation ($M = .95$, $SD = .59$ for faces and $M = .58$, $SD = .53$ for scrambled faces), $F(1, 5) = 1.09$, $ps > .05$.

4.5 Discussion of Chapter 4 Experiment

I examined how the presence of meaningful visual context information during encoding of target words influenced later recollection for the words presented alone at retrieval. Unlike the previous experiments reported in this thesis, I did not find a recollection benefit for words studied with meaningful context information; however, I still showed differences in brain activation for words studied with and without meaningful context information. Whole-brain analysis of fMRI data showed that activation for Remember responses given to words studied with faces compared to scrambled faces was higher in the fusiform gyrus and hippocampus. The same pattern was observed in both a group and individual fROI analysis: There was increased activation in the functionally-defined FFA for Remember responses given to words studied with faces compared to scrambled faces. No such context effect was present at the neural level for Know responses. Further analyses showed that these patterns of activation were found only for those participants who reported higher recollection for words studied with faces. Activation in both the right and left fusiform gyrus was also found to correlate with behavioural performance on the memory task: Activation in these regions increased as the recollection benefit for words studied with faces, as compared to scrambled faces, increased.

4.5.1 Sensory-Specific Reactivation

To examine sensory-specific reactivation in an a priori defined brain region, I used a localizer task to identify the region of the fusiform gyrus most highly activated during the viewing of faces in my participants. Using an fROI approach (Saxe et al., 2006), I was then able to contrast activity for Remember and Know responses given to words studied with faces and scrambled faces in this brain region. The localizer task showed higher activation during the viewing of faces, as compared to houses, in a region in the left fusiform gyrus in the overall group, Groups F, and Group S, which I called the FFA. Although the FFA is often found in the right fusiform gyrus (Kanwisher et al., 1997) other studies have shown bilateral (Bernstein, Beig, Siegenthaler, & Grady, 2002; Haxy et al., 1994) and left (Lobmaier, Klaver, Loenneker, Martin, & Mast, 2008) fusiform activity during face processing.

In both the whole-brain and ROI analyses of the overall group data, activation in the fusiform gyrus and FFA, defined by the localizer task, was higher when participants recollected words studied with faces as compared to scrambled faces. This occurred despite the fact that the faces were not re-presented at retrieval, indicating that the recollection of words studied with faces activated the same brain region used to process such context information. The region identified in the whole-brain analysis was notably close to that identified by the localizer task, constituting further support that this represents sensory-specific reactivation of a face processing region. These results are consistent with those that show the FFA is active when participants imagine faces (Ishai, Ungerleider, & Haxby, 2000; O'Craven & Kanwisher, 2000). Importantly, I did not find a significant increase in FFA activity when know responses given to words studied with faces and scrambled faces were contrasted, even at a lowered threshold, supporting the hypothesis that sensory-specific reactivation is specific to recollection (Johnson & Rugg, 2007; Wheeler & Buckner, 2004).

Notably, this pattern was found for the analysis of Group F data, whereas Group S data did not show differential fusiform activity for Remember responses given to words studied with faces and scrambled faces. A regression analysis was additionally used to identify the brain regions that increased in activation as the recollection benefit for words studied with faces increased across participants. This analysis identified a region of the right and left fusiform gyrus, close to the region identified as the Group FFA in the localizer task. Together, the results suggest that the degree to which participants recruit context-specific brain regions during retrieval is related to a behavioural benefit, in later recollection, for words studied with meaningful context information. Other research suggests that whether participants show sensory-specific reactivation, and subsequent recollection benefits, may depend on the extent to which they engage in processes at encoding that bind item and context information, or the degree to which the item and context can be bound. For example, Nyberg et al. (2000) showed a trend toward higher sensory-specific reactivation in left primary auditory cortex when word-sound pairs were strong as compared to weak associates, suggesting that sensory-specific reactivation may be a function of ‘integratability’, or the binding of context and item information. In the previous experiments of this thesis, I hypothesized that participants who engage in processes that bind item and context information at study will show a recollection benefit for words studied with meaningful context information. The results of the current experiment suggest that this recollection benefit increases as activation in sensory-specific brain regions increases.

4.5.2 Medial Temporal Lobe Activation

The whole-brain analysis of overall and Group F data showed that activation in a region in the right hippocampus/parahippocampus was higher for Remember responses given to words studied with faces compared to scrambled faces. Multiple studies have found results consistent with the notion that hippocampal activation is selective to recollection. For example, Montaldi et al. (2006) showed bilateral hippocampal activation when scenes that were recollected were compared to scenes given high confidence familiarity ratings. My study differs from previously reported ones (Montaldi et al., 2006; Yonelinas et al., 2005), however, in that I did not contrast Remember and Know responses, but rather contrasted Remember responses for words studied with different types of context. Thus, the difference in activation found in my study cannot relate to the experience of remembering per se, but rather reflects a difference in the content/manner of what is recollected, although the current study cannot specify exactly what this difference represents. For example, Remember responses for words studied with faces may have been associated with the retrieval of additional context information than Remember responses given to words studied with scrambled faces in Group F participants, (cf. Dodson, Holland, & Shimamura, 1998), and the hippocampus indexed this increased source retrieval. To my knowledge, the only study that has manipulated the amount of source information retrieved showed that hippocampal activation was related to source retrieval generally and that a region of the posterior parahippocampus increased in activation as the amount of contextual information retrieved increased (Tendolkar et al., 2008; see also Vilberg & Rugg, 2007, who found increased activation in a region adjacent/within the hippocampus when ‘strong’ recollection was contrasted with know responses, and a statistically weaker trend in this direction when ‘weak’ recollection was compared with know response. Also see Maril, Simons, Mitchell, Schwartz, & Schacter, 2003, and Maril, Simons, Waver & Schacter, 2005, who examined the neural substrates of graded recall success). It is thus possible that the medial temporal lobe is involved in two aspects of the mnemonic experience: one that indexes the subjective experience of recollection and another that indexes the amount of contextual information retrieved. While these explanations are speculative and are in need of further testing, these data do suggest a role for the hippocampus beyond the distinction between Remember and Know responses. Specifically, the pattern of activation in the hippocampus differed during recollection of words studied with and without meaningful context information, suggesting that Remember responses can differ in the extent to which they recruit the hippocampus.

4.5.3 Activation in Additional Brain Regions

In both the overall group and Group F whole-brain analyses, participants showed significantly higher activation in various regions of the lateral temporal lobe for Remember responses given to words encoded with faces compared to scrambled faces. Research shows that semantic processing of verbal information recruits anterior (Noppeney & Price, 2002) and lateral posterior (Vandenberghe et al., 1996) regions of the temporal lobe. It is possible that participants engaged in semantic processing to bind the meaningful face context and word information at study, which was reactivated at retrieval. For example, participants may use semantic knowledge to help develop a link, or association, between the item and context information at study. Murnane et al. (1999) have proposed that when item-context integration occurs a new piece of information, ensemble information, is created. The current findings suggest that this integration process involved semantic elaboration and that this semantic information (or ensemble) was reactivated at retrieval. The regression analysis additionally showed that activation in the middle and superior temporal lobe increased with behavioural performance, suggesting that the retrieval of this semantic information is related to recollection benefits for words studied with meaningful context information. I elaborate on this point further in the General Discussion (Chapter 5). Alternatively, the anterior temporal lobe activation may reflect the recapitulation of face processing activity at study, as this region has also been associated with processing face identity information (Damasio, Grabowski, Tranel, Hichway, & Damasio, 1996).

The regression analysis also showed that activation in the bilateral orbitofrontal and left ventrolateral prefrontal cortex increased as the recollection benefit for words studied with meaningful context information increased. Activation in the orbitofrontal cortex is generally found only during studies of emotional memory retrieval (Brand & Markowitsch, 2006); however, Ishai, Schmidt, and Boesiger (2005) have argued that the orbitofrontal cortex is part of a large network, including the fusiform gyrus, involved in face perception. It is thus possible that this region aided in context-specific (face) reactivation. In contrast, activation in the ventrolateral frontal lobes is more common during studies of memory retrieval and Fletcher and Henson (2001) attribute activation in this region to the updating and maintenance of information. As this region did not show differential activity in the whole-brain analysis, the results suggest that, although the updating/maintenance demands did not differ for the recollection of words presented with different context information, this region supports recollection of words studied with meaningful context information.

Group S showed additional left frontal lobe activation for Remember responses given to words studied with faces as compared to scrambled faces. Research shows that the left frontal lobe is involved in various controlled processing functions (Achim & Lepage, 2005; Wheeler & Buckner, 2003). It may be that Group S participants, who did not show a recollection benefit when words were studied with meaningful context information, engaged in a different strategy at retrieval for words studied with faces as compared to scrambled faces, changing that controlled processing demands of the task, thereby accounting for the differences in frontal activation.

4.5.4 Behavioural Performance

Based on the behavioural work presented in this thesis, I expected memory performance to be higher for words studied with faces (meaningful context information) than words studied with scrambled faces. In the current study, however, memory performance was equal for words studied with faces and scrambled faces. It is possible that the scanner environment interfered with the strategy-use in some participants and Experiment 6 of this thesis shows that this can directly influence recognition performance. In Experiment 6, I found that recollection benefits do not depend on what context is presented at study per se, but on the cognitive operations performed on that context, with higher recollection resulting from conditions that direct use a particular strategy - linking/binding item and context information. In the current study, the use of a linking/binding strategy may not have been consistent across participants, resulting in variable recollection benefits from the face versus scrambled face trials. When I took advantage of that variability in the regression analysis, was able to show that activation in the right and left fusiform gyri increased as the recollection benefit for words studied with meaningful context increased. I additionally split participants into groups based on behavioural performance and showed that sensory-specific reactivation occurred only in those participants who showed a recollection benefit for words studied with faces. This suggests that recollection benefits for words studied with meaningful contexts increase as activation in sensory-specific brain regions increase, supporting the notion that sensory-specific reactivation at retrieval is a function of the 'integratability', or the binding of item and context and information at study (Nyberg et al., 2000).

4.5.5 Methodological Aspects

This study provides a significant contribution to our understanding of how context information is stored and retrieved in the brain; however, there are many methodological issues surrounding the analysis of fMRI data. In the current study, three methodological issues deserve comment: How to best examine brain-behaviour relationships, the number of response trials required to obtain stable brain activation patters, and what baseline contrast should have been used to identify the FFA.

In the current study, I was interested in examining a brain-behaviour relationship; specifically, I aimed to identify the brain regions related to increased recollection benefits for words studied with faces. I used two methods to try to answer this question: a group split based on behavioural performance and a correlational analysis. While neuroimaging studies have used both group splits (e.g. Schönberg, Daw, Joel, & O'Doherty, 2007) and correlational analyses (e.g., Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002) to examine such relationships, each method has limitations.

Examining variability in performance by dividing groups based on behaviour can lead to important insights about individual differences in cognitive processing. For example, MacLeod, Hunt, and Mathews (1978) found two patterns of behavioural performance on a sentence-picture comprehension task, and suggested that these patterns related to the adoption of either a linguistic or pictorial-spatial strategy. However, dividing participants into sub-groups based on behavioural performance is an example of what Kriegeskorte, Simmons, Bellgowan, and Baker (2009) call double-dipping. That is, the data used to sort the participants into groups is the same data used in the analysis. They argue that such ‘double-dipping’ can distort descriptive statistics and invalidate statistical inference.

In the current study, participants were divided into two groups based on their memory performance. Unlike previous work (MacLeod et al., 1978), I did not show that there is an independent cognitive or socioeconomic measure that could predict group membership. Research shows that without an independent predictor, the results of any analysis based on such divisions can be distorted (Kriegeskorte et al., 2009). In addition, the analysis relied on ‘if A not B’ logic (i.e., if a brain region active for Group F was not active at the same threshold for Group S, the region was considered to be related to behavioural performance). As a consequence, the analysis did not identify the magnitude of the difference in brain activation between the groups. Without an independent predictor establishing Group F and Group S as valid groups, the interpretations made from this analysis may fail to identify true brain-behaviour relationships.

The correlational analysis performed in this study resolves these concerns since all of the participants’ data was used in the analysis. However, Yarkoni (2009) found that correlations in fMRI studies are often inflated when there is insufficient power (i.e., sample size). He recommends that, to examine correlations, a sample size of minimum 50 individuals is necessary. To obtain such a large sample size requires a large amount of time and money, which many smaller psychology labs simply do not have. Otherwise, he recommends stating the unlikely reliability of the correlations and to be skeptical of any correlation found between brain and behaviour.

In the current study I used both types of analyses to examine relationships between brain activation and behavioural performance. These analyses provided converging conclusions; specifically that sensory-specific reactivation is related to recollection benefits for words studied with faces. These converging results suggest that the findings are reliable. However, there was one discrepancy between the two analyses, within the medial temporal lobe. Whereas increased activation was found in the medial temporal lobe for words studied with faces versus scrambled faces in Group F, but not Group S, no region in the medial temporal lobe was identified in the correlational analysis. Whereas the former finding suggests that activation in the medial temporal lobe is related to recollection benefits for words studied with faces, the correlational analysis directly contradicts this interpretation. This discrepancy points to some of the difficulties researchers face in choosing how to examine brain-behaviour relationships and demonstrates that different methods can lead to different results and theoretical conclusions.

In a future study, to substantiate the claims that sensory-specific reactivation is related to recollection benefits for words studied with context information high in meaningful content, behaviour could be manipulated experimentally. For example, providing instructions at encoding in which some participants bind the item and context (e.g., does the word match the face, as in Experiment 6), and others perform a more surface-based encoding instruction (e.g., identify the gender of the face) would divide participants into groups a priori. Following from Experiment 6 of this thesis, recollection should be higher for words studied under the binding instruction than the surface instruction. One could then examine whether sensory-specific reactivation is higher when participants engage in processes that bind item and context at encoding, as compared to a condition that examines the surface features of the context, testing the hypothesis that sensory-specific reactivation at retrieval is a function of the 'integratability', or the binding of item and context and information at study (Nyberg et al., 2000).

A second methodological concern in the current study concerns the minimum number of events, or trials per condition, that are required to achieve a reliable fMRI signal. To obtain reliable estimates of brain activation, research suggests that at least 20 events of each condition are required (Thirion et al., 2007). In a memory task, the researcher cannot predict a priori how many hits, misses, false alarms, or correct rejections a participant will make. Although pilot testing suggested that participants would make at least 20 Remember and Know responses to each trial type, in the current study, two participants made few (< 20) Know responses per trial type. This limited my ability to make concrete conclusions when brain activation for Know responses was compared. Increasing the amount of time between study and test, or increasing the number of words on the study list, may increase the number of Know responses made in future studies, permitting a better analysis of brain activation relating to familiarity. In addition, choosing to examine recollection and familiarity through confidence ratings, rather than Remember and Know responses, may provide a better opportunity to examine recollection and familiarity at the level of the brain, as suggested by previous work (Montaldi et al., 2006; Yonelinas et al., 2005).

A third methodological issue of this study concerns that baseline conditions used for the fROI analysis. It is possible that the region identified as the fusiform face area (FFA) will change depending on the baseline used (Grady, personal communication). This suggests that, in the current study, the best baseline condition for the localizer scan would have been the same contrast as used in the memory task (i.e., faces – scrambled faces). I did not chose to use scrambled faces as the baseline condition for the localizer task because I wanted participants to engage in a one-back task to ensure they were actively attending the images. I hypothesized that performing a one-back task for scrambled faces would be much more difficult than for intact faces, which would increase the processing demands (and therefore brain activation) during the viewing of scrambled faces. Instead, I chose to use houses as the baseline condition in the localizer task, in line with pervious work (e.g., Yovel & Kanwisher, 2004). Notably, although the left fusiform regions identified in the Overall Group and Group F whole-brain analyses were very close to the regions identified in the fROI analyses, the regions were not identical. This suggests that the FFA may change depending on the baseline used and that careful consideration regarding baseline conditions is required if one wishes to perform a fROI analysis.

4.5.6 Study Extensions

I now describe potential extensions to this study that could further advance our understanding of the brain regions sub-serving recollection. The first possible extension to this study is to show a double dissociation of the reactivation of context information (see Johnson & Rugg, 2007, for an example). The current study shows only a single dissociation, in that participants who showed a recollection benefit had higher activation in the fusiform face area when words studied with faces, as compared to scrambled faces, were recollected. Providing evidence of a double dissociation would provide stronger evidence that recollection of context information involves the reactivation of the sensory-specific brain regions originally used to process that context information. For example, participants show reliable brain activation in the fusiform and parahippocampal gyrus for face and house stimuli, respectively (O'Craven et al., 1999). In a potential experiment, brain activation for Remember responses given to words studied with pictures of faces and pictures of houses could be compared. One would expect activation in the fusiform gyrus to be higher for words studied with faces, as compared to houses, and that activation in the parahippocampal gyrus would be higher for words studied with houses as compared to faces.

Second, the current study did not scan the study phase and consequently could not compare brain activation during the encoding of words studied with versus without meaningful context information. Given that I have hypothesized that participants use a strategy at encoding that associates item and context into ensemble information, which is retrieved through recollective memory processes, fMRI comparisons of encoding activation could provide insight into the brain regions used to engage in such mnemonic strategies. I hypothesize that providing meaningful context information at study will increase left prefrontal cortex activation, since this brain region has been implicated in semantic/elaborative encoding (Demb et al., 1995; Poldrack et al., 1999).

Third, the current study was unable to determine why the medial temporal lobe was more active during Remember responses given to words studied with faces (high in meaningful content) as compared to scrambled faces (low in meaningful content). I have suggested that this difference reflects variation in the amount of source information retrieved. In future studies, participants could be asked to state not only whether they Remember or Know an item but, if the item is given a Remember response, to rate the item on level of contextual detail or vividness of the memory. This type of design could help determine whether the medial temporal lobe has dual roles: one representing the subjective experience of the rememberer, and one indexing the amount of source information retrieved.

4.5.7 Theoretical Implications

These neuroimaging data presents two novel findings. First, when meaningful context (face) information was presented at study, activation in the fusiform gyrus increased during the subsequent recollection of item information presented alone. Importantly, this pattern was present only for Remember and not for Know responses, in line with dual process theories of recognition. In addition, this pattern was found only in those participants who showed a recollection benefit for words studied with faces, and activation in the right and left fusiform gyri increased as the recollection benefit for words studied with faces increased across participants, indicating that the degree to which participants recruit context-specific brain regions during retrieval is related to recollection performance. Second, there was higher activation in a region of the right hippocampus for Remember responses given to words studied with meaningful (face), as compared to non-meaningful (scrambled face), context information. This again was only found in those participants who showed a recollection benefit for words studied with faces. I suggest that the medial temporal lobe may be involved in indexing mnemonic aspects beyond the distinction between remembering and knowing. Patterns of brain activation at retrieval thus depend on the type of context information presented at study and recollection performance is related to the extent that context information is reactivated at retrieval.

Chapter 5
General Discussion

I will briefly review the findings of the experiments in this thesis. I then consider in detail how changing the type of context information changes behavioural performance and the neural regions used during the retrieval of item information, and how normal aging might affect these processes. Finally, I propose future studies aimed at specifying the processes involved in the encoding and retrieval of context information and which examine how context information influences subsequent recollection of item information.

5.1 Summary of Experiments

Chapter 2 tested the hypothesis that participants can use context information high in meaningful content to improve subsequent memory for a list of words. Previous work by Murnane et al. (1999), which examined context reinstatement effects, suggests that participants can integrate item-context pairs into ensemble information at encoding, but only when the context is high in meaningful content. Recent work by Luo et al. (2007) additionally suggests that participants can use extra context information provided at study to reduce memory errors on a later memory test when asked to reject previously studied items on an exclusion test. Following from Murnane et al.'s ICE model, I hypothesized that participants can use meaningful context information to develop ensemble information. I additionally extended this model by suggesting that ensemble information, which contains bound item-context pairs, would be preferentially retrieved through recollective (context-rich) memory processes.

In line with the hypothesis that participants can use meaningful context information to develop ensemble information, Experiment 1 showed that participants had better overall memory, specifically recollection, for words studied with pictures of intact than scrambled faces. In

Experiment 2, I replicated these results and showed that recollection was higher for words studied with pictures of faces than when no image accompanied the study word. Experiment 3 showed that participants had higher memory performance, and recollection in particular, for words studied with upright compared to inverted faces. In Experiment 4, participants showed equivalent memory for words studied with novel or familiar faces.

The results are significant for three reasons. First, they demonstrate that varying the meaningful content of context information changes subsequent item recollection even when that context information is absent at retrieval. Younger adult participants were able to use meaningful context information provided at study as a framework in which to remember item information, and this benefit occurred even when context information high and low in meaningful content was equated on luminance, contrast, and inter-item similarity. Second, the data show that the provision of meaningful context information boosts subsequent item recollection as compared to when no context information is provided. Third, the younger adult participants used contexts high in meaningful content to boost subsequent recollection regardless of whether the contexts were novel or familiar, suggesting that the novelty of the context does not mediate this effect. I suggest that participants use elaborative processes to integrate item and meaningful contexts into ensemble information, improving subsequent item recollection.

In Chapter 3, I examined how context information presented at study affects recollection of words in younger and older adults. According to the associative deficit hypothesis (ADH; Naveh-Benjamin, 2000), older adults have a specific deficit in binding item and context information into cohesive memory traces. A reduced attentional resource account of aging additionally suggests that an age-related deficit in attentional resources reduces older adults' ability to voluntarily engage in effortful encoding processes that support successful memory performance. I hypothesized that because of these deficits, older adults would be less able, or possibly unable, to use context information high in meaningful content to benefit later memory performance. However, instructional manipulations that encourage the binding of item-context pairs were expected to alleviate this deficit.

As predicted, Experiment 5 found that younger, but not older, adults showed higher Remember accuracy when words were studied with context information high, as compared to low, in meaningful content. In Experiment 6, younger and older adults both showed higher Remember accuracy when instructed to bind the item and context information (does the word match the face?) as compared to a surface-based instruction condition (identify the gender of the face). These results suggest that older adults do not spontaneously engage in the processes required to boost recollection when context information high in meaningful content is provided at study. However, instructional manipulations that promote the elaborative processes required to integrate item and context pairs during encoding lessen this deficit. The results additionally suggest that elaborative processes at encoding are required to show later recollection benefits when meaningful context information is provided at study, and that these processes involve linking or associating item-context pairs.

Chapter 4 examined how changing the quality of the context information present during the encoding of target words influenced the neural substrates sub-serving later recollection for the words presented alone. Previous work suggests that activation in the hippocampus (Montaldi et al., 2006) along with reactivation of sensory-specific brain regions (Johnson & Rugg, 2007; Wheeler & Buckner, 2004), sub-serve recollection. To explore the brain regions that support context-rich recollections, rather than compare activation between Remember and Know responses, I chose to compare activation that occurs when participants remember items originally studied with context information high and low in meaningful content. I reasoned that such a comparison could identify the neural regions needed to retrieve specific context information, enabling recollection.

The results of Experiment 7 showed that activation in the fusiform gyrus (and the functionally defined fusiform face area) and hippocampus was higher for Remember responses given to words studied with faces compared to scrambled faces, but only in those participants who showed higher recollection for words studied with faces. A regression analysis additionally showed that activation in the fusiform gyrus increased as the relative recollection benefit for words studied with meaningful (face) compared to less-meaningful (scrambled face) context information increased. These results suggest that encoding context can influence the pattern of recollection responses on a recognition task and that context-specific brain regions implicated during encoding are recruited again during retrieval.

5.2 Theoretical Implications

What do these findings tell us about recollection? This thesis has investigated the encoding and retrieval of context information through an examination of cognitive, age-related, and neural processes. I will now attempt to develop a more unified framework regarding how recollection, and the retrieval of context information, occurs.

The work in this thesis has emphasized the importance of encoding context for subsequent recollection. It suggests that simply providing participants a contextual source high in meaningful content at study increases recollection memory processes at retrieval. I have suggested that this occurs through the use of elaborative processes, and more specifically, through the development of associations and/or links between item and context information. However, the current thesis did not explore why participants might develop these associations, nor did it specific the type of associations/links participants develop when studying item and context information. It is possible that the type of association created varies across participants. Post-experimental questionnaires, described in Chapter 2, suggest that participants use a strategy in which they develop stories or make subjective judgments to link the item and context information to improve their later memory performance. However, other participants stated that they used other mnemonic strategies, such as making items personally relevant, and still showed a recollection benefit for words studied with context information high in meaningful content. Thus, the exact processes used to obtain recollection benefits, or to elaborate upon item-context pairs, may vary substantially between participants. Regardless of this variation, the fact that elaborative processes are used to make such associations should be the same across participants. The notion that participants engage in elaborative processes to bind item-context pairs, improving subsequent recollection, was supported in Chapter 3. Here, I showed that older adults were only able to use context information high in meaningful content to boost subsequent recollection when told to make an explicit link between the item and context information. I suggest that these elaborations help develop what Murnane et al. (1999) describe as ensemble information. Specifically, the ensemble information may be a unique blend of the item, the context, and the associated link created at encoding. When created, the memory is retrieved preferentially through recollective memory processes.

The findings of this study are similar to the classic levels of processing effect, in that they show that processing the meaning of information is an important predictor of future memory performance. However, rather than use instructional manipulations to change the level of processing performed on an item, this research shows that changing the level of meaningful content provided in context information at study can affect subsequent memory performance.

There are in fact two ways in which we could view this data with respect to levels-of-processing theory. We could conceptualize that providing participants context information high in meaningful content at encoding deepens the level of processing performed on the item (i.e., participants use the meaningful context information to engage in meaningful processing of the item information). The deeper level of processing increases the memory strength, improving subsequent memory performance. However, in the introduction of Chapter 2, I stated that we could also conceptualize that varying the level-of-processing simply changes the type of context information bound to item information: deep processing encourages participants to bind subjective/meaningful contexts (thoughts, emotions, etc) to the item, whereas shallow processing promotes the binding of perceptual contexts (colour, font, etc). This is similar to the 'spread of elaborative encoding' originally described by Craik and Tulving (1975), except that it suggests that it is the context, or source, information that is <u>the result of the processing,</u> rather than the <u>type of processing</u> performed on the item (or the strength of the memory), that increases subsequent recollection. Providing a context high in meaningful content at study may simply facilitate the development or rich, meaningful associations between item and context, increasing subsequent recollection. While these two interpretations are similar, they vary in their focus. In a context-based interpretation, the focus is on how the processing changes the context associated with item information, and how that may change recollective memory performance. In contrast, a strength-based levels of processing interpretation suggests that the type of processing changes the memory strength. The context-based interpretation thus specifies a unique mechanism (the development of links between item and context information, whether that context be perceptual or mental, experimentally provided or self-produced) to explain changes in memory performance.

At the neural level, only those participants who showed a recollection benefit when provided context information high in meaningful content at study showed sensory-specific reactivation. In addition, activation in the right and left fusiform gyri were found to increase as the relative recollection benefit for words studied with faces increased across participants. The findings suggest that only when ensemble information is created, by developing a link between item and context information at encoding, will participants show sensory-specific reactivation of context information. This link may thus be essential to the memory trace that binds the item and context information, making it a cohesive recollection.

One prominent model of memory retrieval, first proposed by Moscovitch and Umiltà (1990, 1991), suggests that episodic retrieval requires at least two main components. The first is mediated by the prefrontal cortex (PFC), and represents resource-demanding processes that are needed to maintain and implement strategic aspects of retrieval such as retrieval mode, search and monitoring, and the coordination of competing task demands. The second component of the model, believed to be mediated by the medial temporal lobes/hippocampus (MTL/H), involves the relatively automatic reactivation of memory traces resulting from their interaction with memory cues, a process termed ecphory by Semon (1924; see also Schacter, Eich, & Tulving, 1978). The memory trace itself is presumed to consist of an ensemble of MTL/H and neocortical neurons, the latter mediating the representations of the memory event itself, with the MTL/H acting as a pointer or index to the neocortical representations to which it is bound. At retrieval, the cue is presumed to activate the MTL/H index, which in turn reactivates the cortical representations leading to recovery of the memory trace.

The findings presented in this thesis may be captured within this model with a little elaboration. When meaningful context information is provided at study, participants bind the item and context information by developing links, or associations, between them. This binding may lead to a neocortical representation that embodies not only the item information, but also the context information and the accompanied link or association. Thus, the neocortical representation may involve item, context, and a unique blending of the item and context, or ensemble information, as conceptualized by Murnane et al. (1999). Each of these pieces of information is likely stored in a different sensory-specific brain region; for example, in my study, the item (word) information was likely stored in the visual word form area, the context (face) information in the fusiform face area, and the association, which is likely semantic in nature, in the lateral temporal lobe (shown to be related to semantic processing, e.g., Vandenberghe et al., 1996). Thus, the lateral temporal lobe activation found in the fMRI experiment in Chapter 4 may have represented the ensemble information reactivated at retrieval. The reactivation of these sensory-specific brain regions may thus leads to a vivid, context-rich, memory (see Figure 10). As described in the model (Moscovitch & Umiltà, 1990, 1991), the MTL/H complex acts as an index, or pointer, to these representations (also see Damasio, 1989 and Alvarez & Squire, 1994, who also proposed different cortical storage for different types of information).

However, as demonstrated by the experiment in Chapter 4, the precise role, or roles, of the hippocampus is in need of further specification. The hippocampus has been implicated in recollection (Yonelinas et al., 2002; 2005), source retrieval (Cansino et al., 2002), and in indexing the vividness of the memory (Gilboa, Winocur, Grady, Hevenor, & Moscovitch, 2004). Whether these findings can be unified under a single process (i.e., the indexing of the memory trace), or whether it is best to specify multiple functions (i.e., the hippocampus indexes the subjective experience, the amount of source retrieval, and the richness of re-experiencing) is currently under debate.

In any comprehensive memory model, one must also consider the roles of the frontal and parietal cortices. Imaging studies repeatedly show activation in these two brain regions during memory retrieval (Fletcher & Henson, 2001; Rugg, Otten, & Henson, 2002) and, in our review of fMRI data (Skinner & Fernandes, 2007), both the frontal and parietal lobes showed differential recruitment during recollection and familiarity. As described in the introduction to Chapter 4, the frontal lobes are believed to subserve control processes relating to memory. Theorists have posited various retrieval roles for the frontal lobe. For example, Tulving et al. (1994) suggested that the frontal lobe is involved in the establishment of a retrieval mode, whereas Henson et al. (1999) have suggested a role in monitoring and verification processes. Further research suggests that different regions of the frontal lobe mediate distinct functions. For example, Fletcher and Henson (2001) have attributed updating and maintenance processes, manipulation and monitoring of information, and selection of correct memory responses to the ventrolateral, dorsolateral, and anterior PFC, respectively (for additional theories see Moscovitch & Winocur, 2002; Shallice, 2002). In our review (Skinner & Fernandes, 2007), we showed that, although right dorsolateral prefrontal regions were recruited for both recollection and familiarity, recollection was associated with additional activity in bilateral anterior and superior frontal regions. We suggested that these activations were related to attentional shifts and the successful retrieval of contextual details. Regardless of the specific roles assigned to the prefrontal cortex, the literature indicates that familiarity and recollection recruit both similar and different frontal regions, suggesting that these processes recruit both common and unique brain regions during retrieval.

There is an increasing interest in the role of the parietal cortex in memory processing, though the functional contribution of the parietal cortex to memory retrieval is currently under debate. In our review article (Skinner & Fernandes, 2007), our analysis revealed a division in the superior and inferior parietal lobes, in that the former was associated with both recollection and familiarity and the latter was associated only with recollection. Recent theoretical developments have identified similar divisions in the functional processing of the parietal lobe. For example, Vilberg and Rugg (2008) have replicated the findings of our review, and suggested that the superior region plays a broad role in identifying task-relevant events, whereas the inferior region is tied specifically to successful recollection and forms part of the episodic buffer described in Baddeley's (2000) working memory model. Alternatively, Cabeza (2008) has proposed the dual process attentional hypothesis, suggesting that the dorsal parietal cortex contributes to top-down attentional processes guided by retrieval goals, whereas the ventral parietal cortex supports bottom-up attentional processes captured by retrieval output. In a review, Ciaramelli, Grady, and Moscovitch (2008) have also proposed the “attention to memory” hypothesis. They suggest that the superior parietal cortex is involved in the voluntary allocation of attentional resources during memory retrieval (top-down) whereas the inferior parietal cortex is involved in the more automatic capture of attentional resources by the contents retrieved from memory (bottom-up). Thus, while the specific functions of the parietal lobe vary between theories, all propose different functions for the superior and inferior regions of the parietal lobe and suggest that a unique parietal function, supported by the inferior parietal lobe, contributes to recollection.

While the specific roles of the frontal and parietal lobes during recollection have not yet been elucidated, they are included in my model under the broad terms 'control' and 'attention'. These terms are meant to reflect the notion that these brain regions contribute to retrieval by guiding the reactivation process, the frontal lobes through general control processes (e.g., retrieval mode, monitoring, etc.) and the parietal lobes through general attentional processes (attentional allocation, search processes, etc). As shown in Figure 10, these processes are believed to interact with one another (as in Ciaramelli et al., 2008), and contribute to the frontal-parietal-medial temporal retrieval network outlined in Skinner and Fernandes (2007).

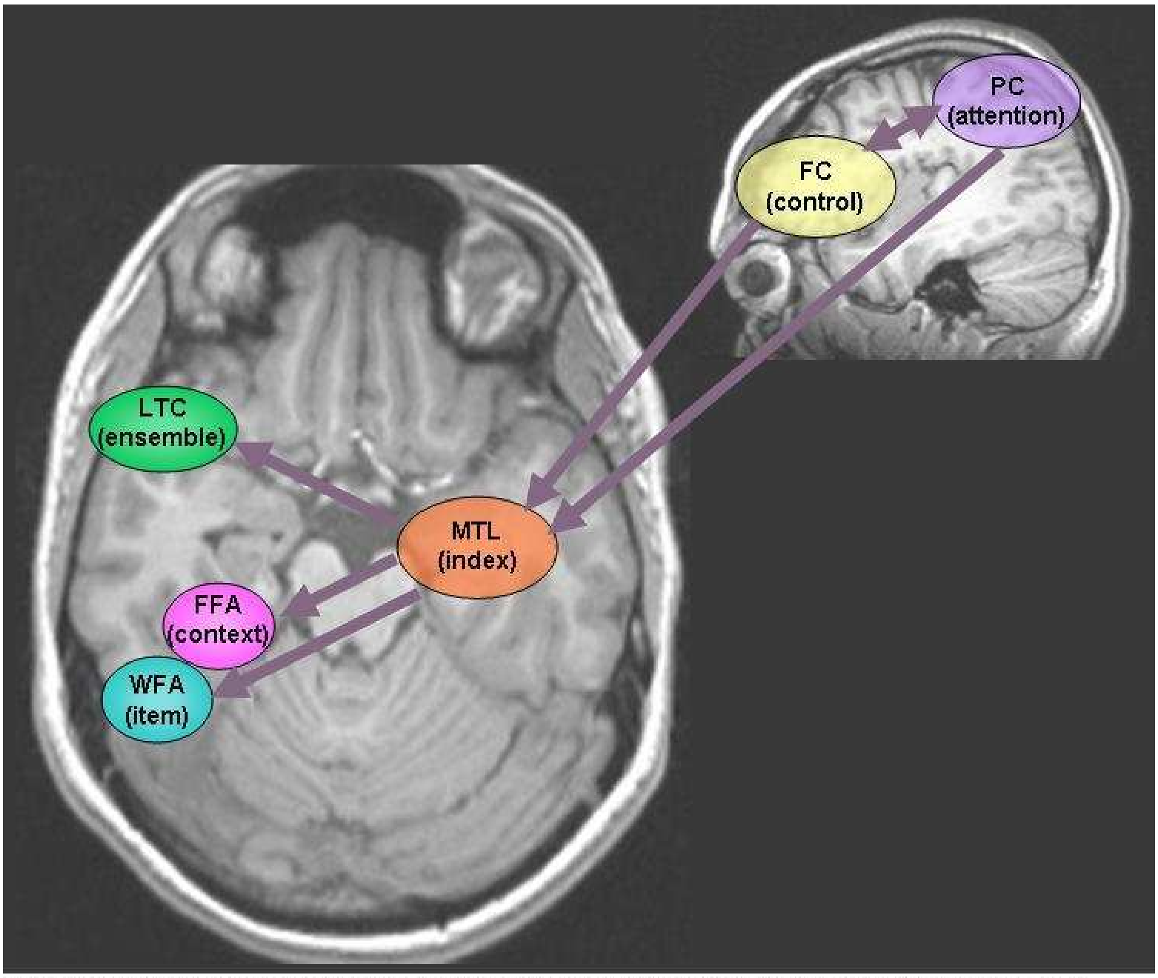

Figure 10. Hypothetical depiction of recollection. The medial temporal lobe acts as a pointer, or index, at retrieval, reactivating item, context, and ensemble information to develop a detailed, cohesive, memory trace. The frontal and parietal lobes guide this reactivation process, mediating general control and attentional processes. FC = frontal cortex; FFA = fusiform face area; LTC = lateral temporal cortex; MTL = medial temporal lobe; PC = parietal cortex; WFA = word form area.

An important theoretical question to consider is whether it is necessary to hypothesize the development of ensemble information or whether the concept of item-context binding alone can account for the findings. The concept of ensemble information is believed to be different from previous notions of item-context binding. Whereas previous theories have suggested that context information can affect the processing of item information, ensemble information is believed to be distinct from either the context or the item, in that it contains the item and context integrated into a new piece of information, created by the participant. Murnane et al. (1999) suggest that participants can use context information high in meaningful content to elaborate upon the to-be-remembered item, which integrates item and context into ensemble information.

Following Murnane et al. (1999), I suggest that the specification of ensemble information can inform our understanding of memory in two ways. First, it conceptualizes the association between the item and context, whether it involves semantic, temporal, or perceptual features, as a unique piece of information. One can conceptualize an item (word) and a context (face) by themselves, but one can also understand the ensemble (which contains the association) as another piece of information stored in memory. Only when these three pieces of information converge will recollection occur. Second, in the preceding paragraphs I have suggested that the ensemble information may contain distinct neural correlates from the item and context information considered alone. This suggestion is somewhat similar to the Binding of Item and Context (BIC) model developed by Diana, Yonelinas, and Ranganath (2007), which suggests that the retrieval of item, context, and item-in-context (i.e., ensemble) information involve three distinct neural regions, the rhinal, parahippocampal, and hippocampal cortices, respectively. As an extension to Diana et al. (2007), I suggest that the reactivation of context, item, and ensemble information, mediated by the medial temporal lobe, occur in sensory-specific brain regions. For example, if an association contains semantic information, it might be stored in the lateral temporal lobe, whereas the parahippocampal place area may be recruited if the association involves a specific location. While such associations may involve a network of brain regions, if, as I have suggested, the association can be reactivated, it is more easily conceptualized as a unique piece of information, rather than an abstract link that exists between two pieces of information (i.e., it is distinct from the item and context considered alone). For example, fMRI studies in the future may be able to specify which brain regions will be reactivated at retrieval depending on the type of ensemble information predicted to be developed.

5.3 Single and Dual Process Theories Revisited

This thesis has worked from a dual process perspective. However, many theorists promote single process models of recognition memory (see Chapter 1). Since the debate between single and dual process models of recognition memory is far from resolved, I now discuss how the results might be interpreted using a single-process, as compared to a dual-process, model.

In the majority of the experiments reported in Chapters 2 and 3, overall memory performance was found to show similar effects of study context as those found for recollection performance. Specifically, recognition memory was higher for words studied with faces than words studied with scrambled faces or inverted faces, and age-related effects of context were found in both overall recognition and recollection performance. However, overall recognition performance was not higher for words studied with faces as compared to no image (although there is a non-significant trend in this direction). Experiment 2, which compared memory performance for words studied with faces and no image, was one of the most important experiments in this thesis, because it tested the claim that meaningful context improves memory. For individuals who promote a single-process model, or who do not accept Remember judgments as a pure measure of recollection, this is a problematic finding.

However, a dual process perspective would not find this pattern problematic. Dual process theorists would suggest that, if study context effects on recognition performance are specific to recollection, combining both Remember and Know responses simply 'waters down' the effect. I suggest that, even if Remember responses are not process pure, the findings demonstrate that context information high in meaningful content provided at study benefits memory for those items in which participants report a context-rich memory.

With respect to the neuroimaging data presented in Experiment 7, if a single-process perspective were used to interpret the findings, the results would suggest that sensory-specific reactivation occurs during retrieval, rather than make the claim that sensory-specific reactivation is selective to recollection. However, whereas higher activation in the fusiform gyrus was found for Remember responses given to words studied with faces as compared to scrambled faces in both a whole-brain and ROI analysis, no such activation was found when Know responses were contrasted. This finding suggests that Remember and Know responses do differ both subjectively and neurally. Given that there are some theorists who argue that the remember-know paradigm is not process pure (Wais et al., 2008), it is possible that future studies using confidence ratings can continue to explore whether sensory-specific reactivation is selective to recollection. For example, following from previous work (Daselaar et al., 2006; Montaldi et al., 2006), sensory-specific reactivation should be associated with a steep increase in activation from medium to high confidence ratings (indexing recollection), rather than be associated with a steady increase inactivation from low to high confidence ratings (indexing familiarity).

In summary, regardless of the perspective adopted, the findings do demonstrate that context information provided at study can affect recognition memory performance and change the brain regions sub-serving retrieval. Specifically, the data show that recognition performance is higher for words studied with context information high versus low in meaningful content, specifically for those items in which participants report a context-rich memory, that older adults show such benefits only when instructed to engage in item-context integration at encoding, and that these memory benefits involves the reactivation of sensory-specific brain regions at retrieval.

5.4 Future Studies Examining Context Benefits on Recollection

While this thesis makes useful strides in our understanding of how context information provided at study affects memory performance on both the neural and cognitive level, future work is needed to continue to specify the cognitive and neural processes involved in the encoding and retrieval of context information, and how the presentation of context information affects memory performance. Our lab is currently involved in four research projects to help shed light on these issues.

First, we are examining whether differences in speed of processing in younger and older adults can account for the age-related deficits in the binding of item-context pairs observed in Experiment 5. Specifically, we are testing younger and older adults in the same paradigm as Experiment 5, but are giving the older adults additional time at encoding to integrate the item and context pairs. I believe that older adults suffer from additional deficits above and beyond a slowing in processing speed so, if the ADH is correct, older adults should continue to show equivalent memory performance for words studied with context information high and low in meaningful content.

In a related line, it is important to examine whether the age-related effects found in Experiment 5 are mediated by feelings of anxiety. Li, Nilsson, and Wu (2004) found that older adults with higher anxiety levels showed lower memory performance, and that this relation was stronger for source, than item, recall. Given that older adults may experience greater anxiety when performing lab-based memory tasks (due to stresses from being in an unfamiliar environment, tested at suboptimal times of day, concern about memory performance, etc.) than younger adults, it is important to determine whether this variable interacts with participants' ability to integrate item and context information, and to have subsequent recollections. For example, it is currently unknown whether testing older adults in their home may help ease older adults' anxiety and increase their memory performance.

Second, we are examining whether older adults will show recollection benefits when meaningful context information is provided at study if they are exposed to more familiar contextual stimuli. For example, Wright and Stroud (2002) have shown that participants are better at lineup witness identification accuracy if the people in the lineup are the same age as the participant: Younger participants are better at identifying younger culprits, whereas older adults are better at identifying older culprits. This has led researchers to suggest that there is an own-age bias in facial recognition. In Experiments 5 and 6, younger and older adult participants were asked to study words presented with face contexts of younger adults (all face stimuli were in the age range of 25-40 years). We are currently examining whether older adults show recollection benefits when the faces provided at study are from the same age group as the participant. If older adults do show an own-age bias, it is possible that presenting older faces (age range 60-80) as the context information provided at study will improve subsequent recollection of target words in older adult participants.

Third, we are testing how the affective valence of the context information provided at study affects later item recollection in younger and older adults. Studies with younger adults demonstrate that they often have enhanced memory for negatively valenced materials (e.g., Oshner, 2000). In contrast, older adults often show increased memory for positively valenced materials (e.g., Charles, Mather, & Carstensen, 2003). It is believed that differences in attention to and perception of stimuli may produce these emotional enhancement effects (Christianson, 1992). We have hypothesized that changing the emotional valence of the context information provided at study may influence memory for target words. In particular, we expect that younger adults will be more likely to recollect items presented with negatively valenced context information at study, and that older adults, who generally fail to show a recollection benefit when meaningful context information is provided at study, will show a benefit when the context information is positively valenced. Preliminary analyses indicate that younger adults show a recollection benefit when pictures, as compared to scrambled pictures, are presented with words at study, regardless of the affective valence. In contrast, older adults appear to show a recollection benefit when neutrally or positively valenced, as compared to negatively valenced, or scrambled pictures are presented with words at study. Thus, context effects on recollection performance may depend on the current goals and social needs of the participants. In a related theme, we are also interested in examining whether changes in the relevance of the context information affect subsequent item recollection. Older adults have been shown to have similar memory performance to young when the stimuli are personally relevant (Davidson, Cook, & Glisky, 2006), and personal relevance may reduce age-related differences in memory performance for affective information (Tomaszczyk, Fernandes, & MacLeod, 2008). Thus, older adults may show recollection benefits when context information high in personal relevance is provided at study.

Fourth, we are currently attempting to find a double dissociation with respect to the sensory-specific brain regions reactivated when meaningful context information is provided at study. In a pilot study, we asked younger adult participants to study words presented with pictures of faces, tools, or scrambled images, and then to perform a remember-know task on the words presented alone. Since the processing of faces and tools has been shown to activate specific regions of the fusiform cortex (Chao, Haxby, & Martin, 1999; Kanwisher et al. 1997), we expected to show a double dissociation of sensory-specific reactivation. That is, activation in the lateral fusiform gyrus activated during the processing of faces should be higher for Remember responses given to words studied with faces as compared to scrambled faces, but not for Remember responses given to words studied with tools as compared to scrambled tools. In contrast, activation in the medial fusiform gyrus activated during the processing of tools, should be higher for Remember responses given to words studied with tools as compared to scrambled tools, but not for Remember responses given to words studied with faces as compared to scrambled faces. This would provide stronger evidence that recollection of context information involves the reactivation of the sensory-specific brain regions originally used to process that context information. However, preliminary data show that recollection for words studied with tools is similar to that of scrambled images, suggesting that participants have difficulty binding word and tool information at study. It is possible that some of the tools (for example, club hammer) were too unfamiliar for some of the participants to elaborate specific links or associations between the item and word. We are in the process of trying to find another form of contextual stimuli that will show a recollection benefit similar to faces to test this hypothesis.

5.5 Summary and Conclusions

In summary, this thesis examined how context information provided at study, but absent at retrieval, influenced recognition memory performance at a cognitive, age-related, and neural level. The results suggest that recollection benefits when visual context information high in meaningful content accompanies study words, and that this benefit is not related to the novelty of the context. Although older adults did not spontaneously engage in the processes required to boost recollection when visual context information high in meaningful content was provided at study, instructional manipulation to bind item and context during encoding lessened this deficit. Neuroimaging findings additionally suggest that providing visual context information high in meaningful content changes the pattern of recollection responses on a recognition task, and that sensory-specific reactivation is related to recollection benefits for words studied with meaningful context information.

I suggest that participants use elaborative processes at encoding that integrate item and meaningful context information into ensemble information. The development of ensemble information, a unique integration of item and context, increases subsequent recollection. Individual differences in the ability to engage in such elaborative processes (e.g., age) predict the presence of such recollection benefits. In addition, context-rich recollection is associated with the reactivation of sensory-specific brain regions, and the extent of this reactivation is related to recollection benefits for words studied with meaningful context information. Taken together, the work suggests that, when meaningful contexts are provided at encoding, participants engage in elaborative processes that bind item and context information into ensemble information, leading to increased recollection and sensory-specific reactivation at retrieval.

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Author's Note

This research was supported by a discovery grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) awarded to MF, and by a post-graduate scholarship from NSERC to ES.