Content-Specific Age-Related Effects on Recollection and Familiarity

by

Patricia Marshall

A thesis submitted in conformity with the requirements for the degree of Master of Arts
Department of Psychology
University of Toronto

© Copyright by Patricia Marshall (2016)
Content-specific age-related effects on recollection and familiarity

Patricia Marshall
Master of Arts
Department of Psychology
University of Toronto
2016

Content-specific age-related effects on recollection and familiarity

Recollection declines with age are associated with hippocampal atrophy whereas familiarity sparing with age are associated with rhinal cortices which undergo minimal atrophy. Memory for specific stimuli is also supported by distinct areas (perirhinal for objects and faces, parahippocampal; hippocampus for scenes). The present study investigated age-related differences in recollection and familiarity for objects, faces, and scenes. We predicted that recollection on the rhinal based object and face tasks would be equivalent for the groups, whereas recollection on hippocampally based scene memory would be impaired for older adults. Younger and older adults completed recognition memory tasks from which recollection and familiarity were derived. Recollection was equivalent for older and younger adults for faces and objects, but reduced in older adults for scenes. These results suggest that standing assumptions regarding the universal degradation of recollection are inaccurate.
# Table of Contents

Table of Contents ................................................................. iii

List of Tables ........................................................................ iv

List of Figures ......................................................................... v

Introduction ........................................................................... 1

Current study ......................................................................... 12

Methods .............................................................................. 12

Materials and Procedure ..................................................... 13

Analyses ............................................................................. 15

Results .............................................................................. 16

Discussion .......................................................................... 20

References .......................................................................... 25
List of Tables

Table One: Medial Temporal Lobe Structures and their Associated Functions and Impairments

Table Two: Means and Standard Deviations for Demographics and Neuropsychological Scores for Younger and Older Adults

Table Three: Mean Hit Rate and False Alarm Rate by Stimulus Category and Age Group
List of Figures

Figure One: Means and Standard Errors for Corrected Recognition Scores by Stimulus Category and Age Group………………………………………………………………………………..19

Figure Two: Means and Standard Errors for Recollection Scores by Stimulus Category and Age Group…………………………………………………………………………………………..19

Figure Three: Means and Standard Errors for Familiarity Scores by Stimulus Category and Age Group…………………………………………………………………………………………..20

Figure Four: Means and Standard Errors for Corrected Familiarity by Stimulus Category and Age Group…………………………………………………………………………………………..20
From moment to moment we are constantly forming new memories; some of these will be strong and recalled easily, others will virtually disappear from our minds. These memories will be comprised of many different components, including the objects or individuals involved, and when and where the event took place. What determines how these memories are stored and recalled, and which aspects are remembered or forgotten, is an area that has been researched extensively. There are two conflicting theories of recognition memory: one-process models and dual-process models. One-process models argue that recognition memory occurs on a continuum from weak to strong recall of an event (Wixted, 2007). Dual-process theories differentiate between two aspects of recognition memory: recollection, whereby events and their associated contextual information are recalled, and familiarity, which involves a general sense that something has occurred or been seen before (Yonelinas, 2002). By a dual-process account of memory, familiarity is a continuous process ranging from weak to strong, whereas recollection is a threshold process that is very strong and accurate. Phenomenologically, familiarity and recollection appear to be different processes whereby familiarity is an automatic and fast response to a previously encountered stimulus, and recollection is a delayed and more effortful process that connects a stimulus to the event with which it was associated.

There is agreement between one-process and dual-process theories that recognition memory occurs in the medial temporal lobe (MTL); however, the two theories disagree on the contribution of MTL structures to this process. Overall, both one-process and dual-process models agree that the hippocampus integrates multimodal stimuli into single memory traces, and that item memory is coded in the perirhinal cortex. The difference between one-process and dual-process models is that one-process theorists assert that both recollection and familiarity occur along a continuum of strength, and that recollection does not depend solely on the hippocampus. One-process models assume that recollection and familiarity can occur in various MTL structures according to what inputs those structures receive (i.e. visual input in the perirhinal cortex). The current study will examine recollection and familiarity across stimulus categories using a dual-process approach.

Dual-process model

Extensive research supports a dual-process model of recognition memory that includes the dissociable processes of recollection and familiarity (Eichenbaum, Yonelinas & Ranganath,
In a review of the literature surrounding the neural mechanisms of recognition memory, Eichenbaum et al. (2007) assert that recollection takes place solely in the hippocampus. A ‘what’ pathway extending from the neocortex (sensory areas) to the perirhinal cortex allows for item memories to be encoded and for the experience of familiarity, and a ‘where’ pathway from the neocortex (parietal cortices) extending to parahippocampal regions allows contextual or spatial information to be encoded. Each of these medial temporal lobe structures has projections to the hippocampus, which is where item and context become associated together into one memory trace, resulting in the experience of recollection when confronted with the previously-encountered stimulus.

Anatomical and imaging studies support this conceptualization of MTL functioning. For example, regional specificity for item and context coding in the MTL is supported by work from Wan, Aggleton, and Brown (1999), who demonstrated that rats have selective activation when presented with either novel or familiar images of individual items or images of groups of spatially arranged items (like a scene). Novel single item images caused increased activation of the perirhinal cortex, compared to familiar single item images. Conversely, novel arrangements of familiar items caused greater activation in the hippocampus, compared to familiar arrangements of familiar items. This appears to indicate that the perirhinal cortex codes for items, while the hippocampus codes for contextual information such as spatial arrangement.

In a study with humans, Davachi and Wagner (2002) also demonstrated anatomical differentiation between relational and item-based memories. The researchers examined the association between MTL structure activation during encoding, and behavioural responses during recognition testing. Two different encoding strategies were used during study: participants studied 200 words through imagery (visualizing a scenario involving the word), and 200 words through reading (backwards). Participants were later tested using the studied words and 400 foils, by rating each word as old or new. Words rated as old were then attributed a study source, imagined or read. Results showed a functional differentiation between the perirhinal cortex, the parahippocampus, and the hippocampus. Perirhinal activation at encoding was associated with later, correct recognition, but not with accurate source recollection. Activation in the parahippocampal cortex and the hippocampus was similar, and correlated with correct item recognition when the source was also correctly recalled, but not with correct item recognition.
alone. The authors concluded that the perirhinal cortex is important for item encoding and retrieval, while the hippocampus and parahippocampal cortex are essential for contextual and associative relationships between stimuli.

Most lesion research supporting a dual-process account of recognition memory involves selective damage to the hippocampus, resulting in impairments to recollection, but not familiarity (Yonelinas et al., 2002). However, evidence of perirhinal damage causing selective deficits to familiarity is needed to support a double dissociation interpretation of MTL functioning. Bowles et al. (2007) conducted a case study on NB, an individual who had undergone resection of the left anterior temporal lobe and large portions of the perirhinal and entorhinal cortices for intractable epilepsy. The authors conducted three different types of recognition memory experiments on NB including Remember-Know (RK), Receiver Operating Characteristics (ROC), and a response-deadline procedure. Overall, NB’s recognition scores were normal. She scored higher than average for Remember judgements in the RK paradigm, but scored below the average on correct Know scores. This suggests that NB, although maintaining normal recognition memory scores, is reliant on recollection alone due to a deficit in familiarity. With the ROC procedure, NB had lower familiarity compared to controls, but no impairment in recollection. Finally, on the response-deadline procedure, which exploits the fact that familiarity occurs faster than more effortful recollection processes, NB’s accuracy on Yes-No speeded responses was reduced compared to her performance on tests that allowed a slower response. This demonstrates a behavioural deficit in familiarity responses over three types of recognition memory testing. In combination with previous hippocampal lesion work demonstrating selective recollection deficits (Yonelinas et al., 2002), we can reason that familiarity processes occur in the perirhinal cortex and recollection processes in the hippocampus.

One-process model

Wixted and Squire (2011) argue that the dual-process theory of recognition memory has a confound: memory strength. There is an assumption that recollection is a strong and accurate threshold-type memory and familiarity is a weaker, less accurate memory that is a continuous process which varies in strength. Therefore, the strength of a memory is used to differentiate between recollection and familiarity. The authors argue that both familiarity and recollection can be weak or strong. For example, source memory (which is assumed to indicate recollection) is
not always associated with the highest confidence ratings, indicating that recollected memories can vary in strength (Wixted, 2007).

One-process models (Wixted & Squire 2011) assert that the hippocampus is responsible for the integration of many aspects of a memory into one memory trace. Imaging work done by Wais, Squire, and Wixted (2010) found that when looking at memories rated with a confidence level of 5-6 (high) there was increased activity in the hippocampus, (regardless of whether source was correctly or incorrectly remembered). In other words, the hippocampus was active not only for correctly recollected memories, but also for incorrect memories rated with a high degree of confidence. The authors argue that the function of the hippocampus is to combine different memory elements together, whereas extra-hippocampal MTL structures including the perirhinal cortex support more singular representations of memory, like simple visual input. They further argue that descriptions of MTL contributions to recognition memory should be based on neuroanatomy and physiology rather than a psychological distinction between recollection and familiarity. Specifically, the functional distinction is not between weak, familiar memories in extra-hippocampal structures and strong, recollected memories in the hippocampus, but rather between simple, stimulus-based memories located in extra-hippocampal structures, and multimodal integrated memories in the hippocampus. Recollection and familiarity processes are presumed to be taking place in domain-specific brain structures associated with the stimulus.

Jeneson, Kirwan, Hopkins, Wixted, and Squire (2010) tested the assumption that the hippocampus selectively supports recollection and that extra-hippocampal MTL structures support familiarity. Healthy controls and individuals with hippocampal damage were presented with images of objects and silhouettes (to study). Participants were then given three tests: a yes-no (Y-N) recognition test (have you seen this object?); a forced-choice recognition test between the studied objects and corresponding, similar-looking foil (FC-C); and a forced-choice recognition between the studied objects and non-corresponding foils, which were similar to another object that had been studied (FC-NC). In this paradigm, familiarity was defined as correct performance on the forced-choice test with the corresponding foils, because participants are making a relative judgment, where a stronger sense of familiarity will cause the correct item to be selected. In contrast, the other two tests (Y-N and FC-NC) require participants to make a more absolute decision about the object. If the hippocampus supports recollection but not familiarity, we would expect individuals with hippocampal damage to perform well on FC-C, but
poorly on the other two tests, relative to controls. In actuality, the authors found that the group with hippocampal damage was impaired across all tests, which supports the notion that the hippocampus is important for both familiarity and recollection.

Staresina and Davachi (2006) demonstrated activation in the perirhinal cortex resulting from associative recognition; a process normally linked with recollection. Associative recognition involves the grouping of multiple stimuli together. In this case, printed nouns were superimposed on a colored square. While under an fMRI, participants were told to imagine a situation in real life where that noun and color would be associated, and to indicate if this was plausible, implausible, or if they were unable to create a mental image. Results indicated that when freely recalled, words were often recalled with the correct color association, although not in every case. This indicates that those memories that were freely recalled had well encoded associations. Activation in both the hippocampus and perirhinal cortex was recorded during encoding of the associations. Interestingly, only activation in the perirhinal cortex was found to correlate with associative recognition of the color of the presented item for free-recall and recognition.

Proponents of the one-process model have offered evidence to suggest that recognition memory may not be as clear-cut as a dual-process model would suggest. It is possible that structures outside of the hippocampus may contribute to recollective and associative processes and that the hippocampus might contribute to familiarity. However, there is abundant literature supporting the well-accepted dual-process model. Most convincingly, a double dissociation between recollection and familiarity impairments can be seen in patients with localized hippocampal and perirhinal damage (Bowles et al., 2007; Yonelinas et al., 2002).

**Estimation methods**

Some commonly used estimation methods for recollection and familiarity are the Remember-Know paradigm, item/associative recognition, Receiver Operating Characteristics, and Process-Dissociation Procedures (PDP). In a RK paradigm, participants are asked to make a Remember response if they can recall contextual details of the study event or to indicate a Know response if they have the feeling the stimulus was in the study event, but cannot recall contextual details of the memory (Tulving, 1985). Item/associative recognition tests require participants to indicate if an item has been previously viewed or not; and if two items were paired together (like
a word pair), or to identify item-context/item-feature pairings (like which list or colour an item appeared in, respectively) (Yonelinas, 2002). Here, recognition of an item can be driven by familiarity or recollection; however, identifying qualitative information about the study event (e.g., associations between items, the context in which they were presented, or detailed item features) is only driven by recollection. A ROC estimate of recollection and familiarity requires participants to rate their confidence in a memory on a Likert scale. Confidence ratings are then plotted as a function of hits (correctly identified Old items) along the y-axis, and false alarms (incorrectly identified Old items) along the x-axis. (Yonelinas & Parks, 2007). A - Y-intercept above zero indicates that there are two memory processes, and the value of the Y-intercept indicates how much recollection is occurring. The curvature of the line indicates familiarity contributions to memory. Finally, a PDP framework for memory asserts that recollection is an effortful and deliberate process whereas familiarity is automatic. The procedure to separate these two processes involves an inclusion and an exclusion component to testing. Participants encounter a study list of stimuli and are later tested. In the inclusion condition, participants give a “Yes” response to any stimulus that had been presented in the study phase (regardless of manner or form in which it is presented), and a “No” response to any New stimulus. In the exclusion task, the participants give a “Yes” response only to a stimulus that had been presented in the study phase, and that exhibits a specified presentation quality set by the test administrator (i.e. order of presentation, modality, spatial location); a “No” response is given to all New stimuli and stimuli not shown with the specified presentation quality (Jacoby, 1991).

**Age-related deficits in recollective memory**

Age-related memory loss is a concern among many older adults, however decline does not manifest uniformly across all memory processes. Recollection and familiarity are reportedly differentially affected by aging, with recollection being more affected relative to familiarity (Anderson et al., 2008; Bastin & Van der Linden, 2003; Koen & Yonelinas, 2016)

However, not all data supports this dissociation. Prull, Dawes, Martin, and Rosenberg (2006) tested three estimation methods within the same group of older adults and younger adults. Only PDP produced comparable familiarity scores for the older and younger group; both RK and ROC estimates showed an age-related deficit in familiarity, as well as the expected age-related deficit in recollection. One reason for this discrepancy may be an age-related inability to accurately interpret mental processes (i.e., confidence in memory) (Prull et al., 2006). RK and ROC
methods both involve subjective participant descriptions of recollection and familiarity. In contrast, PDP is a more objective measure of recollection based on a participant’s ability to recall the source of a memory.

Prull et al.’s (2006) study examined age differences in performance on each estimation method within the same sample separately; that is analyses were not done across estimation methods. Koen and Yonelinas (2016) argued that a direct comparison of age differences across estimation methods must be completed to determine if age interacts with estimation method. This study had participants complete several different estimation methods for recollection and familiarity, including RK, PDP, and ROC. Results indicated that across all estimation methods recollection was negatively correlated with age, while familiarity performance was not correlated with age. Contrary to previous research (Prull et al., 2006), the estimation method did not moderate the relationship between age and recollection or familiarity indicating that recollection is diminished with age, while familiarity is not.

Anderson et al., (2008) extended the finding of declining recollection and intact familiarity to older adults with amnestic mild cognitive impairment (aMCI). The researchers compared recollection and familiarity scores across younger adults, healthy older adults, and individuals with aMCI. A process-dissociation procedure was used where a series of words were presented either visually or auditorily. Words were repeated at variable lags of 0, 3, or 12 intervening words in the same or different modality (visual or auditory). Inclusion instructions required “yes” responses for previously encountered words (regardless of modality), and “no” responses for new words. The exclusion task required “yes” responses only to words repeated in the same modality, and “no” responses to all other stimuli. Familiarity in the absence of recollection is demonstrated when participants give a “yes” judgement to a word repeated in a different modality. Results demonstrated that for older adults (and especially people with aMCI) recollection was impaired. Familiarity scores did not differ among the groups. This indicates a deficit in older adults’ ability to connect an item to its original context.

**Stimulus specificity and MTL structures**

In addition to the notion that recollection and familiarity are supported by distinct regions of the MTL, there is also evidence to suggest that memory for specific stimulus domains (e.g. objects, scenes, faces) are also supported by distinct MTL areas (Duarte, Henson, & Graham,
For example, memory for objects is associated with the perirhinal cortex and lateral entorhinal (Deshmulch, Johnson, & Knierim, 2012), memory for spatial location is associated with the parahippocampal cortex and medial entorhinal (Ekstrom & Bookheimer, 2007; Reagh & Yassa, 2014), and memory for faces is associated with the right perirhinal cortex (Liang, Wagner, & Preston, 2013). Table 1 summarizes findings regarding the various MTL regions and their associated functions and age-related impairments.

Barense et al. (2005) sought to address questions regarding functional specialization in the MTL. Two groups of amnestics were included in the study - one group with hippocampal damage, and the other with MTL damage to non-hippocampal areas including the perirhinal cortex. Four object categories were used: “blobs,” “barcodes,” “bugs,” and “beasts”. For each category, the stimuli varied on two dimensions. Participants made discrimination decisions between pairs of stimuli, until eight consecutive correct trials were reached. Feature ambiguity between the target and the lure varied from low to high. Results indicated that individuals with perirhinal damage were able to discriminate between objects with low, but not high, feature ambiguity. This effect was not seen in individuals with hippocampal damage only who performed normally regardless of feature ambiguity. These results support an account of specialization of function within the MTL, where object processing takes place in the perirhinal cortex, where configurations of features of objects are learned.

Liang, Wagner, & Preston (2013) extended these findings by looking at content-specific activity in different MTL structures. The researchers examined activity in the perirhinal cortex, parahippocampal cortex, entorhinal cortex, and hippocampus (anterior and posterior) during an encoding task. Participants were exposed to blocks of five types of stimuli while in an fMRI: faces, scenes, sounds, visual words, and auditory words. Some blocks included novel presentations, and some included repeated presentations of stimuli. The authors showed that novel faces preferentially activated the perirhinal cortex, while novel scenes preferentially activated the parahippocampal cortex. The anterior hippocampus also responded equally to all content types, whereas posterior hippocampus activation was associated with scene coding. These results indicate content-specific coding within different structures of the MTL; specifically, novel faces illicit activation in the perirhinal cortex, and novel scenes in the parahippocampal cortex and posterior hippocampus.
Recently, Reagh and Yassa (2014) also investigated the differential contributions of MTL sub-regions to item and spatial coding. The researchers had participants perform a multidomain mnemonic discrimination task while in an fMRI. The task involved both an encoding and retrieval component. Stimuli included 260 common objects presented in various locations on a screen. Participants judged the items as indoors or outdoors, and their position from the center (left or right). At retrieval, participants indicated if the object was a repeated image (same object in the same location), object lure (similar object in the original object’s location), spatial lure (same object in a different location), or a completely novel image. Lateral entorhinal and perirhinal activity were associated with object recognition, whereas medial entorhinal and parahippocampal activity were associated with spatial recognition.

**Aging and atrophy in the MTL**

Researchers have found evidence that reductions in episodic memory functioning are associated with steep hippocampal volume decline in late life (Fjell et al., 2013; Rodrigue, Daugherty, Haacke, & Raz, 2013). In contrast, the entorhinal cortex shows minimal atrophy in healthy older adults (Raz, Rodrigue, Head, Kennedy, & Acker, 2004). Episodic memory problems associated with atrophy of the entorhinal cortex appear to be indicative of dementia, and not of normal aging (Du et al., 2006). Data on age-related atrophy of the perirhinal and parahippocampal cortices are scant.

Fjell et al. (2013) conducted an analysis of brain changes across adulthood. Cross-sectional data were taken from with 1100 individuals aged 18-94, and longitudinal data was taken from 142 individuals aged 60-90 in the Alzheimer’s Disease Neuroimaging Initiative database, where participants were followed for one year. Several variables were examined including total brain volume and hippocampal volume. Longitudinal findings supported the cross-sectional data, demonstrating volume reductions in most brain regions, and ventricle enlargement. Important to this paper is the hippocampus, which showed non-linear, steep decline with a critical age of 50 where decline became more pronounced.

Raz et al. (2004) also completed a longitudinal investigation of age related volumetric change in two regions important for episodic memory: the hippocampus and the entorhinal cortex. Fifty-four adults aged 26-82 were examined over a five year period. Results indicated that volume loss of the hippocampus follows with age; with older adults showing a yearly volume loss of 1.8%.
In contrast, the entorhinal cortex showed minimal atrophy in older adults, showing only an annual loss of .53%. Although both structures did decrease in volume with age, the hippocampus shrinkage far exceeded that of the entorhinal cortex.

Du et al. (2006) found results that conflict with those of Raz et al. (2004) regarding atrophy of the hippocampus and entorhinal cortex. The researchers conducted a longitudinal imaging study on hippocampal and entorhinal cortex atrophy. Participants included 42 healthy older adults ranging in age from 58 to 87 years old; 30 participants were without lacunes and 12 with lacunes. Age, subcortical vascular disease, apolipoprotein E4 and hypertension were examined as factors contributing to atrophy. The hippocampus was found to atrophy at a higher rate than the entorhinal cortex; however, in contrast to those findings by Raz et al. (2004), when controlling for the presence of lacunes and hypertension, entorhinal cortex atrophy was related to age.

**Aging and stimulus form**

There is abundant literature on age-related atrophy of MTL structures; however, there is limited literature demonstrating age-effects on memory for different stimulus forms. The literature that does exist supports the idea that memory for different content varies as a function of age (Bartlett, Leslie, Tubbs, & Fulton, 1989; Bruce & Herman, 1983; Cherry & St.Pierre, 1998). For example, Bartlett et al. (1989) found that older adults perform worse than younger adults on a memory for faces task. The researchers examined memory for faces changed in expression, changed in pose, as well as items changed in left-right orientation. Recognition testing involved indicating if faces were New, Old, or Old but changed. Older adults produced more false alarms. This implies an age-related deficit in discriminating old from new items. Younger adults outperformed older adults when discriminating same from changed-pose faces, but not in discriminating same from different orientation or changed expression items. These findings demonstrate age-based deficits in memory for very specific elements of facial stimuli.

Along these same lines, Cherry and St. Pierre (1998) discovered an age-related deficit in picture recognition. Participants viewed line drawings and rated them under one of two encoding conditions: perceptual and conceptual. Drawings were categorized either by orientation (perceptual), or semantic category (conceptual). At test, participants were given picture-fragment and word-fragment completion tasks as an implicit memory task, and free-recall and recognition were used as explicit memory measures. Older adults performed the same as younger
adults for conceptually driven implicit memory tasks, but performed worse on perceptually driven implicit memory tasks. Age deficits were observed for both explicit tasks with younger adults outperforming older adults.

Age-effects of stimuli whereby pictures are easier to remember than words has repeatedly been demonstrated (Ally et al., 2008; Luo, Hendriks & Craik, 2007; Winograd, Smith & Simon, 1982). Ally et al. (2008) sought to demonstrate a picture-superiority effect in younger and older adults using ERPs. The researchers hypothesized that older adults would have an increased ability to access familiarity-based memories of images and would engage in more post-retrieval visualization of images to compensate for impaired recollection. The study included four study-test conditions: word-word; picture-picture; word-picture; picture-word. High-density EEG was recorded at test. Older adults were numerically better than younger adults at object memory, and trended towards worse performance on word tasks. Both groups demonstrated a picture superiority effect, however the older adults benefited from pictures more so than the younger adults.

Finally, age differences have also been demonstrated for spatial memory, or memory for scenes. Memory for familiar and novel perspectives of scenes was investigated using a forced-choice task (Bruce & Herman, 1983). Participants were presented with color slides of 40, four-way intersections in a large metropolitan city. At test, participants were presented with previously viewed intersections from a 0 degree, 90 degree, or 180 degree angle and a novel scene. Younger adults were more accurate than older adults at identifying previously viewed scenes at all degrees of angle.

Overall, older adults appear to have a recognition deficit in most stimulus domains. However, identifying the degree to which these domains are impacted by age, and how this deficit changes when recollection and familiarity are included in analysis should be considered in order to expand on existing theories of healthy aging and memory.

Table 1

<table>
<thead>
<tr>
<th>Hippocampus</th>
<th>Entorhinal</th>
<th>Parahippocampus</th>
<th>Perirhinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recollection and</td>
<td>R</td>
<td>F</td>
<td>R/F</td>
</tr>
<tr>
<td>Item/Context</td>
<td>Context</td>
<td>--</td>
<td>Context</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>Stimulus form</td>
<td>Spatial, Scenes (posterior)</td>
<td>Objects(lateral)</td>
<td>Spatial</td>
</tr>
<tr>
<td></td>
<td>Spatial (medial)</td>
<td>Scenes</td>
<td></td>
</tr>
<tr>
<td>Age-related atrophy</td>
<td>Substantial</td>
<td>Minimal</td>
<td>--</td>
</tr>
</tbody>
</table>

Note. ‘—’ indicates limited information available

Current study

To date, no study has directly investigated how aging impacts recollection and familiarity for different stimulus domains. Given that these processes and their associated brain structures are differentially impacted by aging, it stands to reason that some forms of content-specific memory will remain intact in old age, whereas others will not. In order to have a comprehensive understanding of age-related brain changes and memory loss, content-specific memory changes should be investigated.

This investigation ties together research regarding the effect of age on episodic memory and stimulus form. The relationship between stimulus form (objects, scenes and faces), and dual-process memory in young adults and an aging population was explored using a 2-step item-feature associative recognition paradigm.

Based on the relationship between aging and substantial hippocampal atrophy, it was predicted the older adults would perform worse on recollection measures and memory for scenes. The entorhinal cortex, which remains relatively intact in older adults, should allow for similar performance between the two age groups on familiarity estimates and memory for objects. There is limited data regarding atrophy of the perirhinal cortex where faces are processed. However, age differences are likely to be lesser than those found for hippocampal processes where atrophy is pronounced.

Methods

Participants
The study included 19 young adults (12 females, 7 males) aged 17-23 and 15 older adults (10 females, 5 males) aged 65-80. Older adults were recruited through the Baycrest research participant pool and were paid $12 per hour as an honorarium for participation. Younger adults were recruited from an introductory Psychology course at the University of Toronto and were compensated with course credit for participation. Incentives were provided regardless of whether or not participants completed the study. Parking passes were provided, or public transportation costs were reimbursed for all participants if needed. Only individuals who spoke the English language fluently, and only those who had normal or corrected to normal vision were included. Participants could not have any major medical or psychiatric problems that affect cognition including, but not limited to, untreated hypertension, diabetes, depression, or head trauma.

Participants were pre-screened for cognitive function and English language fluency. The Telephone Interview for Cognitive Status (TICS) is a short, standardized screening test effective at detecting cognitive impairments over the phone (Brandt, Spencer & Folstein, 1988). Scores on the TICS can range from 1-50 where a score below 32 (30 modified) indicates cognitive issues. Older participants scoring below the cut-off during telephone screening were not asked to participate in the study.

The Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) was also used to screen for mild cognitive dysfunction during in-person testing. The MoCA assesses attention and concentration, executive functions, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation. Time to administer the MoCA is approximately 10 minutes. The total possible score is 30 points; a score of 26 or above is considered normal. Individuals scoring below 26 were excluded from analysis.

English language skills were assessed using the vocabulary subscale of the Shipley-2 (http://www.wpspublish.com/store/p/2967/shipley-2). The Vocabulary scale includes 40 items; each requires the respondent to choose the word among four options that is closest in meaning to the given word (Kaya & Delen, 2012).

**Materials and Procedure**

Visual processing speed could affect the rate at which participants are able to encode visual stimuli (Clarys, Isingrini & Gana, 2002). The Wechsler Adult Intelligence Scale III
(WAIS-III) Digit Symbol test was used to measure visual processing speed (Wechsler, 1999). Participants are asked to fill in rows to boxes with a symbol which corresponds to the number apparent in a legend above the test. Scoring involved the counting of correctly copied symbols in a two-minute period.

Stimuli shown to participants included images of objects, faces, and scenes. Sixty colored images of everyday, hand held tools and utensils were taken from Brady, Konkle, Alvarez and Oliva (2008). Each object was shown in two different states (e.g. open/closed, full/empty). Three sets of 20 objects per set were created and randomly assigned to conditions: same (to be tested in the same state as at study), different (to be tested in a different state), and New (an unstudied object). Two sets (40 objects) were assigned to a study set. Object state was balanced across sets (i.e. Object1 in open state for View1, Object2 in closed state for View1). The test list consisted of all 60 objects.

Face stimuli consisted of sixty images of human faces courtesy of Michael J. Tarr, Center for the Neural Basis of Cognition and Department of Psychology, Carnegie Mellon University (http://www.tarrlab.org/, Funding provided by NSF award 0339122). The selected faces included Caucasian, Asian, Hispanic, and Black adults from both sexes. There were two image files for each face; one with a neutral expression, and one smiling. All images were cropped and no clothing or body parts were visible. Three sets of 20 faces per set were created and randomly assigned to conditions: same (to be tested with the same expression as at study), different (to be tested with a different expression), and new (an unstudied image). Sets were equated for facial expression (smiling or not smiling), gender and ethnicity. The same and different sets (40 faces) were assigned to a study set. A test list including all 60 faces was created.

Images of scenes included 60 natural and man-made scenes taken from two different viewpoints. Scene images were taken by Barense lab members. Three sets of 20 scenes per set were created and randomly assigned to conditions same (to be tested in the same orientation as at study), different (to be tested in a different orientation), and new (an unstudied image). Natural and man-made scenes, and indoor or outdoor scenes were equated across sets. Two sets (40 scenes) were assigned to a study set. A test list including all 60 scenes was created.

Informed consent was obtained from all participants. Stimuli were presented using EPrime, a suite of applications for computerized experiments (www.pstnet.com/eprime.cfm). Participants
received a brief introduction explaining the study and were instructed to memorize the images on the computer screen for a memory test they would be completing. Participants were explicitly told the configuration of the images could change at test (i.e. facial expression, object state, scene viewpoint). During the study session, a series of images appeared on the screen. Each image was shown for two, four, or six seconds depending on task (objects, scenes, and faces, respectively) followed by an inter-stimulus interval of one second during which a fixation cross was displayed. After the study phase of the task, participants completed 30 seconds of serial subtraction which functioned as a distractor and prevented rehearsal.

Participants were then tested using a 2-step recognition paradigm. The first step instructed participants to press M for each stimulus they saw in the study list, regardless of any changes in configuration; and to press Z for those stimuli that were New (unstudied). If a response of New (Z) was entered, participants moved onto the next image in the test set; if a response of Old (M) was entered the participant was taken to step two. The second step instructed participants to press M if the image was in the Same configuration (i.e. facial expression, object state, or scene viewpoint); and to press Z if shown in a Different configuration. This study-test procedure was completed for each stimulus domain. Order of task (for faces, objects, and scenes) was counterbalanced across participants for both younger and older adults. After completion of the experiment, a disclosure statement was provided for participants.

**Analysis**

Independent sample t-tests were conducted on the neuropsychological tests and demographic information to determine group differences.

To provide a measure of recognition memory; corrected recognition scores were obtained by subtracting false alarms ("Yes" responses to New items) from hits ("Yes" responses to Old items) from step one of the testing procedure. Corrected recognition scores were examined using a 2 (Younger, Older) by 3 (Faces, Objects, Scenes) by 6 (Task order 1, 2, 3, 4, 5, 6) mixed ANOVA. Adjusted Bonferroni tests for multiple comparisons were used for post hoc comparisons.

In step 1 of the test phase, “Yes” responses to Old items can be due to recollection of the item from the study phase, or to a feeling that the items are familiar without recollection of the study phase context. Therefore, the probability of responding “Yes” in first testing step is computed as Recollection + Familiarity (1 - Recollection). In step 2 of the test session, erroneous
“Same” responses to differently configured items (responding “Yes” to differently configured items) occur only if the items are familiar but not recollected. Therefore, the probability of responding “Yes” to a previously seen item in the second step is equal to Familiarity (1 – Recollection). The probability of erroneous “Same” responses in the second step is subtracted from the probability of hits in the first step in order to determine the effect of the recollection process, Recollection = \( P(“Yes”|\text{Different}_{\text{Step1}}) - P(“yes”|\text{Different}_{\text{Step2}}) \). Familiarity is estimated as the probability of erroneous “Same” responses in the second step divided by the recollection score, Familiarity = \( P(“Yes”|\text{Different}_{\text{Step2}})/(1 - \text{Recollection}) \). Familiarity estimates (\( d’ \)) corrected for guessing (false alarms) are also examined (Yonelinas, Regehr & Jacoby, 1995).

Recollection and familiarity were separately examined using a 2 (Younger, Older) by 3 (Faces, Objects, Scenes) by 6 (Task order 1, 2, 3, 4, 5, 6) mixed ANOVA. Adjusted Bonferroni tests for multiple comparisons were used for post hoc comparisons.

**Results**

*Demographics and neuropsychological results*

Demographic and neuropsychological test data are presented in Table 2. Two younger adults neglected to provide education demographics and two digit symbol scores are removed from analysis due to improper delivery of the task. Younger adults had obtained significantly less education than older adults, \( t (30) = 4.75, p < .001 \). Older adults outperformed the younger adults in vocabulary, \( t (32) = 6.81, p < .001 \), but had significantly slower visual processing speed, \( t (30) = 4.72, p < .001 \). Scores on the MoCA did not differ between the age groups, \( t (32) =-.751, p = .458 \).

*Task performance results*

Mean hit rate and false alarm rate for each group by task are displayed in Table 3. Analyses of corrected recognition determined a main effect of task, \( F (2, 44) = 32.48, p<.001 \), \( \eta^2_p = .60 \) where recognition for faces (\( M = .56 \)) was lower than recognition for both objects (\( M = .83 \)) and scenes (\( M = .79 \)) when collapsed across groups. There was no significant main effect of age group, \( F (1, 22) = 3.84, p=.063 \), \( \eta^2_p = 15 \), or age group by task interaction, \( F (2, 44) = 1.79, p \)
= .075. No significant main effect or interactions were found for task order. Figure 1 displays means for corrected recognition scores across the three tasks for each group.

Analyses of recollection revealed a significant main effect of task, $F(2, 44) = 29.93$, $p < .001$, $\eta^2_p = 0.58$, with post hoc comparisons revealing significantly higher recollection scores for objects ($M = .66$) than for faces ($M = .40$) or scenes ($M = .37$) overall. The age group by task interaction approached significance, $F(2, 44) = 2.89$, $p = .066$, $\eta^2_p = 0.12$, with younger adults scoring higher ($M = .45$) than older adults ($M = .30$) on the scenes task. There was a significant interaction between task and task order, $F(2, 44) = 2.26$, $p = .031$, $\eta^2_p = 0.34$; where face performance was better for orders 2 and 4, and object and scene performance was lower for order 2. No significant main effect of age group was found. Mean recollection scores are represented in Figure 2.

Finally, older adults had higher familiarity estimates than did young adults, $F(1, 22) = 6.04$, $p = .022$, $\eta^2_p = 0.21$; but no other main effects or interactions were significant. Mean familiarity scores by age group and task are presented in Figure 3. When familiarity is corrected for guessing (false alarms), the main effect of age group is strengthened, $F(1, 22) = 9.07$, $p = .006$, $\eta^2_p = 0.94$; where older adults ($M = 1.92$) have higher scores than younger adults ($M = 1.39$). A main effect of task, $F(2, 44) = 9.53$, $p < .001$, $\eta^2_p = 0.30$; is also apparent with familiarity for scenes (2.18) being higher than faces (1.12) when false alarm rates are considered. No significant interaction between age group and task is noted for corrected familiarity, however a numerical difference for the face task between younger (0.85) and older (1.38) adults ($p = .061$) should be noted. Means and standard errors for $d'$ are presented in Figure 4.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means and Standard Deviations for Demographics and Neuropsychological Scores for Younger and Older Adults</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3

**Mean Hit Rate and False Alarm Rate by Stimulus Category and Age Group**

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Hit Rate</th>
<th>False Alarm Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>19.16 (3.02)</td>
<td>70.47 (3.42)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>13.28 (0.89)</td>
<td>16.00 (2.22)</td>
</tr>
<tr>
<td><strong>WAIS-III Digit Symbol</strong></td>
<td>84.35 (7.36)</td>
<td>65.60 (14.40)</td>
</tr>
<tr>
<td><strong>MoCA</strong></td>
<td>27.37 (1.21)</td>
<td>27.73 (1.62)</td>
</tr>
<tr>
<td><strong>Shipley’s</strong></td>
<td>27.63 (3.97)</td>
<td>36.33 (3.31)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stimulus Category</th>
<th>Hit Rate</th>
<th>False Alarm Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faces</td>
<td>0.75 (0.14)</td>
<td>0.27 (0.14)</td>
</tr>
<tr>
<td>Objects</td>
<td>0.89 (0.11)</td>
<td>0.09 (0.07)</td>
</tr>
<tr>
<td>Scenes</td>
<td>0.82 (0.14)</td>
<td>0.10 (0.08)</td>
</tr>
<tr>
<td>Younger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faces</td>
<td>0.83 (0.09)</td>
<td>0.17 (0.09)</td>
</tr>
<tr>
<td>Objects</td>
<td>0.94 (0.05)</td>
<td>0.07 (0.08)</td>
</tr>
<tr>
<td>Scenes</td>
<td>0.84 (0.12)</td>
<td>0.08 (0.09)</td>
</tr>
</tbody>
</table>
Figure 1. Means and standard errors for recognition scores by stimulus category and age group.

Figure 2. Means and standard errors for recollection scores by stimulus category and age group.
Figure 3. Means and standard errors for familiarity scores by stimulus category and age group.

Figure 4. Means and standard errors for corrected familiarity scores by stimulus category and age group.

Discussion

The goal of the current study was to examine a dual-process model of recognition memory in the context of specificity for stimuli in the MTL. It has long been accepted that recollection is a universal process that functions in the same way for all stimulus types (Tulving,
1985; Yonelinas, 2001), and that this recollective process for recalling qualitative memory details or contextual information is impaired with normal aging (Anderson et al., 2008; Koen & Yonelinas, 2016; Wolk, Signoff & DeKosky, 2008). However, with research indicating that different areas of the MTL serve stimulus specific perceptual and memory functions (Barense et al. 2005; Duarte, Hensen & Graham, 2011; Liang, Wagner & Preston, 2013 ), it is possible that qualitative information for these stimulus based memories could be stored and processed in those extra-hippocampal structures associated with specific stimuli. This could at least in part compensate for recollective impairments associated with the hippocampal atrophy that comes with normal aging.

In the present study, the results indicated that younger adults have higher recollection scores for scene memory. This finding is in line with the extensive empirical support for a recollective impairment in older age (Anderson et al., 2008; Koen & Yonelinas, 2014; Wolk, Signoff & DeKosky, 2008). Likewise, familiarity scores were higher for older adults in both the uncorrected and corrected analyses. Yonelinas et al., (1995) argue that response bias may differ based on test instructions for inclusion and exclusion conditions in a process-dissociation procedure (much like our 2-step model) and that the removal of false alarms from analyses corrects for guessing effects. In this case, results indicated an increased reliance on familiarity for older adults, particularly for scenes where hippocampal atrophy would restrict recollective processing. Older adults are able to identify previously viewed items, but recalling details of the event is more challenging.

Before data collection began, several pilot studies were carried out to equate stimulus category set lists for difficulty. A fully equated design was not achieved. Object and scene performance was comparable, while face recognition was more difficult overall. This is likely due to feature overlap between faces being more extreme than would be in scenes or objects. Previous research has reported a recognition impairment for faces in older adults (Bartlett et al., 1989; Boutet, Taler & Collin, 2015; Crook & Larrabee, 1992). This deficit is hypothesized to be due to recollective deficits whereby a high degree of feature overlap in face stimuli requires a significant amount of recollective processing to differentiate between similar features (e.g. eye shape)( Boutet, Taler & Collin, 2015). Novel faces are said to trigger familiarity responses due to previously encountered face representations. Older adults in our study produced significantly more false alarms for faces than younger adults ($p=.020$), but hit rates for younger and older
adults were similar. This indicates that older adults struggle with differentiating novel from studied faces. Although face processing takes place in the right perirhinal cortex (Liang, Wagner, & Preston, 2013), the high degree of feature overlap may require hippocampally based pattern separation to take place. Pattern separation is a process assumed to take place in the hippocampus where memories are broken down into their component parts in order to differentiate highly similar representations (Toner, Pirogovsky, Kirwan & Gilbert, 2009). If Boutet et al., (2015) are correct in stating that facial representations have a high degree of overlap, this could explain why older adults typically perform worse on facial memory tasks, even when the perirhinal cortex is spared in aging. The results of the present study do not indicate an age effect of face recognition; therefore it is likely that intact perirhinal cortices in older adults were able to process facial stimuli as effectively as younger adults.

Objects were easier to recollect for both groups overall. This effect could be due to the nameability of objects. We can more easily assign a name and description to an object than to a complicated scene containing many features, or to a list of many similar faces. For example, when studying a visual object list participants can quickly assign labels: open scissors, closed book, full glass of milk. Naming scenes is more complicated: street scene with building on left and parking lot on right, bathroom scene showing sinks and toilet stalls. Naming faces may be arbitrary without including descriptors; however, when studying many faces descriptors may be overlapping: white man-glasses, black woman-long hair, etc. In this study, age groups did not differ significantly on object memory. This is unsurprising due to object processing being supported by the age-invariable perirhinal cortex (Deshmulch, Johnson, & Knierim, 2012).

Although older adults performed similarly to younger adults on most tasks, they performed numerically worse than younger adults at scene recollection. Bruce & Herman, (1983) demonstrated that older adults have impaired spatial memory as compared to younger adults regardless of degree of viewpoint change in stimuli. Similar results have been found in both human (Park, Puglisi & Lutz, 1982; West, Welch & Knabb, 2002), and nonhuman animal work (Rapp, Kansky & Roberts, 1997) demonstrating an age-related decline in spatial memory. Spatial memory is processed via the ‘what’ pathway extending from the neocortex to the parahippocampal cortex, and ending at the hippocampus (Eichenbaum et al., 2007). Research regarding parahippocampal atrophy is limited, but we know that normal aging results in hippocampal shrinkage and impaired performance on hippocampally based tasks.
The small sample size of the current study could be an issue in identifying important effects and interactions. However, numerical differences in recollection for scenes are pronounced, while age-related numerical differences in recollection for objects and faces are negligible. This indicates that there are differences in how recollection is affected with age as a function of stimulus type and properties. The relative sparing of recollection for both objects and faces indicates that these processes have been less affected by hippocampal age changes. This would imply that standing assumptions concerning the universal degradation of recollection with age (Eichenbaum, Yonelinas & Ranganath, 2007; Tulving, 1985; Yonelinas, 2002) are incomplete. Although recollection may decrease with age overall, it is possible that performance varies as a function of stimulus type.

It is possible that the operational definition of recollection in the current study is not testing for recollective information, but rather item conjunctions. The manipulation of the images involved a perceptual detail change that was specific to the stimulus category. For example, the object task involved identifying a change in state from study to test - this could involve studying scissors in an open position, and being shown closed scissors at test. This information could be processed in terms of conjunctions of object features which could take place largely in the perirhinal cortex. Similarly, facial expression changes are simple compositions of features on a face which are possibly perceived, processed and stored in the right perirhinal cortex. However, the configuration manipulation for scenes was hippocampally dependent (viewpoint/orientation changes). Spatial memory is processed in the hippocampus and parahippocampal cortex. Therefore, it is not surprising that recollection scores would be lower for scenes for older adults, as both the item (scene) and contextual information (viewpoint) are processed and stored in the age-affected hippocampus. However, research does support item-feature perceptual details as a measure of recollection (Yonelinas, 2002). Olsen, Moses, Riggs and Ryan (2012) explain that object features or configurations can be broken down into their component parts. These component part memories are processed separately and used to compare previous representations with very similar new ones - this comparison requires the hippocampus. For example, a working memory deficit for novel stimuli was demonstrated in an individual with MTL damage (Rose, Olsen, Craik & Rosenbaum, 2012). Rose et al. (2012) had a developmental amnestic with selective hippocampal damage perform a forced-choice recognition task for novel or familiar faces or words. Delays were 1 or 8 seconds. The participant was impaired on novel, but not
familiar trials for both faces and words. The researchers suggested that the hippocampus is required for quickly binding stimulus features for novel items.

Taken together, these findings support the notion that recollection may be differently affected by age depending on stimulus category. This is a novel idea; standing assumptions regarding recollection changes in older adulthood assume that hippocampal atrophy will result in an overall recollective impairment. The relative sparing of recollection for objects and faces in the current study suggests content specific effects of age on memory. Recollective deficits in older adults have not been examined as a function of content in the past, but a description of memory change is incomplete without considering how stimulus specificity in the MTL is reflected in recollection performance. This work should be extended to include studies with larger sample sizes to ensure there is sufficient power to detect all effects. By utilizing various behavioural measures and expanding to include structural and functional neuroimaging data, findings regarding age-differences in recognition memory across stimulus types can be more accurately and comprehensively substantiated.
References


