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

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KEYWORDS: memory, aging, context, recollection, familiarity

PsycINFO classification code: 2343

Abstract

We examined how context presented at study affects recollection of words in younger and older adults. In Experiment 1, participants studied words presented with a picture of a face (context-rich condition) or a rectangle (context-weak condition), and subsequently made ‘Remember’, ‘Know’, or ‘New’ judgments to words presented alone. Younger, but not older, adults showed higher Remember accuracy following rich- than weak-context trials. In Experiment 2, we manipulated the type of processing engaged during the encoding of context-word pairs. Younger and older adults studied words presented with a picture of a face under a surface feature (gender) or binding feature (match) instruction condition. Both age groups showed higher Remember accuracy in the binding than surface instruction condition. Results suggest that providing rich contextual detail at encoding boosts later item recollection in younger adults. Older adults, however, do not spontaneously engage in the processes required to boost recollection, though instructional manipulation during encoding lessens this deficit.

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Our memories of objects, events, or words on a study list 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 seen or 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 the person is familiar to us, we cannot remember where we first 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, known as recollection and familiarity (Gardiner, 1988). Whereas recollection refers to the effortful retrieval of detailed contextual information about individual personal episodes, familiarity is thought of as an unspecific sense of having previously encountered a given item or event. To explore this difference, Tulving (1985) created the Remember-Know procedure. In this paradigm, participants are asked to state whether they “Remember” (i.e., recollect specific details about the item from the study phase), or “Know” (item is familiar, but lacks specific details from the study phase) the item is from a previously studied list. Remember responses are believed to reflect recollective memory processes, whereas Know responses align with familiarity-based recognition (Yonelinas, 2001).

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, Williams & Anderton-Brown, 1995; Prull, Dawes, Martin, Rosenberg, & Light, 2006). This finding suggests that memory deficits associated with normal aging specifically affect processes in-

volved in encoding and/or retrieving contextual details of past events. This notion is supported by studies that examine 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). These studies show that older adults have difficulty remembering the context in which an item was presented (Ferguson, Hashtroudi, & Johnson, 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, but rather, there is a disproportionate decline in the processes involved in encoding and/or retrieving contextual details of past events.

One theoretical framework that can be used to explain these findings is the Associative Deficit Hypothesis (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 required to retrieve item information (Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004). We 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 the current study we investigated whether older adults were able to use context to the same extent as young to increase recollection, and what type of processing is required to attain such benefits.

By its operational definition, 'recollection' involves remembering context information, and thus, source memory for the encoding event. This claim is supported by work showing that participants are more likely to provide accurate source information for remember than 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). Given the close relationship between recollection and source memory, one would expect that providing a contextual source that participants can use to distinguish between episodic events would specifically benefit Remember responses.

Previous work suggests that providing context at study can improve recollective memory processes, but only for younger adults. 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.

Although this work suggests that younger, but not older, adults can use context to improve recollection, the work did not specifically examine the qualitative differences in memories that resulted from their manipulation at encoding. In the current study we wished to extend the findings of Luo and colleagues by determining whether providing context during study alters the quality of memory, using a Remember-Know paradigm, and whether this effect differs in younger and older adults.

We also examined how the *richness* of the contextual information present at study affects recollection and familiarity, and whether age interacted with this effect. 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 semantic and perceptual complexity may influence the ability to integrate context and item information into a cohesive memory trace: the more complex the context, the greater the potential to use controlled cognitive processes to successfully bind the item and context information into a distinctive/detailed memory. For example, research shows that cued recall performance, in which a context word is used to prompt item memory, is improved when participants study word pairs in a sentence as compared to isolated pairs (Prior & Bentin, 2003). In the current study, we hypothesized that contexts rich in semantic/perceptual detail would provide greater opportunity to integrate context and item information, as they contain more features that could be bound to item memory.

Since it is recollection, and not familiarity, that depends on the retrieval of context information, benefits to memory performance based on contextual complexity should be specific

to recollection. 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). However, it should be noted that the nature of recollection is not well understood. Although there is some evidence to suggest that recollection is a threshold process, in which participants either succeed or fail in recollecting information about an event (Yonelinas, 1999), other work suggests that recollection may be more continuous, and can vary in degree of detail or specificity (Qin, Raye, Johnson, & Mitchell, 2001). In support of the later model, Dodson, Holland and Shimamura (1998) showed that participants can recollect partial-source information (for example, the gender of a voice) without recalling full-source information (which of two female voices). Regardless of whether recollection is best described as a threshold or a continuous process model, the provision of rich contextual information should improve later recollection, whether that recollection is based on full- or partial-source information.

The extent to which contextual information benefits later memory performance, and recollection in particular, should also depend on the 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 supports 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. Our prediction is that younger, but not older, adults will

show higher recollection the richer the contextual stimuli provided at encoding is. This possibility was tested in Experiment 1.

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 our study, explored in experiment 2, was whether instructional manipulations at encoding that encourage elaborative processing of the link between item and context increase recollection benefits attained from contextual information provided at study, particularly in older adults.

Experiment 1

We tested how the richness of contextual information provided at study influenced later memory performance. Participants studied words presented with either a picture of a face (rich contextual condition) or a rectangle (weak contextual condition), and the Remember-Know

procedure was subsequently used to test recognition memory for the words presented alone. We selected face stimuli for the context-rich condition, as these contain both semantic and perceptual complexity, and reasoned that participants could use these to develop detailed and distinctive memory traces. This hypothesis follows from studies showing that participants are more likely to remember verbal descriptors if the information is paired with a photograph of a face at study than when paired with a name, (Kargopoulos, Bablekou, Gonida, & Kiosseoglou, 2003) schematic face, or geometric shape (Glenberg & Grimes, 1995). In contrast, the picture of a rectangle was selected for the context-weak condition, as it provides relatively little unique context information that can be used to develop such memory traces. We expected recollection to be higher for words in the context-rich relative to the context-weak condition in younger adults, since they would 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 the rich context provided at study to the word, and that older adults have an associative binding deficit (Naveh-Benjamin, 2000), older adults 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.

Methods

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 ($SD = 1.44$, range = 17-22) for the younger adults and 74 ($SD = 5.79$, 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 number of years of education was 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, Piepenbrock & Gulikers, 1995). Two-hundred-twenty-five words were randomly chosen for use in three different study-test cycles. In each of these cycles, the study lists 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 ($M = 486$ 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 (see Figure 1).

Insert Figure 1 here

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 they had associated with the word during study, the temporal order, or the picture presented with the word during study. 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 were not responding on the basis of response confidence.

Following practice, participants completed the three study-test cycles. We 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 (context-rich condition) or a rectangle (context-weak condition) 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 (see Figure 1). 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 16.6° and 5.7° 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 3.5s, 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 4000ms, followed by a fixation cross for 250ms (see Figure 1). Participants could make their response anytime within the 4250ms 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 each study-test cycle. The order of presentation of the word lists for the three study-test cycles was counterbalanced across participants.

Results

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 was not emphasized during the identification task, we nonetheless examined these data. The mean response time (RT) in milliseconds to correct responses in younger and older adults was 1133 (SD = 685) and 999 (SD = 492) for faces, and 1112 (SD = 706) and 992 (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 ($F_s < 1.0$).

Memory Task Performance.

The mean number of missed recognition responses (of 225 items) was .47 (SD = .92) for the younger adults and 1.20 (SD = 2.24) for the older adults, and the mean number of responses made in less than 500ms, representing outliers, was .20 (SD = .56) and 1.20 (SD = 2.46) for the younger and older adults respectively. It is unlikely that such a small percentage of items affected the results, and so they were not excluded from the analysis.

We 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. Data were first analyzed in a 2 (Word type: 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. Table 1 shows the means for each memory measure, condition, and age group.

Insert Table 1 here

There was a main effect of Word type, with higher accuracy for the words studied with faces than words studied with rectangles, $F(1, 28) = 4.99$, $MSE = .01$, $p < .03$. The effect of Age group was also significant, $F(1, 28) = 10.79$, $MSE = .21$, $p < .005$, with younger adults showing higher recognition accuracy than older adults. These effects were accompanied by a marginally significant Word type 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, $t(14) = 3.27$, $p < .01$, but that this was not true in the older adults, $t(14) = 0.17$.

We 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 (Word type) 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 Word type, with higher accuracy for words studied with faces than words studied with rectangles, $F(1, 28) = 9.18$, $MSE = .05$, $p = .005$.

The main effect of Age group was not significant, $F(1, 28) = 2.46$, $p > .05$. Importantly, there was a significant Word type x Age group interaction, $F(1, 28) = 8.98$, $MSE = .05$, $p < .01$.

Planned comparisons showed that younger adults had higher Remember accuracy for words studied with faces as compared to words studied with rectangles, $t(14) = 3.57$, $p < .005$ (twelve of the 15 younger adults showed memory performance in this direction), but that Remember accuracy did not vary with Word type in the older adults, $t(14) = 0.32$.

For Know responses there was no effect of Word type $F(1, 28) = 3.68$ or Age group $F(1, 28) = 1.24$, and no interaction, $F(1, 28) = 3.53$, $ps > .05$. We also calculated independence measures of familiarity (Yonelinas & Jacoby, 1995)¹, and again found no main effect of Word type $F(1, 28) = 2.61$ or Age group, $F(1, 28) = 3.68$, and no interaction $F(1, 28) = 2.56$, $ps > .05$.

Although RT was not emphasized at retrieval, we examined these data in two separate 2 (Word type) x 2 (Age group) ANOVAs for correct Remember and Know responses. There was no effect of Word type, 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, $F(1, 28) = 14.30$, $MSE = 2997859.18$, $p = .001$, and Know, $F(1, 28) = 5.23$, $MSE = 2543973.99$, $p < .05$, responses, with slower response in older adults.

We also examined whether there was a correlation between RT on the identification task performed at encoding and later recollective memory performance. The correlations with face and rectangle RT were non-significant in younger adults ($r = .15$ and $.30$, $ps > .05$, 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 ($r = .64$,

$p < .01$). This similar correlation, with the rectangle identification RT and later recollection, was only marginally significant ($r = .49$, $p < .08$).

Discussion

This experiment examined whether providing semantically and perceptually rich contextual information during study of words improves later recollection of these words when presented alone at retrieval. Younger adults showed better memory for words that were studied with pictures of faces (context-rich condition) than words studied with rectangles (context-weak 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 rich contextual detail 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 context-rich, as compared to the context-weak 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 rich contextual 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 our experiment. Our 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 a direction to support the hypothesis that the face stimuli held the attention of older adults, and that this led

to their *poorer* subsequent recollection of the words paired with faces. Instead, longer RTs to classify face stimuli during encoding were associated with a higher, rather than lower, proportion of accurate Remember responses. Although we 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.

Experiment 1 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 ours, 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, we hypothesized that rich contextual detail 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. It may be that stimuli containing rich semantic and perceptual detail, such as a face, are more easily elaborated upon during study than those containing less detail, such as a rectangle. 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, Java & Richardson-Klavehn, 1996). As well, post-experiment questioning in a similar experiment in our lab suggested that the 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. When younger adults were asked how they made their Remember responses in that experiment,

over 60% reported that they used the pictures of faces to help them remember the words. 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 rectangles.

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 and McDowd, 1987).

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 1, providing specific instructions to engage in such processing may help alleviate this deficit. Our 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.

Experiment 2

In Experiment 2 we examined whether providing explicit instructions on how to encode context during the study phase affected later recollection of words. In so doing we aimed to determine a) what type of cognitive operations are required to promote recollection, and b) whether the age deficit in the use of context information to boost subsequent recollection could 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). 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 1. 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 for words studied with faces should be higher in the binding feature than 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 1, providing specific instructions to engage in such processing may help alleviate this deficit in older adults. Thus, we expected that Remember accuracy would be higher in both younger and older adults for words studied with faces in the binding, than surface, feature instruction condition.

Methods

Participants.

Thirty-two people participated in the experiment. 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 number of years of education was 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 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 1. 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 ($M = 416$ 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 1. 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 1), 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 1) 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 if 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 3500ms 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 phases 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 1. 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

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, $t(30) = 0.67$. 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, $t(30) = 0.18$. As in Experiment 1, although speed of responding was not emphasized during the encoding task, we 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 (SD = 325) and 1364 (SD = 315) for the surface feature condition, and 1576 (SD = 350) and 1969 (SD = 236) for the binding feature condition, respectively. The analysis showed a main effect of Instruction, $F(1, 30) = 78.61$, MSE = 405385.03, $p < .001$, with longer RTs in the binding than surface feature condition, and a main effect of group, $F(1, 30) = 9.71$, MSE = 1357429.88, $p < .005$, with longer RTs in the older than younger adults. The interaction was not significant.

Memory Task Performance.

The mean number of missed responses (of 90 items) was .63 (SD = .89) for the younger adults and 1.38 (SD = 2.16) for the older adults, and the mean number of items responded to in less than 500ms (representing outliers) was .19 (SD = .54) for the younger adults and .19 (SD = .54) for the older adults. As it is unlikely that such a small percentage of items affected the results, these responses were not excluded from the analysis.

We 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. 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. Table 2 shows the means for each memory measure, condition, and age group.

Insert Table 2 here

There was a main effect of Instruction, with higher accuracy for the words studied under the binding feature than the surface feature instruction, $F(1, 28) = 41.25$, $MSE = .31$, $p < .001$. There was no effect of Age group, $F(1, 28) = 2.09$, $p > .05$. There was, however, an Instruction x Age group interaction, $F(1, 28) = 5.48$, $MSE = .04$, $p < .05$, 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, $t(15) = 6.03$, $p < .001$, older adults, $t(15) = 2.11$, $p = .05$), though the size of the difference between these two conditions was larger in younger adults. We 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, $t(30) = 2.09$, $p < .05$.

The ANOVA also showed an Instruction x Order interaction, $F(1, 28) = 9.02$, $MSE = .07$, $p < .01$. 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, $t(30) = 6.02$, and $t(30) = 2.41$, $ps < .05$, respectively, though a calculation of difference scores (as above) showed the effect was larger for those in task order 1.

The mean difference score was .21 ($SD = .14$) for participants in task order 1 and .07 ($SD = .12$) for participants task order 2, which differed significantly, $t(30) = 2.90$, $p < .01$. There was no Order x Age group, or Instruction x Order x Age group interaction.

We 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, $F(1, 28) = 21.47$, $MSE = .40$, $p < .001$. Fourteen of the 16 younger adults and 10 of the 16 older adults showed patterns in this direction. There was no effect of Age group and no Instruction x Age group interaction, $p > .05$.

The analysis for Remember accuracy also showed a significant Instruction x Order interaction, $F(1, 28) = 10.23$, $MSE = .19$, $p < .005$, 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), $t(15) = 4.85$, $p = .001$, this was not true for task order 2 (binding feature followed by surface feature instruction condition), $t(15) = 1.15$, $p > .05$. There was no Order x Age group, or Instruction x Order x Age group interaction.

The analysis for Know responses showed no effect of Instruction, $F(1, 28) = 0.54$, Age group $F(1, 28) = 0.73$, and no interactions, $ps > .05$. A similar pattern was found when we calculated independence measures of familiarity (Yonelinas & Jacoby, 1995).

We 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, $F(1, 21) = .02$, but there was a main effect of Age group, $F(1, 21) = 5.09$, $MSE = 607140.17$, $p < .05$, with responses slower in the older adult than younger adult group. There

was also a main effect of Task order, $F(1, 21) = 7.05$, $MSE = 841092.27$, $p < .05$, 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 Task order, and there were no significant interactions.

Discussion

This experiment examined whether providing explicit instructions on how to encode context during the study phase affected later recollection of words, and whether the age deficit in the use of context-rich information to boost subsequent recollection, found in Experiment 1, 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 than surface 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 1, older adults now showed a boost in recollection from a context-rich encoding condition.

We 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. This suggests that once participants begin to use binding feature processing operations, it is difficult to switch to less elaborative surface feature operations. 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.

General Discussion

We examined whether providing a semantically and perceptually rich context during study altered the quality of subsequent memory for words, using a Remember-Know paradigm. We were specifically interested in whether the richness of contextual information present at study affected recollection and familiarity-based memory, and whether normal aging interacted with these effects. In addition, we examined how providing instructions on how to process the context at study altered later recollection memory in younger and older adults. In Experiment 1, we found that younger, but not older, adults showed a recollection benefit when rich contextual detail was provided at study. In Experiment 2, we 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, though they do not do so spontaneously. These results are discussed in turn.

Experiment 1 showed that younger adults had higher overall memory for words studied with pictures of faces relative to words studied with rectangles, and this effect was specific to words that were given Remember responses. The finding demonstrates that recollective memory benefits when rich contextual detail is provided at study. This result is in line with other work showing that participants are more likely to remember verbal descriptors if the information is paired with a photograph of a face at study than when paired with a name, (Kargopoulos et al., 2003) schematic face, or geometric shape (Glenberg & Grimes, 1995). Older adults, however,

did not show a recollection memory benefit when rich contextual information was provided at study, suggesting that whereas younger adults spontaneously use contexts that are rich in detail 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 memory processes benefit when context is provided at study, but only in younger adults. The older adults in our sample were high-functioning, as indicated by their higher FSIQ estimate relative to younger adults, yet still showed relative deficits in recollection during the context-rich condition. 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 2 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 features 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 can use context provided at study to boost subsequent recollection, but they do not do so spontaneously. This later point suggests that older adults may be able to be trained to use context information to improve their later recollection. Our results support this hypothesis; we 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, & Dagenback, 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. 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 we 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 2, the binding feature instruction condition showed an age difference in Remember accuracy of approximately .10 (compared to an age difference of .17 in the rich (face) context condition in Experiment 1; see Table 1). This suggests that although we were able to boost recollection in older adults by providing instructions that developed associations between item and context, we were 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 associate 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, though future work is needed to test this hypothesis.

Although the current study focused on age-related deficits in the encoding of context information, 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, Rubin & Davidson, 2001; Moscovitch, 1994). In line with this, Glisky et al. (2001) suggest 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 a deficit in the use of controlled processes at both encoding (i.e., elaboration) and retrieval (i.e., initiation of and recovery of source information).

Our findings contribute to recent interest in determining when older adults can (and cannot) use contextual information to improve their memory performance. Our 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) report 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 context to increase later recollection, though further work is needed to determine if this is true.

In summary, Experiment 1 showed that younger, but not older, adults showed a recollection benefit when rich contextual detail was provided at study. Experiment 2 showed 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, though they do not do so spontaneously.

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Acknowledgements

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

Footnote

¹ Performing separate analyses of Remember and Know responses to assess recollection and familiarity makes the assumption that Remember and Know responses are mutually exclusive. Whereas some state that this is a valid assumption (see Gardiner, Java & Richardson-Klavehn, 1996), others have argued that recollection and familiarity are better described as independent, such that items may be either recollected, or known, though a subset may be both recollected and known (Yonelinas & Jacoby, 1995). This independence assumption requires that one divide the number of Know responses by the opportunities available to make a Know response (i.e., $1 - \text{Recollection}$) to gain an accurate measure of familiarity (See Yonelinas & Jacoby, 1995 for further details). We examined familiarity based on the assumption of independence (see Tables 1 and 2), and found that the results did not differ from our analysis of Know responses.

Table 1

Experiment 1. Mean Memory Performance and Response Time in Milliseconds for Words studied with Faces (Face) and Words Studied with Rectangles (Rectangle), in Younger and Older Adults (standard deviation in parentheses).

Measure	<u>Face</u>		<u>Rectangle</u>	
	Younger Adults	Older Adults	Younger Adults	Older Adults
Overall Accuracy	.65 (.14)	.46 (.16)	.60 (.13)	.45 (.15)
Remember Accuracy	.51 (.22)	.34 (.18)	.39 (.19)	.34 (.19)
Know Accuracy	.15 (.15)	.12 (.18)	.21 (.15)	.11 (.17)
Familiarity	.24 (.22)	.14 (.25)	.33 (.17)	.14 (.21)
Response Time Remember Responses	1161 (166)	1650 (403)	1250 (207)	1656 (456)
Response Time Know Responses	1600 (429)	2013 (540)	1578 (390)	2003 (647)

Note: Familiarity was calculated as (Know Hit Rate – Know False Alarm Rate) / (1 – (Remember Hit Rate – Remember False Alarm Rate))

Table 2

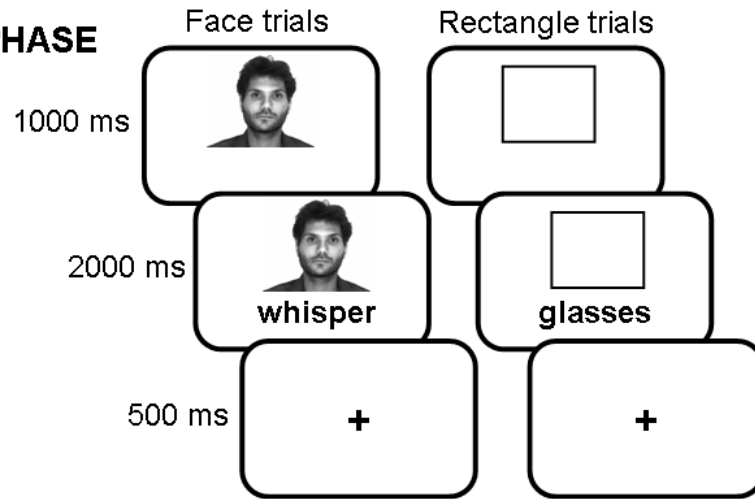
Experiment 2. Mean Memory Performance and Response Time in Milliseconds for Words
Studied Under Surface Feature Processing Instructions and Under Binding Processing
Instructions, in Younger and Older Adults (standard deviation in parentheses).

Measure	<u>Binding</u>		<u>Feature</u>	
	Younger Adults	Older Adults	Younger Adults	Older Adults
Overall Accuracy	.70 (.19)	.57 (.15)	.51 (.14)	.48 (.19)
Remember Accuracy	.60 (.22)	.50 (.17)	.38 (.18)	.41 (.15)
Know Accuracy	.10 (.18)	.07 (.15)	.13 (.18)	.08 (.17)
Familiarity	.22 (.33)	.11 (.28)	.17 (.23)	.12 (.25)
Response Time Remember Responses	1333 (303)	1474 (424)	1342 (289)	1389 (332)
Response Time Know Responses	2169 (498)	2147 (665)	2044 (491)	2233 (579)

Figure Captions

Figure 1. Sample study and test trials used in the experiment. Words were presented together with pictures of faces or a picture of a rectangle during study. On a subsequent memory test, all words were presented alone.

STUDY PHASE



TEST PHASE

