The Benefits and Boundary Conditions of Drawing on Episodic Memory

by

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

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Abstract

Drawing, as an encoding strategy for to-be-remembered words, has previously been shown to provide robust episodic memory benefits in young adults. In this dissertation, I provide experimental evidence that drawing enhances memory in both healthy older adults and individuals with probable dementia. In Experiments 1 to 5, I showed that these populations demonstrated superior episodic memory as measured by free recall for common nouns that had been drawn rather than written during encoding. I suggest that incorporating visuo-perceptual information into the memory trace by drawing pictures enhances memory by increasing reliance on visual-sensory brain regions, which are relatively intact in normal aging and dementia. Further, I provide findings regarding the boundary conditions of the drawing effect, in Experiments 6 to 8, demonstrating that drawing is only beneficial when it is semantically related to the to-be-remembered information. Finally, in Experiments 9 to 11, I demonstrate that while drawing boosts memory for studied information, it also makes one more susceptible to having false memories for related information, than does either writing or mental imagery. These findings suggest that drawing enhances memory by promoting recollection of rich visual contextual and semantic information during retrieval, and this leads to the unintended side effect of increasing false alarm rates to related information. Overall, the findings in this dissertation refine the theoretical explanation for the drawing effect by establishing a variety of circumstances in which drawing is, and is not, beneficial for memory performance.

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Table of contents

List of Tables

List of figures

Chapter 1

Episodic memory is the term used to describe our memory for episodes or events that we personally experience. It has been well known for many years in the memory literature that the way in which we interact with or process information during encoding, when we initially experience an event, determines how successful we will be when later attempting to retrieve that event from memory. For example, one well established finding is the *picture superiority effect* (PSE), wherein memory is superior for information that was initially presented in picture relative to word format (Paivio, 1971). Paivio's (1971) dual-code theory suggests the PSE results from pictures being represented both visually and verbally whereas words are only represented verbally. The dual-code theory and the PSE are an early example of how incorporating an additional way to code information (e.g. visually) benefits subsequent memory performance.

Beyond the format in which information is presented, memory can also be enhanced by the way in which an individual interacts with information during encoding. More specifically, it has been established that a variety of tasks, broadly referred to as *subject-performed tasks*, performed by a participant at encoding can boost subsequent memory performance. For example, one robust finding is that we remember information better when we think deeply about the semantic meaning (i.e. "is 'dog' pleasant?") compared to when we engage in relatively more shallow processing (i.e. " does 'dog' contain the letter a?"), an effect described as *level of processing* (LoP; Craik and Lockhart, 1972). As such, memory performance can be boosted when an individual engages in deeper level of processing of the to-be-remembered information during the initial encoding experience. Other manipulations during encoding that improve memory include the *production effect*, which refers to the finding that reading words aloud compared to silently boosts subsequent memory performance (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). The *enactment effect*, describes the finding that performing a pantomimed action associated with a to-be-remembered word (e.g. the action of brushing one's hair for the target word 'brush') benefits memory performance far more than watching someone else perform the action (Engelkamp, & Zimmer, 1997)., The *generation effect*, refers to the finding that self-generating words based on a cue composed of a synonym of the target word and the target word's first letter (e.g., rapid-f____) benefits memory performance more than simply reading a provided word (Slamecka & Graf, 1978). Each of these subject-performed tasks enhance episodic memory performance, with the main commonality being that when individuals are more actively involved in the processing of information, that information is better subsequently remembered.

In recent years, my colleagues and I have demonstrated that drawing pictures of to-be-remembered words enhances memory on tests of recall and recognition relative to a variety of other encoding tasks including writing, imagining, viewing pictures, and semantic encoding (Wammes, Meade & Fernandes, 2016; Wammes, Meade & Fernandes, 2017; Wammes, Meade, & Fernandes, 2018; Wammes, Roberts, & Fernandes, 2018, Meade, Wammes & Fernandes, 2019). For example, drawing a picture of a dog results in better subsequent memory for the word 'dog' than does writing the word, creating a mental image of a dog, looking at a picture of a dog, or writing out characteristics of a dog. The observed memory benefit from drawing, relative to writing, is referred to as the 'drawing effect', and we have suggested it emerges from the integration of pictorial, motoric, and semantic memory traces (see Fernandes, Wammes, & Meade, 2018, for review). By integrating these various types of processing (visual, motor, semantic) into the memory trace for a given word, there are more opportunities for successful retrieval to occur at a later time. To illustrate, one may recall the specific visual perceptual information of their drawing; they may be able to create a mental image of what they drew, thereby supporting retrieval. Based on some of our previous work (Wammes et al., 2017), it does indeed seem to be the case that at test individuals are able to retrieve, or ‘recollect’, specific details from the encoding context, such as a thought they had, some lines they drew, or the overall picture they created during encoding.

In advancing and refining the theoretical explanation for the drawing effect, it is important to consider *boundary conditions*, described as the ‘who, where, when’ of a theory (Whetten, 1989; Busse, Kach, & Wagner, 2017). Of the various approaches that can be taken to identify boundary conditions, the general aim is to establish the applicability of a theory in different contexts as well as situations in which the theory is not applicable (Whetten, 1989; Busse et al., 2017). In this dissertation, I examine who benefits from drawing by extending the range of the effect to both healthy older adults (Chapter 2) and individuals with probable dementia experiencing severe memory decline (Chapter 3). I then examine and refine the definition of what constitutes ‘drawing’ and the role that the content of a drawing and semantic processing play in the drawing effect (Chapter 4). Finally, I determine the effect of drawing on false memory performance, thereby advancing understanding of the full effects that drawing has on episodic memory (Chapter 5).

Healthy aging results in changes to memory function, which often present as difficulties in retrieving memories. In particular, *episodic* memory, the retrieval of past experiences, is the type of memory that declines most for healthy older adults (Light, 1991; Craik & Jennings, 1992), and to an even greater extent for individuals with dementia (Grady et al., 1988; Price, Gurvit, Weintraub, Geula, Leimkuhler, & Mesulam, 1993) compared to younger adults. The basis of episodic memory loss associated with age is thought to be related to characteristic patterns of change which occur in the brain as we age (Raz, Lindenberger, Rodrigue, Kennedy, Head, Williamson, Dahle, Gerstorf, & Acker, 2005; Raz, Gunning-Dion, Head, Dupuis, & Acker, 1998). These age-related changes include decreased brain volume in widespread regions including the caudate, cerebellum, hippocampus, association cortices, and fusiform, while sensory regions such as the primary visual cortex remain relatively intact (Raz et al., 2005). Similarly, while the underlying cause of dementia varies, the vast majority of cases are largely due to pathology present in the frontal and temporal lobes (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt et al, 1996; Golby et al,, 2005; Koenig et al, 2008). Specifically, Alzheimer's disease is the leading cause of dementia, with pathology such as tangles and plaques largely concentrated in the medial temporal regions which house the hippocampus. These regions most affected by normal healthy aging and, to a greater extent, dementia, are critical for episodic memory function. In particular, the hippocampal region in the medial temporal lobes has long been associated with the formation of episodic memories.

One of the goals for the experiments I conducted on healthy older adults and individuals with dementia was to determine how effective drawing would be as a technique to ameliorate memory deficits. This research question was motivated by findings that visual information, such as pictures, are highly effective in boosting memory performance in both healthy older adults (Craik & Byrd, 1982; Luo et al., 2007; Ally, Waring, Beth, McKeever, Milberg, & Budson, 2008) and individuals with dementia (Ally & Budson, 2007; Ally, Waring, Beth, McKeever, Milberg, & Budson, 2008; Ally, Gold, & Budson, 2009; Embree, Budson, & Ally, 2012). Furthermore, the regions of the brain involved in visual perceptual processing remain relatively intact in both healthy aging (Raz et al, 2005; Raz et al, 1998) and dementia (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt et al, 1996; Golby et al, 2005; Koenig et al, 2008), with suggestion that reliance on these regions during memory formation may aid in the creation of more reliable memories in these populations (Ally, 2012; Embree et al, 2012).

Overview of Experiments

In Chapter 2, I sought to determine the degree to which older adults' memory would benefit from drawing as an encoding strategy (Meade, Wammes, & Fernandes, 2018). The prediction was that drawing would be a particularly effective method to enhance memory as it encourages a more detailed perceptual representation. In Experiment 1, participants were given 40 seconds to either draw a picture of, or write out, each word from a set of 30 common nouns, which was followed by a free recall test for all words. In Experiment 2, an elaborative processing task was added in which participants were asked to list physical characteristics of the objects. In Experiment 3, recognition memory for the words was probed. In Chapter 3, I next investigated the effectiveness of drawing in enhancing memory in individuals with probable dementia across two Experiments (Meade, Ahmad, & Fernandes, submitted). As in Experiment 1, participants were given 40 seconds to either draw a picture of, or write out, each word from a set of 30 common nouns, followed by free recall and then a recognition test. Memory performance was compared in a group of healthy older adults to individuals with probable dementia (MMSE/MOCA range 4 to 26). The main goal of Chapters 2 and 3 was to determine the effectiveness of drawing as a method to ameliorate deficits in episodic memory in these memory-impaired populations.

The purpose of the experiments in Chapter 4 was to determine the extent to which doodling, defined as drawing that is semantically unrelated to to-be-remembered information, enhances memory performance (Meade, Wammes, & Fernandes, 2019). In Experiment 6, participants heard auditorily-presented lists of categorized words. They were asked to either doodle, draw a picture of, or write out, each item while listening to the target words. In Experiment 7, target words were embedded in a narrative story to better resemble a real-world situation in which one might doodle. Participants monitored each auditorily-presented narrative while either free-form doodling, drawing, or writing, in response to the target words. In Experiment 8, we used a structured doodling task at encoding, such that participants shaded in geometric shapes printed on paper rather than creating their own doodles. The results in Chapter 4 refine the definition of the nature and content of drawings which need to be produced in order for the drawing effect to emerge.

In Chapter 5, I investigated the effect of drawing on false memory endorsements in a recognition test (Meade, Klein, & Fernandes, invited resubmission). Both in the work presented in this dissertation and previous work in the literature (Fernandes et al, 2018, for review) drawing has been found to have robust memory benefits for studied information, however, in none of this previous work have false alarms to *un*studied information been examined in relation to drawing. In Experiment 9, I used a paradigm designed to induce a high false alarm rate for novel words that are semantically related to words which were studied either by drawing or writing. I then compared the false alarm rate for drawing to a visual mental imagery task (Experiment 10) as well as the same elaborative processing task used in Experiment 2 in which participants were asked to list physical characteristics of the objects (Experiment 11). The findings in Chapter 5 clarify how drawing impacts various aspects of episodic memory, specifically by demonstrating the effects of drawing on false memory.

Chapter 2: Drawing as an encoding tool: Memorial benefits in younger and older adults

As described in Chapter 1, episodic memory abilities change significantly with age, as evidenced by increased difficulty in retrieving past experiences for older, relative to younger adults (Light, 1991; Craik & Jennings, 1992). It is important to determine whether there are encoding strategies that might provide some reprieve for memory in older adults, by facilitating and strengthening successful encoding and retrieval. For instance, engaging in more active learning at encoding could lead to a more durable memory trace, and providing cues at retrieval may prop up otherwise impaired memory performance. In the current work, we explore the efficacy of drawing as an encoding strategy, which has recently shown promise in improving both free recall (Wammes, Meade & Fernandes, 2016) and recognition (Wammes, Meade & Fernandes, 2017) in younger adults, but has not yet been explored in older adults.

During retrieval, research suggests that age-related memory deficits can be ameliorated when the task environment provides sufficient support. Specifically, the *environmental support hypothesis* suggests that age-related differences in memory are reduced when older adults can rely on the task environment, rather than un-aided self-initiated processing, to commence and subsequently facilitate retrieval (Craik & Broadbent, 1983; Craik & Jennings, 1992). In support of the central point of this hypothesis, age differences are found to be largest on free recall tests, relatively reduced on cued-recall, and smallest on recognition tests, which offer the most environmental support at retrieval, and require the lowest amount of self-initiated processing (Craik & Jennings, 1992; Zacks, Hasher, & Li, 2000).

However, environmental support is not limited to the type of retrieval test that is implemented. Incorporating select forms of environmental support during encoding, such as generating words based on a provided cue (Craik & McDowd., 1987; Mitchell, Hunt, & Schmitt, 1986; Craik & Jennings, 1992) or providing visually rich pictorial material associated with target information during encoding (Luo, Hendriks, & Craik., 2007; Fernandes et al., 2012), similarly alleviates later memory impairments in older adults. With this, there is reason to believe that drawing may also mitigate memory deficits that arise with age. Specifically, drawing incorporates elements of the demonstrably effective aforementioned forms of environmental support (e.g. semantic generation, Craik & McDowd, 1987; pictorial material, Luo et al., 2007), through generating an internal image, then producing a pictorial representation (Wammes et al., 2016; 2017; Fernandes, Wammes, & Meade, 2018). Accordingly, drawing might also serve as a successful method to support and improve memory in older individuals.

Visual Information as Environmental Support

Of the foregoing, the provision of rich pictorial stimuli at encoding has been shown to be a particularly beneficial form of environmental support for older adults (Winograd, Smith, & Simon, 1982; Smith, Park, Cherry, & Berkovsky, 1990; Luo et al., 2007; Ally, Waring, Beth, McKeever, Milberg, & Budson, 2008; Luo & Craik; 2008; Cherry, Hawley, Jackson, Volaufova, Su, & Jazwinski, 2008; Skinner & Fernandes, 2009; Cherry, Brown, Walker, Smitherman, Boudreaux, Volaufova, & Jazwinski, 2012). In fact, the picture superiority effect (PSE), wherein pictures lead to better memory performance than words (Paivio, 1971), has been found to be larger in older than younger adults (Craik & Byrd, 1982; Luo et al., 2007; Ally, Waring, Beth, McKeever, Milberg, & Budson, 2008). In one example, to-be-remembered words were presented alone or alongside either pictorial representations of the words, two-word definitions of the words, or sound effects that were semantically related to the words (Luo et al., 2007). This work yielded the finding that when words were presented alongside pictures, both younger and older adults improved in terms of overall hit rate, which was seemingly driven by an improvement in recollection specifically (as measured by correct attributions about study modality). Importantly, using either of these measures, older adults' performance improved *more* than younger adults, relative to when words were presented alone. Older adults did not show this increased boost in memory for the conditions wherein sounds and definitions were provided. The authors suggest that their findings emerged because in contrast with older adults, younger adults are more likely to *spontaneously* engage in imagery-based encoding strategies when words are presented alone. Accordingly, since older adults are less likely to spontaneously mentally generate visual information during encoding, they gained more when visual information was explicitly built into the encoding environment (and thus did not require self-initiated processing; Luo et al., 2007). In contrast, the authors suggest that pairing the words with sounds did not provide a benefit to memory because the sounds imposed a demand on associative processing, of which younger adults are more proficient (Naveh-Benjamin, 2000).

Given these results, the presence of perceptually rich pictorial information at encoding appears to be a particularly effective tool which boosts memory performance in older adults. Because the act of drawing involves the creation of rich pictorial information, it follows from previous work that when information is drawn at encoding, we should find memory benefits similar to those observed in the PSE. Furthermore, in addition to incorporating rich perceptual information, drawing also involves self-generation of such information (i.e. to take a verbal stimulus and generate an image of what it represents). Specifically, participants are not asked to copy an exemplar picture, but rather to generate their own individualized image of the object and its features. Tasks that involve self-generation, such as when the participant must generate a definition of a word compared to reading a provided definition (Multhaup & Balota, 1997), have been found to benefit memory in both younger and older adults (Alea, Bluck, & Semegon, 2004). Given this, we predicted that drawing would lead to larger memorial benefits for older adults.

Importantly, viewing pictures and using deep LoP have previously been shown to significantly benefit older adults’ memory (Sauzeon, N'Kaoua, Lespinet, Guillem, & Claverie, 2000; Troyer, Häfliger, Cadieux, & Craik, 2006; Castel, 2007; Kirchhoff et al., 2012). Given that drawing was shown to be a superior encoding task relative to both picture viewing and deep LoP, in young adults (Wammes et al., 2016) it is likely that drawing will provide an even stronger form of environmental support at encoding for older adults through the provision of rich perceptual information. The drawing benefit may be similar in magnitude, and perhaps even superior, to young adults given the observed benefits from encoding pictures in older adults (Winograd et al., 1982; Smith et al., 1990; Luo et al., 2007; Ally et al., 2008; Luo & Craik; 2008; Cherry et al., 2008; Skinner & Fernandes, 2009; Cherry et al., 2012). Indeed, incorporating visual perceptual information into the memory trace by drawing pictures at study likely increases reliance on relatively intact visual sensory regions (Raz et al, 2005; Raz et al, 1998) to represent form, structure, angles, or imagine colour, relative to simply writing out words. By taking advantage of brain regions that remain relatively intact with increasing age, drawing may benefit older adults’ memory even more than younger adults. We predict that this rich perceptual information will also serve as contextual detail that can be used to enhance later recollection. Our primary aim in the current study was to not only establish that the drawing benefit occurs in older adults, but to determine whether, through the provision of perceptually and semantically rich environmental support at encoding, drawing (relative to writing) might improve memory *more* in older than in younger adults.

Current Study

In the current study we sought to replicate the drawing effect previously documented in young adults (Wammes et al., 2016; 2017), and to determine whether older adults could similarly benefit from drawing at encoding. We also aimed to determine whether drawing might benefit memory performance *more* in older relative to younger adults, as we predict that drawing would serve as a particularly effective form of environmental support. While it has been suggested that environmental support, which incorporates rich perceptual information, is most beneficial to older adults (Morrow & Rogers, 2008), others have argued that deep LoP is a superior encoding technique for this population (Craik & Rose, 2012). Accordingly, in Experiment 2, we compared drawing with another encoding strategy, which we implemented through a semantic elaboration task. Finally, previous work suggests that perceptually rich visual information benefits memory specifically by enhancing recollection-based (Luo et al., 2007) rather than familiarity-based memory responses (See Yonelinas, 2002 for a review of dual-process models of memory). As such, in Experiment 3, we probed the quality of memory formed through drawing versus writing, using a Remember-Know-New recognition memory paradigm (Tulving, 1985).

Experiment 1

We aimed to determine whether, and to what extent, drawing conferred a benefit to memory, in younger and older adults. Our goal was to compare the relative magnitude of the benefit of drawing, across age groups. In line with the environmental support hypothesis (Craik & Broadbent, 1983; Craik & Jennings, 1992), and previous findings of a larger PSE (Craik & Byrd, 1982; Luo et al., 2007; Ally et al., 2008) and enhanced multisensory integration in older adults (Laurienti, Burdette, Maldjian, & Wallace, 2006; Mozolic, Hugenschmidt, Peiffer, & Laurienti, 2012; Mahoney, Li, Oh-Park, Verghese, & Holtzer., 2011), we predicted that older adults would gain a larger proportional benefit from the drawing effect relative to younger adults.

Methods

Participants

The young adult participants were 24 undergraduate students (3 males and 21 females, M_{age} = 19.38, SD_{age} = 1.28) at the University of Waterloo who received partial course credit for participation. A power analysis was performed to determine how many participants were needed to reach 80% power using the G*Power program (Faul, Erdfelder, Lang, & Buchner, 2007). The expected cohen's d was 1.26 based on the mean of the effect sizes in experiments reported in (Wammes, Meade, & Fernandes, 2016) which indicates that only 8 participants would be needed to achieve 80% power in a within-subjects design. The 24 older adult participants (4 males and 20 females, M_{age} = 78.80, SD_{age} = 7.57) were recruited from the Waterloo Research in Aging Participant Pool (WRAP) at the University of Waterloo, and received token monetary remuneration. 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. All older adult participants scored above 27 (*M* = 28.87, *SD* = 1.10) on the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) which was used to screen for gross neurological impairment.

Materials

Word list. Eighty words were selected from the verbal labels for Snodgrass images (Snodgrass and Vanderwart, 1980), to ensure that all words could be easily drawn. Words ranged in frequency between 1 and 25 (M = 8.23, SE = .72), in length between 3 and 11 letters, (M = 5.56, SE = .20), and in number of syllables from 1 to 4 (M = 1.63, SE = .08).

Due to the *word frequency effect*, words which we encounter with a high frequency in everyday life (for example, ‘chair’) are better recalled than low frequency words (for example, ‘yacht’). If we had had some words which were very high frequency, it could have been the case that participants recalled these words by virtue of their frequency and not due to our encoding manipulation.

Filler Task. Sound files representing low-, medium- and high-pitched tones were created using Audacity software (Mazzoni & Dannenberg, 2000), such that each sine wave tone was exactly 500 ms long, at frequencies of 350, 500, and 650 Hz respectively. The purpose of the distractor task was to disrupt any additional processing that participants may engage in regarding the study material, such as rehearsal of words, and to ensure that we were not assessing ‘short-term’ memory. This technique has been used in our other published research as well (e.g. Fernandes & Moscovitch, 2000), and is recommended by Craik and colleagues (1996) to reduce recency effects in recall.

Procedure

Participants each completed the experiment individually in a testing room. Stimulus presentation, and response recording for the filler task, were controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer with 17-inch monitor. All instructions were presented in English both on-screen and were also read aloud by the experimenter. Participants were not informed that they would be required to complete a later memory test. This incidental encoding paradigm was selected to reduce the possibility that participants would develop a strategy of preferentially focusing on drawn items in anticipation of later testing. Specifically, such memory strategies could range from rehearsing the word, to semantic elaboration by making links to related information. Use of such overt strategies would be problematic given that we want to know how drawing, specifically, versus writing, influences memory performance when all other factors are held constant. Ultimately, we wanted to ensure that participants were not attempting to use strategies other than drawing and writing when encoding the words. While there is evidence demonstrating that older adults perform more poorly than younger adults on incidental memory tasks (Bromley, 1958; Kausler & Lair, 1965; Eysenck, 1974), when directly comparing incidental to intentional memory performance, memory decrements observed in older adults are of a similar magnitude (Crook, Larrabee, & Youngjohn, 1993; Tellez-Alanis, & Cansino, 2004). Use of an incidental rather than intentional memory task should therefore not skew the pattern of results given that similar magnitudes in age-related decrements are observed when comparing these two task types (Crook, Larrabee, & Youngjohn, 1993; Tellez-Alanis, & Cansino, 2004), and comparable effect sizes occur across intentional and incidental designs for other encoding tasks in young adults (Walsh & Jenkins, 1973; Craik & Tulving, 1975).

Encoding. Participants first completed a brief practice session in order to familiarize them with the encoding phase, after which the experiment began. The instructions indicated that depending on the ‘prompt’ word participants saw; they were to either ‘draw’ or ‘write’ the subsequent word on the pad of paper provided. A prompt of ‘draw’ indicated that the participant was to draw a picture illustrating the object that the word on the screen represents, and to continue adding detail until the trial ends. A prompt of ‘write’ meant the participant was to clearly and carefully write out the word multiple times. From the list of 80 words, 30 were randomly selected to be studied, a list unique for each participant. Of these 30, 15 were randomly selected to be drawn, and 15 written, with the presentation of the encoding trial types intermixed. The selection of words was randomized, and the order of the encoding trial tasks was intermixed randomly for each participant to mitigate the possibility of any potential effects of experience or practice with the encoding tasks in consistently and differentially affecting memory performance for the drawn words or other trial types. On each trial, the prompt appeared in the center of the screen for 750 ms, followed by a 500 ms fixation, after which the word to be encoded appeared for 750 ms. Participants then had 40 s to perform whichever task the prompt indicated, either draw or write. A 500 ms tone alerted them that the next item was forthcoming, after which they had 3 s to flip their pad of paper to the next page in preparation for the next prompt. Participants were informed of the time constraints for each item and that they would hear a tone to indicate the end of the trial and the appearance of the prompt and word for the next trial. See Figure 1 for examples of drawing and writing.

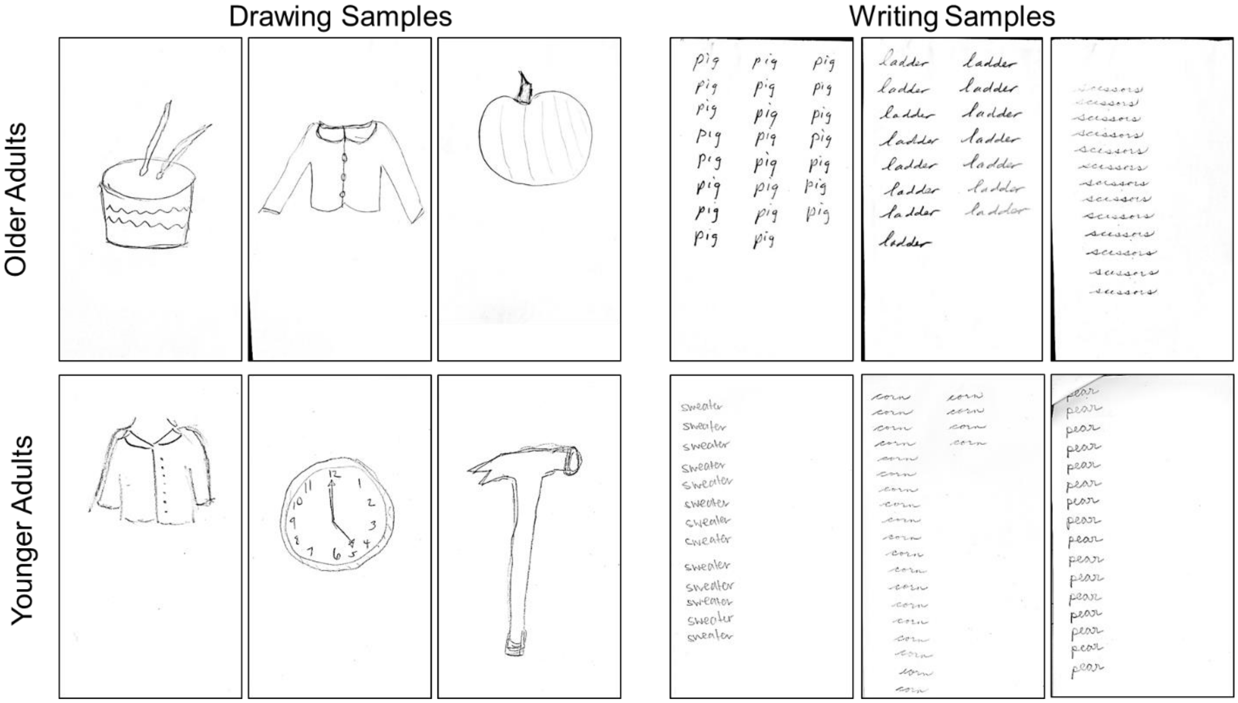

Figure 1. Examples of drawings and writing produced by younger and older adult participants in Chapter 2.

Retention. Following the encoding trials, participants were asked to perform a continuous reaction time (CRT) task as a filler, and to prevent recency effects in memory. Tones were to be classified as low, medium or high, by pressing the 1, 2 or 3 key on a computer keyboard. After hearing samples of each kind of tone, participants proceeded to classify 60 tones, selected at random. For each trial, the tone was played for 500 ms, after which participants had 1500 ms to make their response, for a total of 2000 ms per trial. Participants completed this tone classification task for two minutes.

Retrieval. In the next phase of the experiment participants were asked to freely recall as many words as they could, in any order, either written or drawn, from earlier in the experiment. They were given 2 minutes to write out as many words as they could recall.

Results

The number of words recalled was analyzed in a 2 Age (Younger and Older) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA with age as a between- and encoding type as a within-subjects factor (See Table 1 for means). As determined by Mauchley’s Test of Sphericity The assumption of sphericity was not violated in this experiment or elsewhere in this thesis unless otherwise specified. As expected, the analysis revealed a main effect of encoding trial type, F (1, 46) = 198.16, MSE = 495.04, $p < 0.001$, $\eta = 0.81$ such that drawn words were better remembered than written, and a main effect of age, F (1, 46) = 22.83, MSE = 44.08.17, $p < 0.001$, $\eta_p^2 = 0.33$, such that younger adults recalled more words than older adults, but no Age X Encoding type interaction, F (1, 46) = 0.02, MSE = 0.04, $p = 0.90$, $\eta_p^2 = 0.00$.

Table 1. Means and standard deviations of the number of words recalled in Experiment 1, in younger and older adults following each Encoding Trial type

	Encoding Trial type	
	Written	Drawn
Younger	5.00 (*2.09*)	9.5 (*1.74*)
Older	3.04 (*1.43*)	7.63 (*1.81*)

Given that older adults demonstrated poorer overall memory than younger adults, a finding that replicates previous work (Craik & Jennings, 1992; Zacks et al., 2000), we could not determine the relative memorial benefit that drawing provides each age group. To illustrate, consider comparing a younger adult, who recalled 9 words, 6 of which were drawn and 3 written, with an older adult who recalled 3 words, all of which were drawn. In this circumstance, each participant would show a similar magnitude of drawing-related benefit (+3) if only their raw number of drawn words recalled was considered. However, they would differ greatly when assessing how much they actually relied on the drawing manipulation proportionally. As such, to bypass the drawback of using raw memory performance to compare age groups, we opted to calculate the proportion of drawn and written words recalled by dividing the number of each by the total number of words recalled by each individual participant. In so doing, we could determine the relative benefit from each encoding trial type, and make comparisons across our age groups. See Figure 2 and Table 1 for means, and see Figure 3 for individual performance distributions.

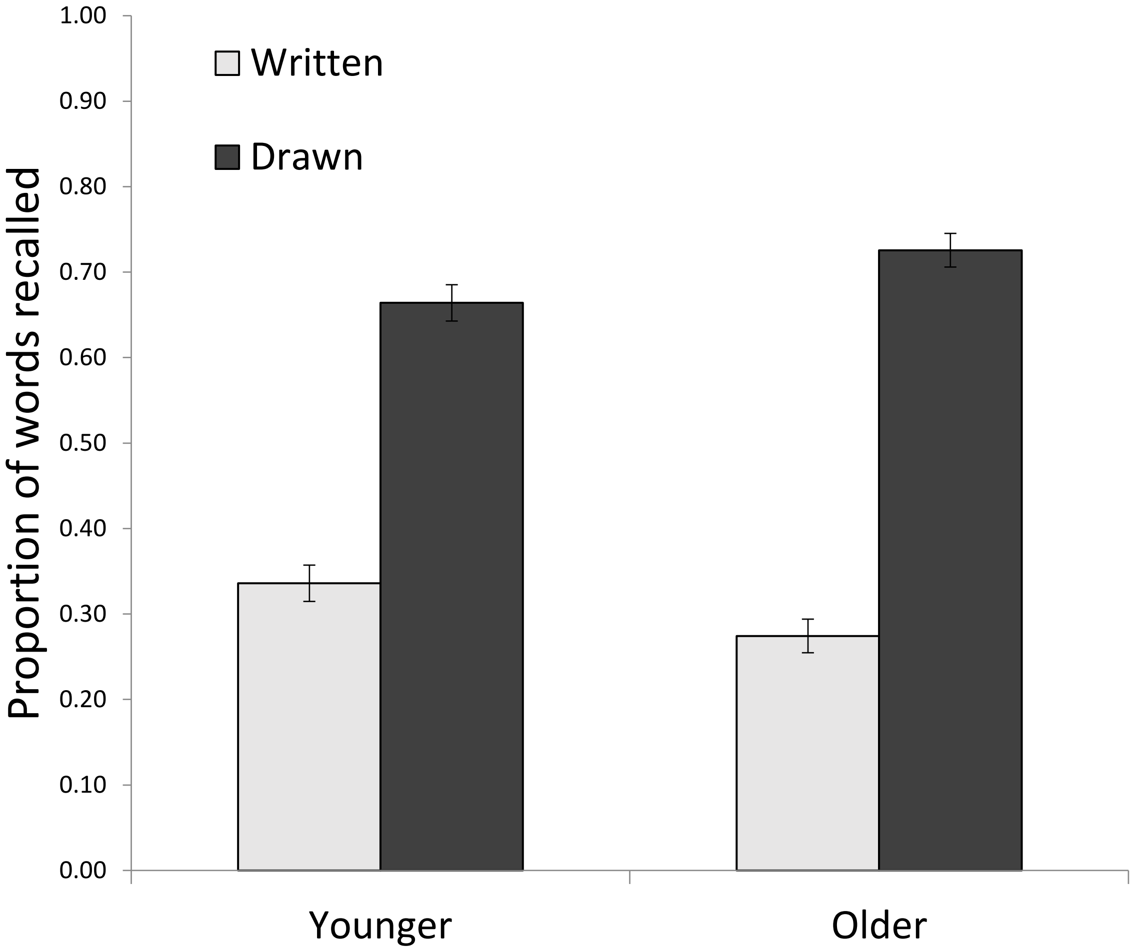

Figure 2. Proportion of words recalled in Experiment 1 for words drawn or written at encoding.

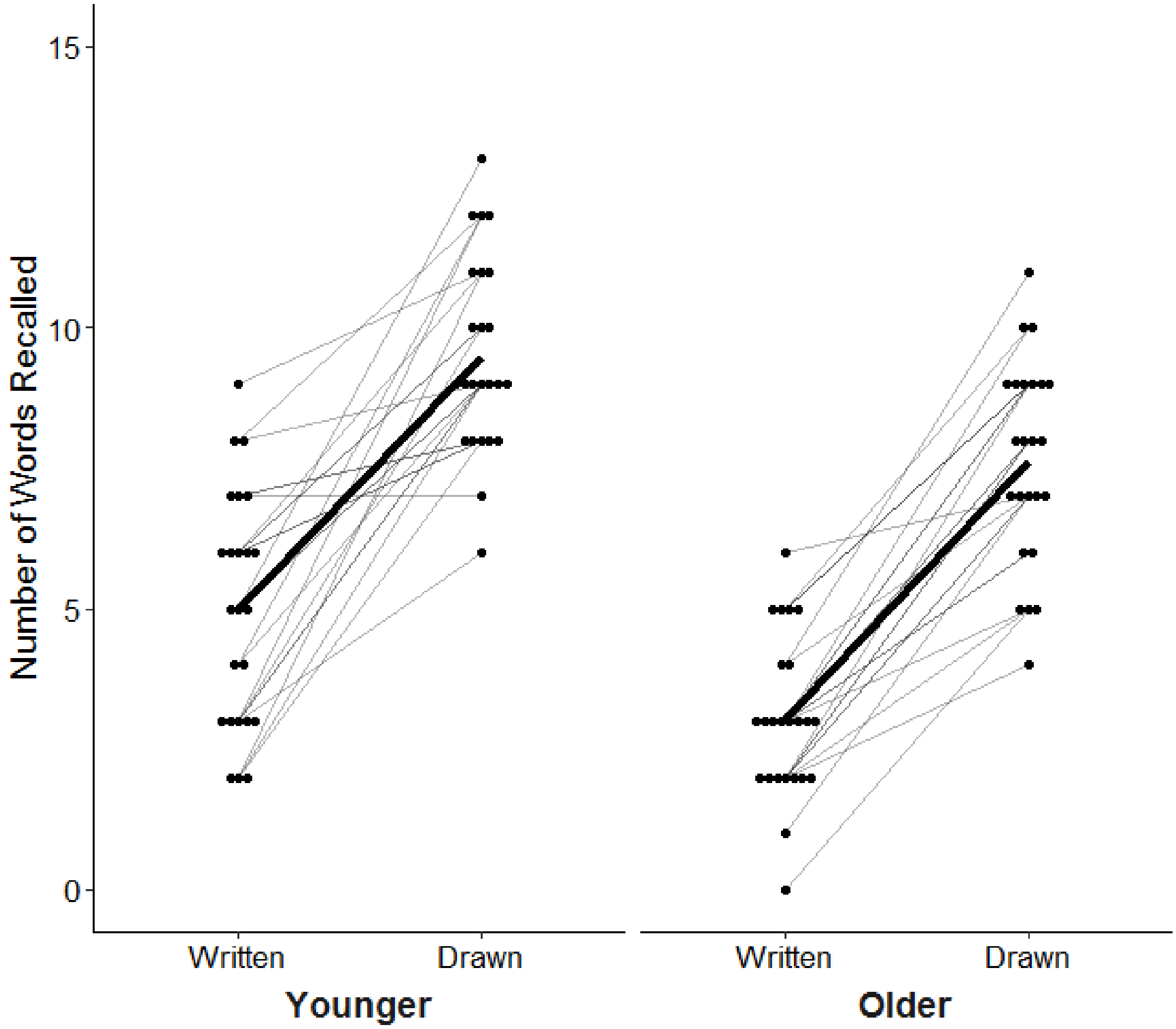

Figure 3. Individual participant performance in Experiment 1 for words drawn or written at encoding, with average performance in each encoding trial type denoted by the thick black line.

A 2 Age (Younger and Older) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA was performed on proportional data with age as a between- and encoding type as a within-subjects factor. The results revealed a main effect of encoding trial type, F (1, 46) = 181.19, MSE = 3.64, $p < 0.001$, $\eta_p^2 = 0.79$, such that more drawn words were recalled than written, but no main effect of age. Importantly, there was a significant Age X Encoding trial type interaction, F (1, 46) = 4.53, MSE = 0.09, $p = .04$, $\eta_p^2 = 0.09$, such that recall output in older adults contained a larger proportion of words that were drawn at encoding, compared to younger adults.

In our sample we had a wide range of age within our older adults group. As such, we examined whether the magnitude of the drawing effect was associated with age within the group of older adults. A Pearson correlation revealed no reliable relationship between age (within our older adult group) and the magnitude of the drawing effect, r = 0.007, p = 0.98 (see Figure 4 for scatter plot). This result indicates that the magnitude of the drawing effect does not vary within the age range of our older adult sample.

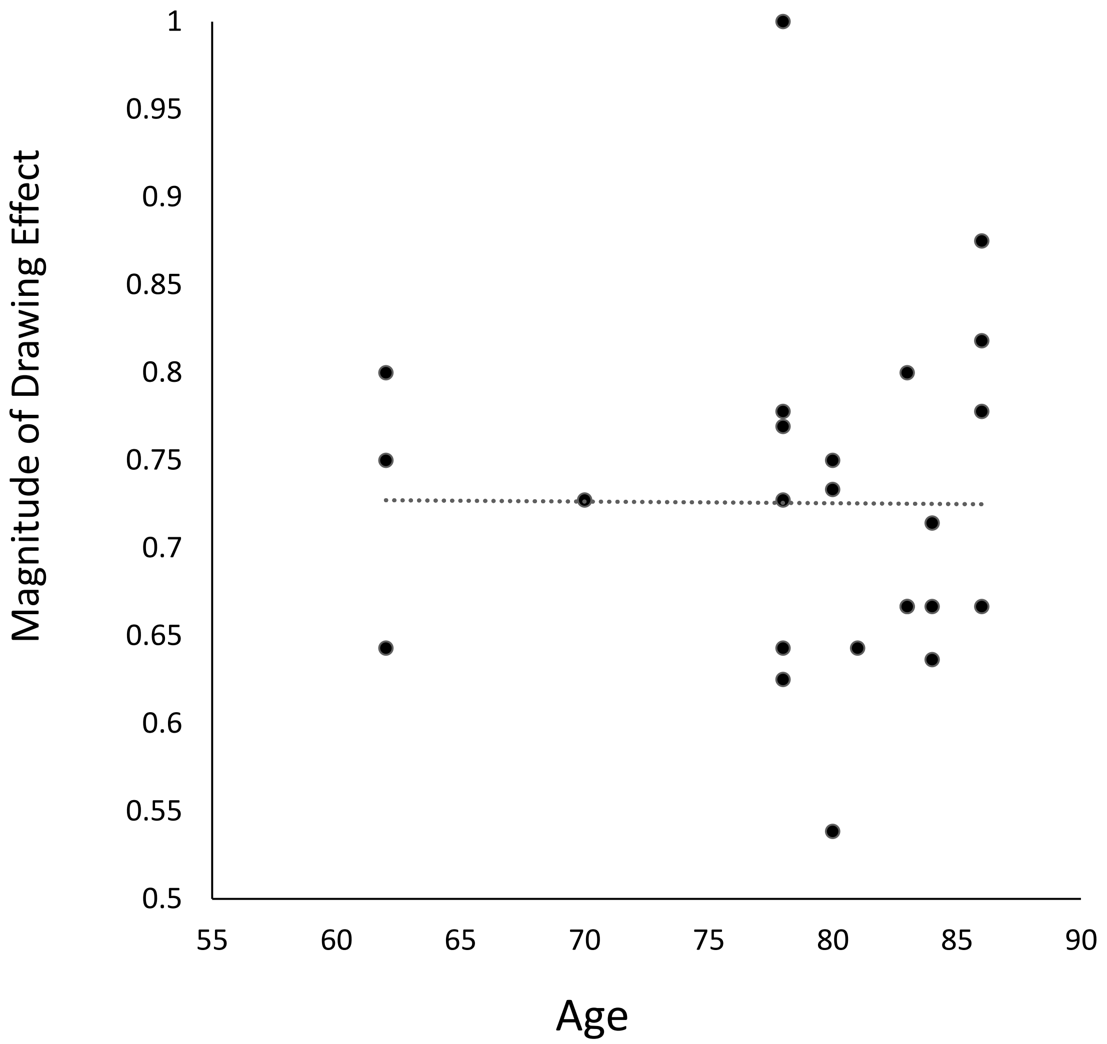

Figure 4. Scatterplot comparing age in the older adult group to the proportion of recalled words that had been drawn at encoding.

Discussion

Analyses revealed that overall, more words were recalled by younger than older adults, a finding consistent with commonly observed age-related memory impairments (Light, 1991; Craik & Jennings, 1992). Importantly, a larger proportion of recalled words were drawn at encoding, with the magnitude of this difference being larger in older than younger adults. Previous work had indicated that older adults demonstrate a larger PSE than younger adults (Craik & Byrd, 1982; Luo et al., 2007; Ally et al., 2008). Based on this, and that pictorial information has previously been used as environmental support to alleviate memory deficits in older adults (Winograd et al., 1982; Smith et al., 1990; Luo et al., 2007; Ally et al., 2008; Luo & Craik; 2008; Cherry et al., 2008; Skinner & Fernandes, 2009; Cherry et al., 2012), we predicted that older adults would benefit more from drawing as an encoding strategy than younger adults. The data from Experiment 1 support this prediction. That creating drawings, like viewing pictures, leads to an enhanced memorial benefit for older adults (relative to younger adults) suggests that this age group can effectively use rich perceptual information as environmental support to improve memory performance. More importantly, the results of Experiment 1 demonstrate that drawing at encoding is a particularly beneficial encoding tool that older adults can use to enhance memory.

Other work has demonstrated that, like pictorial information, semantic encoding (deep LoP), also provides effective environmental support (Sauzeon et al., 2000; Troyer et al., 2006; Castel, 2007; Kirchhoff et al., 2012), which might benefit older adults' memory even more than perceptually rich information (Craik & Rose, 2012). While in Experiment 1 we found that older adults' memory benefitted more from drawing than writing, this could have been driven by a deeper LoP when drawing, rather than due to the provision of rich visual perceptual information.

While our previous research (Wammes et al., 2016) already examined this alternative explanation in younger adults, and ruled it out as accounting for the benefit that drawing affords memory, we nonetheless explored this possibility in the context of a sample of older adults in our next experiment. In Experiment 2, we compared drawing directly to an elaborative encoding task which promotes a deep LoP but does not explicitly provide perceptually rich visual information.

Experiment 2

Our aim in Experiment 2 was to compare the effectiveness of drawing as an encoding tool, to an elaborative task, which we designed to elicit a deep LoP (the semantic meaning of a word), which is generally found to lead to better memory than tasks that promote shallow encoding (such as identifying phonemic features of a word) (Craik and Lockhart, 1972). This is an important comparison condition, as it has been suggested that deep LoP is a highly effective form of environmental support, which results in larger memory enhancements for older than younger adults (Sauzeon et al., 2000; Troyer et al., 2006; Castel, 2007; Kirchhoff et al., 2012; Craik & Rose, 2012). In their review, Craik and Rose (2012) speculate that because older adults are less likely than younger adults to spontaneously engage in semantic processing, the former can benefit more from deep LoP than other forms of environmental support (such as the provision of pictorial information or subject-performed tasks) making semantic processing an ideal encoding task for this age group.

Similar to many deep LoP tasks, drawing involves processing the semantic meaning of a word, given that one must create a mental representation of the to-be-drawn item. As such, drawing likely includes *both* deep LoP and the provision of pictorial information, the latter of which also enhances memory in older adults (Craik & Byrd, 1982; Luo et al., 2007; Ally et al., 2008). In our previous work we compared memory performance for words that were drawn at encoding to a variety of other encoding tasks including a deep LoP, consisting of listing adjectives related to the target noun, visualizing mental images, and simply viewing pictures; in all cases we found that drawing led to superior memory performance (Wammes et al., 2016). Given this, we believe that drawing offers a unique advantage, over and above that provided by a deep LoP, and predicted it would benefit memory more in older adults than an encoding task involving semantic elaboration.

The elaborative encoding task we used here was the same as that used in our previous work (Wammes et al, 2016), in which participants are instructed to write out physical descriptive characteristics of the objects that the words represent. This elaborative encoding trial type was chosen because, like the drawing task, it requires self-generation of semantic and physical information about the object, but without the provision of rich perceptual information inherent in drawings. Additionally, listing characteristics takes longer than other previously used deep LoP tasks (i.e. deciding if an item is living or non-living), allowing us to match encoding time with the drawing and writing conditions.

Methods

Participants

The young adult participants were 24 undergraduate students (5 males and 19 females, $M_{age} = 20.31$, $SD_{age} = 2.04$) at the University of Waterloo who received partial course credit for participation. The 24 older adult participants (7 males and 17 females, $M_{age} = 72.46$, $SD_{age} = 7.81$) were recruited from the Waterloo Research in Ageing Participant Pool (WRAP) at the University of Waterloo, and received $10.00 for one hour of participation. Additionally, all older adult participants scored above 27 (*M* = 29.00, *SD* = 0.93) on the Mini-Mental State Exam

(MMSE; Folstein, Folstein, & McHugh, 1975), indicating normal cognitive ageing, free from major cognitive and neurological impairments.

Materials

The materials were identical to those used in Experiment 1.

Procedure

The procedure was identical to that used in Experiment 1, with the exception that a third encoding trial type called ‘list’ was now included along with the ‘write’ and ‘draw’ prompts. On ‘list’ trials, participants were instructed to write out as many physical descriptive characteristics they could think of for the presented word (for example, ‘furry’, ‘whiskers’, and ‘grey’, for the target word ‘mouse’), until the time allotted for that trial type ended. Due to the addition of a third prompt, the randomly selected list of 30 words was divided into three lists of 10-words each (10 to be drawn, 10 to be visualized, 10 to be written) instead of two lists of 15-words of each trial type as in the prior experiment. Apart from these modifications, the experimental protocol was identical to Experiment 2.

Results

Similar to Experiment 1, we analysed the number of words recalled from each of the encoding trial types (draw, write, and list) for each age group (younger and older adults) (See Figure 5 for overall performance, and Figure 6 for individual performance distributions). A 2 Age (Younger and Older) X 3 Encoding Trial Type (Drawing, Writing, Listing) mixed ANOVA was performed with age as a between- and encoding type as a within-subjects factor. Given that there were three levels of the repeated measure factor, we examined Mauchley’s Test of Sphericity finding it to be non-significant ($\chi 2(2) = 2.28$, $p = 0.32$) thus indicating that the assumption of sphericity has not been violated and there was no need to use corrected df. The analysis revealed a main effect of encoding trial type, F (2, 92) = 58.97, MSE = 137.25, $p <$ 0.001, $\eta_p^2 = 0.56$. When broken down by simple effects contrasts, we found that this effect was driven by better memory for drawn than for written words, F (1, 46) = 116.48, MSE = 546.75, $p < 0.001$, $\eta_p^2 = 0.72$. Listing descriptive characteristics led to worse memory performance than drawing, F (1, 46) = 34.47, MSE = 168.75, $p < 0.001$, $\eta_p^2 = 0.43$, but better performance than writing, F (1, 46) = 24.69, MSE = 108.00, $p < 0.001$, $\eta_p^2 = 0.35$. A main effect of age was also found, F (1, 46) = 31.31, MSE = 108.51, $p < 0.001$, $\eta_p^2 = 0.41$, such that memory performance was better in younger than older adults. There was no significant encoding trial type x age interaction, F (1, 92) = 0.76, MSE = 0.02, p = .47, $\eta_p^2 = 0.02$. As in Experiment 1, proportional data were also analyzed, revealing a pattern of results identical to that found using the number of words recalled from each encoding trial type as the dependent variable[1].

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[1] The proportion of words recalled for each encoding trial type (number of drawn or written words divided by total number of words recalled for each individual participant) was analyzed in a 2 Age (Younger and Older) X 3 Encoding Trial Type (Drawing, Writing, Listing) mixed ANOVA, with age as a between- and encoding type as a within-subjects factor. The analysis revealed a main effect of encoding trial type, F (2, 92) = 46.24, MSE = 0.85, $p <$ 0.001, $\eta_p^2 = 0.50$. When broken down by simple effects contrasts, we found that this effect was driven by better memory for drawn than for written words, F (1, 46) = 86.66, MSE = 3.38, $p < 0.001$, $\eta_p^2 = 0.65$. Listing descriptive characteristics lead to worse memory performance than drawing, F (1, 46) = 26.96, MSE = 1.15, $p < 0.001$, $\eta_p^2 =$ 0.37, but better performance than writing, F (1, 46) = 20.24, MSE = 0.59, $p < 0.001$, $\eta_p^2 = 0.31$. There was no significant encoding trial type x age interaction, F (1, 92) = 0.88, MSE = 0.02, p = .42, $\eta_p^2 = 0.02$.

Table 2. Means and standard deviations of the number of words recalled in Experiment 2 in younger and older adults following each Encoding Trial type

	Encoding Trial type		
	Written	Drawn	List
Younger	3.33 (*1.04*)	7.38 (*1.66*)	5.46 (*1.47*)
Older	1.40 (*1.69*)	5.17 (*1.83*)	3.33 (*1.76*)

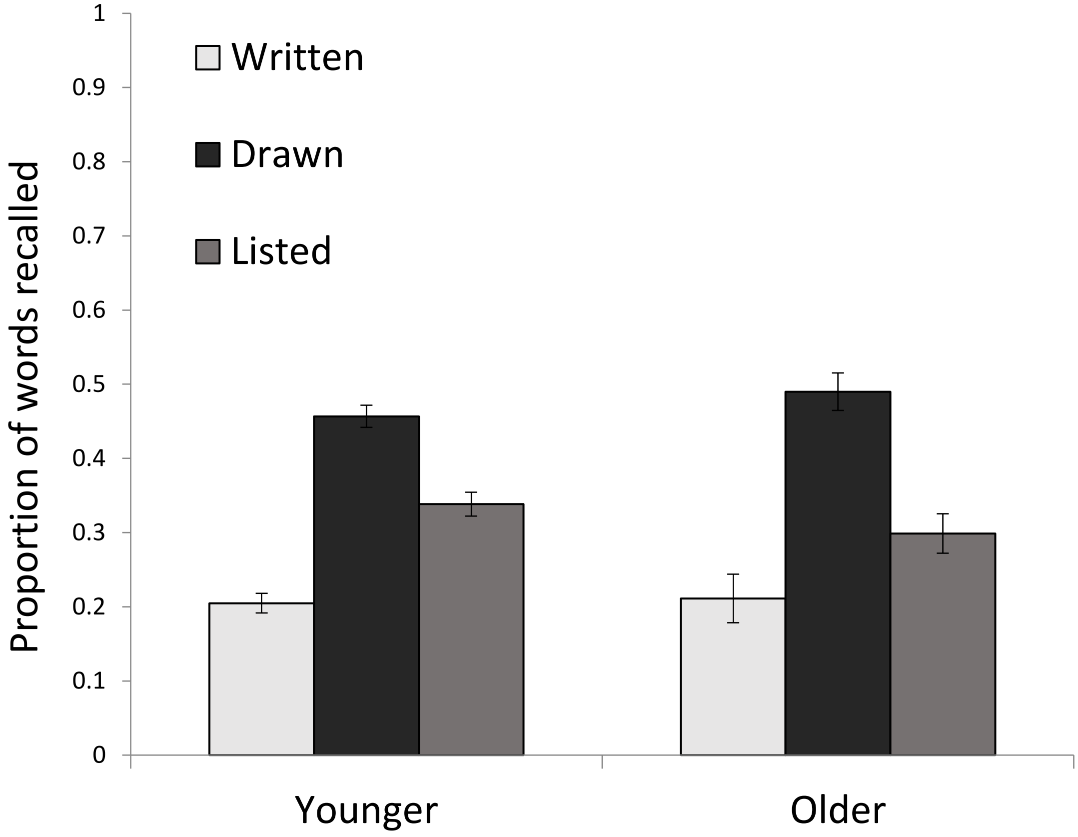

Figure 5. Proportion of words recalled in Experiment 2 for words drawn, written, or listed at encoding.

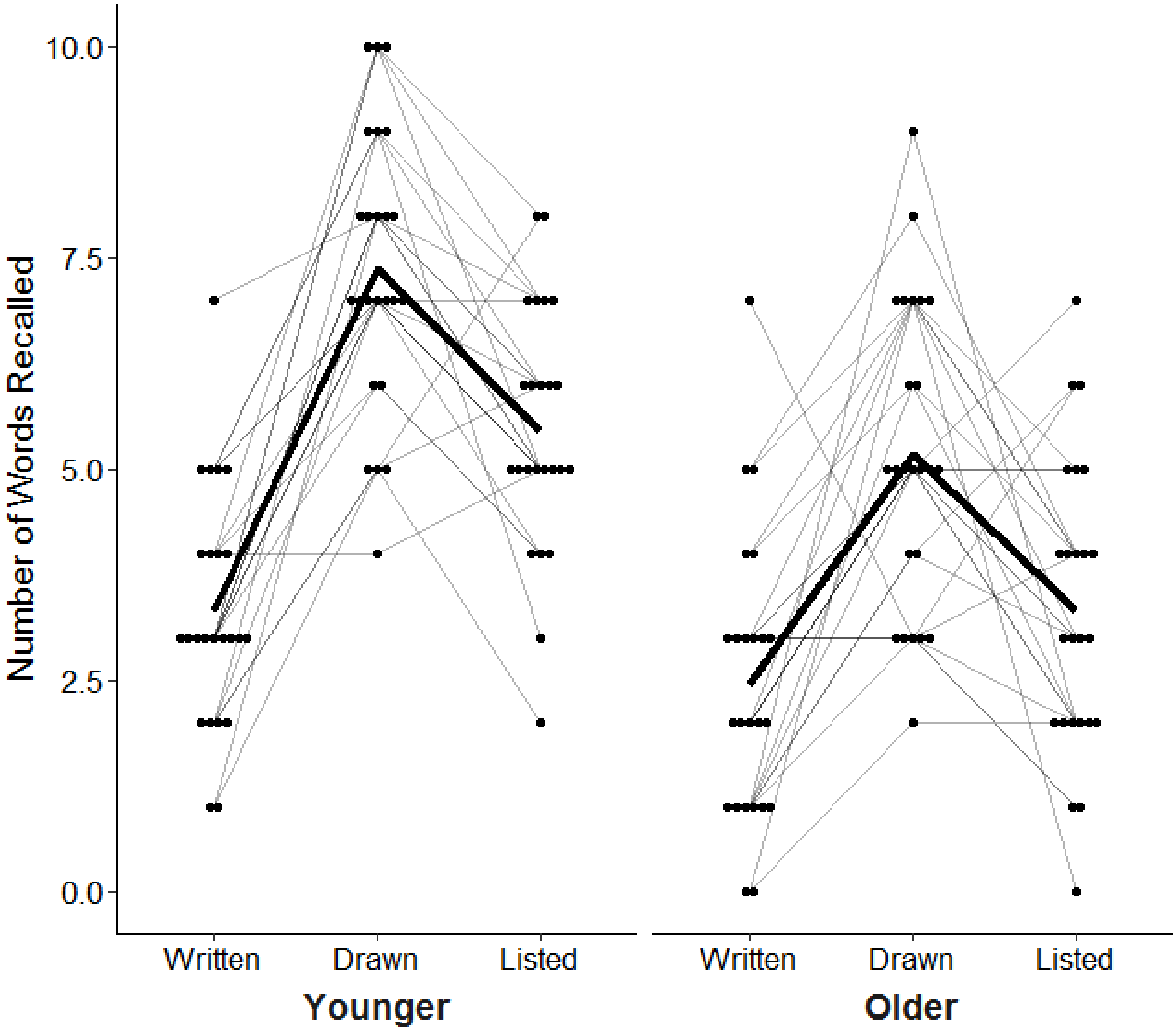

Figure 6. Individual participant performance in Experiment 2 for words drawn, written, or listed at encoding, with average performance for each encoding trial type denoted by the think black line.

Experiment 2 Discussion

The results of Experiment 2 replicate our previous work with young adults (Wammes et al., 2016) demonstrating that drawing leads to superior memory performance relative to an elaborative encoding task of listing physical descriptive characteristics. Here we demonstrate this pattern of results in both younger and older adults, which indicates that while older adults can use elaborative encoding techniques to aid their memory performance (Sauzeon et al., 2000; Troyer et al., 2006; Castel, 2007; Kirchhoff et al., 2012; Craik & Rose, 2012), drawing leads to an even greater memory enhancement in both populations.

One possible reason for the apparent superiority of drawing relative to elaborative encoding is that while both invoke a deep LoP (Craik & Lockhart, 1972) relative to writing out words, drawing also provides perceptually rich visual information in the form of a picture. We believe that drawing incorporates the beneficial underlying mechanisms of two encoding manipulations that have been previously shown to significantly improve memory in older adults, deep LoP (Sauzeon et al., 2000; Troyer et al., 2006; Castel, 2007; Kirchhoff et al., 2012; Craik & Rose, 2012) and the provision of pictorial information (Craik & Byrd, 1982; Luo et al., 2007; Ally et al., 2008), making it a substantially more effective encoding tool than either alone. We believe that drawing promotes the formation of a perceptually rich memory trace, with detailed contextual information relating to the target. If that is the case, it should be reflected in an enhanced quality of memory, as measured on a RKN recognition memory task (reference for RKN here).

Experiment 3

The general age-related decrement observed in episodic memory is disproportionately evident on tasks that measure source or contextual details of what is remembered, as compared to item-specific information (Zacks & Hasher, 2006; Hay, Winocur, & Moscovitch, 2002). One framework employed to interpret this pattern of age-related memory impairment is the dual-process model of familiarity and recollection, wherein the former (akin to a 'gist'-based memory) remains relatively intact in normal aging, while the latter (memory for specific contextual-details) is differentially impaired in older adults (Tulving, 1985; Dywan & Jacoby, 1990; Mandler, Bauer, & McDonough, 1991; Spencer & Raz, 1995; Java, 1996; Jennings & Jacoby, 1997; Yonelinas, 2002; Koen & Yonelinas, 2016). Age-related differences in recollection-based memory have been reduced or completely eliminated in studies where memory for pictorial material was measured or when the encoding environment provided rich perceptual information, such as a picture (Luo et al., 2007; Luo & Craik, 2008) or face (Skinner & Fernandes, 2009) alongside to-be-remembered words.

One explanation for the drawing effect is that participants create perceptually rich pictures during encoding, which then provide detailed contextual information that preferentially enhances recollection at retrieval. Previous work (Luo et al., 2007) using a variation of the process-dissociation procedure (Yonelinas, 1994; Yonelinas & Jacoby, 1994, 1995) suggests that providing pictures at encoding boosts recollection but not familiarity, and that this dichotomy is more pronounced in older relative to younger adults. These findings suggest that for older adults, recollection in particular benefits from the provision of perceptually rich information. Specifically, we wanted to examine whether, as in our previous work (Wammes et al., 2017), drawing at encoding enhances creation of, and later access to, contextually rich information about the to-be-remembered words.

While there has been debate as to whether free recall might be influenced in some small way by familiarity (Mickes, Seale-Carlisle, & Wixted, 2013), recall is certainly not an effective task for differentiating between recollection and familiarity. The most commonly used task to achieve this differentiation is the remember-know-new paradigm (Tulving, 1985). Because we were most interested in determining the role of contextual information (i.e., recollection) in driving the drawing benefit, this form of recognition task was the clear choice. Our predictions for Experiment 3 were that drawing, but not writing, would eliminate the age-related deficit, specifically in recollection.

Methods

Participants

The young adult participants were 24 undergraduate students (3 males and 21 females, M_{age} = 19.50, SD_{age} = 1.93) at the University of Waterloo who received partial course credit for taking part in the study. The 24 older adult participants (5 males and 19 females, M_{age} = 75.63, SD_{age} = 6.99) were recruited from the Waterloo Research in Aging Participant Pool (WRAP) at the University of Waterloo, and received $10.00 in remuneration. Additionally, all older adult participants scored above 27 (*M* = 28.25, *SD* = 0.73) on the Mini-Mental State Exam (MMSE; Folstein et al., 1975), indicating they were free from major cognitive and neurological impairments.

Materials

Stimuli consisted of the same 80 item word list used in Experiment 1.

Procedure

Thirty words were randomly selected from the set of eighty, for presentation in the encoding phase (15 randomly chosen to be drawn and 15 to be written). Encoding instructions and timings were identical to those used in Experiment 1. The same filler task was also implemented between the study and memory test phases. During retrieval, participants were presented with the 30 items from study along with 30 lure words, chosen at random from the set of 80. Participants were given unlimited time to make a response to each word in the recognition test using keys marked ‘R’ for ‘remember’, ‘K’ for ‘know’, and ‘N’ for ‘new’. Recognition memory instructions, for classification of ‘old’ words were as follows: ‘Remember’ means that you have a conscious recollection of the word from the previous phase, such as how and when the word was written or drawn. ‘Know’ means that you have only a feeling of familiarity; you believe that the word was from the previous phase, but cannot recall specifically how or when it was drawn or written. ‘New’ means that the word was not encountered in the study phase. RKN decisions were made on a QWERTY keyboard by pressing separate adjacent keys for Remember, Know, and New, which were labelled with the letters ‘R’, ‘K’, and ‘N’, to ensure participants always were aware of which keys mapped onto each RKN response type.

Results

Our results are separated into three sections. We analyzed overall recognition (collapsing Remember and Know responses together), then Remember and Know responses separately. We analyzed hit rate (out of 15 for drawn and 15 for written trial types) and false alarm rate (out of 30). Data were always analyzed in a 2 Age (Younger and Older) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA with age as a between- and encoding type as a within-subjects factor. Means for each response, trial type, and age group are presented in Table 3 and Figure 7, and individual participant performance distributions are presented in Figure 8.

Table 3. Means and standard deviation for each Measure of recognition performance in each Age Group following each Encoding Trial type in Experiment 3.

Overall Recognition			
		Younger Adults	Older Adults
Hit Rate	Draw	0.99 (0.03)	0.97 (0.04)
	Write	0.88 (0.13)	0.66 (0.25)
FA Rate	Overall	0.03 (0.05)	0.07 (0.11)
Accuracy	Draw	0.96 (0.05)	0.90 (0.12)
	Write	0.85 (0.13)	0.59 (0.29)

Remember Responses			
		Younger Adults	Older Adults
Hit Rate	Draw	0.98 (0.04)	0.97 (0.05)
	Write	0.83 (0.18)	0.58 (0.30)
FA Rate	Overall	0.00 (0.00)	0.04 (0.06)
Accuracy	Draw	0.98 (0.05)	0.93 (0.07)
	Write	0.83 (0.19)	0.54 (0.31)
Process Estimates	Draw	0.91 (0.03)	0.90 (0.17)
Process Estimates	Write	0.60 (0.03)	0.54 (0.29)

Know Responses			
		Younger Adults	Older Adults
Hit Rate	Draw	0.01 (0.04)	0.01 (0.02)
	Write	0.05 (0.09)	0.09 (0.20)
FA Rate	Overall	0.03 (0.05)	0.03 (0.07)
Accuracy	Draw	-0.02 (0.04)	-0.03 (0.03)
	Write	0.04 (0.09)	0.07 (0.08)
Process Estimates	Draw	0.32 (0.53)	0.16 (0.26)
Process Estimates	Write	-0.49 (0.38)	-0.08 (0.33)

Notes: Recollection Process Estimates were calculated by computing the probability (R_old – R_new) that a participant would make a Remember response to drawn and written words, and Familiarity Process Estimates were calculated by subtracting F_new [K_new/(1-R-new)] from F_old [K_old/(1-R_old)], both methods based on Yonelinas (2002). FA = false alarm

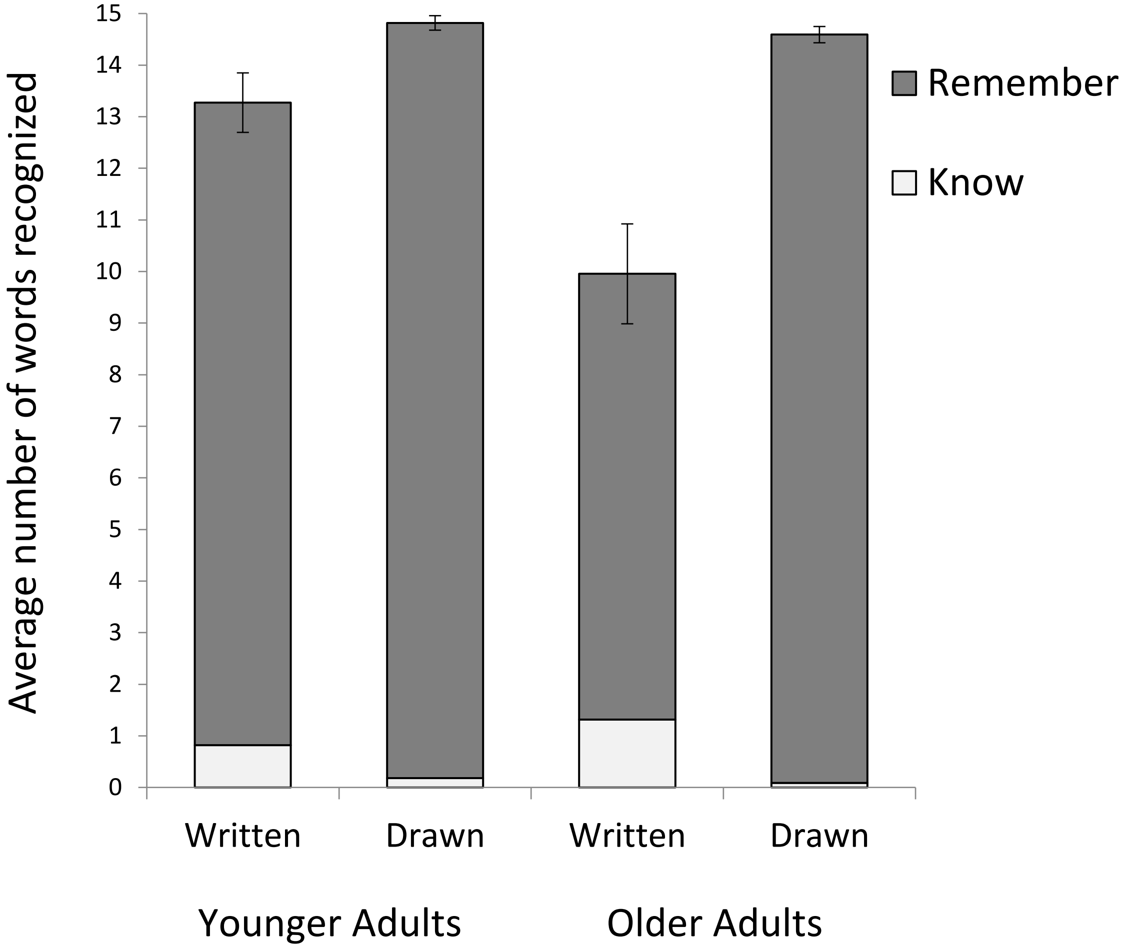

Figure 7. Average number of words assigned Remember responses (denoted by black circles and solid lines) and Know responses (denoted by white circles and dashed lines) in Experiment 3, with average performance for each encoding trial type denoted by thick black and grey lines, respectively.

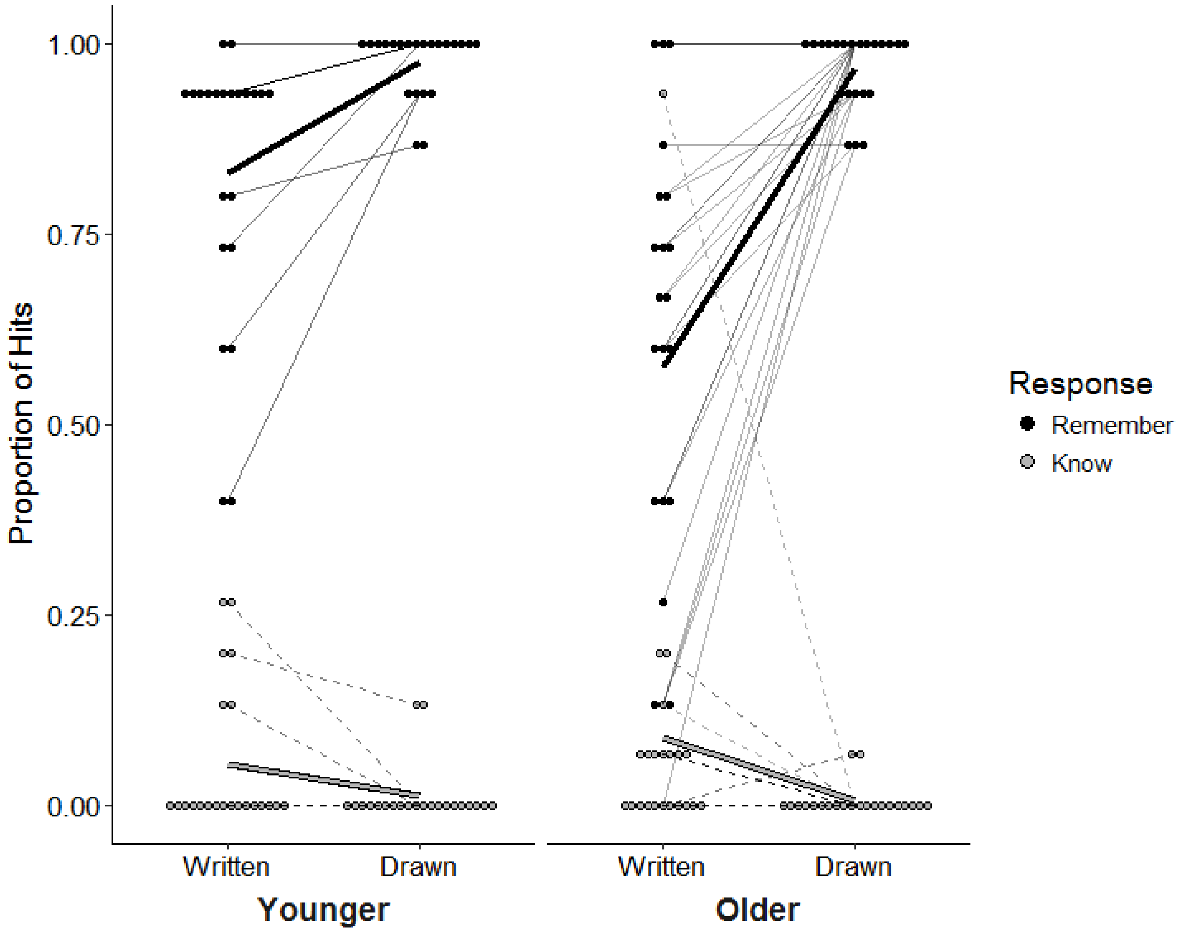

Figure 8. Individual participant performance in Experiment 3 for Remember responses for each encoding trial type.

Overall Recognition

Hit Rate. There was a main effect of encoding trial type, F (1, 46) = 54.91, MSE = 1.11, $p < 0.001$, $\eta_p^2 = 0.54$, such that drawn words were better recognized than written, a main effect of age, F (1, 46) = 12.32, MSE = 0.32, $p = 0.001$, $\eta_p^2 = 0.21$, such that younger adults recognized more words than older adults, and an Age X Encoding trial type interaction, F (1, 46) = 12.86, MSE = 0.26, $p = 0.001$, $\eta_p^2 = 0.22$.

To better understand the interaction, two independent-samples t-tests were performed separately for each encoding trial type to compare hit rate between younger and older adults. For the writing trial type, the analysis revealed a significant difference between age groups, t (46) = 3.59, SE = 0.06, $p = 0.001$, such that younger had a higher hit rate than older adults. In contrast, the results for the drawing trial type indicated that there was no difference between age groups, t (46) = 1.06, SE = 0.01, $p = 0.29$, suggesting that hit rate was equivalent between younger and older adults.

False Alarm Rate. There was no significant difference between age groups, t (46) = 1.04, SE = 0.03, $p = 0.30$.

Remember Responses

Hit Rate. There was a main effect of encoding trial type, F (1, 46) = 62.34, MSE = 2.06, $p < 0.001$, $\eta_p^2 = 0.58$, with higher hit rates for drawn words, a main effect of age, F (1, 46) = 14.10, MSE = 0.53, $p < 0.001$, $\eta_p^2 = 0.24$ with older scoring lower than younger adults, and an encoding trial type x age interaction, F (1, 46) = 14.85, MSE = 0.49, $p < 0.001$, $\eta_p^2 = 0.24$.

To break down the interaction we next conducted two independent-samples t-tests separately for each encoding trial type to compare age groups. For the write trial type, there was a significant difference between age groups, t (46) = 3.86, SE = 0.08, $p < 0.001$, such that hit rate for written words was higher for younger than older adults. In contrast, the analysis for the draw trial type showed no age difference in hit rate for words drawn at encoding, *t* (46) = 0.42, *SE* = 0.01, *p* = 0.68.

False Alarm Rate. We found a significant difference between age groups, *t* (46) = 3.03, *SE* = 0.01, *p* = 0.004, such that older adults had a larger Remember false alarm rate than did younger adults.

Know Responses

Hit Rate. There was a main effect of encoding trial type, *F* (1, 46) = 7.82, *MSE* = 0.15, *p* = 0.008, η_p^2 = 0.15, with higher hit rate for written words. There was no main effect of age, *F* (1, 46) = 1.36, *MSE* = 0.03, *p* = 0.25, η_p^2 = 0.03, nor an encoding trial type x age interaction, *F* (1, 46) = 1.96, *MSE* = 0.04, *p* = 0.17, η_p^2 = 0.04.

False Alarm Rate. There was no significant difference between age groups, *t* (46) = 0.38, *SE* = 0.02, *p* = 0.71, suggesting that false alarm rate for Know responses do not differ with age.

Process estimates.

We also computed and analyzed process estimates for recollection and familiarity based on calculations outlined in previous work (e.g. Yonelinas & Jacoby, 1995). However, because recollection responses were so high in a large number of the participants (that is, their hits were exclusively ‘Remember’ responses), it was not possible to reliably estimate the contribution of familiarity in these individuals. Thus, the analyses based on estimates of recollection and familiarity include only the subset of participants (N=14: 6 younger and 8 older adults) who provided at least 1 Know response to a previously drawn word.

Recollection and familiarity estimates were obtained using the independent RK formulas (Yonelinas & Jacoby, 1995). Recollection was calculated by subtracting the proportion of "remember" judgements to new items from the proportion of "remember" judgements to old items (i.e., recollection = Rold – Rnew). Familiarity for old items was estimated as the proportion of old items that received a "know" response divided by the proportion of items that did not receive a "remember" response (i.e., Fold = Kold/[1 – Rold]). A familiarity estimate for new items was calculated in the same way using the proportion of new items that received "remember" and "know" responses (i.e., Fnew = Knew/[1 – Rnew]). Finally, a corrected familiarity estimate was calculated as the difference between the Fold and Fnew values (i.e., familiarity = Fold – Fnew).

Recollection estimates. We analysed these data in a 2 age (young, old) X 2 encoding trial type (draw, write) mixed ANOVA in the 14 participants who made at least one R and K classification. We found a main effect of encoding trial type, F (1, 12) = 23.45, MSE = 0.79, $p <$ 0.001, $\eta_p^2 = 0.66$, indicating that more words drawn than written at encoding were given recollection responses. There was no main effect of Age, F (1, 12) = 0.16, MSE = 0.005, $p =$ 0.70, $\eta_p^2 = 0.01$, and no interaction, F (1, 12) = 0.22, MSE = 0.006, p = 0.65, $\eta_p^2 = 0.02$.

Familiarity estimates. These data were analysed in a 2 age (young, old) X 2 encoding trial type (draw, write) mixed ANOVA[2]. We found a main effect of encoding trial type, F (1, 12) = 8.60, MSE = 1.90, p = 0.01, $\eta_p^2 = 0.42$, showing a heavier reliance on familiarity for words

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[2] The calculation of familiarity requires one to quantify opportunities for K responses; in a subset of participants (14 participants: 6 younger and 8 older adults) there was no such opportunity as their responses consisted exclusively of R responses. As such, strong conclusions should not be made based on this calculated measure of process estimates of recollection and familiarity. Nonetheless, based on our data, it appears that memory is driven by familiarity moreso for words written than drawn at encoding.

written compared to drawn at encoding, but no main effect of Age group, F (1, 12) = 2.59, MSE = 0.57, p = 0.13, η_p^2 = 0.18, and no interaction, F (1, 12) = 2.84, MSE = 0.65, p = 0.12, η_p^2 = 0.19.

Experiment 3 Discussion

Overall recognition memory and recollection-based R responses showed a significant age difference in hit rate for words that were written during encoding, but no age difference in memory for words that were drawn. The finding that drawing, but not writing, eradicated age differences in recollection-based memory is particularly meaningful for older adults, given that such memory has been found to be significantly impaired in numerous past studies (Dywan & Jacoby, 1990; Spencer & Raz, 1995; Java, 1996; Jennings & Jacoby, 1997; Yonelinas, 2002; Tulving, 1985; Mandler et al., 1991). Consistent with previous work (Luo et al., 2007, Skinner & Fernandes, 2009), our findings suggest that older adults can take advantage of the perceptually rich contextual information offered by the pictorial representation created by drawing, to benefit R-based responding. As in Experiment 1, we found that older adults remembered (freely recalled in Experiment 1 and recognized here in Experiment 3) a larger proportion of drawn words than written compared to younger adults.

What is remarkable is that the age-related deficit in memory performance was found only when the encoding strategy was to write target words; when told to draw them, the age-related deficit was eliminated and older adults' memory was enhanced up to nearly the maximum possible level of performance. We acknowledge that had the memory task been made more difficult (thereby eliminating the possible ceiling effect in younger adults) we might have observed an age-difference for drawn targets. We do however, feel the finding that through drawing, older adults were able to attain remarkably high memory (near maximum), that was comparable to that of young adults, is quite important to document.

Also notable, our findings indicated that hit rate and recollection were enhanced for drawn words, whereas written words elicited more familiarity-based Know responses. This pattern of findings suggests that drawing specifically enhances recollection for both age groups, which we expect is a result of the perceptually rich information provided by drawing pictures that would not be otherwise present, or at least would be less salient in verbal/written information. In line with our predictions, no age-related differences were found in K hit rate, concordant with previous work suggesting that it is only recollection, and not familiarity-based responding, that is subject to age-related decline (Dywan & Jacoby, 1990; Spencer & Raz, 1995; Java, 1996; Jennings & Jacoby, 1997; Yonelinas, 2002; Tulving, 1985; Mandler et al., 1991).

General Discussion

In Experiment 1 we demonstrated that the benefit of drawing relative to writing to-be-remembered information at encoding extends to older adults. In Experiment 2 we examined the extent to which drawing boosted memory, compared to an elaborative encoding task, which is a commonly recommended strategy suggested to older adults as a means to enhance memory (e.g. Craik & Simon, 1980; Craik & McDowd, 1987; Troyer et al., 2006; Castel, 2007; Hashtroudi, Parker, Luis & Reisen, 1989; Kirchhoff et al., 2012; Craik & Rose, 2012; Kamp & Zimmer, 2015). Our data showed that drawing benefitted memory performance more than elaborative encoding, in both younger and older adults. Finally, in Experiment 3 we presented evidence to suggest that drawing, relative to writing, reduces age-related differences in memory, and elevates older adults to near maximum performance levels both in overall memory and R-hit rate. This line of experiments demonstrates clearly that drawing is a highly effective encoding tool that older adults can employ to benefit their memory more than other techniques or strategies such as deep LoP.

Across all experiments, we reliably observed age effects in memory performance, such that younger adults outperformed older adults in terms of the raw number of words retrieved, consistent with previous findings in this area of research (Light, 1991; Craik & Jennings, 1992). Additionally, recognition performance (Experiment 3) was much higher relative to the free recall tests (Experiment 1 and 2), a pattern of findings that is expected based on all previous work in the literature (e.g. Anderson & Bower, 1973; Kintsch, 1970; Mandler, 1980; Tulving, 1976). Together, these findings are also compatible with previous research demonstrating that older adults show larger age-related memory declines in free recall tests relative to recognition (Craik & McDowd, 1987). Of key importance is that, of the words that were successfully remembered, a larger proportion were ones that had been drawn at encoding, and the magnitude of this benefit was larger for older adults in Experiments 1 and 3.

It is difficult to ascertain whether meaning should be ascribed to the low levels of recall that were observed in Experiment 1 and 2 given the lack of normative data on the drawing effect. We can, however, turn to normative data from other recall tasks to calibrate our expectations for these age groups. Younger adults recall 68% of words on the Hopkins Verbal Learning Test (Benedict, Schretlen, Groninger, & Brandt, 1998) and 43% on the Rey Auditory Verbal Learning Test (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2005). In contrast, older adults recall 56 and 27 percent respectively. The memory performance observed in our experiments might be lower due to incidental encoding (Crook, Larrabee, & Youngjohn, 1993; Tellez-Alanis, & Cansino, 2004), or to the detrimental effects of longer list length (30 words, relative to 15 or 12, in the normative data).

Rather than compare drawing to more traditional memory tasks such as reading or speaking words, we carefully chose comparison tasks in each of our Experiments to control for a variety of factors. Specifically, we controlled for *production* (the act of producing something on a sheet of paper for a set amount of time) by using writing as a baseline/control task. This comparison allowed us to rule out the explanation that the drawing benefit to memory is simply due to the participant physically producing something relevant to the to-be-remembered information on a sheet of paper, and is likely instead because it engages rich perceptual and semantic processing of the item. Therefore, in Experiment 2, we compared drawing to a highly elaborative encoding task that consists of producing descriptive characteristics of the objects that the words represent. Additionally, the listing characteristics task does not contain an explicit visual imagery or pictorial component, allowing us to observe the relative benefits of the rich perceptual information present in drawing when matching semantic elaborative processing in the comparison task. While we did observe an overall benefit from drawing relative to listing, it is likely that we did not find a difference in the magnitude of this effect between age groups because of the addition of another encoding trial type, and a reduction in the number of trials per encoding trial type. Ultimately, what we have demonstrated in the current study through use of selected comparison tasks, is that the rich visual perceptual information provided by drawing benefits memory performance in both younger and older adults.

One reason why older adults appear to benefit more from drawing than do young adults (in Experiments 1 and 3) may be partially due to the enhanced multisensory integration which has been previously observed in this age group (Laurienti et al., 2006; Mozolic et al., 2012; Mahoney et al., 2011). We argued in our previous work that drawing promotes the seamless integration of multiple types of memory traces, specifically visual-, motor-, and semantic- traces, thereby enhancing memory for drawn information (Wammes, et al., 2016). The integration of sensory/perceptual information from multiple modalities is suggested to be enhanced in older relative to younger adults, as demonstrated in perceptual discrimination tasks (Laurienti, et al., 2006; Mozolic et al., 2012; Mahoney, Ching, Oh-Park, Verghese, & Holtzer, 2011). For example, Mahoney and colleagues (2011) required participants to make speeded responses to unisensory stimulation, or to multisensory combinations of audio, visual, and somatosensory stimulation, and found that older adults responded faster to multisensory information than did younger adults. The mechanism underlying the observed enhanced integration of information from visual and somatosensory modalities in older adults may also be driving the larger proportional drawing benefit observed in Experiments 1 and 3, given that drawing similarly forces the combination of information from multiple sources (visual, semantic, motor).

The larger proportional benefit of the drawing effect found in older relative to younger adults in Experiments 1 and 3 may also be related to the increased PSE commonly reported in the older age group (Craik & Byrd, 1982; Luo et al., 2007; Ally et al., 2008). In other words, the difference in the magnitude of the effect between age groups might be partially due to the pictorial information that results from drawing, which in turn precipitates the age differences commonly associated with the PSE. In our previous work (Wammes et al., 2016), we presented evidence to suggest that the drawing effect cannot be explained exclusively by the PSE; We showed that memory for words that were drawn during encoding was enhanced, relative to memory for items which participants viewed as pictures or which were presented as words but for which participants created a mental image in their mind. We had also argued in our previous work that drawing results in deeper semantic processing than does writing, as the physical features of an object need to be generated for a participant to decide what to draw. This deeper semantic processing has also been championed in previous work, as an effective means of introducing environmental support for older adults (e.g. Craik & McDowd, 1987). While our own deep semantic encoding orientation (the ‘list’ condition) did boost memory in older adults, its benefit was dwarfed by the beneficial effects of drawing. Thus, while neither the PSE, nor deep semantic encoding can fully account for the overall drawing effect, older adults’ ability to capitalize on the provision of perceptually rich visual information in conjunction with deep semantic processing (Craik & Byrd, 1982; Luo et al., 2007; Ally et al., 2008) at encoding may have led to their enhanced memory benefit for words drawn at encoding.

It is nonetheless important to consider an alternative explanation: that memory in older adults is not necessarily made better by this perceptually rich visual information, but rather that it is made worse by solely relying on verbal processing. In other words, our effect might not be driven by a benefit to drawn items, but rather a cost to written items. A similar argument has been made for the Production effect: saying a word aloud at study leads to better memory performance than reading a word silently (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010). Specifically, evidence both in free recall (Jones & Pyc, 2014) and recognition (Forrin, Groot & MacLeod, 2016) suggests that the production effect arises due to a cost from reading silently, rather than from a benefit of reading aloud. Given that drawing in-part involves some aspects of production (Wammes et al., 2016), it is possible that the drawing benefit similarly arises from relatively diminished performance following the writing encoding strategy. Furthermore, previous neuroimaging findings from Grady, McIntosh, Rajah, Beig, and Craik (1999) indicate that age-related differences in neural activity associated with learning words are greater than those associated with learning pictures. Specifically, the prefrontal, premotor, temporoparietal and cingulate regions that are active during encoding of verbal material are differentially recruited by younger relative to older adults, whereas regions supporting visual memory (such as ventral and dorsal extrastriate) are recruited similarly across age groups. These findings suggest that older adults may encode verbal materials differently, or not as effectively as do younger adults, resulting in larger age differences in memory. In contrast, visual materials may be encoded more similarly to younger adults, thus resulting in smaller age difference in subsequent memory performance. In a similar vein, Ally and colleagues (2008) demonstrated that patterns in high-density event-related potentials (ERPs) related to successful recognition were not significantly different between younger and older adults during retrieval of pictures, but the ERP component was significantly diminished for the older adults during retrieval of words. As such, it is possible that the beneficial effect of drawing is different in magnitude between the age groups not because of the provision of rich perceptual information, but because of degraded memory for verbal material in older adults. This explanation is bolstered by the findings from Experiment 3 in which we found no difference between age groups for recognition of drawn words, while older adults recognized fewer written words than younger adults.

It is important to note that while drawing was found to be the superior encoding task in terms of later memory performance for both older and younger adults across all three experiments, we only observed a larger proportional benefit from drawing for older, relative to younger, adults in Experiments 1 and 3. It is possible that in Experiment 2 it was more difficult to detect differences in the magnitude of the proportional benefit of drawing because there were three encoding tasks (drawing, writing, and listing) rather than two (drawing and writing, as in Experiments 1 and 3), which reduced the number of words (and power) in each trial type. Ultimately, future work should examine the relative benefit that older adults receive from drawing at encoding compared to younger adults to further clarify the differences in proportional memory benefits. The current work is unique in that it is the first to demonstrate that older adults gain substantial benefits from drawing at encoding relative to writing or semantic elaboration encoding tasks.

It is evident that older adults have relatively preserved memory for visual information (Grady et al., 1999; Ally et al., 2008), which can be relied upon for improving memory performance. According to Morrow and Rogers (2008) in their refinement of the environmental support hypothesis, any encoding task which (1) reduces task demands on mental resources and (2) promotes efficient use of resources should constitute an effective form of environmental support. Drawing at encoding accomplishes the first of these environmental support conditions by enhancing task-relevant information which is externalized in the task environment as concrete pictorial information. Second, drawing promotes efficient use of resources likely by making use of visual processing regions that are relatively preserved (Raz et al., 2005) during aging. Accordingly, drawing represents an effective environmental support tool for older adults based on the conditions outlined by others (Morrow & Rogers, 2008) regarding specific aspects of encoding techniques that should enhance environmental support.

In Chapter 2 we have demonstrated that drawing is an effective encoding tool for both younger and older adults, and in some cases disproportionately improves memory in the latter. We suggest that the large drawing effect observed here for older adults is a result of drawing acting as an effective form of environmental support, which takes advantage of retained perceptual processing abilities in relatively intact brain regions. We additionally demonstrate that drawing enhances memory more than a deep LoP task in both younger and older adults. As such, drawing is a highly valuable and unique form of environmental support that can significantly enhance memory performance in older adults.

Chapter 3: Drawing Pictures at Encoding Enhances Memory in Healthy Older Adults and in Individuals with Probable Dementia

In the Chapter 2, it was demonstrated that older adults experience large memory enhancements from drawing relative to writing or listing characteristics. It was suggested that older adults likely benefit from drawing because this task incorporates elements of encoding techniques that are known to enhance memory performance in this age group (Meade et al, 2018), namely semantic generation (Craik & McDowd, 1987) and inclusion of pictorial information (Winograd, Smith, & Simon, 1982; Luo et al., 2007; Ally, Waring, Beth, McKeever, Milberg, & Budson, 2008; Luo & Craik; 2008; Skinner & Fernandes, 2009; Cherry, Brown, Walker, Smitherman, Boudreaux, Volaufova, & Jazwinski, 2012). In Chapter 3, we explored the value of drawing pictures as an encoding strategy to boost memory performance in individuals with probable dementia who demonstrate severe impairments in episodic memory.

Experiment 4

There is evidence to suggest that the picture superiority effect (PSE), wherein studying pictures leads to better memory performance than words (Paivio, 1971), is intact not only in healthy older adults (Luo et al., 2007; Ally et al, 2008), but also in individuals with mild cognitive impairment (MCI) and dementia (Ally & Budson, 2007; Ally et al, 2008; Ally, Gold, & Budson, 2009), with the effect sometimes larger in MCI samples than controls (Embree, Budson, & Ally, 2012). For example, Ally, Gold, and Budson (2009) demonstrated that healthy older adults, patients with MCI, and patients with probable dementia, all exhibited superior memory when common objects were presented as pictures rather than words. Given that drawing results in the creation of a picture, we expected that the mechanisms supporting the memorial advantages afforded by studying pictures, rather than words, should also operate for drawing thereby benefiting memory performance more than writing. In the current study, we expected that like cognitively healthy older adults, individuals with dementia could also benefit from drawing as an encoding strategy. Being able to improve memory through drawing pictures makes this technique highly valuable given that it can easily be implemented in daily life as a behavioural intervention to enhance memory function.

The proposed mechanistic accounts for how pictorial information results in better memory than words in individuals with MCI and dementia, are couched in terms of changes in brain structure and function observed in these populations. The regions of the brain that are most affected across various types of dementias are the frontal and medial temporal lobes (Brand, & Markowitsch, 2008; Ikram et al, 2010). In the most common form of dementia, Alzheimer's disease, the areas most prominently affected are the hippocampus and entorhinal cortex in the medial temporal lobes (Gomez-Isla, Price, McKeel, Morris, Growdon, and Hyman, 1996). In contrast, the primary visual areas and the ventral visual pathway tend to remain relatively more intact throughout progression of the disease, only becoming affected in the more severe stages (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt, Cizadlo, O'Leary, Gold, and Andreasen, 1996). As such, one account for why patients with dementia show memory benefits from studying pictures relative to words, is that they rely on the relatively preserved posterior regions of the brain involved in visual perceptual processing (Ally, 2012; Embree et al, 2012). Indeed, research using function magnetic resonance imaging (fMRI) has demonstrated that while individuals with dementia demonstrate poorer activation in medial temporal lobes, activation in occipital regions remains similar to patterns observed in healthy controls during visual memory tasks (Golby, Silverberg, Race, Gabrieli, O'Shea, Knierim, Stebbins, & Gabrieli, 2005; Koenig, Smith, Troiani, Anderson, Moore, & Grossman, 2008).

It has been suggested that preserved activation in visual processing regions, such as the primary visual cortex in the occipital lobes, reflects a reliance on intact *perceptual fluency* to support memory performance in dementia (Ally, 2012; Embree et al, 2012). Fluency, the ease with which we process information, has been found to remain intact for perceptual features of visual information in probable dementia populations (Ballesteros, Reales, & Mayas, 2007; Fleischman & Gabrieli, 1998). Therefore, preserved perceptual fluency, or processing of visual perceptual information, may support memory for pictorial information in individuals with dementia (Ally 2012; Embree et al, 2012). In addition, it has been suggested that patients with aMCI and mild AD can also take advantage of *conceptual fluency* to enhance memory for pictures over words (Martins & Lloyd-Jones, 2006; Ally, McKeever, Waring, & Budson, 2009; O'Connor & Ally, 2010; Deason, Hussey, Budson, & Ally, 2012; Ally, 2012). One explanation for the picture superiority effect (PSE: Paivio, 1971) is that pictures promote greater conceptual processing than words, resulting in enhanced memory for the former due to a deeper and more elaborate encoding of conceptual information (Hamilton & Geraci, 2006). While individuals with dementia tend to perform poorly on verbal based tasks that depend on conceptual fluency, such as word-stem completion tasks (Fleischman & Gabrieli, 1998), pictorial information may help to promote conceptual processing in this population (Ally et al, 2009; O'Connor & Ally, 2010; Deason, et al, 2012; Ally, 2012). For example, it has been demonstrated that individuals with MCI and dementia can use conceptual information about category membership to boost memory for pictures better than for words (Deason et al, 2012). Furthermore, research examining neural activity using event-related potential (ERP) recordings have found that a late frontal effect thought to be related to conceptual processing is similar between individuals with dementia and controls for memory for pictures, but not for words (Alley et al, 2009). Ultimately the literature thus far indicates that a combination of perceptual and conceptual fluency likely contribute to the intact PSE observed in individuals with MCI and dementia.

Importantly, it has been argued in previous work that drawing promotes both processing of visual and semantic information given that drawing results in superior recall performance compared to viewing pictures, creating mental imagery, or listing characteristics associated with objects (Wammes et al, 2016, Fernandes et al, 2018). Indeed, the task of creating a drawing necessitates access to a conceptual representation of an item and the production of a pictorial image. Incorporating visual perceptual and semantic, or conceptual, information related to an item into the memory trace by drawing pictures at study should enhance memory in individuals with probable dementia far more than writing out words. By recruiting such brain regions that remain relatively intact throughout disease progression (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt, et al, 1996), drawing should provide large memory benefits for individuals with probable dementia.

The goal in Chapter 3 was to compare the magnitude of the benefit of drawing, relative to writing, in healthy older adults and individuals with probable dementia. To this end, we assessed performance in groups of cognitively healthy older adults living in the community and residents living in long-term care facilities who scored below a standard cut-off score on the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) indicating gross cognitive impairment. Following encoding of words by writing or drawing pictures, we assessed both free recall and recognition memory performance. Additionally, we present a replication of our findings in a second experiment in this study conducted with separate groups of participants, using a different recognition test format. We predicted that in each of our experiments both participant groups would gain a larger memory benefit from drawing relative to writing. Additionally, we expected that the magnitude of the drawing effect would be larger in individuals with probable dementia compared to healthy older adults.

Methods

Participants

All participants gave informed consent by signing a consent form prior to participation in the study. Written consent from a subset of our participants with probable dementia was provided by their power of attorney. Additionally, it was made clear that participants were invited to take part of their own free will and were able to leave whenever they wanted if they wished to stop participating. Older adult participants were given $10 remuneration for their participation and residents living in long-term care facilities were either given $10 cash or gifts of equal value depending on the discretion of the long-term care facility manager.

The participants with probable dementia were 13 residents (5 males and 8 females, M_{age} = 84, SD_{age} = 9.50) living in long-term care facilities in the Kitchener-Waterloo region who volunteered to participate. In our first data collection session, 7 participants in our sample were administered the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), all scoring below 26 (*M* = 19.33, *SD* = 6.03, range = 16 - 25). In our second data collection session we switched from using the MMSE as a cognitive screening tool to the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005); the remaining 6 participants in our sample thus completed the MoCA), all scoring below 26 (*M* = 14.67, *SD* = 7.92, range = 4 - 25). As demonstrated by Nasreddine and colleagues (2005) in their original evaluation of the MoCA, scores above 26 indicate normal healthy aging, while individuals diagnosed with either MCI or dementia score below this threshold, with average scores of 22 and 16, respectively. Performance levels in our sample thus indicated that our probable dementia sample had either MCI or dementia, of varying degrees of severity.

In addition, we collected data from 13 healthy older adult participants (3 males and 10 females, M_{age} = 79.72, SD_{age} = 7.36), recruited from the Waterloo Research in Aging Participant Pool (WRAP) at the University of Waterloo, and received token monetary remuneration. 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. To match the probable dementia sample, 7 older adult participants in our sample were administered the MMSE, all scoring above 26 (*M* = 29, *SD* = 1.41, range = 26 - 30), and the remaining 6 older adults completed the MoCA, all scoring above 26 (*M* = 27.83, *SD* = 1.60 , range = 26 - 30) indicating gross neurological impairment was not present. A total of 4 WRAP control participants scored below the established cut-off scores on the cognitive screening measures so were excluded and replaced by participants who scored in the cognitively healthy range.

Materials

Word list. Eighty words were selected from the verbal labels for Snodgrass images (Snodgrass and Vanderwart, 1980), to ensure that all words could be drawn. Words ranged in frequency between 1 and 25 (M = 8.23, SE = .72), in length between 3 and 11 letters, (M = 5.56, SE = .20), and in number of syllables from 1 to 4 (M = 1.63, SE = .08). All words were common nouns of objects that are highly familiar from everyday life (e.g. table, apple, bird).

Filler Task. Sound files representing low-, medium- and high-pitched tones were created using Audacity software (Mazzoni & Dannenberg, 2000), such that each sine wave tone was exactly 500 ms long, at frequencies of 350, 500, and 650 Hz respectively. The purpose of this filler task was to distract, and to disrupt any additional processing of the study material, such as rehearsal of words, and to ensure that we were not assessing ‘short-term’ memory. This technique has been used in our other published research as well (e.g. Fernandes & Moscovitch, 2000), and is recommended by Craik and colleagues (1996) to reduce recency effects in free recall.

Neuropsychological evaluations. Following the experimental sessions we conducted either the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) or the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005).

Procedure

All participants with probable dementia completed the experiment in groups of 6-7 people in rooms with tables, chairs, and a projection screen, at the long-term care facilities where they reside. The healthy older adult participants from WRAP completed the study either in groups, or individually, in classrooms or testing rooms at the University of Waterloo campus, respectively. Stimulus presentation, and response recording for the filler task, were controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) via an IBM computer on either a 17-inch monitor or projected onto a large screen. All instructions were presented in English both on-screen and read aloud by the experimenter. Participants were not informed that they would be required to complete a later memory test, so as to reduce the possibility that participants would implement memory strategies that might confound assessment of our encoding tasks.

Encoding. Participants first completed a brief practice session in order to familiarize them with the encoding tasks of drawing and writing. Participants were encouraged to ask questions for clarification, after which the experiment began. The instructions indicated that depending on the ‘prompt’, seen prior to each individual trial, they were to either ‘draw’ or ‘write’ the target word on the pad of paper provided. For the ‘draw’ prompt, participants were instructed to draw a picture illustrating the object that the word on the screen represents, and to continue adding detail until the trial ends. For the ‘write’ prompt, participants were instructed to clearly and carefully write out the word multiple times. From the list of 80 words, 30 were randomly selected to be studied. Of these 30, 15 were randomly selected to be drawn, and 15 written, with the presentation of the encoding trial types intermixed. On each trial, the prompt appeared in the center of the screen above the target word. Participants then had 40 s to perform either the drawing or writing task, depending on which was indicated by the prompt. A 500 ms tone alerted them to stop performing the task and prepare for the next target word and prompt. They had 3 s to flip their pad of paper to the next page. Participants were informed of the time constraints for each item and that they would hear a tone to indicate the end of the trial and the appearance of the prompt and word for the next trial. See Figure 9 for examples of drawing and writing.

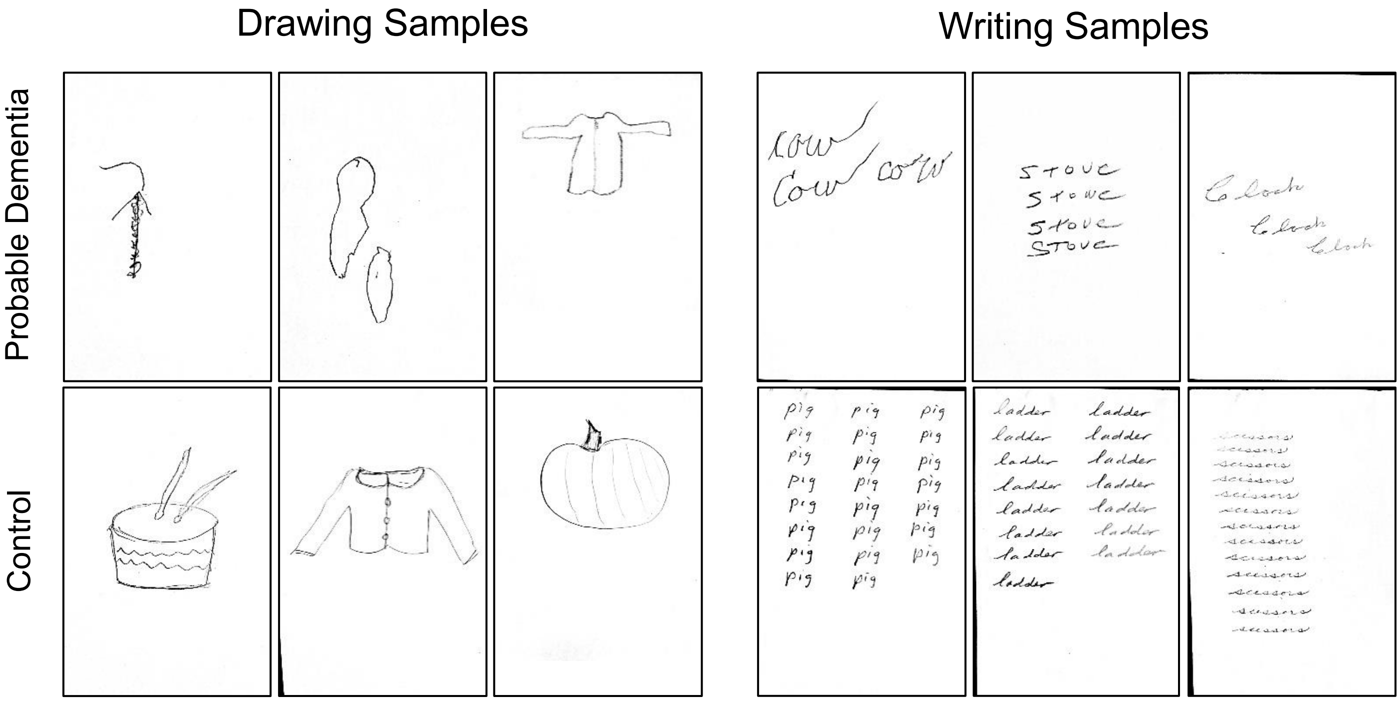

Figure 9. Samples of drawing and writing from individuals with probable dementia and healthy aging controls.

Retention. Following the encoding trials, participants were asked to perform a continuous reaction time (CRT) task as a filler task. Tones were to be classified as low, medium or high, by making a check-mark on a sheet of paper with columns for each tone type and rows for each instance of a tone. After hearing samples of each kind of tone, participants proceeded to classify 60 tones, selected at random. For each trial, the tone was played for 500 ms, after which participants had 1500 ms to make their response, for a total of 2000 ms per trial. Participants completed this tone classification task for two minutes.

Retrieval. In the next phase of the experiment participants were first asked to freely recall as many words as they could, in any order, either written or drawn, from earlier in the experiment. They were given 5 minutes to write out as many words as they could recall on a new sheet of paper. Next, they were given a recognition test composed of all 30 words studied in the encoding phase along with 30 lures randomly selected from the 80-item word list. Each word was positioned on the right side of the sheet of paper with corresponding words 'old or new' on the left. All words on the recognition test were printed in Calibri size 36 font. For each word, participants were instructed to circle 'old' if they recognized the word from the encoding phase or 'new' if they did not recognize it from earlier in the study. There were 2 to 7 such trials presented per page, for a total of 8 pages. Participants were given unlimited time to complete the recognition test. Following completion of the retrieval phase, participants were taken to a separate, quiet location, for administration of the MMSE or MoCA.

Results

Recall Performance

Number of words recalled. The number of words recalled was analyzed in a 2 Group (Probable Dementia and Controls) X 2 Encoding Trial Type (Drawing and Writing) mixed

ANOVA with Group as a between- and Encoding type as a within-subjects factor (See Table 4 for means). As expected, the analysis revealed a main effect of Encoding trial type, *F* (1, 24) = 54.75, *MSE* = 177.23, $p < 0.001$, $\eta = 0.70$, such that words drawn at encoding were better remembered than those that were written. There was also a main effect of Group, *F* (1, 24) = 44.21, *MSE* = 208.00, $p < 0.001$, $\eta^2 = 0.65$, such that the control group recalled more words than the probable dementia group, and a Group X Encoding type interaction, *F* (1, 24) = 17.32, *MSE* = 56.08, $p < 0.001$, $\eta^2 = 0.42$.

To better understand the interaction, 2 separate paired samples t-tests were performed to compare memory performance between the encoding trial types in each group. For the control group, more words were recalled that had ben drawn than written at encoding, *t* (12) = 6.57, $p < 0.001$, and the same was true for the probable dementia group, *t* (12) = 3.41 $p = 0.005$. The interaction stemmed from the fact that the magnitude of the recall benefit for drawing relative to writing was larger for the control than the probable dementia group (See Figure 10). [3]

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[3] Given that individuals with MCI or dementia typically have poorer overall memory than healthy older adults, it is difficult to determine the relative memorial benefit that drawing provides each age group. Given this, we opted to calculate the proportion of drawn and written words recalled by dividing the number of each by the total number of words recalled by each individual participant. For recognition, the number of words correctly recognized was divided by the total number of each word type (15 words for each type) in the recognition test. By taking this approach we could determine the relative benefit from each encoding trial type, and make comparisons across our groups. See Table 4 for means. The proportion of words recalled from each encoding trial type was analyzed in a 2 Group (Probable Dementia and Controls) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA. The analysis revealed a main effect of Encoding trial type, *F* (1, 24) = 69.63, *MSE* = 5.00, $p < 0.001$, $\eta^2 = 0.74$, such that drawn words were better remembered than written, but no main effect of Group, *F* (1, 24) = 3.60, *MSE* = 0.17, $p = 0.07$, $\eta^2 = 0.13$, nor a Group X Encoding type interaction, *F* (1, 24) = 0.39, *MSE* = 0.03, $p = 0.54$, $\eta^2 = 0.02$.

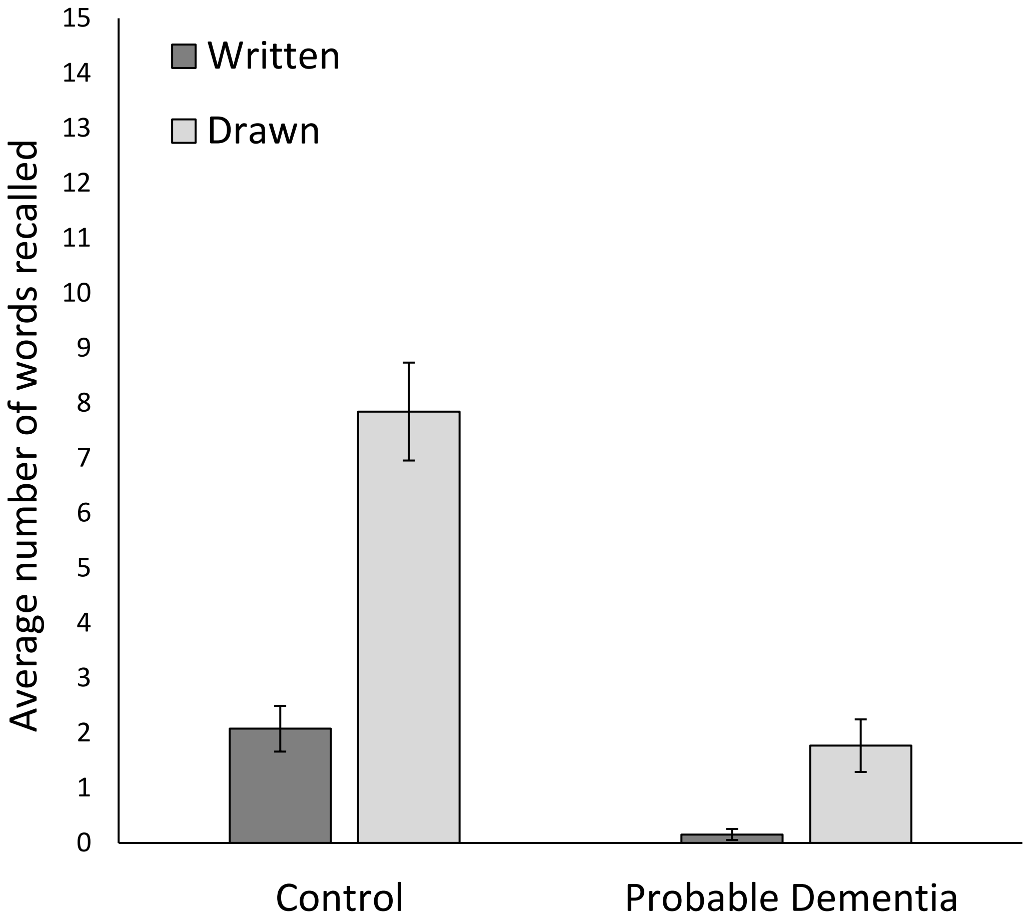

Figure 10. Average number of words recalled in Experiment 4 for each encoding trial type. Error bars show standard error of the mean.

Recognition Performance

Number of words recognized. The number of words correctly recognized was analyzed in a 2 Group (Probable Dementia and Controls) X 3 Word Type (Drawn, Written, or Lure) mixed ANOVA with Group as a between- and word type as a within-subjects factor (See Table 4 for means). As expected, the analysis revealed a main effect of word type, *F* (2, 48) = 26.03, *MSE* = 418.09, $p < 0.001$, $\eta^2 = 0.52$, such that drawn words were better remembered than written, but no main effect of Group, *F* (1, 24) = 0.05, *MSE* = 1.55, $p = 0.83$, $\eta^2 = 0.002$. Additionally, a Group X Encoding type interaction was found, *F* (2, 48) = 12.46, *MSE* = 200.09, $p < 0.001$, $\eta^2 = 0.34$.

To better understand the interaction, we performed two separate repeated measures ANOVAs, one for each of our participant groups, to compare memory for each word type. For the control group, the analysis revealed that memory endorsements differed between word types, *F* (1, 24) = 64.06, *MSE* = 598.26, $p < 0.001$, $\eta^2 = 0.84$. Paired samples t-tests revealed that more memory endorsements were made for drawn words compared to written words, *t* (12) = 4.21, $p = 0.001$, and lures, *t* (12) = 11.67, $p < 0.001$, and for written words compared to lures, *t* (12) = 6.58, $p < 0.001$. For participants with probable dementia, the analysis revealed that memory endorsements did not differ between word types, F (1, 24) = 0.87, MSE = 19.92, p = 0.43, $\eta^2 = 0.07$ (See Figure 11).[4]

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[4] We also analyzed the proportion of words recalled from each encoding trial type in a 2 Group (Probable Dementia and Controls) X 2 Encoding Trial Type (Drawing and Writing) mixed See Table 4 for means). As expected, the analysis revealed a main effect of Encoding trial type, *F* (1, 24) = 15.17, *MSE* = 0.48, $p = 0.001$, $\eta^2 = 0.39$, such that drawn words were better remembered than written, but no main effect of Group, *F* (1, 24) = 2.51, *MSE* = 0.43, $p = 0.13$, $\eta^2 = 0.09$. Additionally, a Group X Encoding type interaction was found, *F* (1, 24) = 6.48, *MSE* = 0.21, $p = 0.02$, $\eta^2 = 0.21$.

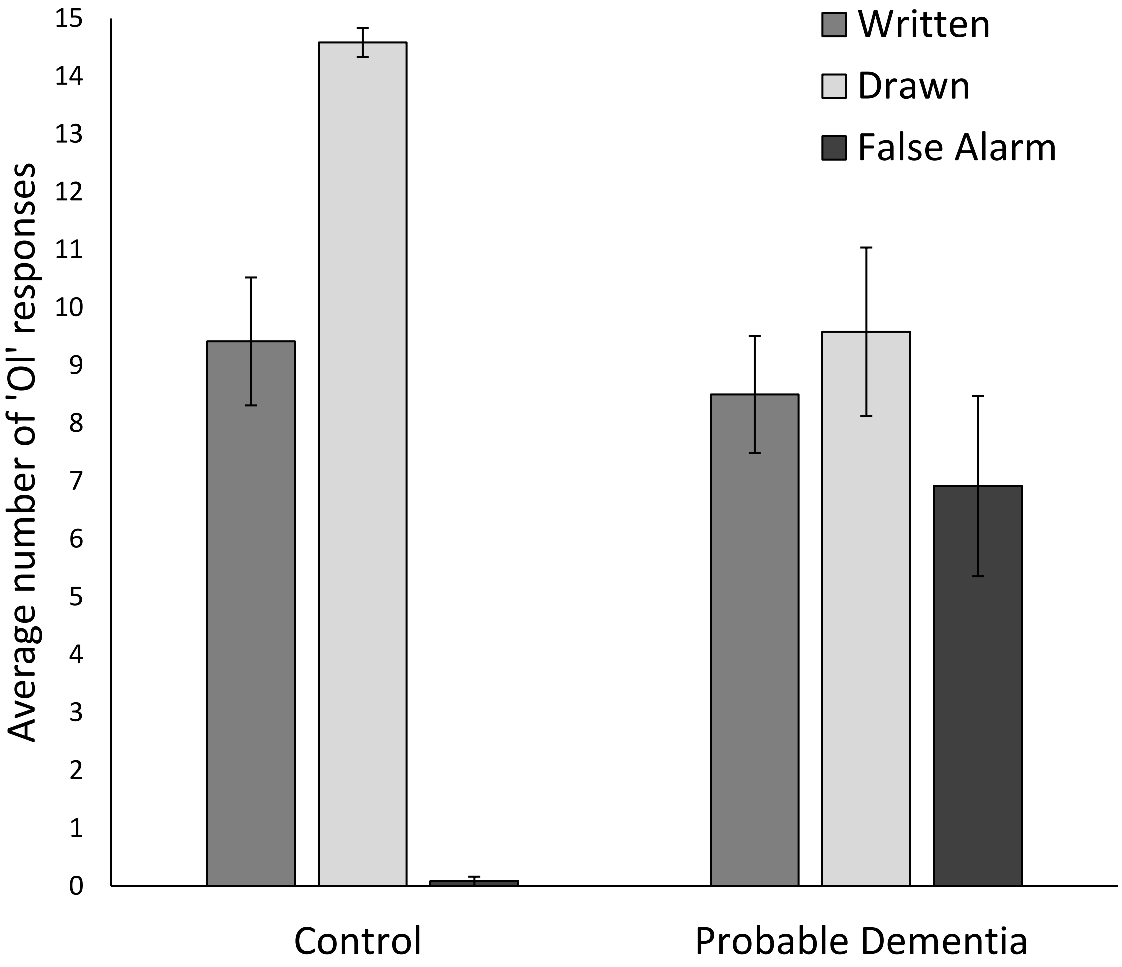

Figure 11. Average number of hits and false alarms in Experiment 4 recognition test for each encoding trial type. Error bars show standard error of the mean.

Table 4. Means and standard deviations of the number of words recalled in Experiment 4, in younger and older adults following each Encoding Trial type.

Experiment 4	Number Recalled		Number Recognized		
	Written	Drawn	Written	Drawn	False Alarm
Control	2.08 (*1.50*)	7.85 (*3.21*)	9.41 (*3.99*)	14.58 (*0.90*)	0.08 (*0.29*)
Probable Dementia	0.15 (*0.38*)	1.77 (*1.79*)	8.50 (*3.78*)	9.58 (*5.45*)	6.92 (*5.83*)
	Proportion Recalled		Proportion Recognized		
	Written	Drawn	Written	Drawn	False Alarm
Control	0.21 (*0.13*)	0.79 (*0.13*)	0.58 (*0.31*)	0.99 (*0.28*)	0.00 (*0.00*)
Probable Dementia	0.05 (*0.14*)	0.72 (*0.43*)	0.52 (*0.28*)	0.59 (*0.39*)	0.21 (*0.20*)

Experiment 5	Number Recalled		Number Recognized		
	Written	Drawn	Written	Drawn	False Alarm
Control	3.20 (*2.12*)	8.20 (*2.65*)	7.93 (*3.84*)	13.53 (*1.60*)	0.13 (*0.35*)
Probable Dementia	0.87 (*1.06*)	2.20 (*2.21*)	10.80 (*4.48*)	7.00 (*3.83*)	2.20 (*3.86*)
	Proportion Recalled		Proportion Recognized		
Control	0.27 (*0.11*)	0.73 (*0.11*)	0.53 (*0.20*)	0.90 (*0.11*)	0.00 (*0.01*)
Probable Dementia	0.25 (*0.30*)	0.61 (*0.37*)	0.47 (*0.26*)	0.72 (*0.30*)	0.07 (*0.13*)

Discussion

Our results demonstrate that, as expected, more drawn than written words were recalled in both cognitively healthy older adults and individuals with probable dementia. The proportion of drawn relative to written words did not differ between our groups, indicating that while individuals with probable dementia benefit from the drawing encoding strategy the magnitude of this benefit appears not to be greater than that observed in cognitively healthy older adults. The enhanced memory performance found in the group of individuals with probable dementia likely arose due to the visual perceptual and semantic processing promoted by the drawing task.

As expected, performance on the recognition test revealed that healthy older adults recognized more drawn than written words. For individuals with probable dementia, there was no difference in recognition of drawn compared to written words. Anecdotally however, patients with probable dementia reported finding it very difficult to understand how to complete the recognition test despite attempts by our research assistants to explain task instructions. For example, many participants in this group continually attempted to circle words other than ‘old’ or ‘new’ on the recognition sheet, suggesting that the format of the test created a cognitive burden for these individuals. Given this, in our next experiment we created a new, simplified recognition test in an attempt to reduce false alarms to lures in the group of participants with probable dementia. An additional issue experienced by those in the probable dementia group was hearing the tone played to indicate a trial was complete. As a result, a number of participants with probable dementia would often fail to stop performing the writing or drawing task for a particular trial and begin the next trial on time. As such, in Experiment 5 we added pauses (never more than 1 minute long) between each trial to ensure all participants were able to properly follow the procedure and ensure that each study item was encoded.

Experiment 5

The goal of Experiment 5 was to provide a replication of the findings in Experiment 4 with a new sample of individuals with probable dementia and cognitively healthy older adults. In addition we used a different format for the recognition test, to try to reduce false alarms. We also included additional neuropsychological evaluations to better characterize our sample. In addition to the MoCA, we assessed performance on the Rey-Ostereith complex figure copying test (Rey, 1941) and the F-A-S Verbal Fluency (Borkowski, Benton, & Spreen, 1967) test, to investigate potential relationships between the drawing effect and visuospatial and verbal processing abilities in our samples. It was expected that memory performance on the free recall and recognition tests would be superior for drawn compared to written words in both healthy older adults and individuals with probable dementia. Additionally, we expected to find a positive relationship between the size of the drawing effect and the Rey-Ostereith complex figure copying test, but not on the F-A-S Verbal Fluency test, given the presumption that the beneficial effects of drawing depend, in part, on visual processing abilities.

Methods

Participants

All participants signed a consent form prior to participation in the study. As in Experiment 4, written consent from a subset of our participants with probable dementia was provided by their power of attorney. Additionally, it was made clear that participants were invited to participate of their own free will and were able to leave whenever they wanted if they wished to stop participating. Older adult participants were given $10 remuneration for their participation and residents living in long-term care facilities were either given $10 cash or gifts of equal value depending on the discretion of the long-term care facility manager.

The participants with probable dementia were 15 residents (4 males and 11 females, M_{age} = 90.71, SD_{age} = 3.25) living in long-term care facilities in the Kitchener-Waterloo region who volunteered to participate. All participants completed the MoCA screening test (Nasreddine et al., 2005), and all scored below 26 (*M* = 15.53, *SD* = 4.73, range = 4 - 24). A total of 3 individuals with probable dementia scored above the established cut-off scores on the cognitive screening measures so were excluded from analysis and replaced by participants who scored in the cognitively impaired range. Performance on the MoCA indicated gross cognitive impairment in this sample, with a high probability that participants in this sample had either MCI or dementia of varying degrees of severity.

In addition 15 older adult participants (8 males and 7 females, M_{age} = 73.00, SD_{age} = 5.00) were recruited from WRAP, and received token monetary remuneration. All participants completed the MoCA (Nasreddine et al., 2005), and each person scored above 26 (*M* = 27.73, *SD* = 1.67, range = 26 - 30) indicative of healthy cognitive aging. A total of 2 WRAP control participants scored below the established cut-off scores on the cognitive screening measures so were excluded from analysis and replaced by participants who scored in the cognitively healthy range.

Materials

The materials were identical to those used in Experiment 4, with the exception of a newly formatted version of the recognition task. Specifically, instead of asking participants to circle ‘old’ or ‘new’ for each word listed in the recognition test, we instead asked them to simply circle any words that they recognized. All words on the recognition test were printed in Calibri size 36 font. For each word, participants were instructed to circle it if they believed it was presented earlier, during the study phase. There were 2 to 6 such trials presented per page, for a total of 9 pages. Apart from this modification, the materials used were identical to Experiment 4.

Neuropsychological evaluations. Following the experimental sessions we conducted the MoCA (Nasreddine et al., 2005).

The Rey-Osterrieth complex figure test (Rey, 1941) was included to assess visuospatial processing abilities (scored according to Meyers & Meyers, 1995). In this test, the participant is given a sheet of paper with a black and white line drawing of a complex figure composed of lines and basic shapes printed at the top. They are instructed to copy the figure on the bottom part of the sheet to the best of their ability, taking as much time as needed. After they have finished, the sheet is taken away and on a new sheet of paper they are asked to again draw the figure to the best of their ability, but this time from memory.

The F-A-S Verbal Fluency test (Borkowski et al, 1967) was included to assess verbal processing abilities. In this test, the individual is told that they will have 1 minute to verbally output as many words as possible that begin with a specific letter, and to avoid outputting proper names and variations of the same word (such as slip, slipped, slipping, slips).

Procedure

The procedure was identical to that used in Experiment 4, with the exception of the new format for the recognition test. Additionally, we made a couple of changes for the probable dementia sample including the addition of pauses between each encoding trial, and removal of the filler task,

The addition of the pauses allowed us to ensure that all participants were ready for the next encoding trial as many of the participants in Experiment 4, with probable dementia, had trouble hearing the tone which indicated the current trial was complete and the next trial was about to begin. Following the tone, and completion of a trial, the researcher waited for research assistants to alert all participants in the probable dementia sample to stop the encoding task and prepare for the next trial before advancing. During the pause, the screen was blank. No more than 1 minute elapsed between each trial, and these pauses ensured that all participant in the probable dementia group were always performing the appropriate task (i.e. either drawing or writing). The pauses were not necessary for the older adult samples who had no difficulties hearing the tones, and following instructions.

We chose to exclude the filler task for the probable dementia sample due to their difficulty with hearing the variations in tones that were to be identified. Additionally, the main purpose of the filler task was to disrupt recency effects in memory, which was unnecessary given that it took more time to explain the subsequent retrieval test to that sample, than the controls.. As well, eliminating the filler task allowed participants in this sample the greatest chance to remember as many words as possible as the delay between study and test was reduced, and distraction between encoding and retrieval was minimized.

Results

Recall Performance

Number of words recalled. The number of words recalled was analyzed in a 2 Group (Probable Dementia and Controls) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA with Group as a between- and Encoding type as a within-subjects factor (See Table 4 for means). As expected, the analysis revealed a main effect of Encoding trial type, F (1, 28) = 44.96, MSE = 150.42, $p < 0.001$, $\eta = 0.62$, such that drawn words were better remembered than written, and a main effect of Group, F (1, 28) = 47.58, MSE = 260.42, $p < 0.001$, $\eta^2 = 0.63$, such that the control group recalled more words than the probable dementia group, and a Group X Encoding type interaction, F (1, 28) = 15.07, MSE = 50.42, p = 0.001, η^2 = 0.35.

To better understand the interaction, two separate paired samples t-tests were performed to compare memory performance between the encoding trial types in each group. For the control group, more words were recalled that had been drawn than written at encoding, t (14) = 3.08, p = 0.008. For the probable dementia group, more words were recalled that had been drawn than written at encoding, t (14) = 5.96, $p < 0.001$. The interaction stemmed from the greater magnitude of recall benefit for drawing relative to writing in the control than probable dementia group (See Figure 12).[5]

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[5] The proportion of words recalled from each encoding trial type was analyzed in a 2 Group (Probable Dementia and Controls) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA (See Table 4 for means). As expected, the analysis revealed a main effect of Encoding trial type, F (1, 28) = 26.09, MSE = 2.48, $p < 0.001$, η^2 = 0.48, such that drawn words were better remembered than written, but no main effect of Group, F (1, 28) = 2.15, MSE = 0.07, p = 0.15, η^2 = 0.07, or Group X Encoding type interaction, F (1, 28) = 0.32, MSE = 0.03, p = 0.58, η^2 = 0.01.

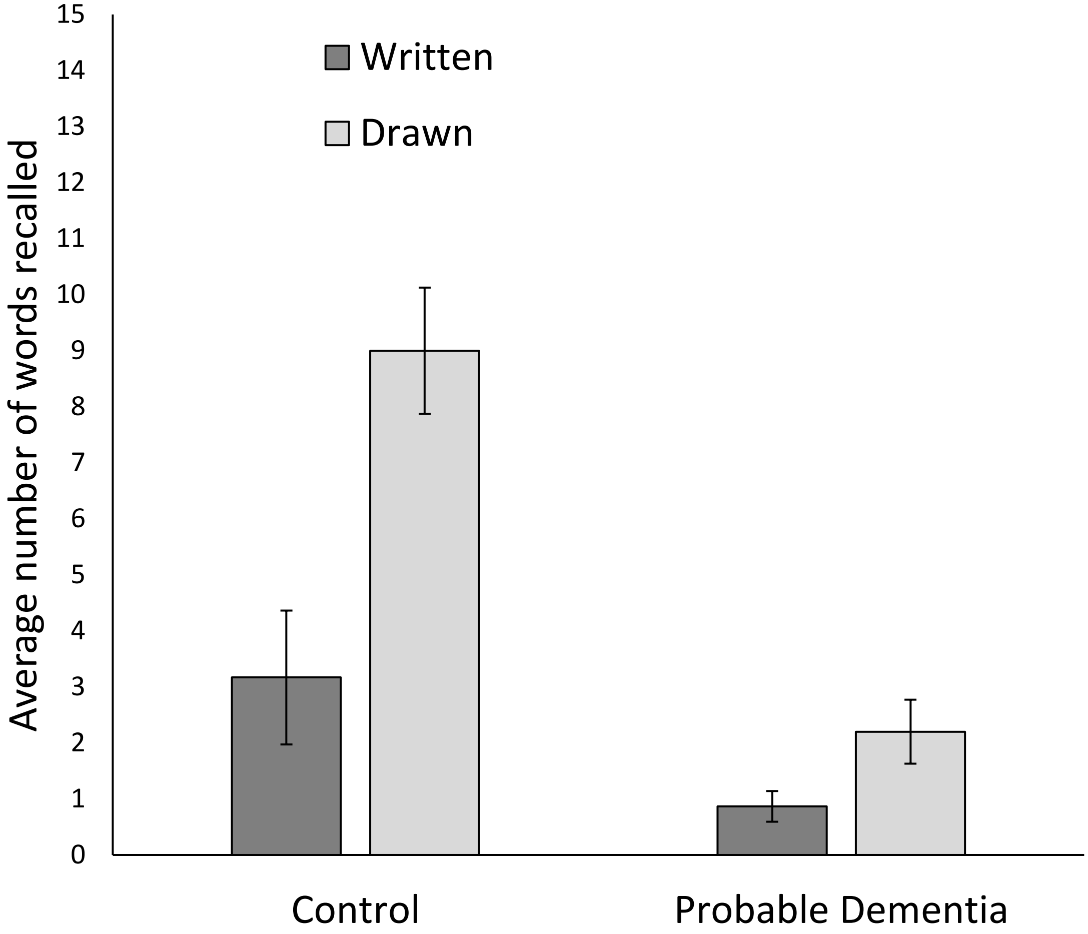

Figure 12. Average number of words recalled in Experiment 5 for each encoding trial type. Error bars show standard error of the mean.

Recognition Performance

Number of words recognized. The number of words correctly recognized was analyzed in a 2 Group (Probable Dementia and Controls) X 3 Word Type (Drawn, Written, or Lure) mixed ANOVA with Group as a between- and word type as a within-subjects factor (See Table 4 for means). As expected, the analysis revealed a main effect of Word type, F (2, 56) = 144.85, MSE = 913.90, $p < 0.001$, $\eta^2 = 0.84$, such that drawn words were better remembered than written, but no main effect of Group, F (1, 28) = 0.35, MSE = 6.40, $p = 0.56$, $\eta^2 = 0.01$. Additionally, a Group X Encoding type interaction was found, F (2, 56) = 6.99, MSE = 44.10, $p = 0.002$, $\eta^2 =$ 0.20.

To better understand the interaction, we performed two separate repeated measures ANOVAs, one for each of our participant groups, to compare memory for each word type. For the control group, the analysis revealed that memory endorsements differed between word types, F (1, 28) = 199.82, MSE = 679.40, $p < 0.001$, $\eta^2 = 0.93$. Paired samples t-tests revealed that more memory endorsements were made for drawn compared to written words, t (14) = 7.55, $p <$ 0.001, and lures, t (14) = 30.86, $p < 0.001$, and for written words compared to lures, t (14) = 9.99, $p < 0.001$. For participants with probable dementia, the analysis revealed that memory endorsements differed significantly across word types, F (1, 28) = 30.22, MSE = 278.60, p < 0.001, $\eta^2 = 0.68$. Paired samples t-tests revealed that more memory endorsements were made for drawn words compared to written words, t (14) = 5.19, $p < 0.001$, and lures, t (14) = 6.11, $p <$ 0.001, and for written words compared to lures, t (14) = 4.43, $p = 0.001$ (See Figure 13).[6]

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[6] The proportion of words recalled from each encoding trial type was analyzed in a 2 Group (Probable Dementia and Controls) X 2 Encoding Trial Type (Drawing and Writing) mixed ANOVA (See Table 4 for means). As expected, the analysis revealed a main effect of Encoding trial type, F (1, 28) = 81.38 MSE = 1.47, $p < 0.001$, $\eta^2 = 0.74$, such that drawn words were better remembered than written, but no main effect of Group, F (1, 28) = 2.63, MSE = 0.22, $p = 0.12$, $\eta^2 = 0.09$, or Group X Encoding type interaction, F (1, 28) = 2.98, MSE = 0.05, $p = 0.09$, $\eta^2 = 0.10$.

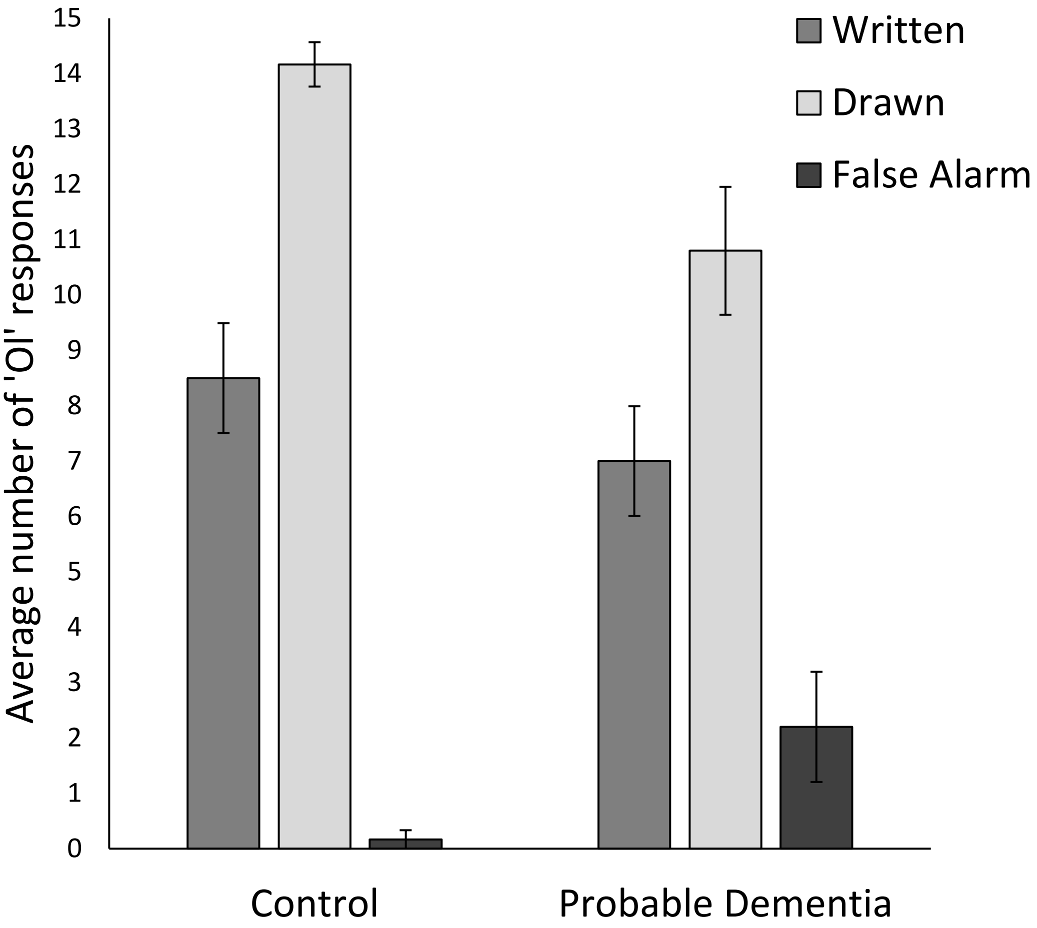


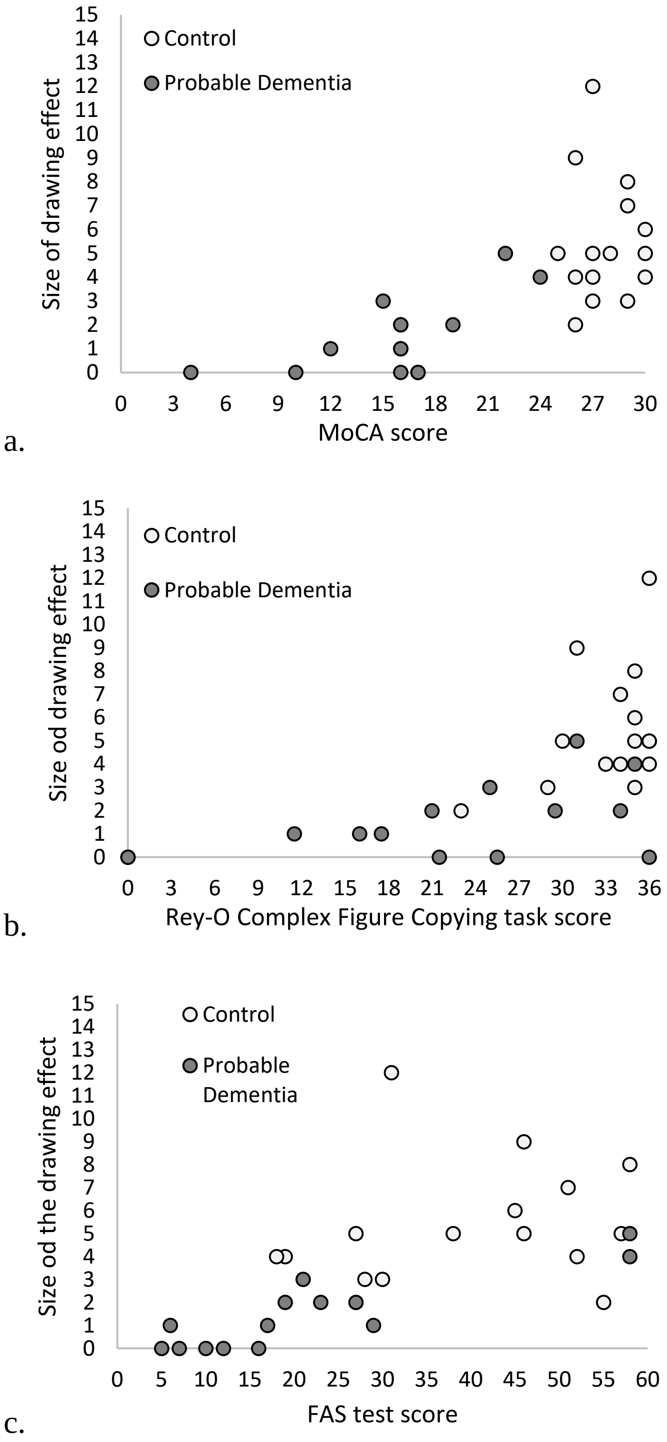
Figure 13. Average number of hits and false alarms in Experiment 5 recognition test for each encoding trial type. Error bars show standard error of the mean.

Correlations between participant characteristics and the drawing effect

Cognitive impairment. In our sample we had a wide range of MoCA scores within our probable dementia group. As such, we examined whether the magnitude of the drawing effect, the difference between the number of drawn and written words recalled, was associated with MoCA score across our groups. A Pearson correlation revealed a positive relationship between MoCA score and the magnitude of the drawing effect, $r = 0.61$, $p < 0.001$, such that the magnitude of the drawing effect increased as MoCA score increased.

Visuospatial processing. Visuo-spatial processing abilities were measured using the Rey-Osterieth Complex figure copying task and scored according to the Meyers and Meyers (1995) administration guide. The average score for the healthy older adult control group was 33.20 (SD = 3.61), and for the probable dementia group was 20.90 (SD = 11.74) out of a total possible 36 points. To determine if any relationship exists between visuospatial processing abilities and the drawing effect in our sample we conducted a Pearson correlation between the difference in number of drawn and written words recalled, and scores on the Rey-Ostereith complex figure copying test. As expected, the analysis revealed a significant positive relationship between the drawing effect and scores on the Rey-Ostereith copying test, $r = 0.64$, $p < 0.001$.

Verbal fluency. The FAS verbal fluency scores were computed for each participant by summing the number of words provided for each of the letters F, A, and S (Borkowski et al, 1967). The average score for the healthy older adult control group was 40.07 (SD = 13.69), and for the probable dementia group was 22.14 (SD = 16.89). To determine if any relationship exists between verbal fluency and the drawing effect in our sample we conducted a Pearson correlation analysis between the difference in number of drawn and written words recalled and scores on the FAS test. The analysis indicated no significant relationship between the drawing effect and verbal fluency, r = 0.36, p = 0.053. See Supplemental Figure 1 for scatterplots of the magnitude of drawing effect correlated with MoCA score, Rey-Osterieth Complex figure copying task, and the FAS test..



Supplemental Figure 1. The size of the drawing effect (number of drawn minus written words remembered) for individual participants plotted against a. score on the MoCA, b. score on the Rey-Osterieth Complex figure copying task, and c. the FAS test for both controls and participants with probable dementia.

General Discussion

In this study we present a pattern of results, replicated in two different samples of participants, demonstrating that drawing pictures as an encoding strategy enhances memory more than writing to-be-remembered target words, in both healthy older adults and individuals with probable dementia. We suggest that the observed memory benefits for drawing relative to writing stem from the rich visual and semantic processing engaged by drawing. Specifically, drawing benefits memory in individuals with probable dementia by taking advantage of intact visual and conceptual fluency, which is thought to be supported by relatively preserved brain regions in the earlier stages of the disease. Indeed, we found that the magnitude of the drawing effect was positively related with visuo-spatial abilities as measured by the Rey-Ostereith copying test, but not reliably with verbal output scores on the FAS test. Overall, these results demonstrate the effectiveness of drawing at encoding as a strategy to ameliorate memory deficits in individuals experiencing memory impairment due to cognitive decline associated with dementia.

The finding that drawing boosts memory performance more than writing in cognitively healthy older adults is consistent with our previous work (Meade et al, 2018). It was by suggested by Meade and colleagues (2018) that older adults benefit from drawing by recruiting processing of visual perceptual information which relies on brain regions in which relatively less shrinkage occurs throughout the normal aging process (Raz et al, 2005). Similar to healthy older adults, individuals with probable dementia likely also benefit from drawing due to the involvement of brain regions recruited for visual processing that remain relatively intact throughout the disease process (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt et al, 1996; Golby et al,, 2005; Koenig et al, 2008). Indeed, previous work has demonstrated that individuals with MCI and dementia receive large memory benefits from studying pictures rather than words

(Ally & Budson, 2007; Ally et al, 2008; Ally et al, 2009; Embree et al, 2012). Specifically, it has been suggested that pictures enhance memory in populations with dementia given that these individuals have relatively preserved perceptual and conceptual fluency (Embree et al, 2012: Ally 2012). Like studying pictures, drawing at encoding involves visual perceptual processing which we argue recruits relatively preserved brain regions, thereby enhancing memory performance relative to tasks such as writing which do not promote perceptual processing.

The finding that the magnitude of the drawing effect was positively related to visuospatial performance on the Rey-Ostereith complex figure copying task provides evidence that the memory benefit from drawing is indeed related to visuospatial processing abilities. Specifically, we suggest that visuospatial processing is required to support the task of thinking about how to visually depict the features of an object. Such processing becomes integrated into the memory trace and reactivated at the time of retrieval (Wheeler, Petersen, & Buckner, 2000; Vaidya, Zhao, Desmond, & Gabrieli, 2002; Danker, & Anderson, 2010). For example, Vaidya and colleagues (2002) provided evidence that studied pictures reactivated occipital regions involved in visual perceptual processing even though only words were presented at test; this work demonstrates that sensory processing regions can become integrated into a memory trace. By recruiting visual perceptual processing abilities, and corresponding regions of the brain that are relatively preserved both in healthy aging and dementia, individuals can create memory traces that are more successfully retrieved. The relationship between the size of the drawing effect and Rey-Ostereith copying test performance indicates that when an individual can better engage in visuospatial processing, this type of information can become better integrated into the memory trace, thereby enhancing memory performance.

Interestingly, while some previous work has found a picture superiority effect of similar magnitude between healthy older adults and individuals with MCI or dementia (Ally & Budson, 2007; Ally et al, 2008; Ally et al, 2009), some have found a larger effect for the latter (Embree et al, 2012). Here we found no difference in the proportional benefit from drawing relative to writing when comparing our healthy older adult and probable dementia groups, indicating that the magnitude of the drawing effect does not differ between these populations. We predicted that we may see a larger benefit for drawing than writing in the individuals with probable dementia compared to controls given our expectation that drawing recruits visual and conceptual processing to an even greater extent than viewing pictures. To elaborate, it has been argued in previous work that the memory trace for drawn information contains both semantic and visual components, and has been demonstrated to boost memory more than viewing or imagining pictures (Wammes et al, 2016, Fernandes et al, 2018). Unlike viewing a picture, in order to create a drawing one must access a conceptual representation of the item and determine how to visually depict each of the features of the item on a sheet of paper. Given that individuals with dementia have the greatest deterioration occurring in frontal and temporal regions (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt et al, 1996; Golby et al,, 2005; Koenig et al, 2008), and demonstrate impaired verbal and conceptual fluency (see Fleischman & Gabrieli, 1998, for review), reliance on relatively intact visual processing regions through drawing should have significant benefits on memory performance. As such, we expected the greater demands on visual and conceptual processing associated with drawing would result in a larger magnitude of the drawing effect for individuals with probable dementia relative to healthy older adults.

One reason why the magnitude of the drawing effect was not larger in our participants with probable dementia may have to do with the fact that we had considerable variability in the degree of cognitive impairment in this sample. For example, MoCA scores for our probable dementia sample ranged from 4 to 24 out of 30, indicating a range of mild to more moderate or severe dementia symptoms (Nasreddine et al., 2005). While brain regions recruited for visual perceptual processing remain relatively intact in the earlier stages of dementia, they do become affected as the disease progresses to a severe stage (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt, et al, 1996). It is possible that the drawing encoding strategy is most optimal for boosting memory in those with mild cognitive impairment, and less beneficial for those with more moderate to severe dementia symptoms. While the current work demonstrates the effectiveness of drawing as an encoding technique for individuals with probable dementia, future work is needed to determine the relative benefits of drawing at various stages of cognitive impairment within this population.

Similarly, we had expected that we might observe a negative relationship between MoCA scores and the magnitude of the drawing effect, given that so few written words were retrieved by participants in the probable dementia group. However, we found a positive correlation indicating those who are cognitively healthier experience a larger memory benefit from drawing relative to writing. It is possible that drawing provides the largest benefits to memory performance for cognitively healthy older adults and those in the range of mild cognitive impairment or mild dementia due to visual processing regions remaining relatively intact only in the earlier stages of the disease (Scarmeas et al., 2004; Braak, & Braak, 1991; Arndt, et al, 1996). It might be that the magnitude of the drawing effect is larger in MCI and mild dementia than those with moderate to severe dementia. Such a pattern would predict a quadratic relationship between cognitive health and the drawing effect in older adults. The small sample size and variability in MoCA scores in the current study do not allow us to explore whether such a relationship exists, however, this may be an interesting direction for future work.

Our findings ultimately demonstrate that drawing pictures is a highly effective technique to boost memory performance not only in cognitively healthy older adults (Meade et al, 2018) but also in individuals with probable dementia. This work builds on a robust literature of previous research demonstrating the beneficial effects of studying pictures relative to words for various populations experiencing MCI and dementia (Ally & Budson, 2007; Ally, Gold, & Budson, 2009; Embree, Budson, & Ally, 2012; see Ally, 2012 for review). Specifically, drawing provides a method by which one can take advantage of the memorial benefits of pictorial information in daily life given that one can themselves create a depiction of information they wish to remember. Investigating behavioural tasks that individuals can use to enhance memory performance is critical to improving the lives of those facing advanced deterioration of memory abilities (Greenaway et al, 2012; Jean et al, 2010). We demonstrate here that drawing is a valuable tool that individuals with probable dementia can use to ameliorate memory deficits.

Chapter 4: Comparing the influence of task-related and -unrelated drawing on memory

The findings from Chapter 3 clearly demonstrate that drawing benefits memory in individuals with probable dementia, despite these individuals having difficulty producing high quality, representational drawings. As such, it is unclear what aspects of drawing are critical in producing this benefit; Does simply drawing scribbles benefit memory? Is there something inherent about the act of engaging in any drawing, putting pencil to paper, that benefits encoding processes? I suspected that the content of the drawing produced, or intended to be produced, does in fact determine the memorial benefit provided by drawing. Specifically, I suspect that accessing a conceptual representation and attempting the visually depict an item are essential to the drawing effect. Therefore, in Chapter 4 the goal was to compare memory performance following encoding by drawing to-be-remembered information as well as various forms of drawing that consist of content *unrelated* to the memory task. This production of 'task-unrelated' drawing can be more generally referred to as 'doodling'.

In the first investigation of doodling behavior, Maclay, Guttmann, and Mayer-Gross (1938) found that people from a variety of different professions tend to doodle either to alleviate boredom or to boost concentration on their current task, highlighting the pervasiveness of doodling in everyday life. Broadly, we define doodling as creating drawings that are semantically unrelated to the information contained in some primary task or activity (e.g. the content of a phone conversation). More recently, countless books have emerged encouraging the behaviour (e.g. The Back of the Napkin, Roam, 2008; The Doodle Revolution, Brown, 2014). As evident in these examples, it is commonly assumed that doodling must have utility; perhaps conferring some kind of advantage to cognitive abilities. However, experimental research examining how doodling might affect cognition is sparse. Clarifying the impact of doodling on memory performance in particular, was of interest in the current study given the pervasiveness of doodling in everyday life.

One study suggests that doodling during encoding of to-be-remembered information benefits later memory performance. Andrade (2009) asked participants to monitor a mock telephone message for the names of people coming to a party, and to write down the names of people who could attend. Half of the group was also asked to ‘doodle’ while listening to the telephone call in order to ‘relieve boredom’, while the other half simply listened to the message, and noted attendees. The doodling group recalled 29% more information on a surprise memory test than those who did not doodle during encoding. Andrade (2009) suggested the reason for the benefit was that the doodling task engaged central executive processes that would otherwise have become devoted to mind-wandering, which would ultimately interfere with efficient encoding. As such, the reduction in mind-wandering afforded by doodling was said to improve participants’ ability to attend to, and thereby encode, primary task information, though mind-wandering was never explicitly measured (Andrade, 2009; Schott, 2011).

It could be argued that the type of ‘doodling’ task used by Andrade (2009), which was to shade in geometric shapes, is not fully characteristic of how doodling is typically done in everyday life. Specifically, shading in geometric shapes is quite different from actually generating scribbles and pictures (free-form doodling), and this latter type of doodling is arguably more akin to how people generally doodle (Maclay, Guttmann, & Mayer-Gross, 1938; Schott, 2011). This issue was addressed in a recent extension of Andrade’s (2009) study conducted by Boggs, Cohen, and Marchand (2017). They compared memory performance following both structured and free-form doodling. Specifically, while listening to a 5-minute pre-recorded mock conversation, participants either shaded in shapes (structured doodling), created free-form doodles, wrote out notes on the content of the recording, or just listened with no accompanying task. On an immediate quiz of the contents of the recording, participants who created free-form doodles had worse memory performance than those in the structured doodling and note-taking conditions. The authors theorized that structured doodling takes up fewer attentional resources than free-form doodling, allowing participants to allocate more attention to the to-be-remembered information. Notably, these results, combined with others in the literature (Chinchanachokchai, Duff, & Wyer, 2011; Chan 2012) indicate that the content and form of doodling might indeed determine the influence of doodling on memory.

Comparing doodling and task-related drawing

In our previous work (Wammes, Meade & Fernandes, 2016; 2017; Fernandes, Wammes, & Meade, 2018) we demonstrated that drawing pictures of concrete nouns during encoding led to better memory compared to writing out words, listing descriptive characteristics, viewing pictures, or imagining the object that the word represents. In demonstrating that drawing is superior to listing characteristics and viewing images, our data showed that our drawing-related memory benefit cannot fully be explained by either a Level of Processing (LoP; Craik & Lockhart, 1972) or a Picture Superiority Effect (PSE; Paivio & Csapo, 1972), respectively. In that work, we theorized that drawing pictures benefits memory through the creation, and seamless integration, of visual, motor, and semantic memory traces during encoding (Wammes et al., 2016; Wammes, Roberts, & Fernandes, 2018). Based on this view, the drawing effect should only be observed when these traces are specifically integrated with the semantic meaning of the to-be-remembered information. We expected that a free-form doodling task that involves some of the same components implicated in the drawing effect (visual and motor), but lacks semantic relatedness to the to-be-remembered information, will not benefit memory performance to the same extent as does drawing. That is, the act of free-form doodling during encoding of new information is unlikely to lead to the same magnitude of benefit to memory as does drawing, and may even impair performance.

According to the LoP framework (Craik & Lockhart, 1972), encoding is enhanced when the semantic meaning of the to-be-remembered information is elaborated upon. Because doodling is unrelated to studied items (i.e. targets), semantic processing of to-be-remembered information would not be facilitated by this action. Past research also suggests that encoding tasks that are not specifically related to the target (as in doodling) do not benefit, and in some cases even impair, memory performance. For example, while verbal production (saying a word aloud) of a subset of to-be-remembered words enhances memory (*the production effect*: MacLeod, Gopie, Hourihan, Neary & Ozubko, 2010), verbal production of a generic response of ‘yes’ to every target during encoding does not (Castel, Rhodes, & Friedman, 2013). Similarly, while performing a motor action associated with a to-be-remembered word enhances memory (*the enactment effect*: Engelkamp, & Zimmer, 1983), non-specific motor action can actually interfere with short-term memory for action-related words relative to related motor actions (Saltz & Donnenworth-Nolan, 1981; Shebani & Pulvermuller, 2013). These findings highlight the beneficial role of encoding tasks that are integrated with the to-be-remembered target, and the comparatively hurtful effect of an unrelated cognitive act. While the drawing effect may rely on mechanisms similar to those sub-serving the production and enactment effects (Wammes et al., 2016), drawing differs in that it likely fully integrates the semantic, visual and motor content of the to-be-remembered information. Therefore, even though both drawing and free-form doodling involve motor, visual, and semantic processing, the latter promotes processing that is not semantically tied to the to-be-remembered information. Because of this, we sought to determine whether doodling would result in poorer memory performance than would drawing at encoding.

In Chapter 4 we examined the effect of both structured and free-form doodling during encoding on later memory performance, relative to that of writing out or drawing pictures of to-be-remembered information. During encoding, participants listened to to-be-remembered words while either creating unrelated doodles, drawing pictures of the word, or writing out the word, for each trial. The target words were structured in categorized lists, presented either intermixed one at a time (Experiment 6), or blocked within narratives (as in a pre-recorded telephone message) format (Experiments 7 and 8). In Experiments 6 and 7, doodling was free-form, or un-structured, apart from the instruction that doodles were not to be related to the auditorily-presented words. In contrast, in Experiment 8, participants ‘doodled’ by shading in geometric figures, as in previous work (Andrade, 2009; Boggs et al., 2017). See Table 5 for a breakdown of the main differences and similarities across the three Experiments in Chapter 4.

Experiment	Word list	Presentation format	Doodling type
6	Mixed	Single words	Free-form
7	Blocked	Embedded within narrative	Free-form
8	Blocked	Embedded within narrative	Structured (shading shapes)

Table 5. Main differences and similarities across Experiments 6 – 8 in Chapter 4.

Experiment 6: Single Words, Free-Form Doodling.

We examined the effect of free-form doodling during encoding on later memory performance, relative to that of writing out or drawing pictures of to-be-remembered words. During encoding, participants listened to to-be-remembered words while either creating unrelated doodles, drawing pictures of the word, or writing out the word, on a given trial. The to-be-remembered items consisted of semantically categorized word lists, presented intermixed, one at a time (Experiment 6). Even though both drawing and free-form doodling involve motor, visual, and semantic processing, the latter does not invoke semantically-related processing of the to-be-remembered information; as such, we predicted that doodling would not produce any benefit to memory and may actually hurt performance, relative to writing.

Method

Participants. Twenty-four participants (15 female) were recruited from the undergraduate population at University of Waterloo, and participated for course credit. Participants ranged in age from 17 to 23 (*M* = 20.08, *SD* = 1.44) and all indicated English as their first language.

Materials. Three 20-item categorized lists of concrete nouns were created (see Appendix A). The words in a given list belonged to one of three categories – vegetables (e.g. tomato), furniture items (e.g. dresser), or modes of transportation (e.g. bicycle). Pencils and notepads (5” x 8”) were provided for students to perform the drawing, writing, and doodling tasks.

Procedure

Participants were tested in groups of five to ten, seated in a classroom such that no two students were sitting directly beside one another. Instructions indicated that they should treat the experiment as an examination, and specifically should avoid any interaction with others, and not look at other participant’s notepads. Participants were not informed that a memory test would ensue, and were simply told that we were interested in studying the best way to record information. We assessed incidental memory to ensure that participants did not willingly adopt another strategy to boost retention, such as, silently rehearsing words or engaging in strategic encoding.

Study Phase. Following a brief practice phase to familiarize participants with the encoding procedures, participants heard a list of 60 words presented in a randomly selected order. These were taken from the three categorized word lists and presented auditorily over the speaker system in the classroom. In a within-subjects design, each auditorily presented word was preceded by a randomized prompt to either ‘draw’, ‘write’ or, doodle’. The prompt was projected visually in Courier New size 36 font onto a screen in the classroom. Following this, participants heard the to-be-remembered word, and were given thirty seconds to complete the prompted task. The end of each trial was indicated by presentation of a 500 Hz tone for 500ms. Participants were prompted randomly to either draw, write, or doodle 20 words for each of the 3 prompt-types presented in this mixed design, for a total of 60 trials.

Task instructions for each prompt were as follows: “If the prompt is ‘draw’ we ask that you draw a picture illustrating the word on the pad of paper provided. Continue adding detail to your drawing until you hear the tone. When you hear the tone, get ready for the next prompt and word”.

“If the prompt is ‘write’ we ask that you clearly and carefully write out the word on the paper provided. Continue re-writing the word until you hear the tone. When you hear the tone, get ready for the next prompt and word.”

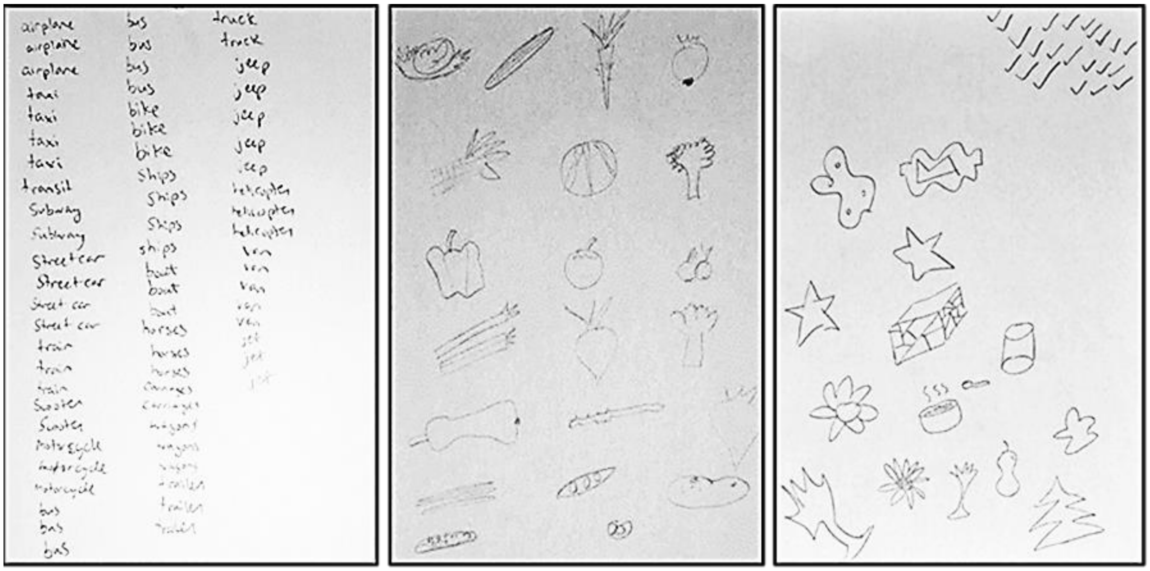
"If the prompt is 'doodle' we ask that you freely draw whatever you desire. There are no limitations to what you may draw, as long as it is unrelated to the content of the message. When you hear the tone, get ready for the next prompt and word."

Retention Phase. To ensure participants were retrieving from long-term rather than working memory, we introduced a retention interval of two minutes. During this time participants completed a continuous reaction time task (CRT). They were asked to classify a series of 60 randomly selected tones as being high (650 Hz), medium (500 Hz), or low (350 Hz), by making checkmarks in corresponding boxes on a sheet of paper, following each tone. Each tone was played for 500ms, with 1500ms between tones, during which participants made their classification decision.

Recall Phase. Upon completion of the retention task, participants were given one minute to freely recall, by writing down, any of the words presented (regardless of trial type) during the study phase. Participants were not made aware that memory would be assessed beforehand.

Results

The number of words correctly recalled was tabulated for each of the Writing, Drawing, and Doodling encoding trial types (See Figure 14 for samples of productions from Write, Draw, and Doodle trial types; see Figure 15 for means). Data were analyzed using repeated-measures ANOVA, revealing a significant difference between Doodle, Draw, and Write trials, F (2, 46) = 60.87, MSE = 3.17, $p < 0.001$, $\eta^2 = 0.73$. Simple effects contrasts revealed significantly lower recall of words in the Doodling compared to Drawing, F (1, 23) = 111.06, MSE = 6.34, $p < 0.001$, $\eta^2 = 0.83$, and Writing, F (1, 23) = 52.85, MSE = 7.88, $p < 0.001$, $\eta^2 = 0.70$, trial types. Additionally, recall was higher in Drawing than Writing trial types, F (1, 23) = 7.81, MSE = 4.80, $p < 0.01$, $\eta^2 = 0.25$.



Write Draw Doodle

Figure 14. Examples of writing, drawing, and free-form doodling. Note that participants were only asked to make check-marks in the doodling conditions in Experiments 7 and 8.

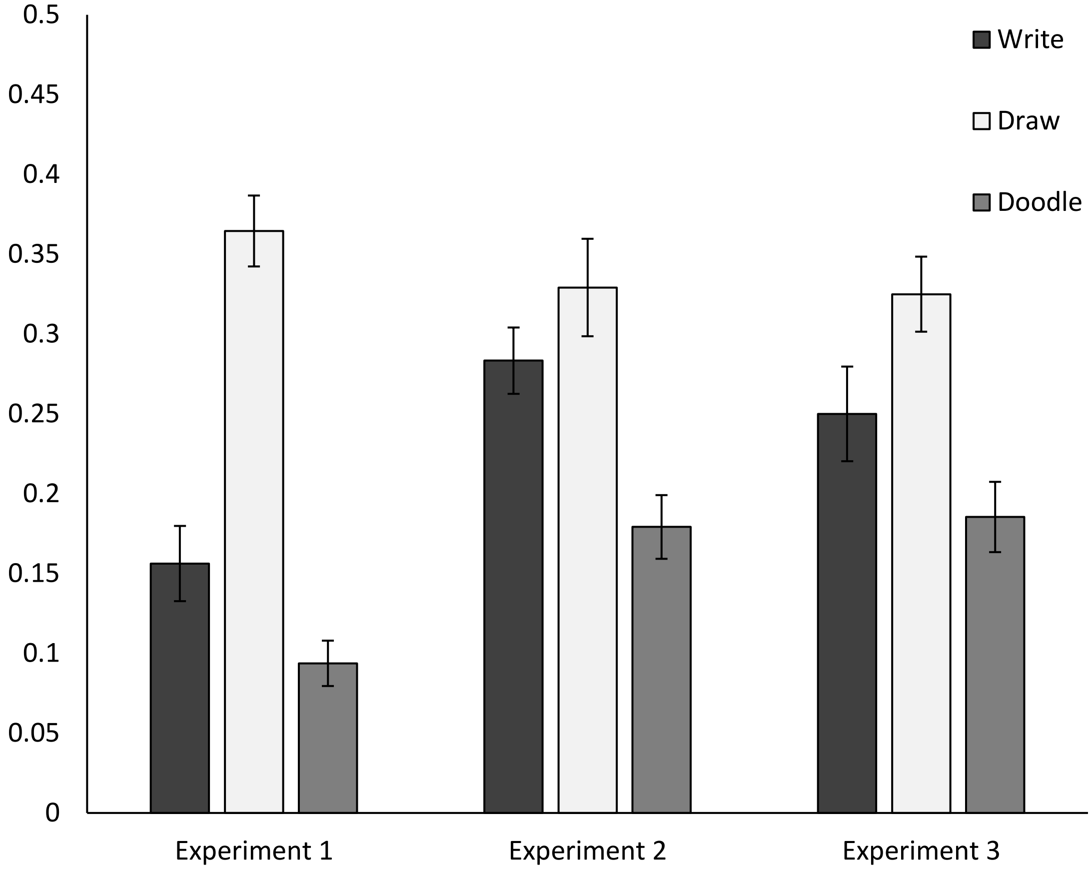


Figure 15. Proportion of words recalled following each encoding trial type in each of the Experiments in Chapter 4. Error bars represent standard error.

Discussion

As predicted, doodling during encoding led to worse subsequent free recall performance than either writing or drawing pictures of words. Additionally, we found that drawing led to better recall performance than writing, replicating our previous findings (Wammes et al., 2016). The pattern of results observed here indicates the importance of the type of semantic component engaged during drawing versus doodling. Despite the fact that doodling required visual and motor components, the semantic component was not specifically related to the to-be-remembered information, hindering memory for the target. This finding likely arose because creating doodles that are unrelated to the to-be-remembered target words did not involve semantic processing of said words. It is possible that doodling may have involved a semantic component, for example, if the doodle contained a flower image the participant likely accessed a semantic representation of flowers, leaves, or even gardens; critically, however, this semantic information was unrelated to the target words for the memory task, accounting for the poorer performance following doodling than drawing trial types. As suggested in our previous work, the better memory for drawn than written targets likely arose because drawing provided not only a semantic and motoric component, but also allowed for an integrated visual component that was absent in the write trial types.

Our results, in terms of the effect of doodling on memory, are in line with those of Boggs and colleagues (2017) who observed poorer memory following unstructured (or free-form) doodling relative to note-taking. However, it is difficult to draw a strong comparison across this study and ours, mainly due to the fact that Boggs et al. (2017) asked participants to doodle or take notes while listening to a recorded conversation, while in Experiment 6 we presented individual words one at a time during encoding, removing any need for participants to monitor for to-be-remembered information. Regardless, it is notable that despite the difference in our paradigm, there was still no evidence for beneficial memory effects of free-form doodling, both in the current study and in Boggs et al. (2017).

Similarly, it is difficult to make comparisons between Experiment 6, and findings from Andrade (2009), due to differences in the type of doodling task, and stimulus presentation format (in a narrative versus single words). Specifically, Andrade (2009), asked participants to engage in a structured doodling task (shading in shapes) while monitoring for target words embedded within a narrative. She found that doodling *enhanced* memory performance for key information in the narrative relative to just listening. The use of a narrative may be particularly important as it has been suggested that the way in which doodling enhances memory is by reducing mind-wandering, thereby increasing the amount of attentional resources available for monitoring of to-be-remembered information (Andrade, 2009; Schott, 2011; Boggs et al., 2017). Thus, it is possible that by presenting the to-be-remembered words one at a time to participants, we eliminated the need for monitoring, and therefore, the opportunity for doodling to provide a benefit. As such, in Experiment 7, rather than presenting words individually, we presented the exact same categorized word lists from Experiment 6, but this time embedded within a narrative.

Experiment 7: Narratives, Free-Form Doodling

In Experiment 7, we aimed to use a procedure and design more analogous to previous studies assessing the effect of doodling on memory (Andrade, 2009; Boggs et al., 2017), as well as the context in which doodling would occur naturally, by embedding target words within a narrative (rather than in a list).

In the new procedure participants listened to pre-recorded narratives lasting 2.5-3 minutes and monitored for target words (from a particular category: furniture, fruits/vegetables, or modes of transportation) which they then wrote out, drew a picture of, or hear while doodling. Categories were used to help participants identify target words within the narrative. It is possible that in this narrative format, free-form doodling would confer a memorial benefit to targets; that is, using this more cohesive (blocked) format of presentation of target items, doodling may reduce mind-wandering and/or improve encoding by way of enhancing attention to targets, as originally proposed by Andrade (2009). However, if free-form doodling actually serves as a distraction (Boggs et al., 2017), we should find that memory following the doodling condition will be poorest, as found in Experiment 6. Finally, as in Experiment 6, we maintain our prediction that drawing will benefit memory more than both doodling and writing, given that drawing additionally provides pictorial information, and is *semantically related* to the study words.

Method

Participants

Twenty-four participants (21 female) were recruited from the undergraduate population at University of Waterloo, in return for course participation credit. Participants ranged in age from 18 to 28 (*M* = 20.42, *SD* = 2.22), and all indicated English as their first language. Data from one participant were replaced, due to a failure to adhere to the instructions during the doodling encoding condition (drawing pictures of the to-be-remembered words rather than doodles).

Materials. Three pre-recorded narratives were prepared, containing the same three 20-item categorized word lists used in Experiment 6 as to-be-monitored nouns (see Appendix A). The lengths of these narratives were 170 seconds (Furniture), 149 seconds (Transportation) and 179 seconds (Vegetables), respectively. Each narrative was recorded by the same female speaker. The mean amount of time between the presentations of each target word within each narrative was 8.26 seconds (*SD* = 2.88).

Retention Task. As in Experiment 6, participants completed the tone identification task during the retention interval between encoding and retrieval.

Procedure

Identical to Experiment 6, participants were tested in groups of five to ten, seated in a classroom such that no two students were sitting directly beside one another. They were not informed that their memory would be assessed, again making this an incidental test of memory for the targets.

Study Phase. Following a brief practice phase, participants were presented a series of three narratives, played aloud, one at a time. Each narrative block was cued by a visually presented prompt to ‘draw’, ‘write’ or, doodle’ printed on a sheet of paper. Each participant in a given session received a different order of prompts such that some wrote target words during the first narrative, some drew pictures of target words, and some doodled. After each prompt, participants were presented with one of the three narratives in its entirety, and asked to monitor for 20 words from a single category. They were then presented with the name of the category on the screen (i.e. vegetables, modes of transportation, or furniture, depending on the narrative) and told to monitor for 20 words from the identified category whilst performing their assigned encoding task. Specifically, participants were told “You will be presented with three recorded telephone messages, one at a time. You will be asked to monitor each of these messages for a specific category of words.” The end of each narrative was indicated by presentation of a 500 Hz tone for 500ms.

Task instructions for each condition were as follows: “If the prompt is ‘draw’ we ask that you draw a picture illustrating each word that belongs to the category indicated. Continue adding detail to your drawing until the next categorized word is heard.”

“If the prompt is ‘write’ we ask that you clearly and carefully write out the word on the paper provided. Continue re-writing the word until the next categorized word is heard.”

“If the prompt is ‘doodle’ we ask that you freely draw whatever you desire throughout the duration of the message. There are no limitations to what you may draw. As long as it is unrelated to the content of the message. When a word belonging to the category indicated is heard, simply denote that you have heard it with a checkmark at the side of the page.”

The checkmark task in the doodling condition was included to provide evidence indicating that participants were indeed listening to and monitoring for the target words. The presentation order of both the narratives and the prompts were counterbalanced across participants, and testing sessions. Narrative order was counterbalanced across sessions (6 different orders), and the order of encoding conditions was counterbalanced within each session (6 different orders). See Figure 16 for an example of one of the narratives.

Retention and Recall Phases. The retention and recall phases were identical to Experiment 6.

“Hi! Are you doing anything on Saturday? I’m having a bbq and was hoping you could come. I’m excited because I plan to use a ton of vegetables from my garden. I have a ton of **lettuce**, I think I’m going to make several different kinds of salad. My garden has done so well this year, I hardly know what to do with all of these vegetables. Actually, do you want to take some **cucumbers**? I think I planted too many, and I just can’t eat all of them. I’ll cut up a couple of them for the salad, along with some **carrots**, though I don’t have very many of those, and they are pretty small, I think they weren’t in a very good spot and didn’t get enough sun. Oh, I will have to remember to not put any **onion** in one of the salads because there are a few people who don’t like them. But I think I will put **spinach** in all of them, since that’s a pretty basic thing to include in a salad, though I remember my brother always hated it and refused to eat it. I will probably put a lot of **cabbage** in too, since I also have quite a bit of that. I’m starting to think I might need to borrow some bowls for this, do you think you could bring your big one? I only have two medium sized bowls. Oh and do you think you could also bring some **broccoli**? I planted some but it didn’t grow, and I would really like some for the salad. Fortunately, the **peppers** grew really well, which I wasn’t expecting because they didn’t turn out last year at all. The only thing that always grows really well is **tomatoes**, I already have a bunch of them sitting on the windowsill, ready to be eaten. That reminds me, I planted some **radish** this year for the first time so I have a few of those, do you think that would be good to put in the salad? I don’t really know what else I would use it for, I should probably try to plant fewer things next year. I didn’t get much **celery** to grow, so maybe i’ll try to plant more of that next time instead of some of the things I don’t eat very often, like **turnips**, I don’t know why I decided to plant those! I definitely won’t try to get any **cauliflower** to grow again either, it didn’t work at all, and I don’t think that I’ll miss it. One thing I would really like to try to grow is **squash**, my mom planted some last year and I was surprised at how big they got, much bigger than most of the ones you would buy at the store. She also has **asparagus**, I might get some from her this week for the bbq, I have a really good recipe for those. My mom always has such great success with her garden, except for the **beets** she tried to grow this year, maybe they are harder to grow than other vegetables. Did those **beans** you planted happen to grow? They usually do well under a variety of circumstances. I always have some of them, maybe I will put some **peas** in the salad for the bbq. Oh I will have to go to the store and get some **potatoes** to bake on the bbq, they will be so good with the chicken. I also think I might get some **corn** to put on the bbq too. Anyway, I hope you can make it, there is going to be so much good food! Bye for now!

Figure 16. Example of one of the narratives with embedded categorized target words highlighted in bolded text.

Results

Recall data (See Figure 15) were analyzed using a repeated-measures ANOVA, and revealed a significant main effect of Condition, F (2, 46) = 9.30, MSE = 6.10, $p < 0.001$, η^2 = 0.29. Simple effects contrasts revealed significantly lower recall of words in the Doodling compared to Drawing, F (1, 23) = 17.01, MSE = 2.70, $p < 0.001$, η^2 = 0.43, and Writing, F (1, 23) = 12.36, MSE = 8.43, $p < 0.01$, η^2 = 0.35, conditions. Additionally, recall did not differ between Drawing and Writing conditions, F (1, 23) = 1.30, $p = 0.27$.

We counted the number of checkmarks (M = 17.73) participants recorded whilst doodling, as well as the number of drawings (M = 17.45 drawings) produced, and the number of written words (M = 19.09), as they provided us with an indirect measure of how many targets in each condition were successfully monitored. We computed a corrected recall score (words recalled / items documented) to determine whether this affected the pattern of findings. Two participants were omitted from this analysis for failing to record any checkmarks. In addition, participants sometimes recalled more words than the number of checkmarks they recorded. In this case, they were given a score of 1. Repeated-measures ANOVA using this dependent measure indicated once again a main effect of Condition F (2, 42) = 9.05, MSE = 0.03, $p < 0.01$, η2 = 0.30. As in the previous ANOVA, simple effects contrasts revealed significantly lower recall of words in the Doodling compared to Drawing condition, F (1, 21) = 15.64, MSE = 0.96, $p < 0.01$, η^2 = 0.43, but now there was no difference between Doodling and Writing conditions, F (1, 21) = 3.22, MSE = 0.09, $p = 0.09$, η^2 = 0.13. Unlike the previous ANOVA, recall was now significantly higher in the Drawing than Writing condition, F (1, 21) = 5.96, MSE = 0.46, $p < 0.05$, η^2 = 0.22.

Discussion

In line with Experiment 6, as well as previous findings (Boggs et al., 2017), we found that even when words were embedded within a narrative, free-form doodling did not benefit memory for targets relative to drawing or writing during encoding. Importantly, we found that drawing benefitted memory more than doodling, suggesting that it is critical that the visual, motor, and semantic requirements of a drawing-based encoding task be semantically related to the to-be-remembered information to confer a benefit.

Another possibility is that free-form doodling encouraged participants to engage in processing of semantically unrelated information (for example, if they were doodling flowers or other objects), leaving fewer attentional resources available to encode the targets. In Andrade's (2009) study doodling was operationalized as 'shading in geometric shapes', and was reported to have an enhancing effect on memory for targets. It might be that generating and creating non-representational designs (such as squiggles or abstract doodles of unrelated information) in our free-form doodling condition consumed more attentional resources than would a structured doodling task such as shading in shapes. Indeed, Boggs et al. (2017) found that while free-form doodling led to worse memory performance than note-taking, there was no difference between note-taking and structured doodling. Given this, we expected that use of a structured doodling task, in Experiment 8, could lead to a benefit to memory performance. As in Experiments 6 and 2, we again predicted that drawing would still result in the best memory for targets.

In raw free recall, drawing did not significantly enhance memory relative to writing, contrary to our previous work (Wammes et al., 2016; 2017). We believe this resulted from the change in presentation format. The narrative format provided a rich enough semantic structure that it reduced any further benefit that drawing might confer, over writing out words at encoding.

Nonetheless, we note that the drawing effect emerged when recall was corrected for the number of targets successfully detected. It is possible that the drawing effect only emerges in the corrected recall analysis because fewer drawn words were attended to than written words; of the words that were encoded memory was better for drawing than writing.

Experiment 8: Narratives, Structured Doodling

In Experiment 8, we changed our free-form doodling task to structured doodling. Specifically, rather than instructing participants to create free-form doodles during encoding of targets, we asked them to shade in geometric shapes on a sheet of paper (as in Andrade, 2009). While free-form doodling likely encourages the integration of motor and visual traces with unrelated semantic information (such as when doodling flowers or houses for example), this should not be the case for structured doodling. We predicted that when doodling consisted of shading of repeated geometric shapes, subsequent memory for targets would be better than that following the write condition, based on findings from Andrade (2009). As in the previous experiments, we expected that words drawn at encoding would be remembered best.

Method

Participants. Twenty-four participants (13 female) were recruited from the undergraduate population at University of Waterloo, in return for course participation credit. Participants ranged in age from 18 to 22 (*M* = 20.00, *SD* = 1.14), and all had indicated English as their first language. Data from one participant were replaced, due to a failure to adhere to the instructions during the doodling encoding condition (drawing pictures of the targets rather than doodles).

Materials. The materials used were identical to Experiment 7, with the exception that the doodling condition now included a sheet of paper with geometric shapes; during that condition, participant were asked to shade in the shapes with a pencil. These structured doodling sheets contained alternating rows of circles and squares, each shape being 1 inch in diameter, with 10 shapes per row (as in Andrade, 2009).

Procedure

The procedure was identical to Experiment 7, with the exception that in the doodling condition participants were asked to shade in geometric shapes on a sheet of paper rather than doodle freely. See Figure 17 for an example of the sheet of shapes participants were asked to shade, based on that used by Andrade (2009).

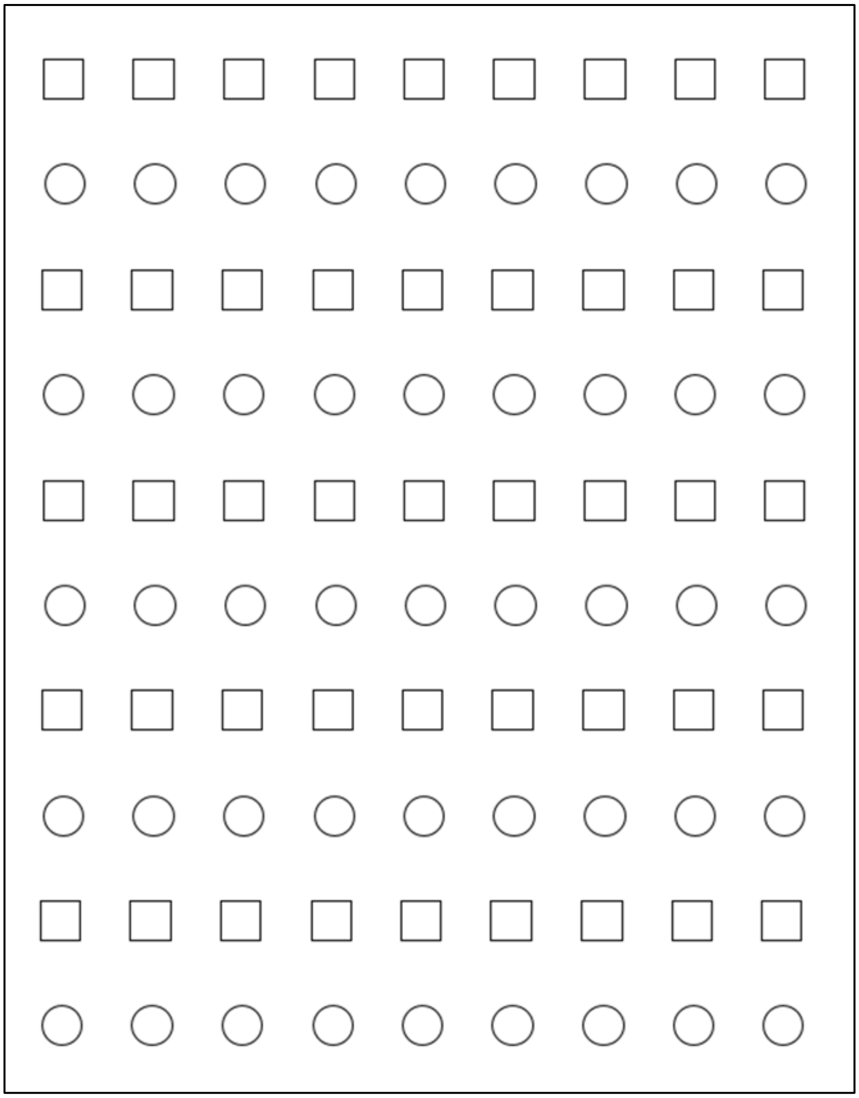


Figure 17. Example of the sheet of shapes participants were asked to shade, modeled after that used by Andrade (2009).

Results

Recall data (See Figure 15) were analyzed using a repeated-measures ANOVA, and revealed a significant difference between doodling, drawing, and writing conditions, F (2, 46) = 7.00, MSE = 6.90, $p < 0.01$, $\eta^2 = 0.23$. Simple effects contrasts revealed significantly lower recall of words in the Doodling compared to Draw conditions, F (1, 23) = 16.09, MSE = 11.97, $p <$ 0.001, $\eta^2 = 0.41$, but no difference between Doodling and Write conditions, F (1, 23) = 3.26, MSE = 12.30, $p = 0.08$, $\eta^2 = 0.12$. The difference in recall between words from the Draw and Write conditions was also non-significant, F (1, 23) = 3.33, MSE = 17.13, $p = 0.08$, $\eta^2 = 0.17$[7].

As in Experiment 7, we also calculated corrected recall based on number of check-marks recorded whilst doodling (M = 19.89), and number of drawings (M = 14.00), and written words (M = 18.89). Three participants failed to record any checkmarks and so were omitted from analysis. A repeated-measures ANOVA revealed an effect of Condition, F (2, 40) = 4.03, MSE = 0.06, $p < 0.05$, $\eta2 = 0.17$. Simple effects contrasts revealed marginally lower recall of words in the Doodling compared to Draw condition, F (1, 20) = 4.13, MSE = 0.63, $p = 0.06$, $\eta2 = 0.17$, and no difference between Doodling and Write conditions, F (1, 20) = 0.14, MSE = 0.02, $p =$ 0.72, $\eta2 = 0.01$, conditions. Additionally, recall was higher in the Draw than Write conditions, F (1, 20) = 10.19, MSE = 0.87, $p < 0.01$, $\eta2 = 0.34$.

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[7] The similar memory performance between drawing and writing both here and in Experiment 7 was unexpected given our previous work demonstrating the robustness of the drawing effect (Wammes et al, 2016). One possibility is that the drawing effect is reduced in magnitude in a paradigm involving a narrative format, and we lacked sufficient power to detect the effect in Experiments 7 and 8. Indeed, when the number of written and drawn words recalled were pooled across Experiments 7 and 8, a paired samples t-test revealed the drawing effect, t(47) = 2.11, p = 0.04, suggesting that the format change from single words to the narrative format reduced, but did not eliminate, the effect.

Discussion

In line with Experiments 6 and 7, we found that even when words were embedded within a narrative, free-form doodling did not benefit memory for targets relative to drawing. In this experiment however, there was no difference in recall performance following structured doodling compared to the writing condition. These results suggest that the *type* of doodling matters in determining the influence of doodling on memory; In Experiment 7, free-form doodling significantly reduced memory compared to writing, but when the doodling task was changed to be more structured, as in the current experiment, there was no statistical difference between these conditions. Such a pattern, across Experiments 7 and 8, is more in line with the findings of Boggs et al. (2017) who found that whereas *free-form* doodling led to worse memory performance than note-taking (akin to our writing condition), there was no difference between note-taking (writing) and *structured* doodling.

General Discussion

We sought to determine the extent to which doodling, during encoding of a set of to-be-remembered targets, might enhance memory performance. In Experiment 6, participants showed poorer free recall for words encoded while free-form doodling, compared drawn or written, with drawing resulting in the best performance. In Experiment 7, when target words were embedded in a narrative story, free-form doodling again led to the poorest subsequent recall of targets compared to when participants engaged in drawing or writing during encoding. In Experiment 8, we changed the doodling condition to a structured one involving shading in shapes, as in Andrade (2009), rather than free-form doodling requiring generation of unique output. We found that structured, in contrast to free-form doodling, led to similar levels of recall compared to simply writing out targets during encoding. Taken together, these findings indicate that unlike task-relevant drawing, structured doodling during study provides no benefits to free recall, and free-form doodling leads to memory costs.

The different patterns observed for free-form versus structured doodling, in Experiments 7 and 8 respectively, are consistent with Boggs and colleagues (2017) who demonstrated no difference in memory performance between structured doodling (shading in shapes, the same task used in the current study) and note-taking, but worse performance for free-form doodling. Similarly, our results are in line with evidence showing that free-form doodling impairs encoding (Chan, 2012; Boggs et al., 2017) while structured doodling does not (Andrade, 2009; Chinchanachokchai, Duff, & Wyer, 2011; Boggs et al., 2017). These results suggest that the *type* of doodling can differentially affect later memory performance. We have replicated and extended the findings from Boggs et al. (2017) by showing that free-form doodling impairs memory performance relative to writing out the to-be-remembered words (Experiments 6 and 7), though structured doodling does not differ from writing's effect on memory (Experiment 8). This latter finding is particularly interesting given that our writing task arguably required fewer attentional resources than the note-taking task used by Boggs et al. (2017) in which participants needed to determine which concepts were noteworthy in the auditory narrative and decide how to record them. It therefore appears that structured doodling only provides a memory benefit relative to doing nothing during encoding (Andrade, 2009; Chinchanachokchai, Duff, & Wyer, 2011; Boggs et al., 2017).

In previous work, shading in simple shapes enhanced memory for telephone message content (Andrade, 2009) and copying shapes improved memory for information heard in advertisements (Chinchanachokchai, et al., 2011) relative to conditions in which the participants simply listened to the to-be-remembered information. Our work differed from these studies in that we compared doodling to drawing and writing conditions instead of to a simple listening task. Based on the available evidence from our study and theirs, however, we can conclude that structured doodling while encoding targets is just as effective an encoding technique as is writing (in our Experiment 8) or taking notes (as in Boggs et al (2017), and may be superior to doing nothing during encoding (Andrade, 2009).

The explanations previously put forward to account for the effect of doodling on memory performance largely center on the role of attentional resources (Andrade, 2009; Schott, 2011; Boggs et al., 2017). Specifically, Andrade (2009) explained her findings by suggesting that doodling reduces the occurrence of mind-wandering and allows one to better attend to the primary task. Based on these suggestions, we thought it might be the case that memory performance would be better following the doodling than writing condition, when the presentation format was a narrative, in Experiments 7 and 8. Specifically, embedding the targets within the mock telephone message requires one to monitor for important information, thus providing a situation in which the suggested mechanism by which doodling improves memory could operate. However, memory was poorest following the doodling encoding condition in Experiment 7 and did not differ from the writing condition in Experiment 8. Furthermore, while intrusions were very rare in the current study, the average number was numerically higher following the doodling (0.6) than drawing (0.06) or writing (0.02) conditions, when pooling data from Experiments 7 and 8. These intrusion rates were too low to warrant statistical analysis, but nonetheless suggest that doodling does not benefit memory for target information.

Expanding on mechanistic accounts of doodling and attention posited by others (Andrade, 2009; Schott, 2011), Boggs and colleagues (2017) explain their observed discrepancy in memory performance between free-form and structured doodling tasks by suggesting that relatively more attentional resources are required to generate free-form doodles. The heavier attentional resource demands during free-form doodling create a bottleneck, making it difficult to attend to to-be-remembered information, thereby hindering encoding relative to structured doodling and note-taking (Boggs et al., 2017). From this perspective, it can be argued that structured doodling demands fewer attentional resources than free-form doodling, resulting in less interference with encoding of the targets. Future work specifically measuring availability of attention whilst free-form versus structured doodling is needed to support this claim.

Free-form doodling and drawing involve similar component traces (visual, motor, and semantic) with the critical distinction being the semantic relatedness of the picture one produces when drawing versus free-form doodling. That free-form doodling is a task composed of similar elements to drawing but does not lead to a memory benefit suggests that the relatedness of the semantic component is an important contributor to the drawing effect. For example, in the case of drawing a cat, one is using their motor system to create a visual interpretation of the semantic representation of a cat, by producing each of the features (legs, tail, ears, etc.) on paper that are part of the overall representation of the target item ‘cat’. When the visual and motor traces are directly linked to the semantic representation of a ‘cat’, they likely create additional routes through which one can later access the memory for the word ‘cat’. In contrast, when the semantic representation being accessed is not related to the to-be-remembered information (as in free-form doodling), the attentional resources devoted to creating the drawing may instead hinder encoding of the target information.

Chapter 5: The benefit (and cost) of drawing as an encoding strategy

While the beneficial effects of drawing on correct retrieval of old items has been demonstrated both in this dissertation and elsewhere (see Fernandes, Wammes, & Meade, 2018, for review), the influence of drawing on falsely remembering new items not presented at study (i.e., ‘false alarm’ responses) has yet to be investigated. Examining false alarm performance in relation to successful retrieval of old items (i.e., ‘hits’) is crucial in developing a complete understanding of the influence that a particular encoding task confers on memory performance. For example, an encoding task that results in both high hit and false alarm rates would produce overall poor memory accuracy (Lockhart & Murdock, 1970). If drawing results in a strong veridical memory for the studied item, it could be the case that one is protected against false alarming to unstudied information (Gallo, Weiss, & Schacter, 2004; Arndt & Reder, 2002). However, it is also possible that drawing promotes a spreading of activation amongst related conceptual representations that share visual and semantic features, and recollection of such contextual information could subsequently make one more susceptible to false alarming (Brainerd, Gomes, & Moran, 2014). Our aim in the current study was to determine the influence of drawing on false alarm rate, to better characterize how drawing at encoding affects subsequent memory performance.

Recollection of a Drawing

According to Dual Process models of recognition memory, successful retrieval involves two qualitatively distinct processes: *recollection* and *familiarity* (Gardiner, 2001; Perfect, Mayes, Downes, & Van Eijk, 1996; Tulving, 1985; Yonelinas, 2002). Familiarity-based memory is a general phenomenological feeling of familiarity with a target, wherein one has the sense that they have been exposed to the item before but cannot attribute any specific contextual details to that feeling. Recollection-based memory describes memory for a rich, vivid experience in which one is able to retrieve specific contextual details about the initial encoding event, such as a specific image or thought they had during encoding, thereby supporting successful retrieval of the studied item (Yonelinas, 2002). The Remember-Know-New (RKN) paradigm is one method used to probe these qualitative differences in memory by asking participants to classify test items as being either ‘New’ in the experiment, or items that they ‘Remember’ or ‘Know’ they saw in the encoding phase, with the latter two responses mapping onto recollection and familiarity, respectively. It has been demonstrated in previous work that a larger proportion of correctly recognized drawn words are recollection-based ‘Remember’ responses than familiarity-based ‘Know’ responses (Wammes et al., 2018). In the same study it was also shown that drawing leads to more accurate source identification of contextual information, as evidenced by superior performance in correctly identifying that words had been drawn compared to written at encoding. These findings suggest that drawing boosts memory performance by providing a perceptually rich encoding environment that specifically enhances recollection of contextual details (Wammes et al, 2018; Fernandes et al., 2018).

Recollection of Target vs. Contextual Information

Critically, while it is generally assumed that reinstatement of contextual source information is evidence of successful retrieval of the target (Mandler, 1980; Yonelinas, 2002), this assumption has been questioned by researchers suggesting that it is possible to only partially recollect the details of an event. For example, one way that recollection has been conceptualized is as a continuum of specificity regarding the contextual information retrieved, spanning from *specific-source memory* to *partial-source memory* (Dodson, Holland, & Shimamura, 1998), wherein the latter would involve reinstatement of only a portion of the contextual source information. More recently it has been posited that one may recollect context and target information separately, such that one can recollect the former in the absence of the latter and vice versa (Brainerd, Gomes, & Moran, 2014). Indeed, high confidence ‘know’ responses suggest that participants can successfully recollect a target without retrieval of contextual source information (Mickes, Seale-Carlisle, & Wixted, 2013). As well, complimentary findings demonstrate that recollection of contextual details can occur in the absence of the target (Lampinen, Neuschatz, & Payne, 1998). Specifically, it has been demonstrated that instances of ‘illusory’ or ‘phantom’ recollection (Brainerd, Payne, Wright, & Reyna, 2003) can be supported by participants ‘borrowing’ content that they recollect about related items that were actually studied during encoding (Lampinen et al, 1998; Lampinen, Meier, Arnal, & Leding, 2005). For example, upon seeing the lure ‘dog’ at test, one might recall that they had seen the word ‘puppy’ at encoding, so ‘dog’ should not be endorsed as an old word. Alternatively, if one is unable to recollect the specific target item, but can recollect contextual information, it is difficult to rule out and correctly reject related lures. As such, better recollection of contextual than target information should enhance the occurrence of false alarming through ‘content-borrowing’ (Lampinen et al, 2005) or misattribution of recollected context to a plausible lure. It may also be possible for spontaneous mental imagery during encoding to be later recollected and falsely identified as having been a studied item due to a failure of source monitoring at test (Foley & Foy, 2008). In all of these cases, it is possible for false alarms to occur as a result of recollected contextual information, which is either visually or semantically associated to the target, supporting memory for related but unstudied information.

As posited by Brainerd and colleagues (2014), relatively greater recollection of either target or contextual information should boost hit rate when presented with previously encountered information, given that both provide information that should aid retrieval of ‘old’ items. Importantly, however, enhanced memory for target information *reduces* false alarms whereas greater memory for contextual information *increases* false alarms. As such, the distinction regarding the type of information recollected about an item drawn at encoding (Wammes et al., 2018) is critical in determining the effect that drawing has on false alarm rate.

The distinction between recollection of contextual and target information is particularly relevant to the drawing effect given the nature of the drawing task. In order to create a drawing, one must sequentially generate and create a depiction of each of the visual features that compose an object; to draw a bird, one will likely recall that it has wings to fly, a pointy beak to reach insects, and claws to grasp, amongst other properties. Given the inherent link between visual features and semantic meaning, the contextual information recollected in relation to drawing could involve both visual and semantic components (Mervis & Rosch, 1981). Subsequent recollection of specific features drawn at encoding could easily be attributed to multiple related items (Lampinen et al, 1998; Lampinen et al, 2005). Specifically, if producing a drawing leads one to focus on the features that comprise the item, it may be more likely that one recollects contextual source information (in the form of visual perceptual or semantic details) than target information, thereby increasing false alarm rates to items that share those visual features (Brainerd et al., 2014).

Current study

In all 3 experiments in the current study we implemented the Deese-Roediger-McDermott (DRM) paradigm, which induces high rates of false alarm responses (Deese, 1959; Roediger & McDermott, 1995). In the DRM paradigm, participants are generally presented with sets of words wherein each set contains words that are all highly semantically related (e.g., table, couch, lamp, desk) to a *critical lure* word (e.g., chair). At test, participants are more likely to falsely recall (Deese, 1959), or incorrectly recognize (Roediger & McDermott, 1995), a critical lure as being from the study phase than an unrelated lure. One explanation for why false alarms to critical lures occur is that, at encoding, a spreading of activation to related concepts (for example, thinking of apple may activate the associated word banana) often activates the critical lure, making the critical lure seem highly familiar on a subsequent test (Roediger & McDermott, 1995). Encoding tasks that promote distinctiveness, such as studying pictures (Israel & Schacter, 1997) or unique fonts (Arndt & Reder, 2003), reading aloud (Dodson & Schacter, 2001), or solving an anagram (Gunter, Bodner, & Azad, 2007), result in a high hit rate that is also reflected in a lower false alarm rate (*the mirror effect*: Glanzer & Adams, 1985; 1990) relative to a non-distinctive encoding task such as simply reading the to-be-remembered words. However, the mirror effect found for distinctive encoding tasks in the DRM paradigm generally only appears in a between-subjects design in which participants study pure lists of words or pictures, with a reduction (Huff, Bodner, & Fawcett, 2013; but see Arndt & Reder, 2002) or elimination (Schacter, Israel, & Racine, 1999) in differences in false alarm rates occurring between relatively distinctive and non-distinctive encoding tasks. Our use of a within-subjects design in the current study limits effects of distinctiveness in our results. Rather, our results should largely depend on the relative amount of target or contextual source information that is recollected for individual words.

Our goal in the current study was to determine what effect drawing at encoding has on false alarm performance. By comparing drawing to a set of different encoding tasks that vary in the amount and type of contextual information that is encoded, and subsequently recollected, we can determine how recollection of drawn information influences false alarm rate. In Experiment

9, participants were asked to either draw pictures of, or to repeatedly write out, each of the words in a series of DRM sets. In Experiment 10, we compared drawing pictures to creating mental images of objects corresponding to the words in DRM sets, given that this task involves a deeper level of processing than writing words (Foley & Foy, 2008). Finally, in Experiment 11, we compared drawing pictures to writing out physical descriptive characteristics of the objects corresponding to DRM set words, given that this task involves a similar degree of focus on contextual source information as drawing.

As a secondary goal, we were interested in investigating whether false alarms to critical lures arose from the recollection of contextually rich perceptual information present in drawing. Given previous findings suggesting that the drawing benefit to memory is primarily driven by contextually rich recollection-based memory (Wammes, Meade, & Fernandes, 2017), we expected that false memories for information related to study material would also be largely recollection dependent, as demonstrated by more ‘remember’ responses to drawn than written critical lures. Specifically, contextual information illuminated by drawing, such as visual features or semantic associations, may be shared by the items within a DRM set and the associated critical lure, thereby supporting false recollection for the latter.

Experiment 9

The goal of Experiment 9 was to determine the effect that drawing at encoding has on false alarm performance relative to writing out to-be-remembered words. We expected to replicate the drawing effect (Wammes et al., 2016) by finding superior memory for studied words that were drawn relative to written. Of key interest was the pattern of false alarm rates. An increase in false alarm rate for drawing relative to writing would suggest that the production of rich visual contextual information during drawing (Wammes et al., 2017) leads to a relative increase in recollection of context rather than target information, whereas a decrease in false alarms would suggest increased recollection of target information. Additionally, it was predicted that a greater proportion of false alarms to critical lures would correspond to recollection-based memory (as indexed by ‘Remember’ responses), relative to familiarity (as indexed by ‘Know’ responses), for drawn, but not written, DRM sets.

Method

Participants.

Participants for Experiment 9 were 38 undergraduate students (26 female, 12 male), at the University of Waterloo, who completed the experiment for course credit. Participants ranged in age from 18 to 21 (*M* = 19.43, *SD* =1.24). All participants had normal or corrected to normal vision and learned English before the age of seven.

Materials.

DRM sets

A total of 20 DRM sets were selected from materials used in previous research (Foley & Foy, 2008). We specifically chose previously used DRM sets which largely contained words that could be drawn or imagined as concrete objects to ensure that participants would be able to create drawings in response to each of the words in each of the sets. For example, we chose to use DRM sets with more concrete words such as the set for ‘*window*’ containing the items ‘*house*’, ‘*door*’, and ‘*frame*’ over sets with more abstract words such the set for ‘*cry*’ which contains ‘*sorrow*’, ‘*whine*’, and ‘*weep*’. Words from an additional 5 DRM sets were used to construct the set of lures included in the test. All DRM sets used in the study can be found in the Appendix.

Filler Task

A continuous reaction time task (CRT) was created by making sound files representing low-, medium- and high-pitched tones. This was done using Audacity software (Mazzoni & Dannenberg, 2000), such that each sine wave tone was exactly 500 ms long, at frequencies of 350, 500, and 650 Hz respectively.

Procedure.

Participants were tested in 5 different group sessions in a small classroom with seating for up to 20 students. Each session ranged from 5 to 10 undergraduate students depending on how many participants signed up for the experiment time slots. Stimulus presentation was controlled using E-prime v2.0 software (Psychology Software Tools Inc., Pittsburgh, PA) and displayed via projection screen at the front of the classroom. Given the group setting, some additional preliminary instructions were given, to ensure participants did not interact with one another or look at one another’s responses. Participants were always separated by at least one empty seat and were instructed to treat the experiment as they would an examination. Additionally, all participants gave informed written consent at the beginning of the experiment.

Encoding

Participants underwent a brief practice phase in order to familiarize them with the encoding phase, after which the experiment began. Participants were not informed that they would be required to complete a later memory test. This incidental encoding paradigm was selected to reduce the possibility that participants would develop a strategy of preferentially focusing on drawn (or written) items in anticipation of later testing. Participants studied a total of 20 DRM sets, one set at a time. Participants performed the same encoding task (draw or write) for each of the 8 words in a given DRM set depending on which prompt appeared at the beginning of the set. All of the words in half of the DRM sets were to be drawn (10) while the other half were to be written (10), with the order of the encoding task (draw or write) randomly selected prior to the presentation of each set; each DRM set had an equal chance of being selected for a drawing or writing condition. For each DRM set, participants used one sheet of paper which had 8 printed boxes and were instructed to use one box per word to perform the encoding task. Each prompt word appeared on the screen for 5000 ms to allow participants enough time to flip over their sheet and ensure they had a new sheet ready for the next DRM set. Each word in a DRM set was presented one at a time, constituting one trial. On each trial, a fixation cross appeared in the center of the screen for 500 ms, after which the word to be encoded appeared for 8 s, during which time participants performed the encoding task, either drawing or writing for the full duration of the trial. A 500 ms tone alerted them that the next word in a set would appear immediately on the screen, or the next prompt and DRM set would begin within 5000 ms, and that they should direct their attention to the screen.

Retention

Following the encoding trials, participants were asked to perform the CRT as a filler task. Tones were to be classified as low, medium, or high, by making a check mark in the appropriate box on a sheet of paper. After hearing samples of each kind of tone, participants proceeded to classify 30 tones, selected at random. For each trial, the tone was played for 500 ms, after which participants had 1500 ms to make their response, for a total of 2000 ms per trial. The retention interval was one minute in length.

Retrieval

In the final phase of the experiment participants were given an RKN recognition test for words, either written or drawn, from earlier in the experiment. The recognition test consisted of

20 critical lures not presented at study, 100 old words (4 from each DRM set), and 20 new unrelated lures. The unrelated lures consisted of 4 words taken from 5 additional DRM sets which were not used in the encoding task. Each word in the recognition test was presented on the screen for 3 s, during which time participants made a response to each word by circling 'R' for 'remember', 'K' for 'know', and 'N' for 'new'. Recognition memory instructions were as follows: 'Remember' means that you have a conscious recollection of the word from the previous phase, such as how and when the word was written or drawn, or any thoughts you had when you previously saw the word. 'Know' means that you have only a feeling of familiarity; you believe that the word was from the previous phase, but cannot recall specifically how or when it was drawn or written, or any thoughts you had when you previously saw the word. 'New' means that the word was not encountered in the study phase.

Results

Old Items.

We conducted a 2 × 2 ANOVA on the proportions of correct 'Old' responses to previously presented items, with Encoding Type (Drawn vs. Written) and Response (Remember vs. Know) as the factors. Specifically, proportions were calculated as the number of correct Remember (or Know) responses to old items divided by the total number of old items (for each encoding type).[8] There was a significant main effect of Encoding Type, $F\ (1, 37) = 177.8$, $MSE = 0.008$, $p < .001$, $\eta_p^2 = .828$, with more 'Old' responses overall (i.e. both Remember and Know responses) to Drawn than to Written items. There was also a significant main effect of Response, $F\ (1, 37) = 471.6$, $MSE = 0.029$, $p < .001$, $\eta_p^2 = .927$, with more 'Remember' than 'Know'

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[8] Due to the difficulty of finding 20 distinct DRM sets consisting of concrete words, 6 (out of 160) studied words were presented as part of more than one DRM set. These words were excluded from analysis – they did not count toward either the "number of Remember (or Know) responses" or the "total number of old items".

responses. Finally, the two factors interacted, F (1, 37) = 263.1, MSE = 0.014, p < .001, η_p^2 = .877. Further analyses revealed that the interaction was due to more ‘Remember’ responses to Drawn than to Written items, t (37) = 17.5, SE = 0.029, p < .001, and more ‘Know’ responses to Written items, t (37) = 6.8, SE = 0.018, p < .001.

New Items.

We conducted a 3 × 2 ANOVA on the proportions of incorrect ‘Old’ responses to new items (including both critical lures and unrelated new lures), with Item Type (Critical Lures from Drawn lists vs. Critical Lures from Written lists vs. Unrelated New Lures) and Response (Remember vs. Know) as within-subject factors. Specifically, proportions were calculated as the number of Remember (or Know) responses to new items divided by the total number of new items (for each encoding type). There was a significant main effect of Item Type, F (2,74) = 67.7, MSE = 0.006, p < .001, η_p^2 = .647, but not of Response, F < 1. We conducted simple contrasts and found that participants were more likely to false alarm to critical lures from drawn lists than to those from written lists, F(1,37) = 25.3, MSE = 0.026, p < .001, η_p^2 = .406, or to unrelated new lures, F(1,37) = 132.9, MSE = 0.023, p < .001, η_p^2 = .782. Participants were also more likely to false alarm to critical lures from written lists than to unrelated new lures, F(1,37) = 46.8, MSE = 0.019, p < .001, η_p^2 = .559. Finally, the effect of Item Type interacted with Response, F (1,37) = 3.6, MSE = 0.012 p = .033, η_p^2 = .088, so we conducted separate one-way ANOVAs to analyze the effect of Item Type separately for each type of Response. There was an effect of Item Type on ‘Know’ responses, F(1,37) = 11.6, MSE = 0.008, p < .001, η_p^2 = .239, given that critical lures both from drawn lists, F(1,37) = 21.2, MSE = 0.017, p < .001, η_p^2 = .364, and from written lists, F(1,37) = 13.9, MSE = 0.012, p = .001, η_p^2 = .273, were more likely to elicit false ‘Know’ responses than were unrelated new lures. Critical lures from drawn lists did not differ from those from written lists in terms of false ‘Know’ responses, F (1, 37) = 1.7, MSE = 0.019, $p = .202$, $\eta_p^2 = .044$. There was also an effect of Item Type on ‘Remember’ responses, $F(1,37) = 11.6$, $MSE = 0.008$, $p < .001$, $\eta_p^2 = .239$, with more false ‘Remember’ responses to critical lures both from drawn lists, $F(1,37) = 60.3$, $MSE = 0.022$, $p < .001$, $\eta_p^2 = .620$, and from written lists, $F(1,37) = 15.1$, $MSE = 0.018$, $p < .001$, $\eta_p^2 = .290$, than to unrelated new lures, as well as more false ‘Remember’ responses to critical lures from drawn than from written lists, $F(1,37) = 21.5$, $MSE = 0.019$, $p < .001$, $\eta_p^2 = .367$. See Figure 18 for plot of all Experiment 9 data.

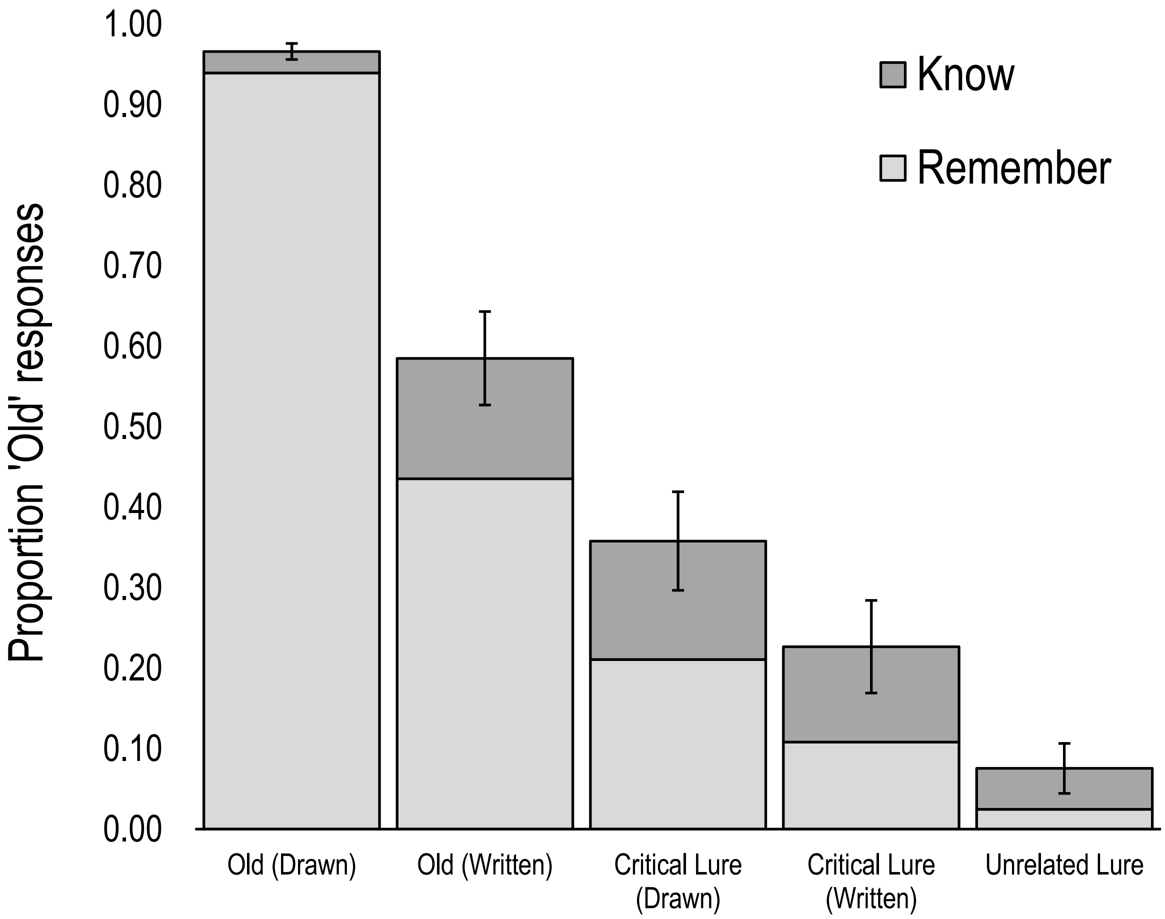

Figure 18. Proportion of ‘old’ responses, with response type denoted in shades of grey, to old items, critical lures, and unrelated lures following drawing and writing encoding tasks in Experiment 9. Error bars show the standard error of the mean.

Discussion

As expected, and replicating previous findings (Wammes et al, 2016; 2017), drawing resulted in a higher hit rate for studied words than writing. The novel finding in Experiment 9 is that drawing pictures of items in DRM sets also led to a higher FA rate to associated critical lures than writing at encoding. Furthermore, the false alarms to critical lures associated with drawn DRM sets were given more ‘Remember’ responses compared to writing, suggesting that false memories for information related to drawing are driven by recollection-based memory.

The finding of a higher FA rate for drawing than writing could be interpreted in a few different ways. First, the observed false alarm pattern may have arisen because writing words in DRM sets at encoding hinders semantic processing of the concept that the words represent, thereby reducing activation of associated critical lures. Specifically, by repeatedly writing out words, participants may be focusing more on the perceptual or orthographic features of the word itself than the object that the word represents. Processing of shallow information, such as orthographic features, instead of deeper, more elaborative processing of semantic information decreases FA rate to critical lures in the DRM paradigm (Toglia, 1999; Rhodes & Anastasi, 2000; Thapar & McDermott, 2001). Indeed, Seamon and colleagues (2003) demonstrated that writing out words in DRM sets reduced false alarms relative to standard instructions of listening to the words at encoding, suggesting that writing is a relatively shallow encoding task, likely reducing relational processing amongst words at encoding. Another possible interpretation is that, in the writing task, participants focused their attention on the target itself (i.e. by writing out the word), whereas in the drawing task, participants produced and oriented focus on information other than the target itself (i.e. the drawing). It may be that this focus on *non*-target information in drawing increased recollection of contextual information and therefore also increased false alarms to critical lures. Specifically, we suggest that participants can recollect particular visual and semantic features from drawings (such as legs and a tail), that are vividly recollected and misattributed to related critical lures during subsequent retrieval (Lampinen et al., 2005; Brainerd et al, 2014). This idea is consistent with the interpretation that drawing results in recollection that consists of a greater degree of rich visual and semantic contextual information (Brainerd et al., 2014). The goal in Experiment 10 was to compare drawing to a task that involves greater processing of the conceptual representation of each of the words in DRM sets, to better determine whether the increase in false alarms was caused by recollection of drawn contextual information.

Experiment 10

In Experiment 10 we compared drawing to the creation of mental visual imagery. Producing mental imagery prompts a relatively deeper level of processing than the writing task used in Experiment 9 (Craik & Lockhart, 1972). This is important because the shallow processing promoted by writing may have ‘protected’ participants from susceptibility to making false alarms to critical lures in Experiment 9. Imagining is an ideal task to use in Experiment 10 given that it does not involve processing of the target *word* itself, but does involve item-specific processing of the target *object*.

We predicted that drawing would still lead to more false alarms than the comparison task in Experiment 10 on the basis that drawing should lead to greater recollection of contextual information than imagining. To elaborate, when provided a concrete noun and asked to imagine the corresponding object, participants can very rapidly bring to mind a representation of the object (Gardini, De Beni, & Cornoldi, 2005; De Beni, Pazzaglia, Gardini, 2007). Creation of a mental image (Gardini et al., 2004; De Beni, 2007) is relatively holistic in that it does not need to be constructed feature-by-feature as does a drawing. Given that drawing promotes greater focus on the individual features compared to imagining a holistic percept of an object, we expect that recollection of drawn items, relative to imagined items, would consist of greater contextual (rather than target) recollection. As such, we expected that drawing should lead to a higher false alarm rate than imagining, and false alarms related to drawing should consist of more recollection-based 'remember' responses.

Method

Participants.

Participants for Experiment 10 were 40 undergraduate students (33 female, 7 male), at the University of Waterloo, who completed the experiment for course credit. Participants ranged in age from 18 to 23 (*M* = 19.71, *SD* = 1.58). All participants had normal or corrected to normal vision and learned English before the age of seven.

Materials.

All DRM sets and filler task materials were identical to those used in Experiment 9.

Procedure.

The general testing procedure was identical to that used in Experiment 9 with a range of 5-12 participants tested at a time in 5 group testing sessions. The only change in the paradigm from Experiment 9 was to the encoding phase. Instead of being asked to 'write' the words in half of the DRM sets, participants were asked to 'imagine' how the object that the word represents looks. As such, half of the prompt words were 'draw' and half were 'imagine'. Additionally, they were asked to make a rating regarding how easily they could bring to mind a vivid mental image for each of the words in a set, an instruction based on previous work assessing the effects of imagery at encoding (Robin & Mahé, 2015; Robin, 2011). The specific instructions given for the ‘imagine’ task were as follows: “Create a mental image of the object that the word represents. Continue focusing on the details of the mental image you have created and then rate the vividness of the mental image on a 1-10 scale by writing a number in a box on the sheet, with one number per box. 0 = it was very difficult or impossible to form an image at all. 10 = it was very easy to form an image.”

Results

Old Items.

We conducted a 2 × 2 ANOVA on the proportions of correct ‘Old’ responses to old items, with Encoding Type (Drawn vs. Imagined) and Response (Remember vs. Know) as the factors. Specifically, proportions were calculated as the number of correct Remember (or Know) responses to old items divided by the total number of old items (for each encoding type). There was a significant main effect of Encoding Type, F (1, 39) = 19.4, MSE = 0.002, $p < .001$, $\eta_p^2 = .332$, with more ‘Old’ responses overall (i.e. both Remember and Know responses) to Drawn than to Imagined items, indicating that Drawn items were more likely to be correctly recognized. There was also a significant main effect of Response, F (1, 39) = 333.5, MSE = 0.081, $p < .001$, $\eta_p^2 = .895$, with more ‘Remember’ than ‘Know’ responses overall. Finally, the two factors interacted, F (1, 37) = 22.8, MSE = 0.006, $p < .001$, $\eta_p^2 = .369$. The pattern of this interaction was similar to that in Experiment 9, with more ‘Remember’ responses to Drawn than to Imagined items, t (39) = 5.3, SE = 0.017, $p < .001$, but more ‘Know’ responses to Imagined items, t (39) = 2.7, SE = 0.011, $p = .012$.

New Items.

We conducted a 3 × 2 ANOVA on the proportions of incorrect ‘Old’ responses to new items, with Item Type (Critical Lures from Drawn lists vs. Critical Lures from Imagined lists vs.

Unrelated New Lures) and Response (Remember vs. Know) as the factors. Specifically, proportions were calculated as the number of Remember (or Know) responses to new items divided by the total number of new items (for each encoding type). There was a significant main effect of Item Type, *F* (2, 78) = 41.4, *MSE* = 0.006, $p < .001$, $\eta_p^2 = .515$, but there was neither a main effect of Response nor an interaction between the two factors, *Fs* < 1. Simple contrasts revealed that all Item Types differed from one another, with more false 'Old' responses to critical lures both from drawn lists, *F* (1, 39) = 63.6, *MSE* = 0.032, $p < .001$, $\eta_p^2 = .620$, and from imagined lists, *F* (1, 39) = 37.4, *MSE* = 0.021, $p < .001$, $\eta_p^2 = .490$, than to unrelated new lures, as well as more false 'Old' responses to critical lures from drawn than from imagined lists, *F* (1, 39) = 13.5, *MSE* = 0.023, $p < .001$, $\eta_p^2 = .257$. See Figure 19.

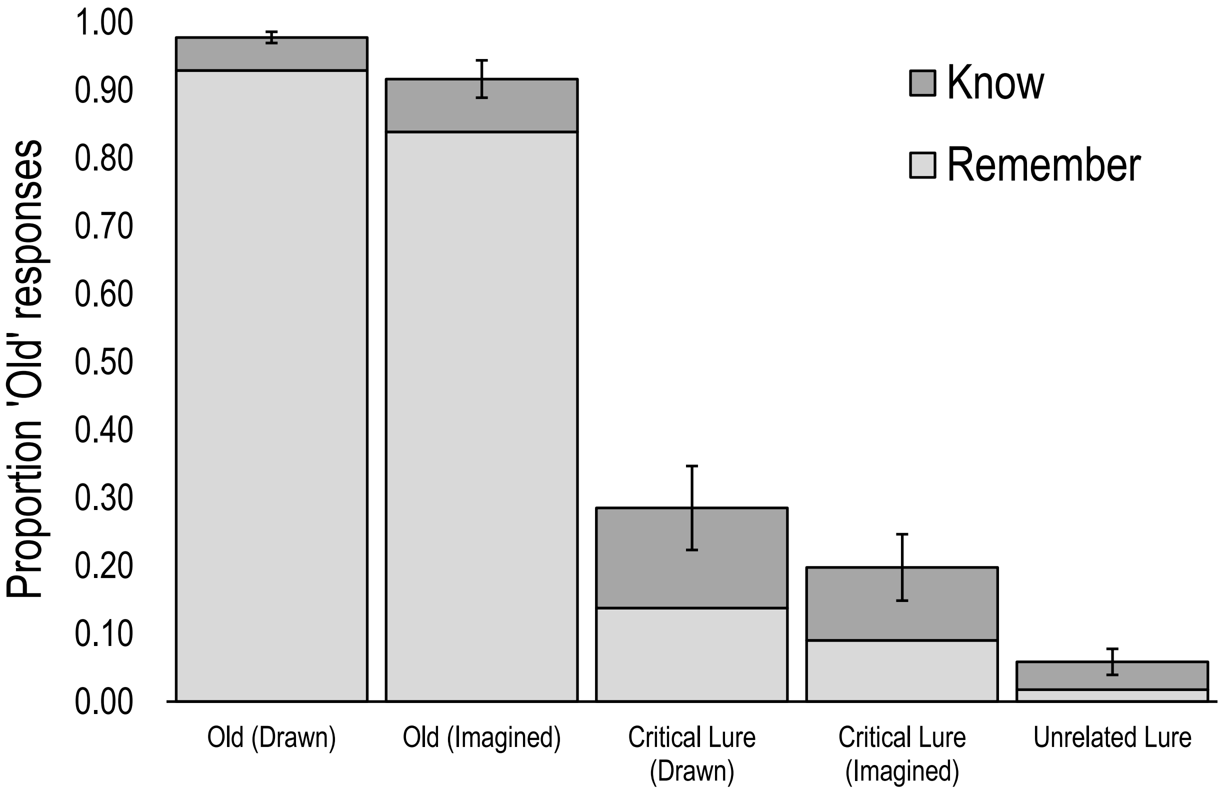

Figure 19. Proportion of ‘old’ responses, with response type denoted in shades of grey, to old items, critical lures, and unrelated lures following drawing and imagining encoding tasks in Experiment 10. Error bars show the standard error of the mean.

Discussion

As expected, and replicating previous findings (Wammes et al, 2016), drawing resulted in a higher hit rate for studied words than creating visual mental imagery. Additionally, drawing also resulted in a larger proportion of Remember responses than visual imagery, suggesting that memory for the former is driven more by recollection than the latter. Similar to our findings in Experiment 9, drawing pictures led to a higher FA rate to critical lures than the comparison task of generating mental imagery at encoding. The increased false alarm rate for drawing suggests that, relative to imagining, drawing led to greater subsequent recollection of contextual rather than target information (Brainerd et al, 2014).

A potential mechanism by which drawing may enhance recollection of contextual information is sequential focus on the features that comprise an object, which could lead to better recollection for those contextual details than for the target. In contrast, when creating a mental image, one can produce a rather instantaneous representation (Gardini, De Beni, & Cornoldi, 2004; De Beni, Pazzaglia, Gardini, 2007; Kosslyn, 1994; Gardini et al., 2004; De Beni, 2007; Rosenfeld & Kaniel, 2011), which does not require elaboration or effortful construction. Of course, some mental images may have rich visual details, however one is not required to sequentially focus on each of the features that comprise the object as they do when drawing. In Experiment 11, we aimed to compare drawing to a task that involves a similar type of sequential processing of the component features of items. If comparing drawing to such a task eliminates the difference in false alarm rate, it would suggest that focus on, and subsequent recollection of, contextual information drives the observed increase in false alarms for drawing.

Experiment 11

In Experiment 11 we compared drawing to a task that we have used in previous work that involves writing out a list of physical descriptive characteristics of the target word (Wammes et al., 2016). This listing task can be conceptualized as a verbal form of the drawing task, as it involves sequentially writing out the characteristics that would otherwise be depicted visually when drawing. Like the drawing task, the listing task requires one to focus on each of the features that comprise an item, which should similarly lead to enhanced recollection of contextual information. Unlike the drawing task, the listing task results in a list of words rather than a final holistic depiction of the target with all of the features integrated together. As such, while both tasks should lead to substantial recollection of contextual information, drawing should lead to relatively greater target recollection than listing. Given the expectation of enhanced recollection of target information for drawing compared to the listing task, we expected to observe a reversal of the results from Experiment 10 such that false alarm rate is decreased for drawing relative to listing. Additionally, we predicted that the rich visual information provided by drawing would result in more recollection-based ‘remember’ responses than writing out features in the listing task.

Method

Participants.

Participants for Experiment 9 were 36 undergraduate students (29 female, 7 male), at the University of Waterloo, who completed the experiment for course credit. Participants ranged in age from 18 to 22 (*M* = 19.37, *SD* = 1.37). All participants had normal or corrected to normal vision, and learned English before the age of seven.

Materials.

All DRM sets and filler task materials were identical to those used in Experiments 9 and 10.

Procedure.

The general testing procedure was identical to that used in Experiments 9 and 10 with the exception that participants were randomly asked to either ‘draw’ or ‘list’ in response to the 20 DRM sets (10 sets per encoding trial type). For the ‘list’ prompt, participants were instructed to list physical descriptive characteristics of the object that the word represents for the full trial duration. They were given the example that for the item ‘mouse’ they might list characteristics such as ‘furry’, ‘small’, long tail’, etc.

Results

Old Items

We conducted a 2 × 2 ANOVA on the proportions of correct ‘Old’ responses to old items, with Encoding Type (Drawn vs. Listed) and Response (Remember vs. Know) as the factors. Specifically, proportions were calculated as the number of Remember (or Know) responses to old items divided by the total number of old items (for each encoding type). There was no significant main effect of Encoding Type, F (1, 35) = 0.86, MSE = 0.0002, p = .361, η_p^2 = .024, but there was a main effect of Response, F (1, 35) = 2248.76, MSE = 0.01, p < .001, η_p^2 = .985, with more ‘Remember’ than ‘Know’ responses overall. There was also a significant interaction between the two factors, F (1, 35) = 15.55, MSE = 0.004, p < .001, η_p^2 = .308 such that Drawn items were more likely than Listed items to elicit ‘Remember’ responses, t (35) = 3.66, SE = 0.012, p < .001, and less likely to elicit ‘Know’ responses, t (35) = 4.11, SE = 0.009, p < .001.

New Items

We conducted a 3 × 2 ANOVA on the proportions of incorrect 'Old' responses to new items, with Item Type (Critical Lures from Drawn lists vs. Critical Lures from Listed lists vs. Unrelated New Lures) and Response (Remember vs. Know) as the factors. Specifically, proportions were calculated as the number of Remember (or Know) responses to new items divided by the total number of new items (for each encoding type). There was a significant main effect of Item Type, $F\ (2, 70) = 33.52$, $MSE = 0.006$, $p < .001$, $\eta_p^2 = .489$, but there was neither a main effect of Response, $F\ (1, 35) = 0.81$, $MSE = 0.03$, $p = .375$ $\eta_p^2 = .023$, nor an interaction between the two factors, $F\ (2, 70) = 1.90$, $MSE = 0.01$, $p = .157$, $\eta_p^2 = .051$. Simple contrasts revealed that all Item Types differed from one another, with more false 'Old' responses to critical lures both from Drawn lists, $F\ (1, 35) = 26.40$, $MSE = 0.025$, $p < .001$, $\eta_p^2 = .430$, and from Listed lists, $F\ (1, 35) = 56.49$, $MSE = 0.026$, $p < .001$, $\eta_p^2 = .617$, than to unrelated new lures, as well as more false 'Old' responses to critical lures from Listed than from Drawn lists, $F\ (1, 35) = 8.89$, $MSE = 0.020$, $p = .005$, $\eta_p^2 = .202$. See Figure 20.

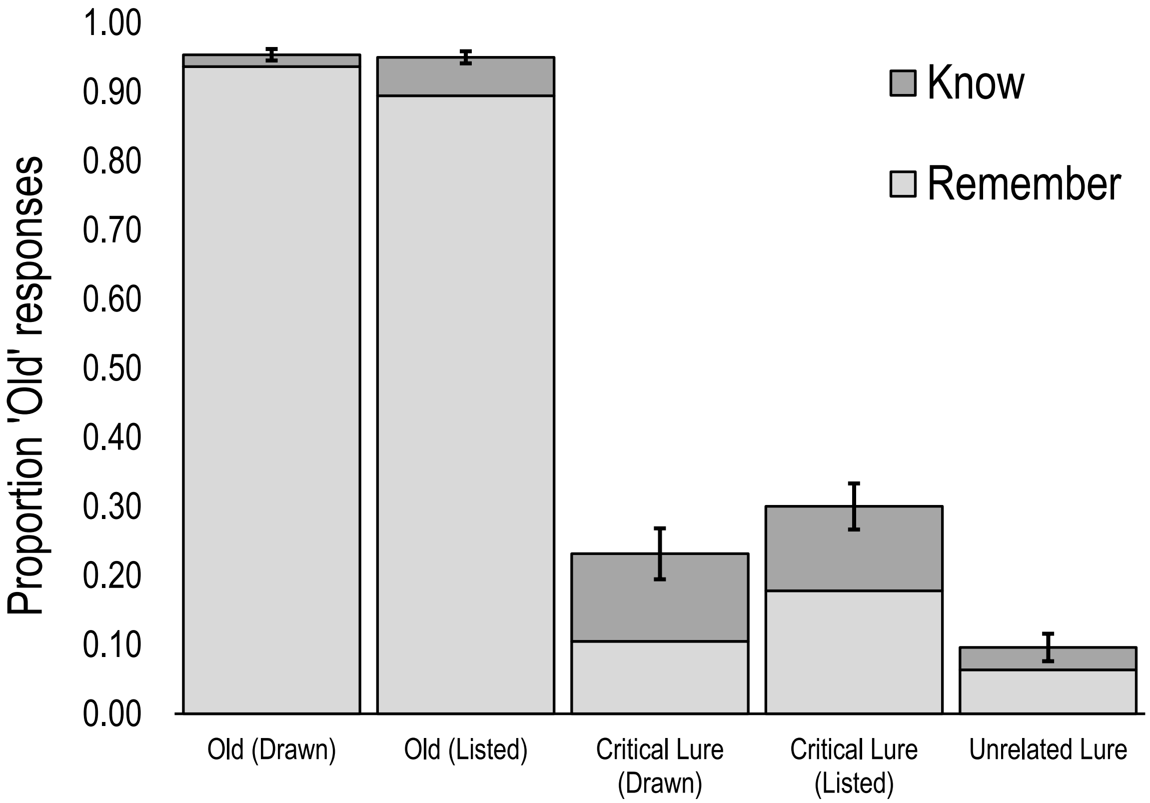

Figure 20. Proportion of ‘old’ responses, with response type denoted in shades of grey, to old items, critical lures, and unrelated lures following drawing and listing encoding tasks in Experiment 11. Error bars show the standard error of the mean.

Discussion

In line with previous work (Wammes et al., 2017), drawing words led to more correct Remember responses than listing physical descriptive characteristics of the object that the word represents. Such a pattern suggests that memory for words that were drawn at encoding was enhanced by a Recollection-based memory retrieval process. Although there was no significant difference in overall hit rate between the two tasks, this was likely due to a ceiling effect, given that hit rate in both conditions surpassed 95%. Despite the lack of difference in hit rate, the finding that drawing led to a larger proportion of Remember responses suggests that memory for drawn items was driven by retrieval of vivid perceptual information which boosted recollection. Of primary interest was the analysis of FA rate for critical lures. As expected, we found that drawing at encoding led to a lower FA rate than listing characteristics of to-be-encoded items. We suggest that this pattern of findings is due to drawing and listing both enhancing recollection for contextual information, with drawing also leading to relatively superior target recollection than listing.

General Discussion

It has been well established in the literature that drawing pictures to illustrate words at encoding benefits memory for those words more than a variety of other encoding tasks (Wammes et al., 2016; 2017). In the current study we have demonstrated that despite drawing leading to a higher hit rate than writing and mental imagery, it also resulted in a higher FA rate to critical lures in a variant of the DRM paradigm (Experiments 9 and 10). In Experiment 11 we reversed the pattern of false alarms found in Experiments 9 and 10 by comparing drawing to a semantic listing task which resulted in a reduction in FA rate to critical lures for the drawing relative to the listing task. Our findings are consistent with previous work demonstrating that drawing provides robust memory benefits for studied words (Wammes et al, 2016), an effect which is largely driven by enhanced recollection-based retrieval (Wammes et al, 2018). Replicating previous findings, in the current study we demonstrated that drawing led to superior recognition of studied words compared to writing and imagining in Experiments 9 and 10 (Wammes et al, 2016). The lack of a difference in hit rate in Experiment 11 was potentially due to the use of DRM set words as targets, rather than semantically unrelated words (as used in Wammes et al, 2016), which resulted in a ceiling effect in memory for the drawn and listed word sets. In characterizing the quality of memories retrieved, we found that correct recognition of old words that were drawn at encoding were more likely to be assigned recollection-based ‘remember’ than familiarity-based ‘know’ responses relative to each of the comparison tasks across all three experiments. Altogether, our results demonstrate that while drawing benefits memory for studied words through the depiction of visually rich contextual information, it can have the unintended consequence of increasing false alarm rates relative to encoding tasks that promote more target-specific recollection.

Our findings provide further insight not only into the extent of the recollection benefit that drawing provides relative to other encoding tasks, but also into the specific *type* of information that is recollected about a drawn item. The novel finding in this study, that drawing raises FA rates relative to writing and imagining, suggests that drawing results in increased recollection of contextual information (Lampinen et al, 2005; Brainerd et al, 2014). It has been suggested that recollection can be ‘partial’ (Dodson et al, 1998) or consist of mainly contextual, as opposed to target, information, which subsequently leads to both increased hit and false alarm rates (Brainerd et al, 2014). Specifically, as recollection of contextual information (such as visual perceptual detail of a drawing) improves relative to recollection of target information, one becomes more susceptible to false alarms for related (lure) information. This is specifically because tasks that promote target recollection should protect one from false alarming and support correct rejection of lures (Brainerd et al, 2014). The ability to use recollection of a target item to confirm that a related lure is not a 'match' has been described as recollection rejection (Brainerd et al, 2003) and recall-to-reject (Lampinen, Odegard, & Neuschatz, 2004). To return to the example used in the introduction, upon seeing the lure 'dog' at test, one might recall that they had seen the word 'puppy' at encoding, so 'dog' should not be endorsed as an old word, whereas if one is unable to recollect the specific target item (i.e. the word 'puppy') but can recollect contextual information (i.e. their drawing of a puppy), it is difficult to rule out and correctly reject related lures. A similar possibility is that focus on an individual feature may have produced spontaneous imagery (e.g. when focusing on 'tail' for 'puppy' one might spontaneously imagine a dog, cat, or other animal with a similar tail) which could then be recollected and misattributed as a studied item at test (Johnson, Raye, Foley, & Foley, 1981; Foley & Foy, 2008). Ultimately, we suggest that drawing specifically enhances recollection of contextual information that supports memory for old items but also makes one more susceptible to false alarming to related items.

Our findings indicate that the task of creating a drawing specifically leads to greater focus on contextual information in comparison to writing and imagining. When writing or imagining, one is processing the target item itself; either the exact target word, or a holistic visual representation of the target. Alternatively, to draw, for example, a bird, one will likely recall that it has wings to fly, a pointy beak to reach insects, and claws to grasp, amongst other properties, which all must be sequentially depicted on the sheet of paper. As such, drawing promotes focus on the individual features that comprise an object, which offer both visual perceptual and semantic information that may be better recollected than the associated target word. Our finding of higher false alarm rates following drawing in Experiments 9 and 10 is readily accounted for by the explanation that drawing primarily enhances contextual recollection compared to writing and imagining, which promote target recollection. In addition to the focus on contextual information, drawing also results in a final holistic representation of the target item once all of the component features have been depicted. In Experiment 11 we compared drawing to a listing task which equally requires one to focus on individual features of objects but does *not* result in a holistic integration of those components. As expected, this reversed the FA pattern from the first two experiments, with drawing leading to lower false alarm rates than listing physical descriptive characteristics. The Experiment 11 results suggest that while both drawing and listing enhance contextual recollection through focus on component features of items, drawing may also lead to relatively greater target recollection given that integration of all features into a holistic representation is required in order to depict the target.

We expected that if drawing enhances recollection of contextual information, false alarms related to drawn items should be more likely to be assigned recollection-based ‘remember’ responses than those for written or imagined items. This result did indeed emerge in Experiment 9, where false alarms to drawn critical lures were more often ‘remembered’, and false alarms to written critical lures were more likely to be given familiarity-based ‘know’ responses. This pattern suggests that when false alarming to a drawn critical lure, participants were able to recollect vivid details that supported their false recollection which were not available for written critical lures. Such details likely consisted of visual perceptual or semantic information from actual drawn items that were borrowed during false alarming (Lampinen et al, 2002). However, it was surprising that we did not find this pattern when the comparison task was imagining in

Experiment 10, in which the difference in false alarms between conditions was not driven by increases specific to 'remember' or 'know' responses. It is possible that in this experiment, increased contextual recollection actually resulted in an increase to both remember and know response rates. For example, even if a participant recalled drawing a picture of a puppy, they may have made a 'know' response if they could not also recall seeing the target word itself. Importantly, the pattern of both increased hit and false alarm rates for drawing in Experiments 9 and 10 suggests that drawing leads to relatively greater contextual than target recollection compared to writing and imagining (Brainerd et al, 2014).

It is also worth noting how our findings relate to explanations others have put forth to account for observed reductions in FA rates for encoding tasks that involve visual imagery in the DRM paradigm (Israel & Schacter, 1997; Schacter et al., 1999; Koustaal & Schacter, 1997; Dodson & Schacter, 2002). Specifically, one might have expected drawing to *reduce* FA rate across all of our experiments due to the distinctiveness heuristic (Israel & Schacter, 1997; Dodson & Schacter, 2002) which suggests that because one expects to have vivid memories of the visual imagery present at study, it is easy to reject lures that lack an associated visually detailed pictorial memory. Similarly, the impoverished relational encoding account (Hege & Dodson, 2004) holds that detailed visual perceptual information promotes item-specific processing and reduces relational processing and spreading of activation to semantic associates (Hege & Dodson, 2004). Given our use of a mixed within-subjects design in this study, neither of these effects are likely to have strongly influenced our key findings. First, the distinctiveness heuristic account is generally used to explain results from between-subjects (or blocked within-subjects) studies, because it is not clear how the participants' response criterion could be differentially adjusted for two item types when they are mixed together in a single test (Stretch &

Wixted, 1998). Second, Huff and colleagues (2013) conducted a meta-analysis in which they compared distinctive and non-distinctive encoding tasks in within-subjects and between-subjects designs. They found strong effects of distinctiveness only for between-subjects designs, suggesting that this effect does not play a strong role in within-subjects designs.

Finally, it is important to note that we did not compare drawing to traditional DRM instructions, in which the participant is read a list (or multiple lists in a row) of highly related words and then asked to write down as many of the words as they can remember (Deese, 1959; Roediger & McDermott, 1995). Previous work has demonstrated that tasks that invoke item-specific processing, such as generation (Gunter, Bodner, & Azad, 2007), studying pictures (Israel & Schacter, 1997; Schacter, Israel, & Racine, 1999), or focusing on unique characteristics (McCabe, Presmanes, Robertson, & Smith, 2004), reduce false alarms to critical lures relative to the standard DRM procedure instructions. Given these previous findings, a comparison of drawing to standard DRM instructions would most likely follow the same pattern.

In the current study we instead chose to compare drawing to other encoding tasks that require generation and varying degrees of processing of target and contextual information. For example, by comparing drawing to repeatedly writing out words in Experiment 9, we are able to determine that the resulting false alarm rate is not simply due to production of the to-be-remembered information on a sheet of paper. Furthermore, comparing drawing to visual imagery and listing characteristics in Experiments 10 and 11 allowed us to better establish the mechanisms by which drawing influences false alarm performance. In interpreting the nature of the ‘cost’ associated with drawing, it is important to keep in mind that the cost is relative to other tasks involving item-specific processing of the study words (i.e. writing and imagining).

Conclusions

In this study we have demonstrated that while recollection is enhanced for drawn words relative to various encoding tasks across all three experiments, drawing also increased false alarm rates compared to writing and imagining tasks. We suggest that the observed pattern of both increased hit and false alarm rates is due to drawing resulting in relatively greater recollection of contextual information (Brainerd et al, 2014). Indeed, when comparing drawing to a listing-based encoding task in Experiment 11, which does not involve generation of a holistic representation of the target, drawing resulted in a relatively lower false alarm rate. Overall, we suggest that, because drawing is a sequential task that promotes focus on depiction of the visual features that comprise objects, it both enhances memory for studied items and makes one more susceptible to false alarming to related information.

Chapter 6: General Discussion of PhD Experiments

In this dissertation I have provided quantitative evidence which, when taken together, refine a number of boundary conditions of the drawing effect on episodic memory. Specifically, I have established that the drawing effect extends to two memory-impaired populations, both healthy older adults and individuals with probable dementia. Additionally, I demonstrated that the drawing effect only emerges when the content of the drawing is semantically related to the to-be-remembered information. Finally, I determined that while drawing boosts memory for previously encountered information, it also has the unintended side-effect of increasing susceptibility to falsely remembering unstudied information. Overall, these findings advance our theoretical understanding of how drawing during encoding benefits memory.

To summarize the set of findings in Chapter 2, a larger proportion of the words recalled in Experiment 1 had been drawn than written at encoding, and this effect was larger in older relative to younger adults. In Experiment 2, drawing improved memory in both younger and older adults more than an elaborative encoding task consisting of listing descriptive characteristics of the target nouns. In Experiment 3, older and younger adults drew or wrote out words at encoding, and subsequently provided Remember-Know-New recognition memory decisions. Drawing reduced age-related differences in Remember responses. This overall pattern of findings revealing the highly beneficial effect of drawing on older adults' memory is arguably due to 1) reduced demands of self-initiated processing which provide environmental support (Craik & Broadbent, 1983; Craik & Jennings, 1992; Morrow & Rogers, 2008), and 2) the recruitment of visual sensory processing brain regions which remain relatively more intact throughout healthy aging than those supporting memory and verbal processing (Raz et al, 2005; Raz et al, 1998). This latter point is consistent with the original conceptualization of the mechanism by which the drawing effect benefits memory in that it indicates that visual perceptual processing is a main component of the drawing effect (Wammes et al, 2016; Fernandes et al 2018 for review). In particular, the visual perceptual information afforded by drawing becomes integrated into the memory trace during encoding, which provides an additional trace that can be relied upon to retrieve information at a later time.

In Chapter 3, it was found that *both* healthy older adults and participants with probable dementia had written recall, and visual recognition, that was higher for words that were drawn than written during encoding. This finding was particularly striking given the severe degree of memory impairment in MCI and dementia populations and the impoverished quality of the drawings produced by the participants with probable dementia tested here. Despite the fact that many individuals with probable dementia created drawings that were often times not representational (scribbles that did not resemble the intended object) the drawing effect still emerged. That the drawing effect persists in individuals with probable dementia who have difficulty producing highly representational drawings suggest that an important aspect of the drawing effect is the process of accessing a conceptual representation of the object and internally determining how it should be visually represented. To illustrate, to draw a bird one must access a conceptual representation for ‘bird’ to be able to determine how to visually depict each of the features of which it consists. As such, for both healthy older adults and individuals with probable dementia, I suggest that drawing pictures during the encoding phase enhanced memory by increasing reliance on visual-sensory brain regions, which are relatively intact in normal aging and dementia, as well as promoting access to a conceptual representation of the object.

In Experiment 6, Chapter 4, participants showed poorer free recall for words encoded while free-form doodling, compared to words that were drawn or written, with drawing resulting in the best performance. When monitoring for target words embedded in a narrative format in Experiments 7 and 8, doodling led to the poorest subsequent recall for targets compared to drawing or writing during encoding. Doodling, both in the form of drawing content that is not related to to-be-remembered information, or shading shapes, does not enhance memory; only when drawing content was related to the to-be-remembered information did the drawing effect emerge (Experiment 7). These results highlight that the content of the drawing is critical in producing a beneficial memory effect, and that it not simply any form of drawing which will enhance memory performance. Specifically, to obtain a memory benefit from drawing, one must engage in semantic conceptual of the item being depicted, which results in deep encoding of the to-be-remembered information. This internal process of accessing a conceptual representation of the item is critical to the drawing effect, and consistent with findings in Chapter 3 suggesting that the quality of the drawing produced is relatively less important.

Additionally, another important aspect of the findings in Chapter 4 is that the drawing effect did not emerge in the raw number of words recalled when target words were embedded into a narrative format. This suggests an additional boundary for the drawing effect; that drawing is relatively highly attention demanding resulting in the effect becoming attenuated when attention needs to be divided or frequently re-directed. Importantly, when taking into account the number of words that were encoded (the corrected recall scores in Experiments 7 and 8), the drawing effect does emerge, indicating that while drawing may interfere with ability to simultaneously monitor auditory information, the drawing strategy does still boost memory for information encoded using this technique.

In Chapter 5, I found that while drawing led to higher hit rates relative to writing (Experiment 9) and creating visual mental imagery (Experiment 10), it also led to higher false alarm (FA) rates to critical lures in a variant of the Deese-Roediger-McDermott (DRM) paradigm. When compared to an encoding strategy requiring listing of object features (Experiment 11), drawing led to a lower false alarm rate. As outlined in Chapter 5, I suggest that these findings indicate that memory of drawn information largely consists of contextual information involving the visual features that comprise drawings of objects. I have further argued that the increased false alarm rate for drawing relative to writing and imagining and the sequential nature of the drawing task, indicate that drawings promotes a spreading of activation amongst semantically similar objects. As such, I suggest that the drawing effect is partially due to the spreading of activation amongst visually and semantically related conceptual representations.

Limitations & Future Directions

The main limitation of this dissertation is that I have assumed specific brain regions, such the primary visual cortex in the occipital lobes, are involved in the memory trace for drawn information, but have not presented any data to directly demonstrate this is indeed true. This assumption is supported by research using functional magnetic resonance imaging (fMRI) to examine the involvement of sensory specific processing in episodic memory for pictorial information (Wheeler, Petersen, & Buckner, 2000; Vaidya, Zhao, Desmond, & Gabrieli, 2002; Danker, & Anderson, 2010). For example, studying pictures results in subsequent reactivation of occipital regions involved in visual perceptual processing even when only words are presented at test (Vaidya et al., 2002). Thus, the literature suggests that sensory processing regions can become integrated into a memory trace, such as visual processing regions suspected to be involved in drawing, and relied upon to support retrieval at a later time.

However, to directly investigate the functional activity associated with memory for drawn information, I have recently collected and begun analyzing data from an fMRI study. In this study, 20 young adult participants first encoded 90 words by drawing a picture (30 words), writing (30 words), or listing physical descriptive characteristics (30 words) outside of the MRI scanner. They then entered the MRI scanner and functional brain activity was recorded while they completed a recognition test for all 90 studied words alongside 90 new lures. During the recognition test they viewed a computer screen through a set of MRI compatible goggles. One word at a time appeared on the screen and they pressed one button if they thought the word was 'old' and another button if they thought a word was 'new'. This paradigm allowed me to examine memory activity during instances when participants correctly retrieve words from memory that were encoded using one of the three different encoding tasks. In preliminary analyses I have averaged activity across all the words of a specific encoding type (such as all drawn words) which were correctly remembered. The goal is to then contrast the averaged activity between the three word types (of the three encoding conditions) to determine what activity is specific to each, when controlling for the others.

The main comparison of interest will be drawing contrasted with writing, wherein I expect drawing to recruit regions involved in visual sensory, motor, and semantic processing to a greater extent than writing. In relation to visual perceptual processing, I expect greater activity for drawing in the bilateral extrastriate visual cortex, namely fusiform, lingual, middle occipital, and inferior temporal gyri, based on previous work examining memory for pictures relative to words (Vaidya et al, 2002). For the motor component, I expect to observe activity in the primary motor cortex & sensorimotor networks, given that these areas have been linked to memory following enactment of actions (Macedonia, & Mueller, 2016; Kronke, Mueller, Friederici, and

Obrig, 2013; Masumotoa et al, 2012). It will be particularly interesting to see if activity in these areas involved in motor processing are more active for memory for drawn than written words, given both tasks require physical motor control of a pencil. Importantly, however, the motor involvement in drawing is much more unique then writing and more directly tied to the visual perceptual details of a drawing which are well recollected, and as such may be more integrated into the memory trace for drawing than writing. Finally, I expect that the semantic component of the drawing effect will involve activity in inferior frontal and medial temporal regions, posterior parahippocampal gyrus (Breweret al., 1998; Wagner et al., 1998), and left MTL (Kohler, Moscovitch, Winocur, &McIntosh, 2000), which have been found to be recruited for deep semantic, relative to shallow, processing. When memory for drawn words is contrasted with the memory for words from the listing characteristics task, I expect the main differences in activity to be in regions involved in visual perceptual and motor processing. This overall pattern of findings would provide direct evidence establishing the neural mechanisms underlying the drawing effect.

Furthermore, these data can be used not only to advance our theoretical understanding of the drawing effect, but also to illuminate how multiple sensory traces can become integrated into a singular memory trace. Drawing provides a unique opportunity to examine how multiple traces, namely visual perceptual and motor processing, become integrated together and then reactivated at the time of retrieval. Research in the literature has largely focused on how individual modalities are reactivated at the time of retrieval (such as visual processing). However, our experiences are largely multimodal, with information from multiple sensory and perceptual modalities becoming bound together. For example, imagine remembering when you cut up some vegetables for supper yesterday; you can likely recall how this *looked*, *felt*, and *smelled*. In my future work I will be investigating how we integrate information from rich multimodal experiences into a memory trace and how these aspects of an experience become reactivated during retrieval. Specifically, I aim to use fMRI and an analysis technique called multivoxel pattern analysis which would allow me to examine how activity from various modalities is functionally connected within a larger network of brain activity.

Future Research on the Aging and Memory

I am also currently planning future work to examine memory function in healthy older adults using fMRI. As mentioned previously, older adults have impaired episodic memory, however, we do not currently have a complete understanding of how the aging brain gives rise to this memory decrement. Neurocognitive models of episodic memory posit that the hippocampus in the medial temporal lobes directs reactivation of cortical regions responsible for sensory-specific processing that was engaged during the initial encoding event (Danker, & Anderson, 2010). Recent findings have demonstrated that the hippocampus engages pattern completion involving cortical reinstatement of specific patterns of activity engaged during initial encoding (Danker, Tompary, & Davachi, 2016; Liang & Preston, 2017). As well, a greater degree of overlap in the specific pattern of activation between the initial encoding experience and subsequent remembering is related to better memory and higher confidence for remembering specific details (Thakral, Wang, & Rugg, 2015; Liang, & Preston, 2017). The emerging literature investigating whether older adults demonstrate the same degree of sensory-specific cortical reactivation as young adults has produced mixed results. While some studies have demonstrated no age-related differences (Wang, Johnson, de Chastelaine, Donley, & Rugg, 2016) others have observed a reduction in encoding-retrieval similarity in older adults (Trelle, Henson, & Simons, 2018). Determining the conditions under which cortical sensory-specific reinstatement remains intact in older adults is critical to understanding how the brain gives rise to commonly observed age-related deficits specific to episodic memory.

Studies employing neuroimaging techniques to investigate brain activity demonstrate a pattern of normal healthy age-related brain changes involving reduced activity and decreased specificity in posterior cortical regions involved in sensory processing, coupled with increased activity in frontal regions involved in higher order thought processes such as attention and decision making (Reuter-Lorenz, & Park, 2010). This pattern is suggested to be a compensatory mechanism resulting from 1) deficient recruitment of sensory processing regions and 2) decrements in attentional control reflected in changes in recruitment of frontal regions. In support of point 1), older adults show less differentiation of neural patterns in sensory-specific regions (referred to as dedifferentiation), which likely underlies deficits in distinguishing between similar items or information in memory (Park, Polk, Park, Minear, Savage, & Smith, 2004; Trelle et al, 2018). In support of point 2), older adults commonly display deficits in attentional control in behavioural paradigms (Hasher, & Zacks, 1979; Luo, & Craik, 2008) and over-recruitment of frontal regions has been linked with greater impairments in attentional control (Dennis, Daselaar, & Cabeza, 2007).

Importantly, age-related changes in attentional control should play a critical role in the success of recruitment of sensory processing regions during encoding. To illustrate, the cortical sensory information (e.g. color or location) that becomes integrated into the episodic memory trace by the hippocampus, and subsequently reinstated during retrieval, depends on how attention is allocated during encoding. For example, attending to the color of an object, rather than its location on the screen, results in greater activity in sensory regions that process color information and greater subsequent memory for said information (Uncapher, & Rugg, 2009). As such, greater reliance on frontal than posterior sensory regions in older adults could reflect impairments in directing attention to sensory information, thereby reducing the extent to which sensory information is recruited, bound into an episodic memory trace by the hippocampus, and then subsequently reinstated during remembering.

Additionally, it has long been suggested and evidenced behaviourally that environmental support in the form of a structured encoding task and/or simplified test benefits memory performance in older adults (Craik, Byrd, 1982; Luo, & Craik, 2008). It is therefore possible that creating a structured encoding environment that directs focus to processing of visual perceptual information will result in enhanced recruitment and subsequent reinstatement of activity in cortical sensory regions. Indeed, it has been demonstrated that when attention is directed to specific visual features of stimuli during encoding, over-recruitment of frontal regions is reduced in older adults during retrieval (Dulas, & Duarte, 2014). These findings suggest that providing environmental support through directed attention at encoding can reduce age-related differences in patterns of brain activity supporting episodic memory. However, the effects of manipulating direction of attention at encoding has not been examined on reinstatement of patterns of activity between encoding and retrieval in sensory specific brain regions, in either younger or older adults.

It is yet unclear whether older adults are unable to recruit sensory processing brain regions during memory retrieval as well as younger adults, or if changes in attentional control and encoding strategies influence the degree to which older adults will spontaneously process and encode sensory information. In future work, I plan to answer this question by testing whether age-related differences in sensory-specific reinstatement occur when attention is or is not specifically directed toward the processing of sensory information. When a task requires direction of attention to visual perceptual information, older adults should rely to a greater extent on sensory processing brain regions which are more successfully reinstated at retrieval compared to when verbal or semantic processing can be preferentially engaged. One way to test this hypothesis, is to examine neural activity using fMRI while words are encoded by drawing, creating mental imagery, or viewing pictures (with corresponding word), and during retrieval of old and lure words. The encoding task would require participants to physically engage with and process visual perceptual information to varying degrees. The task would involve an MRI compatible tablet which could rest on participants' laps and with which they could interact while arms are secured at the elbows to reduce motion artifacts in fMRI data. Cortical reinstatement would be examined using representational similarity analysis (Kriegeskorte, Mur, & Bandettini, 2008) to determine the degree of similarity between neural activity during encoding and retrieval of specific words. I expect age-related decrements in cortical reinstatement would be smallest for drawing, largest for viewing pictures, and in between for mental imagery, given the relative degree of focus on visual details required for each task. These findings would suggest that when attention is directed to visual information (such as for drawing and imagining) older adults rely to a greater extent on sensory processing regions, which are more successfully reinstated at retrieval compared to when verbal or semantic processing can be preferentially engaged (such as when viewing pictures). This pattern of findings would suggest that age-related deficits in cortical reinstatement can be ameliorated when an encoding task is implemented that enhances focus on perceptual sensory information.

General Conclusions

In this dissertation, I have provided experimental evidence furthering definition of the boundary conditions of the drawing effect. I suggest that drawing promotes recollection of rich visual contextual and semantic information, which enhances memory when semantically linked to related to-be-remembered information, and is particularly beneficial for older adults both with and without dementia. However, this recollection of contextual information leads to the unintended side effect of increasing false alarm rates to related, but previously un-encountered information. Overall, the findings in this dissertation refine our understanding of how drawing benefits memory performance by establishing a set of circumstances in which drawing does, and does not, improve episodic memory.

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