PhD thesis

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Al-Abdulla, M.

Full bibliographic citation: Al-Abdulla, M. 2023. The effects of normal ageing and processing style on explicit and implicit memory. PhD thesis Middlesex University

Year: 2023

Publisher: Middlesex University Research Repository

Available online: https://repository.mdx.ac.uk/item/14v88v

The Effects of Normal Ageing and Processing Style on Explicit and Implicit Memory

A thesis submitted to Middlesex University in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Maryam Ali Al-Abdulla
M00736093
Director of Studies: Dr Emma Ward

Department of Psychology
Middlesex University London
October 2023

The Effects of Normal Ageing and Processing Style on Explicit and Implicit Memory

Maryam Ali Al-Abdulla

Abstract

Explicit memory (e.g. recognition) declines with age, but there is disagreement about whether implicit memory (e.g. priming) declines or remains intact with age. Processing style is one primary factor that may explain this discrepancy: there is evidence that ageing does not affect conceptual (meaning-based) and perceptual (feature-based) processing equally, yet processing demands have varied in prior studies. The aim of this thesis is to understand how the type of cognitive processing affects the magnitude of age effects on implicit memory. Five experiments were conducted (four online and one lab-based) to compare the performance of young (18-30 years) and older (+65 years) adults on a range of implicit tests while varying conceptual /perceptual processing at encoding (Experiments 1A, 1B and 2), and both encoding and test (Experiments 3-4). In Experiments 1A and 1B a perceptual implicit memory task (Continuous Identification Task with Recognition; CID-R) was used, while in Experiment 2 a conceptual implicit task (Category Exemplar Generation; CEG) was used, and a recognition task was also included to assess explicit memory. In Experiment 3 both conceptual and perceptual tasks were used in a within-subjects design, and the conceptual implicit task was changed to Category Verification with Recognition (CV-R). Experiment 4 replicated Experiment 3 but was performed in person after COVID-19 restrictions ended.

The results showed an age-related decline in explicit memory in all experiments except Experiment 3, and the key finding in relation to implicit memory is that age differences were affected by the type of processing. In most cases, priming was reduced by age when items were encoded conceptually and the test phase involved perceptual processing. These new findings challenge the widely held view that implicit memory remains stable with age and suggest that age differences in implicit memory are mediated by the type of processing at encoding and test.

Acknowledgements

I would like to express my deepest gratitude to my supervisor, Dr Emma Ward, for her support, guidance, and encouragement throughout this journey. I am truly grateful to have you as my supervisor. Special thanks also go to my second supervisor, Professor Tom Dickins, who was always happy to assist when needed. I would also like to extend my thanks to all members of Jones, Silas & Ward lab. I am grateful for their patience and willingness to answer my questions and provide valuable feedback, and for the valuable discussion. I am fortunate to have been part of this lab.

I would like also to extend my heartfelt appreciation to my parents, sisters, and my brother for keeping me in their prayers. I am grateful for your presence in my life. Your encouragement and understanding have meant the world for me. I would also like to thank my husband for standing beside me. I also want to thank my friends for their support, and I especially want to thank my friend Mariam for being an incredible listener whenever I needed someone to talk to.

Special thanks to Qatar University for sponsoring this project. Lastly, I would like to express my sincere appreciation to all those who participated in this project. Without their involvement, this research would not have been possible.

With appreciation,
Maryam

Declaration

This thesis is the result of my own work, and it is not submitted for any other degree or any other institutions. Experiment 4 reported in Chapter 5 was presented at the Aging and Cognition conference in Leuven (April 2023): Al-Abdulla, M.A., & Ward, E.V. (2023). *Effects of ageing and processing on perceptual and conceptual priming and recognition*. Poster presented at the Aging & Cognition Conference, Leuven, Belgium, April.

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Chapter 1: Introduction

The global proportion of older individuals is increasing. At present, approximately 12 million individuals in the United Kingdom are aged 65 years or above, of whom: 5.4 million are over the age of 75 years, 1.6 million are over the age of 85 and approximately 500,000 are over the age of 90 years; 14,430 are centenarians (ONS, 2018a, 2018b). In 2017, there were 962 million people over the age of 60 worldwide, which was more than twice the number in 1980. In 2050, older people are predicted to account for 35% of the population in Europe, 28% in Northern America, 25% in Latin America and the Caribbean, 24% in Asia, 23% in Oceania and 9% in Africa (United Nations, 2017). As the number of older people is increasing globally, age-related issues are predicted to become more prevalent. Ageing is associated with a range of health issues, but perhaps the most well documented feature of ageing is memory decline. Changes in memory in normal ageing are mild in comparison to those in Alzheimer's disease (AD), but nevertheless can have an impact on the lives of older adults (e.g. remembering recently learned information; remembering to take medication at a certain time, etc; e.g. Budson & Price, 2005). Given the advancing age of the population, it is important to clearly understand the impact of normal ageing on different expressions of memory. In the following subsections, the chapter will introduce two key forms of human long-term memory (LTM) before exploring how they are affected by normal ageing.

1.1 Explicit and Implicit Memory

There are different forms of memory that support daily tasks and various techniques to measure them. Cognitive psychologists have categorised up to five memory systems that show different rates of decline with age (see Luo & Craik, 2008). Therefore, not all types of memory decline at the same rate across the lifespan. This thesis focuses on the two primary types of (LTM): explicit and implicit memory.

Explicit memory (sometimes called declarative memory) is defined as the conscious retrieval of previously learned information or prior experiences, while implicit memory (sometimes called nondeclarative memory) is evident when previous experiences affect performance on tasks that do not require conscious recollection of those experiences (Schacter, 1987). Thus, these forms of memory have very different characteristics. Generally, explicit memory is implicated in any form of conscious retrieval (e.g. explicitly recalling facts or previously learned information), while implicit memory does not involve conscious effort to retrieve. A common everyday example of implicit memory is the activity of riding a bicycle – with practice one does not need to consciously retrieve the processes involved in order to perform the task.

Explicit memory can be directly tested in the laboratory by instructing participants to retrieve specific information from a previous study episode (reviewed in Roediger & McDermott, 1993). For instance, in a recall task, participants are presented with a series of items (words/objects) and then asked to recall as many items as they can. Alternatively, in the case of recognition, which is a very common measure of explicit memory, participants study a list of items (words/objects) before being asked to differentiate between previously studied (old) and new items. According to previous research, ageing affects performance on free recall tasks to a greater extent than recognition tasks (e.g. Craik & McDowd, 1987; Danckert & Craik, 2013; Light & La Voie, 1993; Moscovitch & Winocur, 1992; Naveh-Benjamin & Craik, 1995; Nyberg et al., 2003; Whiting & Smith, 1997); as reported by Rhodes et al. (2019) in their meta-analysis, age differences are greater in recall (0.89 effect size) than in recognition (0.54 effect size).

It has been argued that recognition tasks show smaller age-related decline compared to recall because the provision of a cue provides much-needed environmental support to access information stored in memory (Craik & Saltouse, 2008), whereas free recall, involving a free search of memory, requires more self-initiated processing and is much more effortful. One example is a study directly comparing age effects on tests of recall versus recognition (Danckert & Craik, 2013), which reported a larger age difference between young and older adults on recall than recognition. Also, the meta-analysis where comparing recall and recognition, reported an effect size of 0.50 for recognition and 0.97 for recall (La Voie & Light, 1994). However, other studies have reported approximately equivalent age effect in recall and recognition tasks (e.g. Botwinick & Storandt, 1980; Verhaeghen et al., 1998; White & Cunningham, 1982).

Priming is a common test for implicit memory in which memory is tested indirectly without informing participants that the task is related to previously studied information (reviewed in Roediger & McDermott, 1993). There are many types of priming tasks, and these can be broadly broken down in terms of their processing requirements: perceptual versus conceptual. Perceptual priming tasks engage participants with purely perceptual information of stimuli (i.e. their physical appearance), and common tasks include perceptual identification, word-stem completion (WSC), word-fragment completion (WFC), lexical decision and solving anagrams. In a typical perceptual identification task, participants are exposed to a series of stimuli (words/objects) either very briefly or in a degraded form and asked to identify (i.e. name) the items as quickly as possible (see example in Figure 1). Priming is evident when stimuli that were presented during a prior encoding phase are identified faster or more accurately than new items (e.g. Ballesteros et al., 2007; Berry et al., 2012; Buchner & Wippich, 2000; Fleischman & Gabrieli, 1998; Light et al., 1992, 2000; Mitchell & Bruss, 2003; Ward et al., 2013b). Priming is considered a robust phenomenon, and many studies have shown that, in both healthy young and older participants, individuals tend to identify studied items faster than unstudied ones (reviewed in Berry et al., 2012). Additionally, numerous studies have demonstrated that a priming effect can be produced by a single exposure to a stimulus (e.g. Rybash, 1996).

In WSC and WFC tasks, words are presented (e.g. HOUSE, TRUCK), following which participants are asked to complete word stems (e.g. TR_ _ _) or word fragments (e.g. H_ _ SE) with the first word that comes to mind. Priming is evidenced when the prior exposure increases the likelihood of using words that were presented earlier. Although WSC and WFC are generally considered to be perceptual tests, this has been debated (discussed in detail in section 1.3.2).

In contrast to perceptual priming tasks, conceptual priming tasks engage participants with the content and meaning of stimuli. Common tasks include category exemplar generation/ production (CEG/CEP), fact competition, and category verification (CV). In a typical CEG task participants are presented with stimuli (words/objects) during an encoding phase, and later on, in the test phase, they are given various category cues (e.g. animals or clothing) and asked to produce as many exemplars as possible from that category within a given time frame (see example in Figure 2). Priming is evident if more previously studied than novel exemplars are generated. In a CV task, participants are asked to judge whether or not presented items match a given category cue as quickly as possible (e.g. 'cat' → type of animal?) (see example in Figure 3). In the CV task, priming is shown by faster responses to stimuli that were presented during a prior encoding phase compared to those for new items.

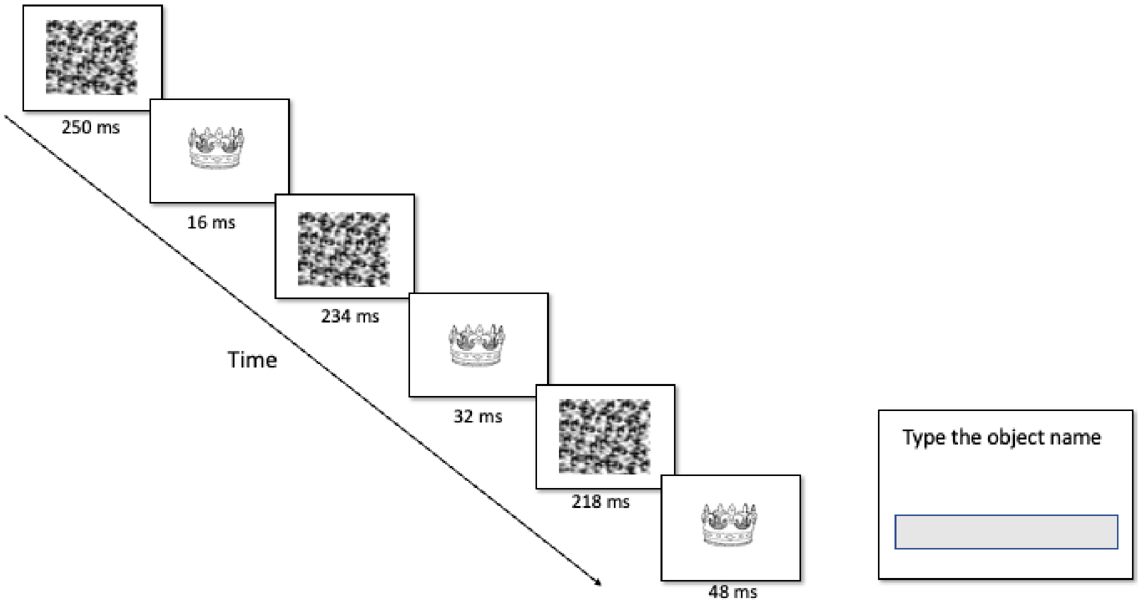

***Figure 1*.** An Example of a Common Perceptual Identification Task.

Note. An example of a single trial within a perceptual identification task (continuous identification). A stimulus (in this case an object – either studied or new) is presented very briefly and gradually clarifies from a background mask. An object will initially be presented for 16 milliseconds (ms; screen refresh) and immediately masked. The object and mask presentation will then alternate with the object presentation increasing by 16 ms each time and the mask decrease by 16 ms each time. The effect is that the object appears to gradually clarify. Participants are instructed to identify the item as quickly as possible by pressing a key and then typing their response ('crown') into a box. The response key press captures their response time (RT), and RTs for studied versus new items are compared to examine priming.

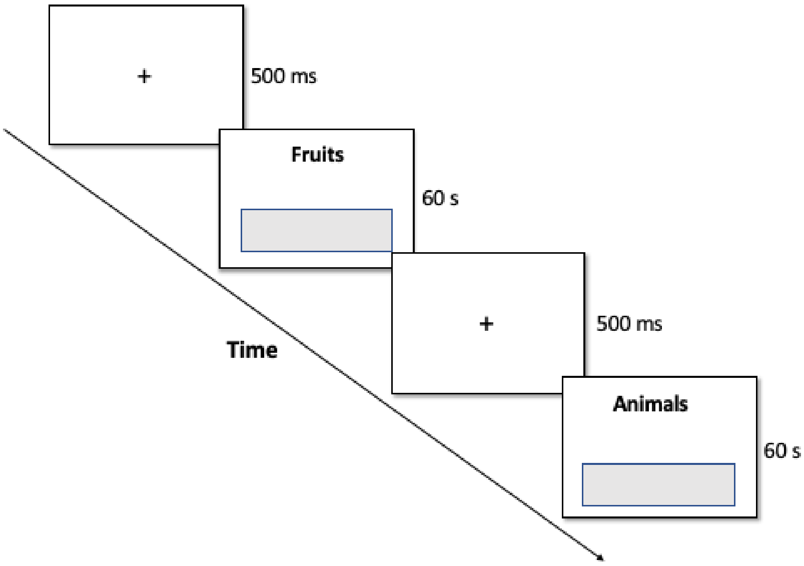

Figure 2. An Example of a Common Category Exemplar Generation (CEG) Task.

Note. An example of trials within a typical category exemplar generation (CEG) task, where participants are shown category cues and asked to generate as many exemplars as possible (to be typed into the box). In the example here participants have one minute to produce as many exemplars as possible in response to the category cue, but timings have varied across studies.

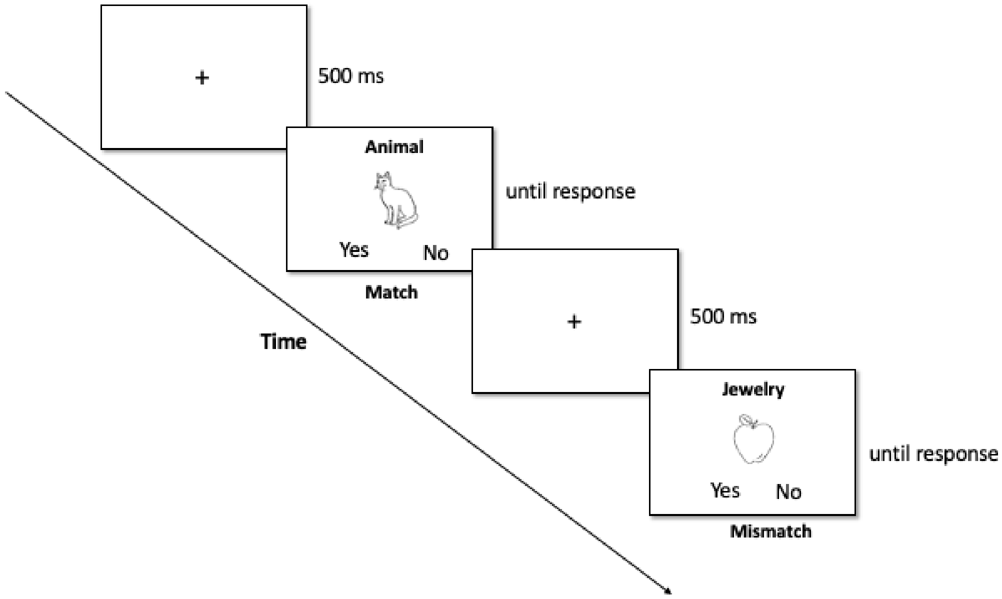

Figure 3. An Example of a Common Category Verification (CV) Task.

Note. An example of trials within a typical Category Verification (CV) task. Participants are presented with items (in this case objects – some studied and some new), and on each trial they are asked to decide if the item matches the given category label as quickly as possible ('Yes' or 'No'). Response time (RT) is captured upon keypress, and RTs for studied versus new items are compared to examine priming.

1.1.1 Single Versus Multiple Memory Systems

A longstanding debate surrounds whether explicit and implicit forms of memory are driven by a common underlying system (e.g. Berry et al., 2006, 2008b, 2008a, 2012; Buchner & Wippich, 2000; Nosofsky et al., 2012), or independent memory systems (e.g. Gabrieli, 1998; Gabrieli et al., 1999; Schacter, 1987; Schacter & Tulving, 1994; Squire, 1992, 2004, 2009; Stark & McClelland, 2000; Tulving & Schacter, 1990). This debate is briefly reviewed in the following subsections.

1.1.1.1 Multiple Memory Systems

1.1.1.1.1 Experimental Evidence

The notion that explicit and implicit memory are driven by distinct cognitive systems is supported by a range of evidence that experimental manipulations (e.g. attention) that affect performance on explicit tasks have no significant effect on implicit task performance (e.g. Jacoby et al., 1989; Kellogg et al., 1996; Mulligan & Hartman, 1996; Parkin et al., 1990; Parkin & Russo, 1990; Russo & Parkin, 1993; Schmitter-Edgecombe, 1996; Szymanski & MacLeod, 1996; Wolters & Prinsen, 1997). For example, in Parkin et al.'s (1990) study participants performed WFC (implicit) and recognition (explicit) tasks following encoding in which attention was manipulated in two conditions: full attention and divided attention. Participants were asked to perform a verification task in which they decided whether a presented sentence made sense or not. In the divided attention condition, half of the participants were also asked to monitor a series of tones that occurred every 3-7 seconds and decide if the tones were low, medium or high pitch while performing the verification task. In the test phase, a recognition task was given to participants with 40 items per page in test booklet, followed by two fragment completion tasks. For the recognition task, participants were required to judge if they had seen the word previously, and in the WFC task, participants were required to complete word fragments with the first word that came to mind. The results showed that recognition was impaired by the attentional manipulation, but priming was not affected. Another study by Szymanski and MacLeod (1996) showed evidence for a dissociation between priming and recognition by using a Stroop-style manipulation during encoding. In the full attention condition, participants read words and ignored the text colour, and in the reduced attention condition, participants stated the text colour and ignored the words themselves. Following the encoding phase, participants took part in implicit (lexical decision task) and explicit memory (recognition) tests. In the implicit memory test, participants were instructed to decide whether presented words (studied/new) were real English words or not. In the recognition test, participants were presented with words (studied/new), and were instructed to decide if they had been presented previously or not. The results indicated an effect of attention on recognition and no effect on priming.

Other studies have shown that while explicit memory is susceptible to forgetting, priming can persist over time. For example, in a study by Ward et al. (2013b), participants performed two encoding phases with a delay of 60 minutes between them. During these phases, participants decided if presented objects matched given category names. Different items were presented in the two phases. Finally, the participants performed a CID-R task (continuous identification task with recognition) to assess explicit and implicit memory. The results showed that recognition was affected by the delay, while priming was not affected. Additionally, in one study that used a longitudinal design and tested priming and recognition over four sessions of delay (immediate, 1 day, 1 week, and 1 month). In all, 72 participants (24 young adults, 24 young elderly, and 24 old elderly) took part in the study; the findings demonstrated that recognition was reduced as an impact of delay, while priming remained and did not significantly decline (Wiggs et al., 2006). In another study by Tulving et al. (1982), participants performed WFC and recognition tasks, and after one week they returned to be tested again. The magnitude of priming showed no reduction over seven days, while there was a significant reduction in recognition. Other studies have shown that priming can persist across months and even years. Cave (1997) used a picture naming task to examine priming and observed that even with a single and brief exposure, priming persisted for 48 weeks. In another study, Larzabal et al. (2018) examined whether participants could quickly identify a stimulus that had been presented for a few seconds between 8 and 14 years earlier and found intact priming. Mitchell (2006) also demonstrated extremely long-lasting implicit memory. In a replication of his earlier study (Mitchell, 1989), the participants demonstrated intact priming 17 years following an initial study despite chance levels of explicit memory and, in extreme cases, an inability to remember participating in the initial study at all.

Over many decades, several other experimental manipulations, such as deep (conceptual) versus shallow (perceptual) processing, study duration, modality change, and more, have produced differential effects on explicit and implicit memory (reviewed in Roediger & McDermott, 1993) Further, as was discussed in section 1.1, explicit versus implicit tasks have quite different requirements, so it is perhaps unsurprising that sometimes differences in outcomes may arise. It has been argued that it is crucial to make explicit and implicit tasks as comparable as possible in order to determine if the two forms of memory are supported by a single or multiple memory systems. By matching all characteristics of the tasks except the instructions, Reingold and Merikle, (1988) suggested that one will be able to make suitable comparisons. Using this approach, Merikle and Reingold (1991) reported a finding that they claimed reflects true implicit memory in the absence of explicit memory. In the study phase, two words were presented on each trial, and participants were instructed to read aloud the one word that had arrows pointing to it. Later, in the test phase, new and old words were presented against a mottled background. Half of the participants performed an explicit task and half performed an implicit task. In the explicit task, participants judged whether the word was old or new, and in the implicit task, participants judged whether there was a high or low contrast between the word and the background. In the high-contrast condition, words stood out against the background, but in the low-contrast condition, words blended into the background. The main discovery was robust priming for both cued and uncued items, whereas recognition for uncued item was at chance. This finding has been extensively referenced in the literature to indicate that explicit and implicit memory are driven by different memory systems.

1.1.1.1.2 Neural Dissociations

The preservation of implicit memory in clinical cases despite reduced explicit memory is another key strand of evidence for the multiple systems perspective that explicit and implicit memory are driven by separate memory systems. For example, patients with amnesia due to damage to the hippocampus or medial temporal lobe typically have difficulty with explicit memory assessments but do not necessarily show reduced performance on implicit memory tests (Cave & Squire, 1992; Conroy et al., 2005; Graf et al., 1982, 1984; Hamann & Squire, 1997a, 1997b; Parkin, 2013; Reber & Squire, 1999; Smith & Oscar-Berman, 1990; Stark & Squire, 2000; Verfaellie et al., 1996; Warrington & Weiskrantz, 1970, 1974). As reported by Hamann and Squire (1997a), patient E.P., who had severe amnesia, showed chance levels of recognition when tested yet exhibited intact priming for the same stimuli. This evidence has also been shown in clinically depressed patients, in which intact priming is observed despite impaired explicit memory (e.g. Roediger & McDermott, 1992). Further evidence reported by Gabrieli et al. (1999) suggests that AD patients show reduced explicit memory but intact implicit memory. In contrast to these observations, there is also evidence that patients with damage to right occipital brain regions show intact recognition and impaired priming (e.g. Gabrieli et al., 1995; Keane et al., 1995), further strengthening the notion that these forms of memory are driven by distinct systems. An example was reported by Gabrieli et al. (1995), who presented a patient with a lesion in the right occipital lobe who showed impairment specifically to visual implicit memory, but intact explicit memory as tested using cued recall and recognition tasks. The literature on normal ageing can significantly add to this theoretical debate. Given evidence that explicit memory declines with age, researchers have taken a keen interest in attempting to understand whether implicit memory remains stable as it does in amnesia (reviewed in section 1.2).

Further evidence for the notion of multiple memory systems driving explicit and implicit memory comes from functional imaging (e.g. Jernigan & Ostergaard, 1993; Schott et al., 2005). For example, Schott et al. (2005) developed a paradigm to examine priming in the absence of explicit memory. Word stems completion (WSC) was used to assess explicit memory and implicit memory, and participants were asked to complete the stem with the first word that came to mind (implicit) and to judge if the presented word was shown previously in the encoding phase (explicit). The behavioural data showed that priming occurred for old items in the absence of recognition (i.e. participants used the studied words more often than unstudied words as answer for the stem although they did not remember it was presented previously), and functional magnetic resonance imaging (FMRI) data showed that priming was associated with decreased hemodynamic response in a number of brain areas (occipital, inferior temporal, and prefrontal cortices) while explicit memory was associated with other brain areas (parietal temporal, and prefrontal). These findings indicate strong support that implicit and explicit memory are driven by different memory systems.

1.1.1.2 The Single-System Perspective

The single-system perspective argues that explicit and implicit memory are not necessarily driven by distinct systems. Supporters of this view believe that explicit and implicit memory are driven by single underlying memory system. Many of the arguments in favour of this view stem from considerations of methodological weaknesses surrounding some of the aforementioned dissociation evidence, that is, when a manipulation appears to affect one form of memory and not the other. As will be discussed in 1.3.2, implicit memory tasks are generally less reliable than explicit tasks, so observations of reductions in explicit memory as a function of a given manipulation coupled with no effect on priming may simply be due to the lack of statistical reliability of the implicit task.

There are other methodological reasons that might result in dissociations, including how explicit and implicit memory are tested during an experimental session. For example, capturing explicit and implicit memory in separate phases of an experiment, even within the same participants, may introduce differences. For example, measuring priming and recognition in separate phases means there will be a longer delay for one task than the other, and participants may become fatigued in the second task. To solve this issue, it has become more common to measure implicit and explicit memory trial-by-trial for each experimental item. One effective approach is to utilize the Continuous Identification with Recognition (CID-R) task, a method that captures both priming and recognition measures for each test item on every trial, as demonstrated by Stark & McClelland, (2000). Also, it is crucial to point out that many studies show similar effects on explicit and implicit memory (e.g. Berry et al., 2006; Crabb & Dark, 2003; MacDonald & MacLeod, 1998; Stone et al., 2000; Ward et al., 2020), providing evidence for a single memory system. An example of this is Berry et al. (2006). In their study they attempted to replicate the findings of Merikle and Reingold (1991; reported in section 1.1.1.1.1). The results showed that recognition and priming were both affected by the attention manipulation (i.e. greater recognition and priming for cued than uncued items). Another example is the study carried out by Ward et al. (2020) in which attention was manipulated during the encoding phase. In the encoding phase, pairs of objects were presented in cyan and magenta (overlapping), and participants were instructed to attend to one colour and ignore the other. In the test phase, participants performed a CID-R task. The results showed a main effect of attention on both priming and recognition.

In another study reported by Crabb and Dark (2003), attention was manipulated in the encoding phase, which involved digit and word presentation. For the word condition, participants were instructed to ignore the digits that were presented around the word and press a key if they noticed a vehicle name. In the digit condition, participants were instructed to ignore the words and press a key once they detected the presence one of the two digits that were shown at the beginning of the sequence. This was followed by a recognition task, where participants were instructed to decide if words (studied/new) had been presented previously during the encoding phase, and finally by a perceptual identification task where participants were instructed to name the presented word using a microphone as quickly as possible. The results showed an effect of attention on both priming and recognition.

Finally, studies using computational models can offer further insight. The single-system model developed by Berry et al. (2008) is based on the assumption that a single underlying memory signal drives priming and recognition, but there are independent sources of random noise, the variance of which is greater in priming (due to the lower task reliability in implicit memory tasks). This model has been able to predict several dissociations reported in the literature that have previously been taken as evidence for multiple-memory systems (including several of those discussed in section (1.1.1.1.1), and those seen in patient populations (discussed in section 1.1.1.1.2). Thus, it seems likely that dissociations may be caused by differences between explicit and implicit tasks themselves, and many empirical findings that at first glance seem to point to multiple memory systems are not incompatible with the single-system perspective.

1.2 Explicit and Implicit Memory in Normal Ageing

The previous section presented introductory information related to implicit and explicit memory, how they are typically measured, and the ongoing debate as to how they are organised (see section 1.1.1). In this section, the effects of normal ageing on explicit and implicit memory will be discussed. For decades, scientists have made a significant effort in cognitive ageing studies to examine the effect of normal ageing on both explicit and implicit memory. The effect of normal ageing has most extensively been examined by measuring and comparing differences between young and older adults' performance on various memory tasks.

1.2.1 Explicit Memory in Normal Ageing

There is clear evidence of an age-related decline in explicit memory (e.g. Abbenhuis et al., 1990; Conroy et al., 2005; Craik & Schloerscheidt, 2011; Jelicic, 1996; Light et al., 1986; Light & Singh, 1987; Mitchell, 1989; Monti et al., 1996; Morcom & Rugg, 2004; Nilsson, 2003; Russo & Parkin, 1993; Small et al., 1999; Ward et al., 2013a, 2020; Wiggs et al., 2006).This effect has been reported in cross-sectional studies and in longitudinal studies assessing changes over time in the same person (e.g. Christensen et al., 1997; Davis et al., 2001; Fleischman et al., 2004; Hultsch et al., 1992). According to Fleischman et al. (2004), explicit memory deterioration in people aged 85 years is more than twice that of people aged 75 years. They determined that explicit memory declines at a rate of 0.109 units annually (aggregate explicit measure), tested over a four-year period using seven explicit memory tasks including immediate and delayed recall and recognition of stories, numbers, and words, mostly taken from the Wechsler Memory Scale Revised (Wechsler, 1987). Another longitudinal study by Davis et al. (1990) over a 10-year period showed a decline in explicit memory tested using two recognition and two recall tasks.

Cross-sectional studies have also shown that people over the age of 60 years perform worse than those in their 20s on recognition and recall tests (e.g. Burke & Light, 1981; Craik &

Schloerscheidt, 2011; Howe, 1988; Hultsch & Dixon, 1990; Jelicic, 1996; Ward, 2018; Ward et al., 2015, 2017, 2020). For example, Nilsson's (2003) study included several assessments to measure explicit memory over an individual's lifespan, including free recall, cued recall, source recall and recognition of actions and short sentences. The results showed a clear reduction with age starting from the mid-20s. In a recent study conducted by Ward et al. (2020), recognition declined steadily in a sample of 1072 participants aged 12 to 82 years. To elaborate, recognition peaked in mid-young (25-34 years) adults before gradually declining throughout the rest of the lifespan. Also, Ward et al. (2013b) showed a significant decline in recognition in older adults compared to young adults in two experiments. Another example that showed a decline in explicit memory was reported by Abbenhuis et al. (1990), who compared older (*M* age = 72.8 years) and young (*M* age = 23.3 years) adults' performance on a recognition task. Participants were told to read words presented on the screen and select the word they had previously seen. The results revealed that young participants performed significantly better than older participants. Another example is Wiggs et al. (2006), in their study, a recognition task was employed to assess explicit memory. The results revealed that young adults (*M* age = 27.1 years) demonstrated significantly better performance than the young-elderly group (*M* age = 70.0 years), while the young-elderly group outperformed the old-elderly group (*M* age = 78.3 years).

1.2.2 Implicit Memory in Normal Ageing

As was reviewed above, considerable empirical research has demonstrated a clear decline in explicit memory with age. Because of this, there has been a profound interest in establishing whether implicit memory is affected by age. However, despite decades of research, whether implicit memory is affected by ageing or remains intact is still a matter of debate. For example, Mitchell and Bruss (2003) examined differences in implicit memory in young and older adults on five tasks: WFC, WSC, CEG, picture fragment identification and picture naming. The results did not indicate any reliable age differences for these tasks, and the authors came to the conclusion that most implicit memory processes remain stable throughout adulthood. Other evidence for the preservation of implicit memory comes from longitudinal studies. For example, Fleischman et al. (2004) showed no change over a 4-year period in elderly females on a battery of implicit memory that included the following tasks: category-exemplar production, WSC, word identification and picture naming. The study recruited a large cohort of older adults aged 65 years and above (*n* = 161), and changes in terms of conceptual, perceptual, production and identification processes were examined over annual data collections. This lack of change in priming over time is consistent with the findings of several other longitudinal studies (Christensen et al., 1997; Davis et al., 2001; Hultsch et al., 1992).

Overall, intact implicit memory in normal ageing has been reported in many studies using many different tasks, such as WSC (Light & Singh, 1987; Mitchell & Bruss, 2003; Park & Shaw, 1992; Dick et al., 1989), WFC (Gopie et al., 2011; Jelicic, 1996; Light et al., 1986; Mitchell & Bruss, 2003; Rybash, 1994), perceptual identification (Ballesteros et al., 2007; Light & Singh, 1987; Wiggs et al., 2006), picture fragment identification (Mitchell & Bruss, 2003), CEG (Isingrini et al., 1995; Light et al., 2000; Light & Albertson, 1989; Mitchell & Bruss, 2003; Monti et al., 1996), lexical decision (Karayanidis et al., 1993; Moscovitch, 1982), picture naming (Mitchell, 1989) and object decision (Gordon et al., 2013; Schacter et al., 1992; Soldan et al., 2009). However, in contrast, other studies have shown that younger adults have significantly better implicit memory than older adults on a range of different tasks, including perceptual identification (Abbenhuis et al., 1990; Keane et al., 2004; Russo & Parkin, 1993; Ward, 2018, 2022; Ward et al., 2013a, 2013b, 2020), WSC (Chiarello & Hoyer, 1988; Davis et al., 1990; Hultsch et al., 1991; Schugens et al., 1997; Small et al., 1995), homophone spelling (Davis et al., 1990), CV (Ward, 2022; Light et al., 2000), category production (Jelicic, 1996), and CEG (Maki et al., 1999; Maki & Knopman, 1996; Stuart et al., 2006).

A study by Ward et al. (2013b) found a decline in implicit memory with normal ageing. In two experiments, priming was measured using a perceptual identification task (CID-R), and stimuli were pictures of everyday objects. In two experiments, priming was numerically but not statistically lower in older adults than in younger adults; however, when the researchers analysed the pooled priming data to increase the statistical power, the results indicated a significant age difference in priming. Furthermore, Ward et al. (2020) showed a statistically significant decline in implicit memory over the lifespan by using the same CID-R task with a larger sample. This study recruited a large sample of participants (*n* = 1072) aged 12 – 82 years during a residency at the Science Museum, London, to examine lifespan differences in priming. The findings showed a peak in priming in mid-young adults (around 25 years of age), before a gradual decline. Another study by Ward (2022) conducted online also showed a significant age effect on implicit memory. In this study, a CV task served as a conceptual priming task and perceptual identification (CID) was used as a perceptual priming task. Young adults performed better than older adults in both tasks. In another study by Maki et al. (1999), 164 participants were assigned to six groups: 20-39, 40-49, 50-59, 60-69, 70-79, and 80 years and above, and given a fragmented object identification (FOI) task. Participants in the oldest group performed significantly worse than those in other groups. The study also showed a small but reliable age effect on a CEG task.

On the whole, the literature contains many inconsistent findings where age effects on implicit memory are concerned, making it impossible to draw conclusions at present. Some studies show intact implicit memory with age, while others show that implicit memory declines with age.

Whether ageing affects implicit memory is an important question to examine for several reasons. If implicit memory is preserved in healthy older adults, then it may be used to support interventions for individuals experiencing cognitive impairment (e.g. implicit strategies to boost everyday tasks), and robust implicit tasks may be used as a diagnostic tool for AD (Fleischman, 2007), as explicit memory decline is often considered as a beginning of AD (e.g. Terry & Katzman, 1983; Welsh, 1992). Additionally, if implicit memory remains intact with age, this would be a key evidence that explicit and implicit memory are driven by separate and independent memory systems.

1.3 Understanding the Discrepancies in the Literature

There are many potential reasons for the vast discrepancies surrounding age effects on implicit memory in the literature, including statistical power, task reliability, participant characteristics, explicit contamination, and task processing characteristics. These concerns will be overviewed in the following sub-sections.

1.3.1 Statistical Power

One possible reason for the inconsistent findings between studies concerning age effects on implicit memory is related to statistical power. That is, many studies have failed to use an adequate number of participants to reach the required statistical power needed to detect reliable age effects on priming. In other words, true effects of age on implicit memory may have not been reliably detected. Priming in prior studies has usually been numerically lower in older adults than in young adults, suggesting that there is a small but real effect of age on implicit memory that has not reached statistical significance. As will be reviewed in detail in section 1.3.2, effects on priming are typically smaller than effects in explicit memory, so it is crucial that studies have adequate power to detect real effects. It is essential to calculate required sample sizes, yet most studies have failed to do so and have relied on relatively small numbers of participants – typically 20-30 per age group. This issue has been raised in the past (reviewed in Fleischman, 2007; Ward & Shanks, 2018), and in recognition of this limitation, newer studies in this field are beginning to power their samples.

Interestingly, a meta-analysis of 36 effect sizes by La Voie and Light (1994) revealed a small but significant effect of age on priming. This suggests that there is a small but real reduction in implicit memory with age that has often gone undetected in the literature. However, it is important to note that some studies with very large samples and adequate statistical power have failed to detect age differences in priming, making the situation more complex. For example, Park and Shaw (1992) used a WSC task to examine priming in a substantial number of participants (140 per age group) but found equivalent levels of priming in both young and older adults. In contrast, a reliable age effect on implicit memory was found in a study that tested only 11 participants (Abbenhuis et al., 1990). Therefore, one cannot conclude that the inconsistent patterns of age effects in the literature are solely due to issues with sample sizes and statistical power.

1.3.2 Task Reliability

Task reliability is another issue that should be considered, given that a wide range of priming tasks have been employed in the literature, yet each has different requirements and may be more or less sensitive to detecting age differences. It is well-documented that priming tasks are statistically less reliable than explicit tasks, and this may explain why age effects are more readily detected on explicit tasks (e.g. Buchner & Brandt, 2003; Buchner & Wippich, 2000; La Voie & Light, 1994; LeBel & Paunonen, 2011; Light & Singh, 1987; Meier & Perrig, 2000; Ward et al., 2013b). For example, Ward et al. (2013b) assessed the reliability of priming (perceptual identification) and recognition tasks using split-half correlations, and reported statistically greater reliability in recognition than priming.

In another example, Buchner and Wippich (2000) demonstrated that WSC tasks are statistically less reliable than recognition tasks. They also used a split-half correlation method to examine reliability, and reported scores of $r = 0.35$ and $r = 0.88$ for WSC and recognition, respectively. They argued that the instructions in WSC tasks (to complete stems with the first word that comes to mind) allows greater flexibility (especially considering the number of possible solutions) than a typical recognition task, in which participants simply discriminate between previously studied and new items (simply ‘yes’ or ‘no’). That is, the instructions in WSC may encourage participants to adopt different strategies, resulting in noisy data due to the variability of responses, which in turn makes it difficult to statistically detect age differences. In addition, many studies employing WSC have used words with many possible solutions (more than 10); therefore, there is a lower probability of participants finding an answer relatively rapidly, whereas in WFC there are typically only one or two solutions.

Buchner and Wippich (2000) directly demonstrated that the lack of reliability in WSC can explain the absence of age differences in priming, but also showed that perceptual identification can be sensitive to age differences. They presented evidence that perceptual identification is a more reliable measure than tasks such as WSC, demonstrating equivalent reliability levels to a recognition task. This was explained in terms of the more rigid instructions in perceptual identification, which reduces response variability and noise. That is, the instructions to identify items (words/objects) as quickly as possible are more stringent than those to complete words/fragments with the first word that comes to mind.

Among the many different types of implicit memory task, requirements and instructions have varied hugely. As well as processing requirements (discussed in section 1.3.5), instructions, reliability and so on, tasks also differ in terms of the type of response. Some require the production of a response, while others rely on identification. This is another important difference that must be considered when discussing factors that may underly the discrepancies in the literature. Past research has demonstrated that compared with identification processes, production processes are more affected by age (e.g. Light et al., 2000; Rybash, 1996), yet most studies have not considered or controlled for this.

WSC has been used for many years to examine implicit memory. However, researchers have raised several issues that should be taken into account. For example, it has been claimed that the way that the WSC task is performed involves a numerous search and selection processes (e.g. Winocur et al., 1996). When the participant is trying to complete a stem, they must search the whole lexicon to find a possible answer. Considering the word-stem H_ _ _, there are many possible solutions (e.g. Hair, Home, Half, and Hail) whereas, in tasks like perceptual identification there is only one solution: the correct name of the item to be identified. Situations in which there are many potential answers may be particularly problematic for older adults, since there is evidence that they experience impairment in search and selection processes (e.g. Mitchell & Bruss, 2003; Ryan et al., 2001; Toth, 2000). According to Winocur et al. (1996), due to weak search strategies in older adults they tend to perform poorly on WSC tasks.

On the whole, task differences and reliability are important issues to be considered, yet only a few studies have taken them into account (Buchner & Wippich, 2000; Mitchell & Bruss, 2003; Small et al., 1995; Ward et al., 2013a).

1.3.3 Participant Characteristics

Participant characteristics encompass to the demographic information of individuals involved in a research study, including factors such as age, gender, education level, and more. It can also include information about health status and medical history. Understanding participant characteristics is important in any research practice for two reasons: to ensure that the sample is representative of the target population, and to control potential confounding variables. Age and cognitive status are two key characteristics that may affect the outcomes of studies in this particular field.

Participant ages have differed drastically across ageing studies, and evidence shows that priming in participants aged above 70 years (often referred to as old-old) show more decline compared with those aged under 70 years (often referred to as young-old) (e.g. Davis et al., 1990; Maki et al., 1999). Other concerns include variations between participants with respect to cognitive function, premorbid intelligence, health, vision and education level; all of which are correlated with memory function and may affect performance on implicit memory tasks (e.g. Christensen & Birrell, 1991). These factors have varied tremendously across studies, or not been assessed at all, making conclusions about whether implicit memory declines in normal ageing impossible to reach. In particular, some studies on normal ageing have not administered appropriate neuropsychological assessments, such as the Mini Mental State Exam (MMSE; Folstein et al., 1975), to rule out any non-normal cognitive impairment in older participants. Therefore, previous studies might have inadvertently included participants with mild cognitive impairment (MCI) or (AD) in addition to healthy older adults in their samples. This is important because implicit memory may be differentially affected in MCI and/or AD than it is in normal ageing. For example, Fleischman (2007) reported that priming declines in AD. Including a preclinical or clinical sample in normal ageing studies makes it impossible to draw conclusions about the fate of implicit memory in normal ageing.

1.3.4 Explicit Contamination in Implicit Tasks

Given that implicit tasks seek to assess memory indirectly – that is, without participants' conscious awareness, it is important that the true purpose of the tasks be disguised. Following an encoding phase, implicit memory tests are usually framed to participants as a separate, unrelated task, and no reference is made to previously studied information. However, a concern is that participants may become aware that items from the earlier encoding phase are being repeated and attempt, of their own accord, to use an explicit memory strategy to perform the task. For instance, on a WSC task, instead of completing word-stems with the first word that comes to mind, participants may recall words from the encoding phase, turning the implicit test into an explicit one. This is a critical issue when examining age differences; explicit memory declines with age, so young adults are at an advantage when using explicit strategies.

It is crucial for ageing studies to minimise or control for potential explicit contamination. A common method is to attempt to reduce the likelihood that participants will become aware of the association between the study and test phases, or to limit exposure times and processing resources (MacLeod, 2008). Russo and Parkin (1993) found age differences in priming when using a fragmented picture completion task; however, the age difference disappeared when they controlled for explicit memory by asking young participants to complete a dual task. A few other studies conducted over the years have attributed significant age differences in priming to explicit contamination (see Geraci & Barnhardt, 2010). Mitchell (1995) conducted a meta-analysis that reviewed 36 studies and showed that, when accounting for explicit contamination, the effect of age disappeared. Another widely cited meta-analysis that reported an age effect on implicit memory was criticized for not accounting for explicit contamination (la Voie & Light, 1994). Mitchell and Bruss's (2003) study controlled for explicit contamination by limiting the time in the test phase (three seconds), and they also asked participants to rate their level of awareness of the relationship between the study and test phases. By minimising the exposure time to three seconds, they forced participants to focus on responding to the task and ensured that participants did not have the time to rehearse items shown in the study phase. The study used five implicit memory tasks: WFC, WSC, CEG, picture naming, and picture-fragment identification, and reported stable implicit memory in all tasks.

Another common method for controlling explicit contamination is to include a post-test awareness questionnaire to determine how many participants became aware that items from the study phase were repeated during the test phase. This is often a graded questionnaire, with initial questions probing participants regarding their understanding of the purpose of the study and whether they noticed any connection between the different tasks. Later questions gauge whether they became aware of repeating items and whether they used any particular strategy to help them in the implicit task (e.g. Bowers & Schacter, 1990). Responses on the post-test questionnaire can either mean that aware participants were excluded, or allows the comparison of aware participants' priming scores compared to those of the unaware participants.

Limiting explicit contamination is a key consideration for studies, and considerable effort has been made to reduce test awareness. However, there is emerging evidence that some tasks are more susceptible to explicit contamination than others. Tasks such as WSC may encourage the use of explicit strategies. If participants become aware that word-stems can be completed with previously studied words, this may become their preferred strategy. On the other hand, it has been argued that tasks requiring speeded judgements with reaction time measure are less susceptible to explicit contamination. The rapidity of judgement occurs too quickly for the engagement of explicit strategies (Brown et al., 1991, 1996; MacLeod, 2008) . A common speeded priming measure is the continuous identification with recognition (CID-R task; see Figure 1), which is a form of perceptual identification task. This task captures a measure of explicit and implicit memory concurrently (Stark & McClelland, 2000), meaning that it is not performed under standard implicit (unaware) conditions. In this task, an item is identified on every trial (priming measure) immediately before a recognition judgement (explicit measure). Thus, participants are aware that previously presented items from a prior study phase are repeated on the test. Nevertheless, a range of evidence indicates that this task is not affected by explicit contamination. For example, Ward et al. (2013b) found no difference in priming when the priming phase (CID) was presented separately (and participants were monitored for spontaneous test awareness) versus when priming was presented alongside recognition (CID-R). Overall, 55% of young and 50% of older adults were categorised as 'aware' when the priming task (CID) was presented without a concurrent recognition judgement; however, priming did not differ between aware and unaware participants (young or older). In addition, Ward et al. (2013b) established that priming was unaffected when participants were provided with optimal or adverse information for explicit processing (Experiments 3a-3b). That is, the performance on the priming task did not show any improvement by advising participants whether the next item was previously studied or new and did not worsen when these explicit cues were incorrect.

1.3.5 Processing Requirements

As outlined above, there are many potential issues that may have caused the discrepancies in the literature. Most of the above factors have received some attention, but whether age effects on implicit memory vary according to the particular processing requirements of the task has not received as much attention.

Processing style (e.g. levels of processing) is a key factor that may interact with age and influence effects on both explicit and implicit memory. Perceptual processing (sometimes called shallow) is data driven and engages participants with the physical features of stimuli, while conceptual processing (sometimes called deep) draws upon elaborate processing of the content and meaning of items. Many studies have illustrated how processing (deep/conceptual versus shallow/perceptual) produces different effects on memory (e.g. Craik & Lockhart, 1972). It is well-documented that deep/conceptual processing leads to greater explicit memory (recall and recognition) compared with shallow/perceptual processing (e.g. Brown & Mitchell, 1994; Craik & Lockhart, 1972; Gabrieli et al., 1999; Graf & Mandler, 1984; Lockhart & Craik, 1990; Mitchell & Perlmutter, 1986; Monti et al., 1996; Roediger et al., 1992). For instance, in Monti et al.'s (1996) study, 24 young and 24 older participants took part in a recall task following a two-block study phase. In the conceptual processing condition, participants were asked to decide if the presented exemplar was manmade or natural, and in the perceptual processing condition participants were asked to decide if the presented word was in uppercase or lowercase letters. Following the study phase, participants were instructed to recall as many words as possible. This study showed that conceptual processing enhanced explicit memory: recall was greater following conceptual encoding (M = 30.1%) compared with perceptual encoding (M = 9.5%). Another example is by Mitchell and Perlmutter (1986). In this study, 16 young and 16 older adults completed a conceptual (animate or inanimate word decision) and perceptual (upper or lowercase letter decision) encoding phase for word stimuli, followed by recall and recognition tasks. Based on their findings, young and older adults produced greater recall for the conceptual encoding condition, and similarly, recognition was greater following conceptual encoding compared with that in perceptual encoding.

There is some evidence that, compared to perceptual processing, the ability to engage in conceptual processes declines to a greater extent in normal ageing (e.g. Eysenck, 1974; Fleischman & Gabrieli, 1998; Gabrieli et al., 1999; Geraci & Hamilton, 2009; Jelicic, 1996; Morcom et al., 2003;

Morcom & Rugg, 2004; Roediger & Blaxton, 1987; Rybash, 1996; Weldon, 1991). For example, according to the processing deficit hypothesis (e.g. Eysenck, 1974), young adults are better able to take advantage of processing in a deep manner, however, older adults are less effective when encoding information conceptually, and this leads to age differences in memory for the studied information (e.g. Eysenck, 1974; Mason, 1979; Simon, 1979). Eysenck's (1974) study showed an interaction between age and type of encoding (conceptual/perceptual), suggesting that recall was greater following conceptual encoding than perceptual encoding but only evident in young adults. That is, older adults showed more difficulty than young adults at encoding information in a conceptual manner. This may explain why some prior studies show a decline in implicit memory in older adults on conceptual priming tasks that engage participants with semantic features of stimuli, including CEG (Jelicic, 1996; Maki et al., 1999), word association (Grober et al., 1992), CV (Light et al., 2000), and category exemplar production (CEP; Stuart et al., 2006). However, it is important to note that others have reported age-invariant priming on these tasks (e.g. Brooks et al., 2001; Isingrini et al., 1995; Java, 1996; Light et al., 2000; McEvoy et al., 1995; Mitchell & Bruss, 2003; Monti et al., 1996; Small et al., 1995). Further, some studies have produced null age differences on perceptual tests including word-stem and word-fragment completion (e.g. Fleischman & Gabrieli, 1998; Light et al., 1986; Mitchell & Bruss, 2003), perceptual identification (Ballesteros et al., 2007; Light et al., 1992; Sullivan et al., 1995; Wiggs et al., 2006), and picture naming (e.g. Mitchell et al., 1990), but yet others have reported reduced priming on these tasks (e.g. Abbenhuis et al., 1990; Chiarello & Hoyer, 1988; Russo & Parkin, 1993; Small et al., 1995; Ward et al., 2013b, 2020). Small et al. (1995) is one of only a handful of studies that has contrasted priming in perceptual and conceptual tasks, reporting similar priming in young and older adults on a fact completion task (conceptual), despite a significant age difference on a word-stem completion task (perceptual).

Researchers have also hypothesised that normal ageing may reduce attentional processes linked with production processes while identification processes remain spared (e.g. Fleischman & Gabrieli, 1998; Gabrieli et al., 1999) (discussed in section 1.3.2). The previously outlined study by Fleischman et al. (2004) examined age differences on conceptual and perceptual tests involving a mix of production and identification processing. The authors used priming tasks that strongly activate conceptual processes (CEG) versus perceptual processes (WSC, word identification, picture naming), production processes (CEP, WSC), and identification processes (word identification, picture naming). Results showed that among all these tasks, priming did not differ. However, according to Fleischman and Gabrieli, (1998) age-effects may still be linked to the processing of items during the encoding phase.

Prior studies have mixed requirements during encoding – some have encouraged conceptual encoding (e.g. semantic categorisation), while some have encouraged perceptual encoding (e.g. orientation judgements), and others have presented stimuli with no specific instructions. In this situation, it is impossible to know which type of processing participants engaged in. Age differences in priming following conceptual encoding have been reported in a number of studies (e.g. Light et al., 2000; Russo & Parkin, 1993; Ward et al., 2013b), and other studies have reported no age effect following perceptual encoding (e.g. Park & Shaw, 1992; Soldan et al., 2009, experiment 3) (for a recent review see Ward, 2022). In one study by Stuart et al. (2006) participants were asked to count vowels (perceptual) or make preference judgements (conceptual) during encoding, and priming was reduced by age in the conceptual but not the perceptual condition. However, it is unclear whether the pattern of age differences was caused by the type of processing at the encoding stage or by the type of priming task, as participants who performed perceptual encoding completed a WSC task (perceptual), whereas participants who performed conceptual encoding completed a CEG task (conceptual).

Another study by Ward et al. (2020) manipulated processing during encoding in a sample of 1072 participants. Participants performed either a conceptual or perceptual encoding task before perceptual priming and recognition were measured using the CID-R task. The data showed an age effect on priming and recognition, but there was no interaction with processing. However, the authors argued that the processing manipulation may have been ineffective, as encoding phase response times (RTs) were equivalent in the perceptual and conceptual conditions, and stimulus exposure times were potentially long enough for participants to process information in a conceptual manner even in the perceptual condition (there is evidence that conceptual processing can occur with relatively rapid presentation times; e.g. Potter et al., 2014). Additionally, it is important to note that there was no conceptual priming measure in this study. In fact, to the best of current knowledge, only one prior study by Ward, (2022) has systematically manipulated processing at both encoding and test to examine the combined effect on priming in ageing. In this study, during the perceptual encoding block participants were asked to judge if a words first and last letters were arranged alphabetically, and in the conceptual encoding block participants were asked to decide if the word depicted a living or non-living item. Following the encoding phase, participants completed two implicit memory tasks that differed in regard to the type of processing: a CV task (conceptual priming) and a perceptual identification task (perceptual priming). In the CV task, participants were instructed to decide if the presented word matched the given category (yes/no), and in the perceptual identification task participants were instructed to identify the presented word under a mask. The results demonstrated greater priming in young adults compared with older adults in both the perceptual and conceptual priming tasks, but only when prior encoding was perceptual.

On the whole, the mixed observations in the literature where age differences in priming are concerned may reflect interactions between processing at encoding and test (Franks et al., 2000; Roediger & Blaxton, 1987; Roediger & McDermott, 1993), but this has not been thoroughly examined. This is the main aim of the present thesis.

1.4 The Current Project

Explicit memory declines in normal ageing; however, to date, there is no clear conclusion regarding implicit memory. Some studies have reported a difference between young and older adults, while others have reported intact implicit memory. The present thesis aims to address several issues that may have contributed to the discrepancies in the literature, the most important being to systematically manipulate task processing characteristics to examine the effect on age differences in priming. A recognition task was also included in the studies to facilitate a comparison of the effects of ageing on both explicit and implicit memory.

Several experiments were conducted to shed light on whether implicit memory declines or remains stable with age, and in each, the manipulation of processing was implemented. Experiment 1A examined age differences in explicit (recognition) and implicit (perceptual identification) memory and interactions with processing at encoding. The CID-R task was used in this experiment, and conceptual/perceptual processing was manipulated during encoding to provide much-needed insight into its interactions with age effects on subsequent priming. As a follow up to Experiment 1A, Experiment 1B examined changes in implicit memory within the same individuals over time, studying the effect of a medium delay (8-10 months) on priming. The participants were the same as those in Experiment 1A. Following Experiments 1A and 1B, which used a perceptual priming task, Experiment 2 examined the effect of conceptual/perceptual processing during encoding on priming in young and older adults on a conceptual priming task (CEG). Experiment 3 then examined the effect of conceptual/perceptual encoding on both conceptual and perceptual priming tasks in young and older adults using a within-subject design. This study used a category verification (CV; conceptual) and CID (perceptual) tasks to assess priming, and both included a concurrent recognition judgement to allow comparison of age effects on explicit and implicit memory. All of these experiments were conducted online due to the unfortunate Covid-19 that persisted for the majority of the PhD program. However, following the easing of the restrictions in the final year, Experiment 4 was conducted. A substantial in-person replication of Experiment 3 with a few necessary modifications.

1.5 The Importance of Pre-registration

Pre-registration is a relatively new revolution in the scientific community. In a paper published by van ’t Veer and Giner-Sorolla (2016), they reported two types of pre-registration. In the first type, known as reviewed pre-registration (PRP) and also called “a registered report” (e.g. Nosek & Lakens, 2014), where studies are subjected to peer review based on their theoretical grounds and methods prior to data collection. If the researcher follows the strategy in this form of pre-registration, the research will be published regardless of the results. The second is unreviewed pre-registration (UPR). As is obvious from its name, it does not include any reviewers prior to data collection, and this is the type adhered to in this thesis (explained below).

Researchers have started sharing their research questions, methods, hypotheses, and analysis pipeline before they commence data collection (e.g. van ’t Veer & Giner-Sorolla, 2016). The entire research proposal/plan is documented on an external website with all details. There are many benefits to this: It enables the researcher to consider their study question, think about potential design issues and avoid them before beginning the study. Other substantial benefits relate to prediction and post-diction. Epistemologies define post-diction as the data used to generate hypotheses (why something occurred). In post-diction, the data are known in advance, while prediction is defined as data acquisition (what will occur). In prediction, data are used to challenge the likelihood of an incorrect prediction. Failing to distinguish between post-diction and prediction can lead to overconfidence in post-diction, and treating post-diction as predication reduce reproducibility (Munafò et al., 2017). The practice of pre-registration encourages researchers to develop sound hypotheses and suitable analysis plans in advance, serving as an important tool for differentiating between predictions and post-dictions.

Researchers can sometimes be motivated to obtain positive results, even if they are inaccurate. For example, a researcher may design a study to prove a theory, but when observing the data, they may forget the original purpose and become biased by what they discover. This scenario is referred to as cognitive bias (Christensen-Szalanski & Willham, 1991). However, pre-registration involves planning the study protocol and analyses in advance so that it is not only suitable given the hypothesis, but planned before looking at the data, which reduces issues such as bias, p-hacking and type-one errors. It also increases the credibility of the research by providing proof that the research team settled on the analysis plan before looking at the data. Therefore, it prevents researchers from using analysis and data manipulation to produce the desired results or to conduct multiple analyses. Pre-registration is also beneficial for replication, as readers are given full and transparent details about the study.

Pre-registration can be completed on various websites (e.g. https://aspredicted.org/; see Simmons et al., 2021). However, all experiments in this project were registered on the Open Science Framework (OSF; https://osf.io). The OSF is a free technology that facilitates the cycle of research, by providing the ability for researchers to not only pre-register their study protocols, but also store data, code, and other materials. In the experimental chapters in this thesis, the URL for each experiment registration is provided.

1.6 Challenges Due to the COVID-19 Pandemic

There were some challenges related to Covid-19 while completing the experiments for the PhD. Following the design for Experiment 1A and obtaining ethical approval through the Middlesex Online Research Ethics (MORE) system, and the significant amount of time which was consumed on the process of setting up and programming the study using E-prime, unfortunately, just as data collection for this experiment was about to commence, and after all the initial preparation, the research had to be abruptly stopped in March 2020 when the UK went into the first national lockdown. All in-person testing at Middlesex was halted. In the UK, the initial lockdown lasted for several months, and following this there were several smaller lockdowns totalling approximately 1.5 years of the PhD. When it became clear that the lockdown was going to be for an indefinite period, the decision was made to move the experiments online. This was initially very disappointing, and involved changes to the ethics application, including an amendment related to the mode of data collection from the lab to online testing, and changes to some of the tests themselves (see below), OSF entry and experimental setup. This required a significant amount of time. The next step was to find a suitable platform for online testing. Online research in this field was virtually non-existent, but members of the Jones, Silas, & Ward lab suggested a website for online experimental studies called Gorilla (gorilla.sc), to which the Middlesex Psychology Department had recently subscribed. Gorilla is a behavioural science research tool that uses different programming languages like JavaScript and Python allowing participants to perform tasks in their homes and on their own computers. Fortunately, there is evidence that Gorilla is capable of running sensitive reaction time (RT) experiments (Anwyl-Irvine et al., 2019), and attendance at a virtual conference provided the opportunity to gain insight into conducting experimental research online, during which a number of talks were given on researchers' experiences and tips. Subsequently, the decision was made to use the Gorilla platform to run the studies. There were also some useful lab meetings at Middlesex in which experiences using Gorilla were shared.

Moving to online testing also necessitated changing the cognitive screening measures, as most of them were inappropriate for online testing. The original intention was to use the Mini-Mental State Examination (MMSE; Folstein et al., 1975), the Wechsler Test of Adult Reading, and various subtests of the Wechsler Adult Intelligence Scale. However, all of these tests require administration by the researcher and interaction between the researcher and the participant. For example, in the MMSE the researcher needs to ask the participant a series of questions and record the responses, and some of the questions require an action or the participant needs to repeat information and phrases. Therefore, the originally planned tests were inappropriate for online testing. This experience made it clear that a cognitive screening test that can be used without researcher supervision is missing in the literature and needs to be developed. The Early Dementia Questionnaire (EDQ; Arabi et al., 2013) was used instead of the MMSE in Experiment 1A, as it can be administered without researcher supervision. The EDQ was developed in Malaysia as a screening tool to identify early dementia. Dementia symptoms on the EDQ questionnaire were divided into six different domains including: memory, concentration, emotions, sleep disturbance, physical symptoms, and others. The researchers Arabi et al. (2013) argue that the English version of MMSE was not suitable due to language and cultural differences, and therefore, the EDQ questionnaire was developed. However, after using the EDQ, there were clear limitations. The EDQ involves 20 items/sentences that should be completed by the participant on a Likert scale taking into account the previous two years, for example, “*require check list as memory support*”: “*Never* (0)”, “*Seldom* (1)”, “*Sometimes* (2)”, “*Always* (3)”. The numbers in parentheses are summed to provide an overall score (range, 0–60), and a score above seven indicate possible early dementia. Based on the experiments conducted, it was found that the EDQ is a poor instrument for screening cognitive impairment. The paper presenting the EDQ (Arabi et al., 2013) asserts that a participant who scores above seven out of 60 is deemed to have serious memory problems or early dementia. However, this was not the case in the sample; many participants who scored above seven were clearly unimpaired, and they were deemed eligible to take part in the study. Their communication and their performance on the experiment itself did not show any evidence of impairment. No one showed difficulty in reading or writing, and it was obvious from the collected data that they had normal functions. All of this is discussed in more detail in Chapter 2 where the findings of Experiment 1A are discussed. Hence, no older participants were excluded from the online studies on the basis of cognitive screening, and it could be argued that the EDQ is inadequate for screening cognitive impairment.

Challenges in relation to the recruitment of older participants also arose due to online testing, and gaining access to the target population proved to be difficult initially, and although a number of older adults were recruited through the University of the Third Age (U3A), data collection progressed slowly. It is believed that, without the pandemic, older participants could have been found and reached out in various public places easier. However, tight lockdown restrictions made this impossible for many months. In addition, a minimum connection speed of 8 Mbps was required to ensure that low internet speeds did not affect stimulus presentation times or the recording of RTs. Unfortunately, many older adults seemed to have poor internet speeds, and due to the pandemic, they were unable to use public internet in cafés. Another issue encountered during the recruitment of older participants was their lack of computer experience, leading to difficulties in downloading the EDQ, which was required to be returned via email prior to taking part in the online study (Experiment 1A). If testing had taken place in a laboratory setting, none of these issues would have arisen.

One other initial concern related to online testing was the possibility of random responses from non-human participants. Non-human responses (e.g. bots or automated form fillers) have become quite popular, especially with the increasing number of online studies that offer a financial reward (Dennis et al., 2018). This issue can lead to large distortions in the final results (Crede, 2010). However, in all conducted experiments, no automated responses were detected, as confirmed by careful screening of the data. For example, bots cannot perform the recognition task with above-chance accuracy, nor do they have the ability to type in names of objects, especially given that trials were randomised between participants. Therefore, there is confidence that the experiments were completed by real participants. Cheating and/or not following instructions were additional concerns, considering that in online studies, participants could feasibly write information down or fail to follow instructions in other ways given the lack of supervision. For example, participants could take written notes during the memory task or use the internet to look up answers for other parts of the task. However, it is not believed that this occurred in the experiments, as response RTs looked normal and highly comparable with similar lab-based studies. Moreover, each phase of the experiment was paced, with fixed, brief time limits, which would have prevented participants from looking up answers or attempting to cheat. Another consideration to think about, especially in ageing studies, is that some people may not disclose their true age. This is an important issue for researchers to consider when conducting online studies. However, the Prolific platform (www.prolific.co) that was used in many of the online studies in this thesis requires that all participants give their basic demographic information when signing up and before being able to take part in any studies (see Greene & Naveh-Benjamin, 2022). Prolific also enables pre-screening option to allow researchers to include only participants within a target population, such as older adults for example. Nevertheless, as hard as there was an effort to control the online experiments, these sorts of experimental studies can never be as controlled as in a laboratory setting, where it can be assured that participants perform the task as intended.

1.6.1 Advantages of Online Testing

Although there was an initial feeling that moving to online testing was a setback, later on, numerous advantages of online testing were discovered. As mentioned, it has been demonstrated that Gorilla is sensitive to capturing reliable RTs, as well as replicating well-known paradigms such as the flanker task (Anwyl-Irvine et al., 2019), and reassurance was found following a talk at the Virtual BeOnline Conference (2021), where several researchers stated that their data gathered during online testing were comparable to those collected in a lab environment. Their advice was implemented in the setup of the online studies, with clear instructions provided to participants to ensure their understanding of the task and the conditions under which to attempt it. For example, participants were instructed to: (1) complete the experiment in a private space, free of distractions such as phones, television, etc, (2) complete the task when they had ample time as the experiment cannot be paused or restarted, and (3) read all instructions thoroughly and only start the experiment when they were confident that they understood how to perform the task.

Once the hang of online recruitment was gained, it was found that online testing provided an excellent way of accessing large samples and was much faster than in-person testing. Since four experiments (Experiments 1A, 1B, 2 and 3) were conducted online, a larger and more diverse population could be accessed than would have been possible in the laboratory, where reliance would on local residents. In contrast, research conducted in the lab often faces the challenge of finding participants willing to travel to campus. Further, although online testing was initially slow, it was still much faster than lab testing and allowed for the recruitment of multiple participants at a time, whereas this would not have been possible in the lab. Online testing also opened other doors in terms of recruitment, as the recruitment service Prolific was discovered, which allowed for the recruitment of a large volume of participants of all ages. Participants also found the online format convenient, as they were able to choose a time that best suited their situation. For example, parents were able to do the online experiment after their children were asleep. The ability to complete the test at any time also allowed working participants to participate who would not have been able to do so otherwise. Finally, conducting studies online using Gorilla provided valuable experience and knowledge in relation to this new way of conducting experiments. While many studies have been conducted on memory and ageing, none had previously been completed online, so the present body of work provides much-needed insight into this mode of testing. Believing that online testing will become the most common way to conduct experiments in the future.

Chapter 2: The Effects of Processing During Encoding on Perceptual Implicit Memory (Experiment 1A and 1B)

2.1 Chapter Introduction

As discussed in Chapter 1, normal ageing clearly affects explicit memory, but there is ongoing disagreement about whether or not implicit memory declines with age. Task processing requirements have varied considerably between past studies, and this may underly some of the inconsistencies in the literature. No study has thoroughly examined this issue, hence the aim of this PhD. Experiment 1A examined age effects on explicit (recognition) and implicit (perceptual identification) memory using the CID-R task, and interactions with processing (conceptual/perceptual) during encoding. Although there is abundant evidence that ageing affects explicit memory, the recognition task was included here in order to compare the effects on explicit and implicit memory. Participants were exposed to a stream of objects during the encoding phase, half of which were processed in a conceptual manner, and half in a perceptual manner, prior to the CID-R task to measure perceptual priming and recognition. It is important to not just conduct cross-sectional studies, comparing young and older adults at one point in time, but also examine longitudinal changes in implicit memory over time in the same individuals and measure changes in priming over delays. In order to study the effect of a medium delay (8-10 months) on perceptual priming, the same participants from Experiment 1A were invited to take part in Experiment 1B to perform the identical task in Experiment 1A.

2.2 Experiment 1A

Experiment 1A was pre-registered on the OSF prior to data collection (https://osf.io/uz2ka; under the name of ‘Experiment 1’). All pre-registered steps and analyses were followed, and any changes or additional analyses are clearly stated. The raw data and analysis file for the final sample are available in the OSF (https://osf.io/t7b2y).

2.2.1 Hypotheses

Based on prior literature the following hypotheses were made: (a) greater recognition in young than older adults. (b) greater priming in young than older adults (e.g. based on Ward et al., 2020). (c) It was expected that conceptual processing during encoding will lead to greater recognition than perceptual processing, but given the lack of prior research, no directional hypothesis was made in relation to priming. (d) It was expected that an interaction between age and processing would emerge, with greater recognition for conceptually processed items in young adults, and weakest recognition for perceptually processed items in older adults. No directional hypothesis for this interaction was made for priming.

2.2.2 Methods

2.2.2.1 Participants

The sample size was estimated using G*Power, with an estimated effect size of 0.15, alpha set at .05, and power set at 0.85. This resulted in a total required sample size of 70 participants (35 young and 35 older). Young adults aged between 18 and 30 years (*M*= 20.51, *SD* = 3.16; 29 females and six males) and older adults aged between 65 and 87 years (*M*= 70.49, *SD* = 4.84; 18 females and 17 males) participated in this experiment. Young participants were recruited from the Middlesex University recruitment system (Sona; 24 participants) and social media (11 participants), and older participants were recruited from the University of The Third Age (U3A; www.u3a.org.uk; 15 participants) and Prolific.ac recruitment service (20 participants). All participants were rewarded with course credit or payment at a rate of £9 per hour. Ethical approval was granted from the Middlesex University Research Ethics Committee (Approval code: 8701). Eligibility criteria for participants included that all older participants should be free of dementia, and all participants were fluent in reading and writing in English, had normal/corrected vision, and had received at least a general certificate of secondary education (GCSE) qualification. A formal measure of pre-morbid intelligence was taken (the multiple choice component of the Mill Hill Vocabulary Test; Raven et al., 1988), and older adults were screened for cognitive impairment using the Early Dementia Questionnaire (EDQ; Arabi et al., 2013) (see section 2.2.2.4). The demographic data for the participants can be seen in Table *2.1*.

Table 2.1. Participant Characteristics in Experiment 1A

Characteristics	**Young Adults** ***M*** **(*SD*)** **(*n* = 35)**	**Older Adults** ***M*** **(*SD*)** **(*n* = 35)**
Age (years)	20.51 (3.16)	70.49 (4.84)
Gender (M/F) (*n*)	6/29	17/18
Education (years)	14.89 (1.57)	15.26 (2.73)
Highest Qualification (*n*)		
GCSE or equivalent	3	8
A level or equivalent	27	8
Bachelor's degree	4	11
Master's degree	1	6
PhD	0	2
Working or Retired (*n*)	NA	
Working Full-time	-	2
Working Part-time	-	7
Retired	-	26
Health Status (*n*)		
Excellent	16	9
Good	14	19
Adequate	5	6
Poor	0	1
Extremely Poor	0	0
Trouble of Vision (*n*)		
Yes	0	0
No	34	35
Somewhat	1	0
Mill Hill Vocabulary *	15.83 (5.34)	24.20 (4.06)
EDQ	NA	11.15 (7.33)

Note. Standard deviations for all mean values are given in the parentheses. The multiple-choice part of the Mill Hill Vocabulary Test (Raven et al., 1988) was used, which served as a standard measure of pre-morbid intelligence with a maximum score of 33. The EDQ (Arabi et al., 2013) is a short cognitive screening test consisting of 20 items with a maximum score of 60. *Significant differences between groups, p < .05.

2.2.2.2 Design

Experiment 1A involved a mixed factorial design with Age (young/older adults) as the between-subjects factor, and Processing during encoding (conceptual/perceptual) as the within-subjects factor. Perceptual priming and recognition were measured using the continuous identification with recognition (CID-R) task described previously in Chapter 1. The priming segment, which involved perceptual identification, examined the proportion of priming based on response times (RT new – RT old)/RT new). Considering that slower responses in older adults compared to younger ones can artificially boost priming scores when calculated based on RTs, the approach chosen was to calculate priming in proportion to baseline RTs (e.g. Faust et al., 1999). Recognition was based on *d* prime: z(hits) – z(false alarms).

2.2.2.3 Stimuli

All visual stimuli were taken from the Bank of Standardized Stimuli (BOSS), a large photobank providing norms for more than 15 dimensions (e.g. familiarity, visual complexity, and manipulability; Brodeur et al., 2010, 2014). The online experiment was constructed using Gorilla.sc (https://gorilla.sc/) on a screen size of 2560 × 1600 pixels, and stimuli were 320 × 320 pixels presented in colour. The mask used in the priming task was 384 × 384 pixels presented in white and black and was created using a script that randomly superimposed lines and arcs of a similar thickness onto lines of objects in the stimuli see (Figure 4A). Approximately half of the stimuli were naturally occurring items, and the other half were manufactured (Figure 4B). Participants completed the experiment online on their own computers, and screen sizes varied between 1189 × 669 pixels and 2048 × 1152 pixels. Therefore, the exact size of the images for any given participant depended on their screen size, but stimuli were automatically configured by Gorilla to fit within the confines of the zone. In total, 160 stimuli (*M* familiarity = 4.37, *SD* = 0.36) were used across two counterbalanced experimental blocks: conceptual encoding followed by CID-R test; perceptual encoding followed by CID-R test. Eighty items were presented in each block, 40 in the encoding phase and 80 at test [40 previously studied (20 perceptual and 20 conceptual items) and 40 new].

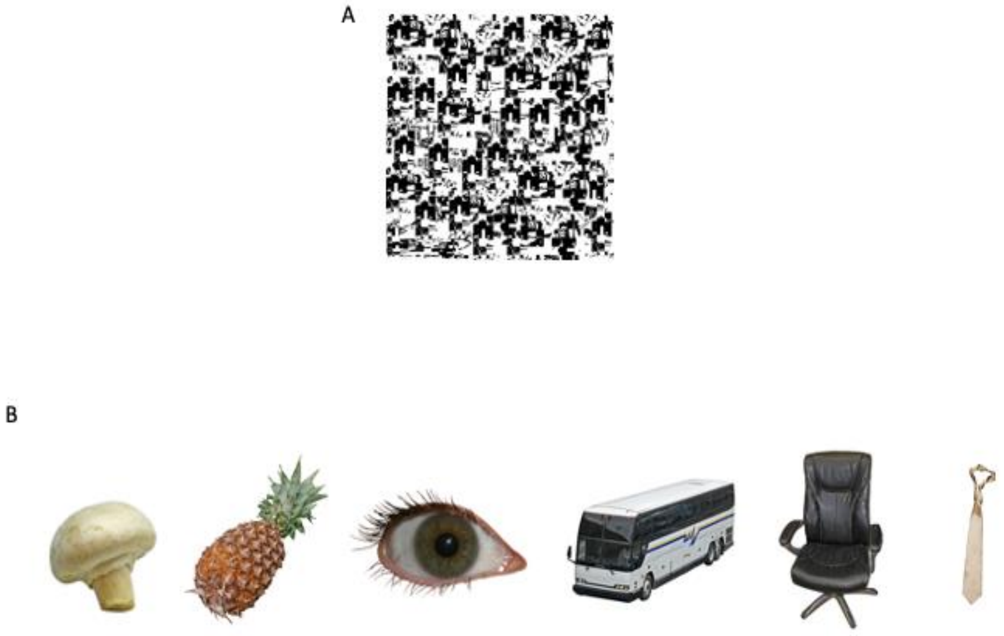

Figure 4. Examples of Mask and Stimuli Used in Experiment 1A.

Note. (A) the black mask used in the CID-R task in Experiment 1A. (B) Examples of objects used as stimuli in Experiment 1A.

2.2.2.4 Procedure

Due to the global Covid-19 pandemic, the study was created online using Gorilla Experiment Builder (https://gorilla.sc/), and participants performed the task in their homes using their own computers (desktops or laptops, not phones or tablets). There were restrictions regarding the browser type that could be used; only the following browsers were allowed: Chrome, Firefox, Safari and Internet Explorer, to minimise differences that can arise when using different browsers. A minimum connection speed of 8 Mbps was required, to ensure that slow internet speed did not affect the presentation of images or recording of RTs. The study link was sent to participants via email, but some accessed the experiment through Prolific or the SONA system. Participants were asked to complete the online study in a quiet room and only when had ample time, as they were instructed that once they started the study, it could not be paused or resumed at a later time. Participants were fully briefed about the nature of their involvement in the study and provided informed consent by ticking a box on the screen. The experimental task would only proceed if the consent box was ticked. All participants gave their consent, confirming that they had read and understood the information sheet, and that they met all the eligibility criteria. This included consenting that they were free of cognitive impairment or dementia, aged between 18-30 years for young adults or 65 years and above for older adults, fluent in English, had normal vision (corrected with glasses was acceptable), and did not suffer from colour blindness. Following this, background information was collected on age, sex, self-reported health, years of education, highest qualification achieved, self-rated vision, and professional status (working or retired).

2.2.2.4.1 Experimental Task

2.2.2.4.1.1 Encoding Phase

The experiment was divided into two counterbalanced blocks: one involving conceptual processing in the encoding phase, and one involving perceptual processing in the encoding phase. During encoding, participants viewed 40 objects. On each trial, a black fixation ('+') was presented for 500 ms, followed by an object presented in the centre of a white background screen for a duration of 500 ms. In the conceptual condition, participants judged whether each object was manmade or natural, a decision that required participants to access the meaning of the object, and in the perceptual condition they judged whether each object was upright or tilted, a decision that required participants to engage with purely physical features of the stimuli to judge the rotation. To respond, participants were instructed to use keyboard keys 'Z'= upright/natural; 'M'= tilted/manmade. Participants were asked to respond as quickly as possible. The instructions to press either 'Z'= natural, 'M'= manmade (conceptual condition) or 'Z'= upright, 'M'= tilted (perceptual condition) remained on the screen until participants made the decision. There were 40 trials in each block, and stimuli were presented in new random for each participant.

2.2.2.4.1.2 Filler Phase

Between the encoding and test phases, there was a brief mental arithmetic filler phase that took three minutes to be completed. The purpose was to provide an unrelated non-verbal task to avoid primacy and recency effects and ensure that all participants have the same duration between the encoding and test phases. In the filler phase, participants were presented with random numbers (1-9) and their task was to decide as quickly as possible whether each number was odd or even by selecting an on-screen response option. A fixation cross ('+') was presented for 500 ms, followed by a number presented for 5000 ms.

2.2.2.4.1.3 Test Phase – CID-R Task

The CID-R task was used to assess priming and recognition, and two separate CID-R tests were performed – one per block (i.e. following the conceptual and perceptual encoding phases). The two CID-R tasks were identical except for the stimuli. Eighty objects appeared in each CID-R task (40 studied in the encoding phase immediately prior and 40 new), and on each trial, measures of priming and recognition were captured. Participants were informed that on each trial the object would be presented, but it would be behind a mask and difficult to see at first. They were instructed that the object would appear to flash and emerge from behind the mask, gradually becoming clearer. On each trial, the object was initially presented for 16 ms (screen refresh rate) and immediately masked (Figure 5). The object and mask presentation then alternated with the object's presentation increasing by 16 ms each time and the mask duration decreasing by 16 ms each time, with the effect that the object appears to gradually clarify. Participants were instructed to identify the object as quickly as they could by pressing the 'Space bar'. At this point, their identification RT was captured, and they were prompted to type the object name into a box on the screen and then press 'Enter'. Following the priming measure, the same object was presented again for a recognition judgement, whereby participants were prompted to judge whether the object was previously shown in the encoding phase or was new. Participants were informed that half of the objects were presented previously, and half were new. Participants responded on a six-point scale where 1= Sure no, 2= Think no, 3= Guess no, 4= Guess yes, 5= Think yes, 6= Sure yes (Figure 5). A six-point scale was used to allow a broad range of "yes (recognise)" and "no" (do not recognise) responses that capture different levels of confidence, which is thought to overcome potential issues with response bias (e.g. Ward et al., 2013b). That is, participants who may be less sure about whether they recognise a particular item have the option of selecting 'guess yes' rather than having to choose between simply yes and no (where some participants may be more likely than others to select "no" when they feel like they are guessing). In this way the use of a recognition scale is more sensitive than a simple yes/no response. The use of such a scale also provides a possibility for more detailed analysis of confidence in recognition judgements, however, this was not possible in any experiment in this thesis because participants did not always use all response options. Thus, in all experiments the scores on the scale were collapsed into 'yes' (4-6) and 'no' (1-3) responses for analysis and this is very common practice. In the event that a participant had not identified the object in the priming task by the time it was fully presented (7000 ms), then the task automatically moved to the recognition judgement. Missed priming trials such as this (i.e. with RTs above 7000 ms) were removed before analysis.

2.2.2.4.1.4 Background Tests

Older participants were first required to complete the EDQ (Arabi et al., 2013; see Appendix) as a brief cognitive screening. It was used in place of the MMSE (Folstein et al., 1975; which was not suitable for online administration) in an attempt to ensure that the sample of older adults met the criteria of having no cognitive impairment. This was emailed to older participants, and they completed the questionnaire and emailed it back to the researcher prior to taking part in the study. The EDQ is a short questionnaire consisting of 20 items, which participants answered on a Likert scale: (0) Never, (1) Seldom, (2) Sometimes, (3) Always (e.g. Require check list as memory support). As discussed previously, on the OSF entry, it was specified that participants scoring above seven would be excluded. However, in practice this was not feasible (discussed later).

In addition, all participants also completed a standard pre-morbid intelligence test (The multiple-choice part of the Mill Hill Vocabulary Test; Raven et al., 1988; see Appendix). This task was chosen as it is suitable for completion online by participants without supervision. In this test, participants were shown 33 single words and asked to select from one of six options of other words that matched the meaning of the target word (e.g. Lavish: unaccountable, romantic, extravagant, selfish, lawful, and prise; maximum score = 33). Finally, at the end of the experiment (Experimental task), participants performed a short awareness questionnaire containing four questions adapted from Bowers and Schacter (1990): (1) What do you think was the purpose of the identification task you performed? (2) Did you suspect prior to the start of the identification task that you would be tested on your memory of the pictures? (3) Did you try to use your memory of the pictures to help you in this task? ('Yes'/'No') (4) If yes do you think this strategy helped you, and how so?

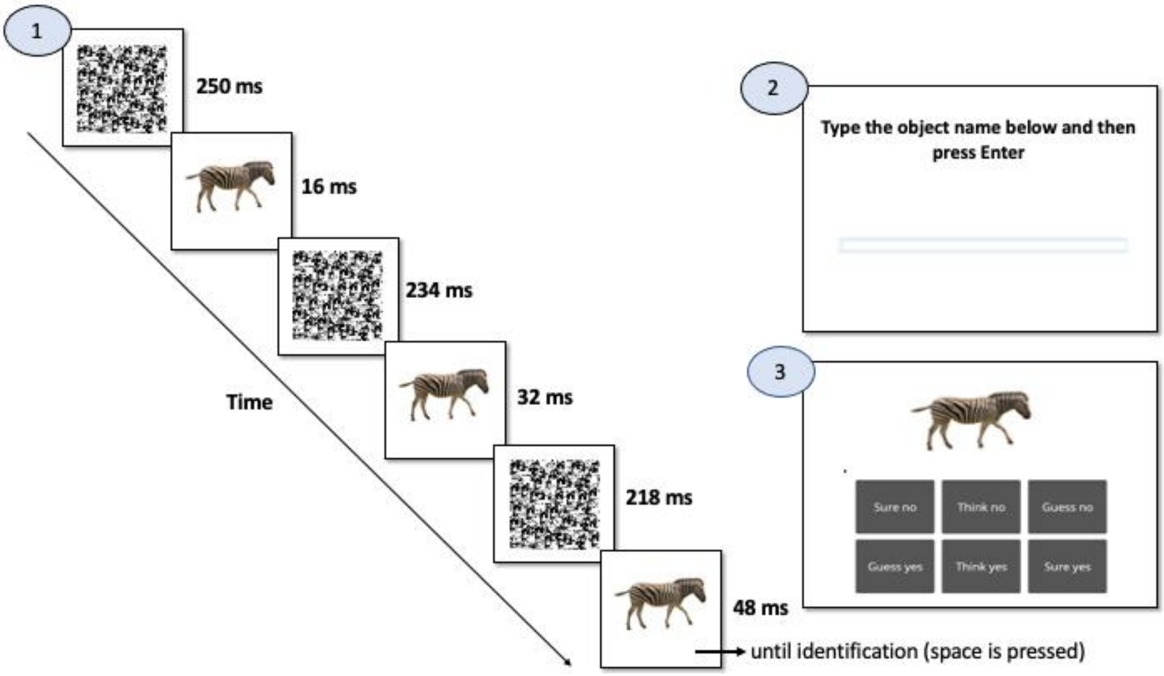

Figure 5. The Continuous Identification with Recognition (CID-R) Task Used in Experiment 1A.

Note. Depiction of a single trial within the CID-R task to assess priming and recognition. Participants were instructed to identify the emerging object as quickly as possible (priming segment), before making a recognition judgment. In the priming segment the object is initially shown for 16 milliseconds (ms), and following this the duration of object presentation increased by 16 (ms) on each presentation while the mask duration decreased by this amount. The clarification procedure ceases at the point at which participants identify the object (RT captured) and participants are then prompted to type the object name into a box prior to making a recognition judgment.

2.2.3 Results of Experiment 1A

2.2.3.1 Analysis

To examine the hypotheses, the main analysis involved separate 2 Age (young/older) × 2 Processing (conceptual/perceptual) repeated measures analysis of variance (ANOVA) on priming and recognition scores, with Age as a between-subjects variable, and follow-up test comparisons in the event of a significant interaction. An alpha level of .05 was used for all statistical tests. Partial eta squared (η_p^2) effect sizes are reported for ANOVA effects and Cohen's *d* and confidence interval for *t*-tests. Bayes factor analysis was conducted for any non-significant effects, with BF10 values of less than 1/3 considered support for the null hypothesis (Dienes, 2014). All data were analysed using JASP version 0.16.2 (JASP Team, 2023).

2.2.3.2 Data Screening and Exclusion

Participants were excluded if they did not meet the eligibility criteria, if they failed to complete the experiment task in full or follow the instructions. Twenty participants in total were replaced for the following reasons: 19 participants failed to follow the experiment instructions (did not press the 'Space' key as instructed in the identification task), and one participant requested to withdraw their data. It was stated in the OSF pre-registration that older participants who score above seven on the EDQ (Arabi et al., 2013) screening for cognitive impairment would not be eligible to perform the experimental task. However, in practice exclusions based on the EDQ were not feasible in this study, so no participants were excluded on the basis of their EDQ score. Twenty-two participants scored above seven on the EDQ, but it was clear that these participants were not cognitively impaired for various reasons: (1) there were no issues with their correspondence with the researcher in relation to the study and reported that they had no concerns with cognitive impairment; (2) all participants confirmed during informed consent that they were free from cognitive impairment/dementia and did not have any concerns in relation to their memory; (3) there were no outliers in the experiment data to suggest abnormal memory function. The decision to disregard the EDQ data and allow all older participants to take part in the Gorilla task was based on the apparent weaknesses of the EDQ as a screening measure and was discussed further in Chapter 1. Usually, in this form of research, the Mini-Mental State Exam (MMSE; Folstein et al., 1975) is the preferred choice of cognitive screening measure, and indeed the original intention was to use this task before the necessity of moving online due to the pandemic. Unfortunately, the EDQ does not appear to be an appropriate screening tool for self-administration (explored further in the discussion).

2.2.3.3 Encoding Phase

The proportion of correct responses and associated response times (RT) in the conceptual and perceptual encoding blocks is summarised in Table *2.2*. In the perceptual encoding block, since the correct answer (upright/tilted) was somewhat subjective, accuracy was calculated based on the majority response by participants. That is, if the majority of participants judged a presented image as tilted, then tilted was considered the correct answer.

Data were analysed using a 2 (Age) × 2 (Processing) repeated measures ANOVA. There were main effects of Processing, $F(1, 68) = 222.98$, $p < .001$, $\eta_p^2 = 0.77$, and Age, $F(1, 68) = 8.73$, $p < .001$, $\eta_p^2 = 0.11$, on accuracy in the encoding phase, but no significant interaction between Processing × Age $F(1, 68) = 0.38$, $p = .538$, $\eta_p^2 = 0.01$, (BF10 = 0.30). Participants were generally more accurate in the conceptual (Marginal Mean = 91.75%) than the perceptual (Marginal Mean = 76.25%) encoding block (i.e. in their natural/manmade judgements compared to upright/tilted judgements), and young adults (Marginal Mean = 85.64%) were more accurate than older adults (Marginal Mean = 82.36%). On RTs in the encoding phases, there was no main effect of Processing $F(1, 68) = 1.34$, $p = .251$, $\eta_p^2 = 0.02$, (BF10 = 0.33) or Age, $F(1, 68) = 0.02$, $p = .903$, $\eta_p^2 = 2.19$ (BF10 = 0.32), and no significant interaction between Processing × Age, $F(1, 68) = 0.70$, $p = .405$, $\eta_p^2 = 0.01$ (BF10 = 0.32).

Table 2.2. The Performance of Young and Older Adults in the Encoding Phase in Experiment 1A

Encoding Phases	**Young Adults** ***M* (*SD*)**	**Older Adults** ***M* (*SD*)**
Accuracy (%)		
Conceptual Encoding	93.07 (6.16)	90.43 (7.27)
Perceptual Encoding	78.21 (6.08)	74.29 (6.18)
RTs (ms)		
Conceptual Encoding	966 (283)	922 (285)
Perceptual Encoding	979 (360)	1004 (492)

Note. Standard deviations for all mean values are given in the parenthesis.

2.2.3.4 Recognition

As outlined in the method, recognition was captured within the CID-R task. Across the whole CID-R task a number of trials were removed for each participant, which was based on various pre-registered criteria used to determine which trials would be excluded (discussed in section 2.2.3.5 as primarily relates to priming). The total number of excluded trails in the CID-R task in this experiment was 423 out of 5600 in the young group, and 589 out of 5600 in the older group.

To assess recognition, *d′* was calculated for each participant by subtracting z-transformed hits (proportion of old items judged old) minus z-transformed FA (proportion of new items judged old), (see Figure 6 and Table *2.3*). The Snodgrass and Corwin (1988) correction was applied to hit and false alarm rates with values of zero or one (i.e. Hit rate = (n Hits + 0.5) / (n old + 1); FA rate = (n FAs + 0.5) / (n new+1) prior to calculating *d'*.

Data were analysed using a repeated measures ANOVA with the within-subjects factor of Processing (conceptual versus perceptual) and between-subject factor Age (younger versus older adults). There were significant main effects of Processing, *F*(1, 68) = 149.81, *p* < .001, η_p^2 = 0.69, and Age, *F*(1, 68) = 23.92, *p* < .001, η_p^2 = 0.26, and a signification interaction between the two, *F*(1, 68) = 21.24, *p* < .001, η_p^2 = 0.24. The significant main effect of Processing indicated that participants showed greater recognition in the conceptual condition (Marginal Mean: d prime = 1.55) than the perceptual condition (Marginal Mean: d prime = 0.07), and the significant main effect of Age indicates that young adults (Marginal Mean: d prime = 1.12) outperformed older adults (Marginal Mean: d prime = 0.50).

Follow-up paired t-tests (all two-tailed) indicated that recognition in young adults was greater in the conceptual condition (*M* = 2.14, *SD* = 0.93) than the perceptual condition (*M* = 0.10, *SD* = 0.27), *t*(34) = 12.22, *p* < .001, *d* = 2.07, 95% CI [-2.37, -1.69], and similarly in older adults (conceptual *M* = 0.96, *SD* = 1.07; perceptual *M* = 0.04, *SD* = 0.26, *t*(34)= 5.27, *p* < .001, *d* = 0.89, 95% CI [-1.28, -0.57]). Independent t-tests (two-tailed) showed no significant difference between young adults (*M* = 0.10, *SD* = 0.27) and older adults (*M* = 0.04, *SD* = 0.26) in the perceptual condition, *t*(68) = 1.05, *p* = .299, *d* = 0.25, 95% CI [-0.06, 0.19], (BF10 = 0.39), but in the conceptual condition recognition was significantly greater in young adults (*M* = 2.14, *SD* = 0.93) than older adults (*M* = 0.96, *SD* = 1.07), *t*(68) = 4.91, *p* < .001, *d* = 1.17, 95% CI [0.70, 1.66].

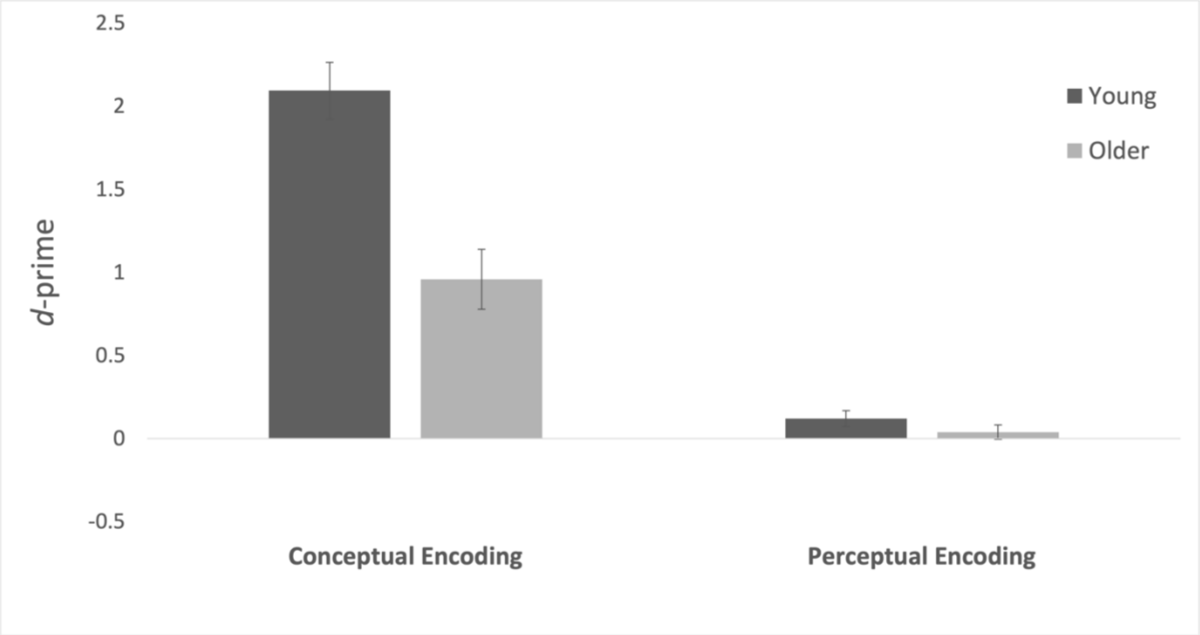

Figure 6. Recognition in Young and Older Adults in the Conceptual and Perceptual Conditions in Experiment 1A.

Note. Error bars represent standard error of the mean (SEM).

Table 2.3. The Proportion of Hits, FA, Misses, and CR in Experiment 1A

Measure	**Conceptual Condition**		**Perceptual Condition**	
	Young	**Older**	**Young**	**Older**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Hits	0.87 (0.12)	0.86 (0.15)	0.58 (0.21)	0.67 (0.32)
False Alarms	0.25 (0.30)	0.56 (0.41)	0.55 (0.21)	0.66 (0.32)
Misses	0.13 (0.12)	0.13 (0.15)	0.42 (0.21)	0.32 (0.32)
CR	0.75 (0.31)	0.44 (0.41)	0.45 (0.21)	0.34 (0.32)

Note. Hits: old items correctly judged old; Misses: old items incorrectly judged new; FA: new items judged old; CR: new items correctly judged new. CR stands for correct rejection, and FA stands for false alarms. Standard deviations for all mean values are given in the parentheses.

2.2.3.4.1 Additional Recognition Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether recognition was above zero in each condition. Recognition (Figure 6) in young adults was significantly above zero in the conceptual, $t(34) = 13.53$, $p < .001$, $d = 2.29$, 95% CI [1.82, 2.46,] and perceptual conditions, $t(34) = 2.31$, $p = .027$, $d =$

0.39, 95% CI [0.01, 0.20]. However, in older adults recognition was above zero only in the conceptual condition, *t*(34) = 5.32, *p* < .001, *d* = 0.90, 95% CI [0.59, 1.33]. The perceptual condition was not significantly above zero in older adults, *t*(34) = 0.90, *p = .*377, *d* = 0.15, 95% CI [-0.05, 0.13], (BF10 = 0.26).

2.2.3.5 Priming

Trials associated with incorrect object identifications were removed (spelling mistakes were permitted), as well as any trials with RTs below 200 ms, above 7000 ms (the point in the clarification procedure at which the object was fully displayed), or greater than 3SD from the mean (for old and new items separately). Priming was calculated by subtracting each participant's mean RT for old items from their mean RT for new items, expressed in proportion to their mean baseline (new item) RT [(RTnew – RT old)/ RT new] and averaged across participants (see Figure 7 and Table *2.4*).

Data were analysed using a repeated measures ANOVA with the within-subjects factor of Processing (conceptual versus perceptual) and between-subject factor Age (young versus older adults). The results showed main effects of Processing, *F*(1, 68) = 340.52, *p* < .001, η_p^2 = 0.83, and Age *F*(1, 68) = 14.64, *p* < .001, η_p^2 = 0.18, and a significant interaction between Processing × Age, *F*(1, 68) = 18.64, *p* < .001, η_p^2 = 0.22. The significant main effect of Processing indicated that participants showed greater priming in the conceptual condition (Marginal Mean: prop. priming = 0.16) than the perceptual condition (Marginal Mean: prop. priming = -0.05), and the significant main effect of Age indicated that young adults (Marginal Mean: prop. priming = 0.08) outperformed the older adults (Marginal Mean: prop. priming = 0.03).

Follow-up paired t-tests (two-tailed) indicated that priming in young adults was significantly greater in the conceptual condition (*M* = 0.21, *SD* = 0.08) than the perceptual condition (*M* = -0.05, *SD* = 0.09), *t*(34) = 17.22, *p* < .001, *d* = 2.91, 95% CI [0.23, 0.29], and similarly for older adults, their priming was significantly greater in the conceptual condition (*M* = 0.11, *SD* = 0.06) than the perceptual condition (*M* = -0.06, *SD* = 0.07), *t*(34) = 9.42, *p* < .001, *d* = 1.59, 95% CI [0.13, 0.20]. Independent t-tests (two-tailed) showed no significant differences between young (*M* = -0.05, *SD* = 0.09) and older adults in the perceptual condition (*M* = -0.06, *SD* = 0.07), *t*(68) = 0.19, *p* = .850, *d* = 0.05, 95% CI [-0.03, 0.04], (BF10 = 0.25), but in the conceptual condition priming was significantly greater in young adults (*M* = 0.21, *SD* = 0.08) than older adults (*M* = 0.11, *SD* = 0.06), *t*(68) = 6.09, *p* < .001, *d* = 1.46, 95% CI [0.07, 0.13].

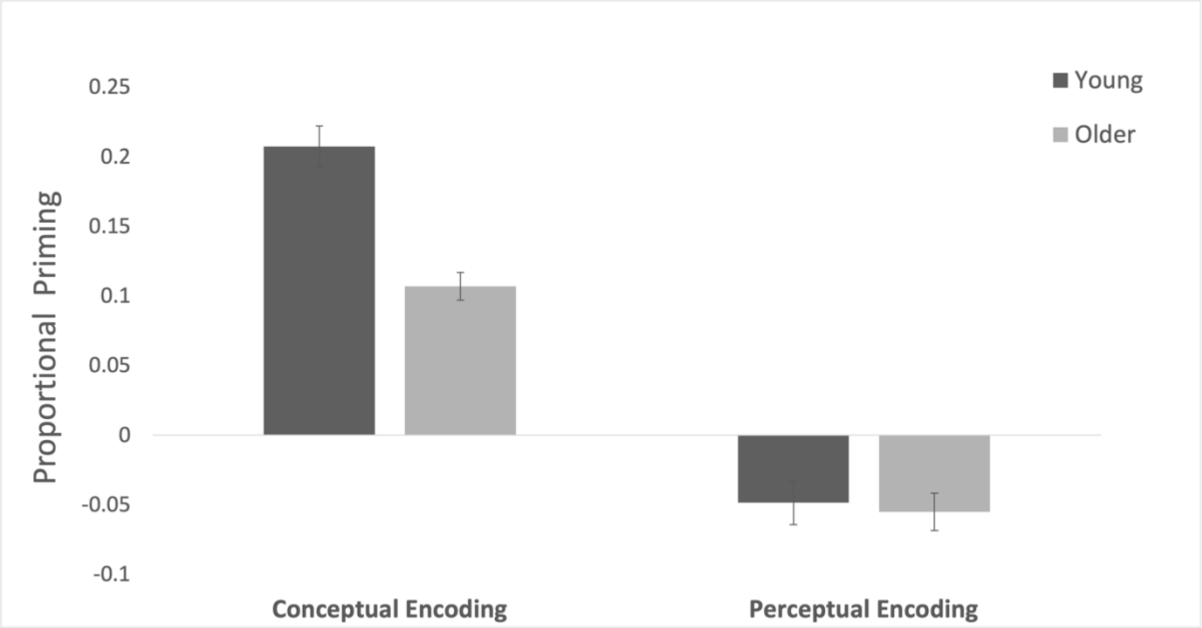

Figure 7. Priming in Young and Older Adults in the Conceptual and Perceptual Conditions in Experiment 1A.

Note. Error bars represent standard error of the mean (SEM).

Table 2.4. Mean RTs for Young and Older Adults in Experiment 1A

Measure	**Conceptual Condition**		**Perceptual Condition**	
	Young	**Older**	**Young**	**Older**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
RT Old (ms)	2501 (534)	3315 (616)	2808 (585)	3680 (678)
RT New (ms)	3157 (573)	3718 (659)	2673 (534)	3501 (672)

Note. Standard deviations for all mean values are given in the parenthesis.

2.2.3.5.1 Additional Priming Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether priming was above zero in each condition. Priming (Figure 7) in young adults was significantly above zero in the conceptual condition only, *t*(34) = 15.25 , *p* < .001 , *d* = 2.58, 95% CI [0.18, 0.24], and similarly priming in older adults was significantly above zero only in the conceptual condition, *t*(34) = 10.99 , *p* < .001, *d* = 1.86, 95% CI [0.09, 0.13]. Priming in the perceptual condition was negative in both young and older adults: Young: *t*(34) = 3.53 , *p* = .001 , *d* = 0.60, 95% CI [-0.08, -0.02]; Older: *t*(34) = 4.46, *p* < .001 , *d* = 0.75, 95% CI [-

0.08, -0.03]. In general, priming occurred more frequently in the conceptual condition than the perceptual condition (Table *2.5*).

Table 2.5. Number of Participants Showing a Positive Priming Score in the Conceptual and Perceptual Conditions in Experiment 1A

Conditions	**Conceptual Condition**	**Perceptual Condition**
Young Adults (*n*)	35	10
Older Adults (*n*)	34	6
Total (*n*)	69	16

2.2.3.6 Awareness Questionnaire

Participants completed a brief awareness questionnaire at the end of the experiment (see section 2.2.2.4), to gauge whether they became aware of the purpose of the identification (implicit memory) task. During the priming segment of the CID-R task participants identified objects as they emerged, but if participants became aware that this task was related to memory, it is possible that they may have attempted to use an explicit strategy, and this could affect the overall results (although, note from the General Introduction that there is much evidence that the CID-R task is immune to explicit contamination). Given that a concurrent recognition judgement is captured on every trial, participants are aware that their memory is being tested, but they are not specifically informed that the identification task is also a form of memory test. If an explicit strategy somehow facilitates object identification, for example, by speeding up responses, this could artificially boost priming, and young adults would be at an advantage given their greater explicit memory. Any participant who identified the purpose of the identification task and stated that they had become aware during the course of the task was deemed aware at the time of testing. In total, six young and seven older adults became aware that the identification priming task was related to memory. As so few participants were deemed aware at the time of testing, and as the number did not reach the 20% as reported in the pre-registration, no further analysis was conducted to compare aware versus unaware participants, but the means are presented in Table *2.6*.

Table 2.6. Priming Scores for Aware and Unaware Participants in Experiment 1A

Awareness Questionnaire	**Aware**	**Unaware**
	***M* (*SD*)**	***M* (*SD*)**
Conceptual Priming (prop. Priming)		
Young	0.24 (0.05)	0.21 (0.09)
Older	0.14 (0.05)	0.10 (0.06)
Perceptual Priming (Prop. Priming)		
Young	-0.06 (0.05)	-0.05 (0.09)
Older	-0.08 (0.09)	-0.05 (0.07)

Note. Standard deviations for all mean values are given in the parenthesis.

2.2.3.7 Covariate Analysis (not pre-registered)

An independent sample t-test showed that older adults (*M* = 24.20; *SD* = 4.06) had significantly better performance than young adults (*M* = 15.83; *SD* = 5.20) on the Mill Hill Vocabulary Test (Raven et al., 1988), *t*(68) = 7.51, *p* < .001, *d* = 1.80, 95% CI [-10.60, -6.15]. However, there were no significant differences between young and older adults on the other collected variables, including years of education, *t*(68) = 0.70, *p* = .484, *d* = 0.17, 95% CI [-1.43, 0.68], (BF10 = 0.30) (see Table *2.1*). As the Mill Hill scores significantly differed between groups, the repeated measures ANOVA for priming and recognition were repeated with the Mill Hill scores entered as a covariate to verify whether differences in Mill Hill did not influence the age effect. The ANCOVA on recognition revealed a main effect of Age, *F*(1, 67) = 29.78, *p* < .001, η_p^2 = 0.31, and a significant interaction between Processing × Age, *F*(1, 67) = 19.99, *p* < .001, η_p^2 = 0.23, but no main effect of Processing, *F*(1, 67) = 1.63, *p* = .207, = 0.02, (BF10 = 8.88). The significant main effects of Age indicated that young adults (Marginal Mean: d prime = 1.26) outperformed the older adults (Marginal Mean: d prime = 0.36). The ANCOVA on priming revealed main effects of Processing, *F*(1, 67) = 58.67, *p* < .001, η_p^2 = 0.47, indicating a greater priming following conceptual (Marginal Mean: prop. priming = 0.16) than the perceptual (Marginal Mean: prop. priming = -0.05), and a main effects Age, *F*(1, 67) = 18.55, *p* < .001, η_p^2 = 0.22, indicating a greater priming for young adults (Marginal Mean: prop. priming = 0.09) than older adults (Marginal Mean: prop. priming = 0.01). However, the was no interaction between Processing × Age, *F*(1, 67) = 1.40, *p* < .241, η_p^2 = 0.02, (BF10 = 736.38). Thus, differences between groups in Mill Hill scores did not contribute to the observed age differences in priming and recognition.

Table 2.7. Summary of Results for Experiment 1A

	F-statistic	**p-value**	**Effect size (η_p^2)**
Encoding phase			
(a) Accuracy			
Processing	222.98	<.001	0.77
Age	8.73	< .001	0.11
Processing x Age	0.38	.538	0.01
(b) RT			
Processing	1.34	.251	0.02
Age	0.02	.903	2.19
Processing x Age	0.7	.405	0.01
Recognition			
Processing	149.81	<.001	0.69
Age	23.92	<.001	0.26
Processing x Age	21.24	<.001	0.24
Priming			
Processing	340.52	<.001	0.83
Age	14.64	<.001	0.18
Processing x Age	18.64	<.001	0.22

Note. This table summarised the key results obtained from Experiment 1A.

2.2.4 Discussion of Experiment 1A

Some studies have found a clear decline in implicit memory, while others have reported that it remains intact. Processing requirements during encoding is a key factor that may have influenced prior results, since this has varied considerably in prior research. In Experiment 1A, age effects on perceptual priming (CID) were systematically examined, along with whether manipulating conceptual and perceptual processing during encoding interacts with age effects. The performance of young (*M* age = 20.51 years, *SD* = 3.16) and older adults (*M* age = 70.49 years, *SD* = 4.84) on a perceptual priming task was compared, and recognition was also assessed to compare the effects of age on explicit and implicit memory.

The data of Experiment 1A showed effects of both age and processing on explicit and implicit memory, as well as a significant interaction between the factors. Specifically, young adults showed significantly greater recognition and priming than older adults only for conceptually studied items. Recognition and priming for perceptually encoded items were not significantly above zero, except for recognition following perceptual encoding in young adults. The finding of a clear age effect on implicit memory following conceptual encoding is consistent with a number of studies. Some utilized the CID-R task, while others employed a similar perceptual identification task (e.g. Abbenhuis et al., 1990; Russo & Parkin, 1993; Ward, 2018, 2022; Ward et al., 2013a, 2013b, 2020), and go against prior arguments that perceptual priming remains stable with age (e.g. Ballesteros et al., 2007; Henson et al., 2016; Jelicic, 1996; Light et al., 1992; Light & Singh, 1987; Rybash, 1996; Sullivan et al., 1995; Wiggs et al., 2006). Additionally, the age effect on the perceptual identification task following conceptual encoding is consistent with an earlier study that also reported an age effect on priming using the stem completion task which was followed by conceptual encoding (Small et al., 1995). However, different findings were reported by Henson et al. (2016). They recruited a large number of participants (*n* = 305), and during the encoding phase, images were presented superimposed on background scenes. Participants were asked to construct a story linking the object and scene (conceptual processing), and in contrast to the findings of the present study they found that priming (perceptual identification; identifying an image under a mask) was not affected by age. Additionally, the Ballesteros et al. (2007) study yielded results that contradicted the findings of the current study. Their study showed that priming was not affected by age using a speeded picture naming test following an encoding phase in which participants named images of objects (conceptual processing). However, the sample size in this study was very small (12 young and eight older adults), which might be the reason for the failure to detect an age difference.

The age effects on priming were greater following conceptual than perceptual encoding (i.e. an Age x Processing interaction). This was as expected given evidence that conceptual processes are reduced in normal ageing (e.g. Jelicic, 1996; Morcom & Rugg, 2004; Rybash, 1996; Weldon, 1991). For example, there is evidence that older adults are less effective than young at encoding information specifically using conceptual processing, and this is known as the processing deficit hypothesis (Eysenck, 1974). This hypothesis predicts that age differences in memory are greater when information requires deeper processing. This was shown in a number of studies that reported that older adults benefit less than young adults when using conceptual processing (e.g. Eysenck, 1974; Mason, 1979; Simon, 1979). For example, Eysenck (1974) reported an interaction between age and type of encoding, indicating that recall was greater following conceptual than perceptual encoding but only in young adults. The significant interaction between age and processing on both implicit and explicit memory in the present study is not consistent with the results of Ward et al. (2020), who found that processing at encoding had no effect on explicit or implicit memory using the CID-R task. However, they argued that their manipulation of processing style during the encoding phase was not effective as the relatively long exposure time in the perceptual encoding condition may have allowed participants to process the information conceptually, and they also pointed out that response RTs were equivalent in the conceptual (*M*= 701 ms) and perceptual (*M*= 700 ms) conditions. This potential confound with exposure time in the study time is an important issue to consider, given that memory is known to increase with longer exposures to stimuli. Similarly to Ward et al. (2020), in the present study there was also no difference in the speed of judgements in the encoding phase in the conceptual and perceptual conditions, suggesting that participants may have been processing similarly in the two conditions. This is a key potential limitation – it is possible that the exposure time in the study phase (500 ms) was long enough to allow participants to encode information in a relatively deep manner even in the perceptual encoding condition. However, there was a significant main effect of processing on both priming and recognition in the test phase, suggesting that the processing manipulation was successful here. However, it is important to further consider potential confounds with exposure duration (discussed further in the General Discussion).

The study by Stuart et al. (2006) in which the type of processing during encoding was matched with the processing type at test showed similar findings as reported in this study. Eighty young (*M* age = 22 years) and older (*M* age = 62 years) adults participated in this study. In the perceptual encoding condition, participants counted vowels in visually presented words, followed by a perceptual priming test (WFC), whereas in the conceptual encoding condition, participants were asked to rate words on a 7-point pleasantness rating scale, before completing a conceptual priming test (category exemplar production; CEP). Age differences emerged in the conceptual condition (conceptual encoding followed by a conceptual priming task), however, in the perceptual condition (perceptual encoding followed by a perceptual priming task) there were no differences between young and older adults. Similarly, in this study there was no age difference in priming on the perceptual priming task following perceptual encoding. There was an age difference in priming on the perceptual task following conceptual encoding, but this condition was not included in the Stuart et al. (2006) study.

The findings in relation to explicit memory are consistent with multiple studies which used recognition to measure explicit memory (Abbenhuis et al., 1990; Nilsson, 2003; Ward, 2018; Ward et al., 2013a, 2013b, 2020; Wiggs et al., 2006). The Wiggs et al. (2006) study showed that younger adults (*M* age = 27.1 years) were significantly better at recognising images from a previous phase than young-elderly adults (*M* age = 70.0 years), and young-elderly were significantly better than old-elderly adults (*M* age = 78.3 years). Additionally, Nilsson's (2003) findings showed a dramatic decline in explicit memory with age. Further, in the present study the effect of processing was significant on explicit memory as expected. The results showed that recognition in young and older adults was greater following conceptual encoding compared with perceptual encoding. This finding replicates a number of previous studies that showed that conceptual/deep processing enhances recognition (e.g. Mitchell & Perlmutter, 1986; Monti et al., 1996). For example, Mitchell and Perlmutter (1986) conducted a study involving both young (*M* age = 23.4 years) and older (*M* age = 64.6 years) participants. They were tasked with judging whether words were in uppercase or lowercase letters (perceptual processing) or whether the word was animate or inanimate (conceptual processing) before engaging in recall and recognition tasks. the results indicated that both young and older adults demonstrated greater recall and recognition following conceptual processing compared to perceptual processing. These effects of processing on recognition also appear to extend to implicit memory. That is, in the present study there was a significant effect of processing on implicit memory, which indicted that conceptual processing leads to greater priming than perceptual processing. This is consistent with findings reported by Brown and Mitchell (1994) in a meta-analysis. They reported that 133 studies showed a greater priming following conceptual processing compared with perceptual processing, and only 32 studies showed a greater priming following perceptual processing, and four showed equivalent priming in the conceptual and perceptual processing.

It is important to mention that the findings of the present study did not support that matching the processing type in the encoding and test phases leads to better memory (i.e. perceptual encoding followed by a perceptual priming test; e.g. Roediger & Blaxton, 1987; Roediger & McDermott, 1993; Ward, 2022). The transfer appropriate processing account states that perceptual priming should be greatest following perceptual encoding, given the overlap in the type of processing required. However, priming on the CID-R task following perceptual encoding was not above zero in young and older adults – in fact, it was negative overall. This might be because both groups found the perceptual encoding task more difficult than the conceptual encoding task. Both groups had lower accuracy in this condition compared with the conceptual condition. Additionally, their average response time in the perceptual encoding condition (Young: 979 ms, Older: 1003 ms) was a little slower compared with the conceptual condition (Young: 966 ms; Older: 922 ms), although this did not reach significance. Expected slower reaction times for young and older adults in the conceptual than the perceptual encoding condition, due to the fact that conceptual processing requires additional processing and therefore more time. The unexpectedly slower RTs in the perceptual encoding condition than conceptual encoding condition may be explained by the general difficulty that participants faced in the perceptual condition, meaning they needed longer to make a decision than in the conceptual condition. In addition, it is possible that the nature of the conceptual decision (manmade/natural) was more straightforward compared to the (upright/tilted) decisions in the perceptual condition, which are relatively more subjective. Given these potential issues in the perceptual encoding condition, this may have affected later performance in the test phase.

When comparing the performance of young and older adults it is important to control the differences in participant background characteristics (e.g. education level, intelligence, etc.) as much as possible. In Experiment 1A, the multiple-choice component of the Mill Hill Vocabulary Test (Raven et al., 1988) was used to assess verbal intelligence. The findings revealed a difference between young (*M* = 15.83; *SD* = 5.20) and older adults (*M* = 24.20, *SD* = 4.06), as expected given that older adults typically have greater exposure to vocabulary compared to young adults. This finding is consistent with other studies that utilized the same test (e.g. Ward, 2022). The main analysis was repeated with Mill Hill scores treated as a covariate to verify if differences in verbal intelligence contributed to the age effect that was observed. The results showed that the main effect of age on both priming and recognition was not affected by including Mill Hill scores as a covariate. Therefore, confidence exists that the decline in explicit and implicit memory was not influenced by the differences between young and older adults in the vocabulary scores.

The test awareness questionnaire at the end of the experiment was used to determine how many participants became aware of the purpose of the implicit task. It revealed that 13 participants in total were aware (six young and seven older adults). Considering the small number of participants there was no statistical comparison of the scores of aware versus unaware participants, however, looking at the means, priming was greater for aware participants (Y: 0.24, O: 0.14) than unaware participants (Y: 0.21, O: 0.10) in both groups, but only in the conceptual condition. Whereas in the perceptual condition priming was greater for unaware (Y: -0.05, O: -0.05) than aware (Y: -0.06, O: -0.08) participants. Also, it should be noted that based on previous studies, the CID-R task as a speeded test is thought to be immune to explicit contamination, as the identification of items in the perceptual identification task occurs quickly so participants do not generally have the time to engage to explicit strategies (Brown et al., 1991, 1996; MacLeod, 2008; Ward et al., 2013b). Indeed, several previous studies have shown no differences in priming scores between aware and unaware participants on this type of task (Brown et al., 1996; Ward et al., 2013b). Giving this, it is unlikely that age effects on implicit memory were affected by explicit contamination.

Despite the care taken to design a controlled online experiment, this study nevertheless has some limitations. Because testing was conducted online, the preferred MMSE (Folstein et al., 1975) test could not be used as a screening for cognitive impairment in older adults. Suitable methods were investigated, and the EDQ (Arabi et al., 2013) was chosen, as it was deemed suitable for online testing. This was used to ensure that older participants in the final sample did not suffer from cognitive impairment or dementia. However, there were clear limitations with this task as was discussed in Chapter 1. Although many older participants scored above the cutoff threshold for inclusion (a score >7), these participants were clearly not impaired, and the decision was made to include them. As such, it was necessary to go against what was initially written in the pre-registration. The pre-registration process has been a learning curve. It is noted that it is acceptable to deviate from the pre-registration if there is a valid reason, and achieving exactly what was originally planned can sometimes be difficult (Nosek et al. 2018). Feeling that too many participants would have been lost if the pre-registration criteria to exclude anyone with an EDQ score of >7 were strictly followed, it would have been extremely challenging, lengthy, and costly to reach the required sample size if the majority of the sample needed to be replaced. On reflection, the EDQ has fairly generic instructions, which may be construed in different ways by different participants. For example, in relation to item one on the scale, '*I require a checklist as a memory support'*, all participants responded that they did, and indeed the use of lists and planners to remember appointments, shopping items, etc., is common among most adults, regardless of age. Also, in a study by Arabi et al. (2016) which reported correlation scores among items, this item had the lowest score (r = 0.292) compared to moderate correlations among other items. Due to the lack of understanding and clarity around such items, it is apparent that the scores for this item were highly inflated. Also, in the same paper, Arabi et al. (2016) the researchers revised the wording of questions 11 and 15, and this suggested change also raises questions about the reliability of the questionnaire. Another important point is that the questionnaire was developed in Malaysia, so it was potentially the wrong decision to use here in the UK because differences between the cultures may require different cutoff thresholds. Despite this, there were also many strengths in this study. It is among the first to shed light on whether processing during encoding moderates age effects on priming, and the first online study on this topic. The online format was not only efficient, but the findings can be viewed as reliable since the patterns of data closely mirror the findings of many previous lab studies (e.g. Abbenhuis et al., 1990; Russo & Parkin, 1993; Ward, 2018; Ward et al., 2013a, 2013b, 2020).

In light of the inadequacy of the EDQ in screening older participants, the utilization of the recognition task presented an advantage. That is, 'normal' performance on the recognition task was able to be used as an indication that the older participant did not have cognitive impairment / dementia, with the rationale that if an individual was impaired than this would be evident on the test – i.e. they would perform considerably poorer than healthy older adults and would stand out as an outlier. Nevertheless, this should be treated with caution as such explicit memory tests are not a validated diagnostic tool. However, it is worth noting that prior research has indicated that a decline in explicit memory signifies the onset of AD (e.g. Terry & Katzman, 1983). This issue will be further explored in the General Discussion, particularly in relation to online experiments that may not be able to employ a standard cognitive screening test.

In conclusion, Experiment 1A used a CID-R task (perceptual priming measure) and revealed declines in both explicit and implicit memory with age. This observation supports the theory that these two forms of memory are driven by a single underlying memory system (e.g. Berry et al., 2006, 2008a; Nosofsky et al., 2012), and this issue will be considered further in conjunction with the findings from other experiments in the General Discussion. Importantly, in this experiment priming and recognition were both reduced in older compared to young adults following conceptual encoding, but there were no age differences following perceptual encoding. These results suggest that processing during encoding affects age differences in priming and may account for the wide array of discrepancies in the literature. It is important to extend upon these initial observations by examining age effects on conceptual priming following perceptual versus conceptual encoding. This will be the topic of Chapter 3.

2.3 Experiment 1B

Experiment 1B (Middlesex University Research Ethics Committee Approval code 8701) was pre-registered on the OSF prior to data collection (https://osf.io/zk7b2), and the raw data and analysis file for the final sample are available in the OSF (https://osf.io/t7b2y). The experiment was designed to examine the effect of an 8-10 month delay on priming and recognition in young and older adults, to understand changes in implicit and explicit memory as a function of a medium delay. Unfortunately, the study did not work out as hoped for two reasons: (1) the number of participants who took part in this follow-up experiment was very low: 15 young and 13 older adults. No firm conclusions can be drawn on the basis of such a small sample, the size of which is far lower than the pre-registered requirement, but nevertheless the experiment is reported here as part of this PhD thesis for completeness, and some exploratory analyses were performed. (2) due to a technical issue with participant anonymous ID numbers, the matching of participants scores from Experiments 1A with those in Experiment 1B posed difficulties, so on a practical level, examination of the effect of delay on priming and recognition at the individual level was not feasible.

2.3.1 Hypotheses

The following predictions were originally made on the pre-registration: (a) Main effect of age: based on the outcome of Experiment 1A, it was expected that younger adults would achieve greater priming and recognition than older adults. (b) Main effect of delay on recognition (comparing recognition scores from the two experiments), with lower performance on the delayed test. No directional hypothesis was made in relation to the effect of delay on priming, as some studies have shown a clear effect of delay on priming and some studies show no effect of delay on priming (e.g. Cave, 1997; Mitchell et al., 1990; Tulving et al., 1982; Ward et al., 2013b; Wiggs et al., 2006), (c) Main effect of processing: Based on Experiment 1A, it was predicted that there would be greater priming and recognition for conceptually studied items than perceptually studied items. (d) Interaction between age and processing: Based on Experiment 1A, an age effect on priming was expected to emerge for conceptual items only.

2.3.2 Methods

2.3.2.1 Participants

The same participants from Experiment 1A who agreed to participate in a follow-up study were invited to take part in the study. Fifteen young and 13 older adults participated in this study. Background data, including age, sex, education level, health status, were not collected for a second time, as the plan was to match each participants’ data in this experiment with their data in Experiment 1A. However, this did not work as discussed in above. Participants were entered into a prize draw to win one of two Amazon vouchers – one young and one older were randomly selected and received Amazon vouchers totalling £9.

2.3.2.2 Design

Age effects were examined by making a comparison between the performance of young and older participants on explicit (recognition) and implicit (priming) memory tasks, with priming and recognition again measured using the CID-R task used in Experiment 1A. The effect of delay was intended to be measured by comparing the priming and recognition scores of this experiment and Experiment 1A, but as mentioned above unfortunately this was not possible due to a technical error that prevented matching up the individual scores. Processing (conceptual versus perceptual) was manipulated within-subjects in Experiment 1A, whereby items were encoded in a conceptual or perceptual manner in a blocked design.

2.3.2.3 Stimuli and Procedure

The same stimuli from Experiment 1A were repeated as old items (conceptually and perceptually studied items). However, the new items used in the test phase of Experiment 1A were replaced with different new items in this experiment. A total of 160 coloured stimuli were used (taken from the BOSS; Brodeur et al. 2010, 2014; *M* familiarity = 4.36, *SD* = 0.37), which included 80 old [40 perceptual and 40 conceptual], and 80 new items. The experiment was once again conducted online using Gorilla.sc. Participants performed the same test phase (CID-R) task as in Experiment 1A and no encoding phase. The test phase was separated into two procedurally identical blocks of 80 items to allow participants a brief break in the middle. The order of trials was randomised between participants. The procedure for the CID-R task was identical to that in Experiment 1A. Between the two blocks, participants completed a filler task identical to that in Experiment 1A.

2.3.3 Results of Experiment 1B

2.3.3.1 Analysis

To examine the hypotheses, the following analyses were originally planned: separate 2 Age (young/older) × 2 Processing (conceptual/perceptual) × 2 Delay (test 1 [immediately following encoding, Experiment 1A] vs test 2 [Delayed test]) mixed ANOVAs on priming and recognition scores, with follow up comparisons for any significant interactions. However, due to the technical error that prevented matching participants from Experiment 1A to those in Experiment 1B, direct examination of the effect of delay was rendered impossible. As such, the analyses reported below are based on a 2 (Age) × 2 (Processing) ANOVA on the priming and recognition scores from Experiment 1B. All data were analysed using JASP version 0.16.2 (JASP Team, 2023).

The total number of trials excluded from the CID-R task was as follows: out of 2400 trials, 224 trials were removed from participants in the young group, and out of 2080 trials, 279 trials were removed from participants in the older group. Note that the total number of trials in the young and older participant groups is unequal because there were unequal numbers of participants in the two groups (15 young and 13 older).

2.3.3.2 Recognition

The recognition score (*d* prime, Figure 8 and Table *2.8*) was calculated in the same way reported in Experiment 1A.

The ANOVA showed main effects of Processing, *F*(1, 26) = 18.61, *p* < .001, η_p^2 = 0.42, and Age, *F*(1, 26) = 4.34, *p* = .047, η_p^2 = 0.14, however, there was no interaction between Processing × Age, *F*(1, 26) = 2.48, *p* = .128, η_p^2 = 0.09, (BF10 = 0.80). The significant main effect of Processing indicated greater recognition in the conceptual condition (Marginal Mean: d prime = 0.58) than the perceptual condition (Marginal Mean: d prime = 0.35), and the significant main effect of Age indicated in contrast to expectations that older adults (Marginal Mean: d prime = 0.58) outperformed young adults (Marginal Mean: d prime = 0.35).

2.3.3.2.1 Additional Recognition Analysis (not pre-registered)

One sample t-tests were conducted to confirm whether recognition was above zero in each condition. Recognition (Figure 8) in young adults was significantly above zero in the conceptual, *t*(14) = 6.53, *p* < .001, *d* = 1.69, 95% CI [0.29, 0.56], and perceptual, *t*(14) = 3.71, *p* = .002, *d* = 0.96, 95% CI [0.12, 0.44] encoding conditions. Similarly, recognition in older adults was significantly above zero in the conceptual, *t*(12) = 6.36, *p* < .001, *d* = 1.76, 95% CI [0.48, 0.99], and perceptual encoding conditions, *t*(12) = 4.69, *p* < .001, *d* = 1.30, 95% CI [0.23, 0.62].

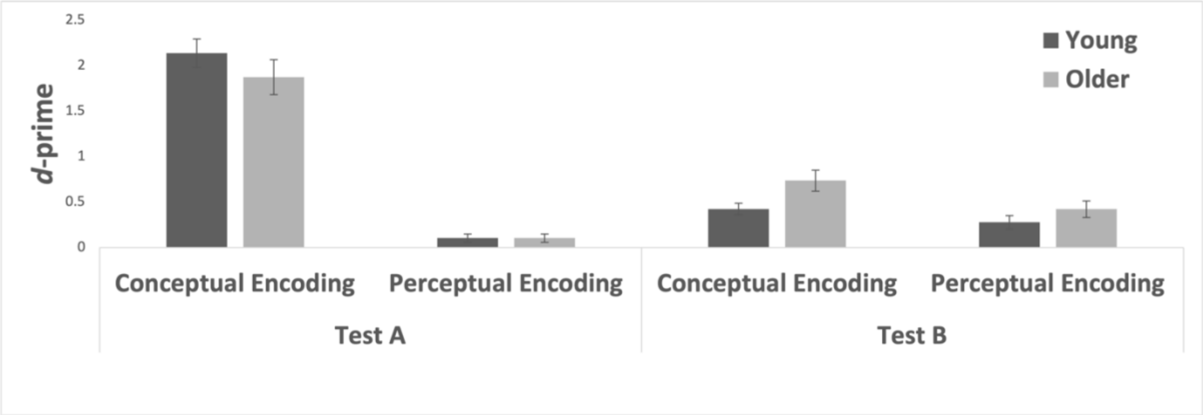

Figure 8. Recognition Scores in Experiment 1A (Test A) and 1B (Test B).

Note. A technical issue prevented matching participants between experiments, so only Experiment 1B was included in the current study analysis, but data from Experiment 1A is included here for comparison of means. Error bars represent standard error of the mean (SEM).

Table 2.8. Proportion of Hits, Misses, FA, and CR in Experiment 1B

Measure	**Conceptual Condition**		**Perceptual Condition**	
	Young	**Older**	**Young**	**Older**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Hits	0.68 (0.15)	0.77 (0.14)	0.63 (0.18)	0.68 (0.14)
Misses	0.32 (0.15)	0.23 (0.14)	0.37 (0.18)	0.32 (0.14)
	Young		**Older**	
	***M* (*SD*)**		***M* (*SD*)**	
FA	0.52 (0.19)		0.53 (0.23)	
CR	0.48 (0.19)		0.47 (0.23)	

Note. Hits: old items correctly judged old; Misses: old items incorrectly judged new; FA: new items judged old; CR: new items correctly judged new. FA stands for false alarms, and CR stands for correct rejection. Standard deviations for all mean values are given in the parentheses.

2.3.3.3 Priming

Priming scores (Figure 9 and Table *2.9*) were calculated in the same way as reported in Experiment 1A. The ANOVA showed a main effect of Processing only, *F*(1, 26) = 5.54, *p* = .026, η_p^2 = 0.18, no significant main effect of Age, *F*(1, 26) = 0.001, *p* = .974, η_p^2 = 4.22, (BF10= 0.32), and no significant interaction between Processing × Age, $F(1, 26) = 1.26$, $p = .273$, $\eta_p^2 = 0.05$, (BF10 =0.62). The significant main effect of Processing indicated greater priming in the conceptual condition (Marginal Mean: prop. priming = 0.08) than the perceptual condition (Marginal Mean: prop. priming = 0.05).

2.3.3.3.1 Additional Priming Analysis (not pre-registered)

One sample t-tests were conducted to confirm whether priming was above zero in each condition. Priming (Figure 9) in young adults was significantly above zero in the conceptual, $t(14) = 7.61$, $p < .001$, $d = 1.96$, 95% CI [0.05, 0.09] and perceptual, $t(14) = 3.60$, $p = .003$, $d = 0.93$, 95% CI [0.02, 0.09] conditions. Similarly, priming in older adults was above zero in the conceptual, $t(12) = 6.23$, $p < .001$, $d = 1.73$, 95% CI [0.05, 0.11], and perceptual, $t(12) = 2.89$, $p = .014$, $d = 0.80$, 95% CI [0.01, 0.07] conditions.

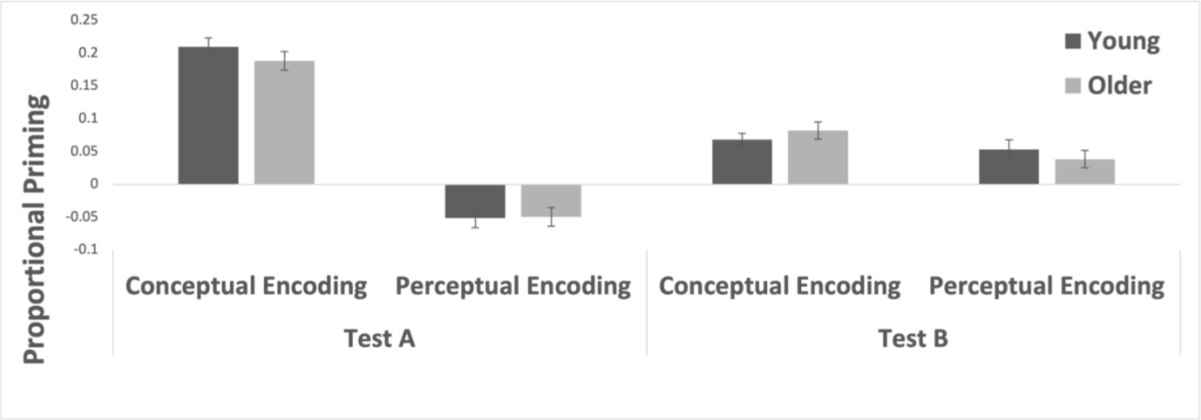

Figure 9. Priming in Experiments 1A (Test A) and 1B (Test B).

Note. A technical issue prevented matching participants between experiments, so only Experiment 1B was included in the current study analysis, but data from Experiment 1A is included here for comparison of means. Error bars represent standard error of the mean (SEM).

Table 2.9. Mean RTs for Young and Older Adults in Experiment 1B

Measure	**Conceptual Condition**		**Perceptual Condition**	
	Young	**Older**	**Young**	**Older**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
RT Old (ms)	3081 (533)	3601 (451)	3133 (564)	3777 (409)
	Conceptual Condition		**Perceptual Condition**	
	Young		**Older**	
	***M* (*SD*)**		***M* (*SD*)**	
RT New (ms)	3308 (570)		3918 (394)	

Note. Standard deviations for all mean values are given in the parenthesis.

Table 2.10. Summary of Results for Experiment 1B

	F-statistic	**p-value**	**Effect size (η_p^2)**
Recognition			
Processing	18.61	<.001	0.42
Age	4.34	.047	0.14
Processing x Age	2.48	.128	0.09
Priming			
Processing	5.54	.026	0.18
Age	0.001	.974	4.22
Processing x Age	1.26	.273	0.05

Note. This table summarised the key results obtained from Experiment 1B.

2.3.4 Discussion of Experiment 1B

The main goal of this experiment was to understand changes in explicit and implicit memory over time (8-10 months) within the same individual, in order to see how age differences in priming and recognition are affected by a delay. However, the effects of delay were not included here in the analysis due to technical issue that prevented matching each participants' data in this experiment with the data in Experiment 1A. Therefore, only age and processing factors were included in the analysis.

The results of Experiment 1B showed an age effect on explicit memory (recognition) only, and a main effect of processing on both explicit and implicit memory. The age difference in explicit memory was surprising given that here older adults performed better than young adults in both conditions (conceptual and perceptual). This finding is inconsistent with previous studies that found a dramatic decrease in explicit memory as an effect of age (e.g. Nilsson, 2003; Ward, 2018; Ward et al., 2013a, 2013b, 2020). It is interesting to observe that although older adults performed significantly worse than young adults when there was no delay between the encoding and test in Experiment 1A, in Experiment 1B older adults performed significantly better than young adults. This observation suggests that recognition in older adults may be more resistant over time than in young adults. However, due to the very small sample size and low power, refraining from further interpretation is advisable, as statistically significant results from a low sample size may not imply a true effect (e.g. Button et al., 2013).

The main effect of processing on explicit and implicit memory, indicating that young and older adults showed greater priming and recognition following conceptual than perceptual encoding, this was expected and consistent with the findings in Experiment 1A. The observation that conceptual processing enhances priming and recognition aligns with earlier studies (e.g. Mitchell & Perlmutter, 1986; Monti et al., 1996), which demonstrated greater recall and recognition following conceptual processing. Additionally, Brown and Mitchell's (1994) meta-analysis reported 79% of the studies revealed greater priming following conceptual rather than perceptual processing. The present study indicates that the effect of processing at encoding is persistent over time on both explicit and implicit memory. That is, there was a significant effect of processing on priming and recognition in Experiment 1A, and this was still significant after an 8–10-month delay.

Although the delay factor was not included in the analysis due to the fact that matching each participants' data with his/her data from Experiment 1A was impossible, but (Figure 8 and Figure 9; priming and recognition scores) provides a generally reduction in priming and recognition scores. This numerical decrease (in the conceptual condition only) raises the possibility that delay may have an impact on both explicit and implicit memory. However, these results should be interpreted with caution as the delay effect was not included in the analysis, and there is a very small sample size.

While it is unfortunate that this experiment did not work out as planned, understating the effects of delay on priming and recognition was not a major aspect of this thesis. However, it is important to include the study in the thesis for transparency and completeness. In the pre-registration, it was noted that a drop in sample size was anticipated, as is common in follow-up research. However, the total of 28 participants to represent both age groups was unexpected. To try to gather more participants a reminder was sent after 20 days from the first invitation, but the number of participants remained low. Using G power to calculate the study power with 28 participants, actual power was at just 0.42. Generally, power of 80% is considered the minimum (e.g. Akobeng, 2016). Therefore, strong conclusions about the effects of ageing on priming and recognition cannot be drawn from this follow-up study. However, the data is encouraging to suggest that the effects of processing are persistent over time – that is, compared to perceptual encoding, conceptual processing led to significantly greater recognition and priming in participants even after an 8-10 month delay.

Chapter 3: The Effects of Processing During Encoding on Conceptual Implicit Memory (Experiment 2)

3.1 Chapter Introduction

This chapter will introduce Experiment 2. The aim of Experiment 2 was to examine age differences in explicit and implicit memory and interactions with processing at encoding using a similar design to Experiment 1A, but with a conceptual priming task (Category Exemplar Generation; CEG). Experiment 1A showed that perceptual priming as measured by the CID-R task was affected by age only following conceptual encoding, so the goal of this experiment was to examine age and processing effects on conceptual implicit memory. Does similar patterns emerge when processing is varied during encoding on the CEG (conceptual) implicit task? Much previous research has concluded that the CEG task involves conceptual processing (reviewed in Mitchell & Bruss, 2003), and it has also been suggested that CEG is comparable in terms of processing with explicit tests (Isingrini et al., 1995). As with Experiment 1A, a recognition task was used to assess explicit memory, to compare age effects on explicit and implicit memory, however, in this experiment, implicit and explicit memory were measured in different experimental phases. Given the nature of the CEG task it was impossible to measure them concurrently trial-by-trial as in Experiment 1A. Another important difference between Experiment 1A and this experiment is that the CEG task is based on an accuracy measure (number of correct responses) whereas the CID priming task is based on RT (latency measure). Experiment 2 was pre-registered on the OSF prior to data collection (https://osf.io/uz2ka). All pre-registered steps and analyses were followed, and any changes or additional analyses are clearly stated. The raw data and analysis file for the final sample are available in the OSF (https://osf.io/t7b2y).

3.1.1 Hypotheses

Based on previous literature reviewed in the General Introduction, the following predictions were made: (a) Main effect of age on recognition, with greater recognition in young than older adults. No directional hypothesis was made in relation to the effect of age on conceptual priming. (b) Main effect of processing at encoding, with greater recognition following conceptual processing than perceptual processing. No directional hypothesis was made in relation to the effect of processing on conceptual priming. (c) Interaction between age and processing, with greater recognition for conceptually processed items in young adults, and weakest for perceptually processed items in older adults. No directional hypothesis in relation to the interaction effect was made in relation to conceptual priming.

3.1.2 Methods

3.1.2.1 Participants

The required number of participants was the same as in Experiment 1A. Thirty-five young adults aged 18 to 30 years (*M* age = 24.40 years, *SD* = 3.74, 15 females, 19 males, and one unspecified), and 35 older adults aged 65 and 82 years (*M* age = 70.57 years, *SD* = 4.35; 21 females and 14 males) took part in this experiment. Young adults were recruited from Prolific (2 participants) and social media (33 participants), and older participants were recruited from the U3A (21 participants), and Prolific (14 participants). All participants were rewarded a payment at a rate of £9 per hour. Ethical approval was granted by the Middlesex University Research Ethics Committee (Approval code: 8701). Eligibility criteria for participants were the same as in Experiment 1A, and the same background tests were administered (reported in Table *3.1*), with the exception of the EDQ. Given the problems identified with the EDQ in Experiment 1A, this was not administered in Experiment 2. Note that Experiments 1A and 2 were pre-registered at the same time so it is stated that the EDQ would be used here although it was not. At the time of conducting the experiment, awareness of other suitable cognitive screening tests to be used online without supervision was lacking. However, participants were asked at the informed consent stage to tick a box to confirm that they are free of dementia and have no concerns with their cognitive function.

Table 3.1. Participant Characteristics in Experiment 2

Characteristics	**Young Adults** ***M*** **(*SD*)** **(*n* = 35)**	**Older Adults** ***M*** **(*SD*)** **(*n* = 35)**
Age (years)	24.40 (3.74)	70.57 (4.35)
Gender (M/F/Unspecified) (*n*)	19/15/1	14/21/0
Education (years)	16.71 (2.50)	15.91 (3.99)
Highest Qualification (*n*)		
GCSE or equivalent	5	11
A level or equivalent	9	6
Bachelor's degree	10	12
Master's degree	11	3
PhD	0	3
Working or Retired (*n*)	-	
Working Full-time	-	2
Working Part-time	-	3
Retired	-	30
Health Status (*n*)		
Excellent	15	3
Good	17	27
Adequate	3	5
Poor	0	0
Extremely Poor	0	0
Trouble of Vision (*n*)		
Yes	0	0
No	34	35
Somewhat	1	0
Mill Hill Vocabulary *	20.60 (3.91)	23.86 (4.65)

Note. Standard deviations for all mean values are given in the parentheses. The multiple-choice part of the Mill Hill Vocabulary Test (Raven et al., 1988) was used, which served as a standard measure of pre-morbid intelligence with a maximum score of 33. *Significant differences between groups, p < .05.

3.1.2.2 Design

The design of this experiment was the same as Experiment 1A. That is, the study involved a mixed factorial design with Age (young/older adults) as the between-subjects factor and Processing (conceptual/perceptual) as the within-subjects factor. In this experiment conceptual priming was measured using a category exemplar generation (CEG) task, indexing the proportion of previously studied relative to new items produced (i.e. N new items produced in new categories – N studied items produced in old categories). Recognition was calculated based on accuracy measure [*d* prime: z(hits) – z(false alarms)].

3.1.2.3 Stimuli

All visual stimuli used in the encoding phase were again taken from the Bank of Standardized Stimuli (BOSS; Brodeur et al., 2010, 2014). The experiment was once again administrated on Gorilla and was constructed on screen size of 2560 × 1600 pixels. Because participants completed the experiment on their own computers, screen sizes varied between 1200 × 800 and 2560 × 1440 pixels. A total of 72 coloured stimuli were presented during the encoding blocks (*M* familiarity = 4.39, *SD* = 0.35). The total of 72 items was chosen as to allow six images in each category. Thirty-six pictures were presented in the conceptual encoding phase, and 36 in the perceptual encoding phase. There were 12 category names altogether in the CEG task (outdoor sports items, birds, jewels, electronic devices, kitchen items, vegetables, musical instruments, stationary/office supplies, animals, cleaning products/items, insects, and medical instruments), but these were split into two blocks. That is, there were two CEG tasks, one was following each encoding phase (conceptual/perceptual), and the order of blocks was counterbalanced. The total of 12 categories in the CEG tasks was selected as identical to the number of previous studies using this task (e.g. Isingrini et al., 1995). Thus, during each CEG test phase there were six categories – three old and three new.

3.1.2.4 Procedure

Similarly to the previous experiments, the experiment was conducted using Gorilla Experiment Builder (https://gorilla.sc/), and participants performed the task in their homes using their own computers (desktops or laptops, not phones or tablets). There were restrictions regarding the browser type that could be used; only Chrome, Firefox, Safari and Internet Explorer, to minimise differences that can arise when using different browsers. A minimum connection speed of 8 Mbps was required, to ensure that slow internet speed did not affect the presentation of images or recording of RTs. Participants were asked to complete the online study in a quiet room and only when had ample time, as they were instructed that once they started the study, it could not be paused or resumed at a later time. Participants were fully briefed about the nature of their involvement in the study and provided informed consent by ticking a box on the screen. The experimental task would only proceed if the consent box was ticked. All participants gave their consent, confirming that they had read and understood the information sheet, and that they met all the eligibility criteria. This included consenting that they were free of cognitive impairment or dementia, aged between 18-30 years for young adults or 65 years and above for older adults, fluent in English, had normal vision (corrected with glasses was acceptable), and did not suffer from colour blindness. Following this, background information was collected on age, sex, self-reported health, years of education, highest qualification achieved, self-rated vision, and professional status (working or retired).

3.1.2.4.1 Experimental Task

3.1.2.4.1.1 Encoding Phase

The procedure for the encoding phase of this experiment was the same as in Experiment 1A. The encoding phase was divided into two counterbalanced blocks: one involving conceptual processing in the encoding phase, and one involving perceptual processing in the encoding phase. That is, during the encoding phase there was a stream of 36 objects, in each trial, a black fixation was presented for 500 ms, followed by an object presented for 500 ms. In the conceptual condition, participants judged whether each object was manmade or natural, a decision that required participants to access the meaning of the object, and in the perceptual condition they judged whether each object was upright or tilted, a decision that required participants to engage with purely physical features of the stimuli to judge the rotation. To respond, participants were instructed to use keyboard keys Z= upright/natural; M= tilted/manmade. Participants were asked to respond as quickly as possible. The instructions to press either Z= natural, M= manmade (conceptual condition) or Z= upright, M= tilted (perceptual condition) remained on the screen until participants made the decision.

3.1.2.4.1.2 Filler Phase

Between the encoding phase and the CEG task there was a brief mental arithmetic filler phase, which was the same as the one outlined in Experiment 1A. The filler phase took three minutes to be completed. The purpose was to provide an unrelated non-verbal task to avoid primacy and recency effects and ensure that all participants had an approximately equal duration between the encoding and test phases. In the filler phase, participants were presented with random numbers (1-9) and their task was to decide as quickly as possible whether each number was odd or even by selecting an on-screen response option. A black fixation was presented for 500 ms, followed by a number presented for 5000 ms.

3.1.2.4.1.3 Test Phase – CEG

Following each encoding phase there was a test phase to assess conceptual implicit memory (CEG) followed by a recognition task. To reduce the possibility that participants might anticipate that the CEG task was related to memory, the recognition task was always conducted after the CEG task. In the CEG task, participants were given six different category names (three related to studied item categories, and three unstudied), one at a time, and they were asked to generate as many example items from that category as possible within a 45 second timeframe (e.g. ANIMALS – duck, squirrel, etc). Participants were asked to type their answers directly into a box on the computer screen, and a countdown clock was displayed for the final 10 seconds for each category to indicate that time was about to run out (Figure 10). The 45 seconds timeframe was chosen based on a mixture of prior studies and piloting. Most prior studies used 60 seconds (e.g. Jelicic, 1996; Maki et al., 1999), but when piloting this seemed a bit too long.

3.1.2.4.1.4 Test Phase - Recognition Task

Following the final CEG task block participants performed a recognition task. The CEG (priming task) and the recognition task were presented separately in this experiment rather than concurrently trial by trial as in Experiment 1A because it was impossible to have recognition judgment on each trial because of the nature of the CEG task. During the recognition task, 60 items were presented (30 new, 15 old-conceptual, and 15 old-perceptual), and participants were prompted to judge whether the object was previously shown in the encoding phase or was new. Participants were informed that half of the objects were presented previously, and half were new. Participants responded on a six-point scale where 1= Sure no, 2= Think no, 3= Guess no, 4= Guess yes, 5= Think yes, 6= Sure yes. No time limit was imposed.

3.1.2.4.2 Background Tests

Following the test phase, participants performed the multiple-choice component of the Mill Hill Vocabulary test (Raven et al., 1988; see Appendix), and at the end of the experiment, participants performed a short awareness questionnaire containing six questions adapted from Bowers and Schacter (1990): (1) What do you think was the purpose of the category exemplar generation task you preformed? (2) Did you think that any of the categories reflected pictures that were shown in the first part of the experiment? (3) were you aware of this as you were performing the task, or did you become aware of this afterward / in hindsight? (4) Did you suspect prior to the category exemplar generation task that you would be tested on your memory of the pictures? (5) Did you use your memory of the pictures to try to help you in the task where you had to come up with category items? ('Yes'/'No') (6) If yes, do you think this strategy helped you, and how so?

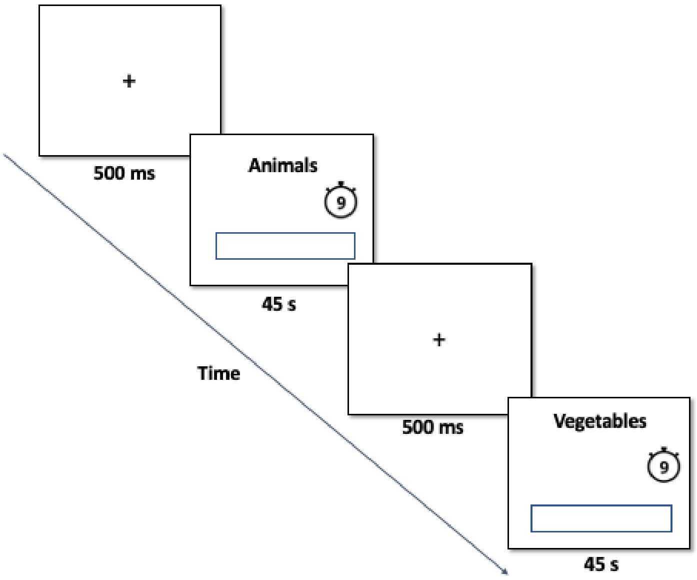

Figure 10. The Category Exemplar Generation (CEG) Task Used in Experiment 2.

Note. In this task, participants were instructed to produce as many exemplars as possible within 45 seconds for each category by typing them in the given box. In the final 10s a countdown clock was displayed to inform participants that time was about to finish.

3.1.3 Results of Experiment 2

3.1.3.1 Analysis

The main analyses in this experiment were the same as in Experiment 1A. As before. Separate 2 Age (young/older) × 2 Processing (conceptual/perceptual) repeated measures analysis of variance (ANOVA) on priming and recognition scores, with Age as a between-subjects variable, and follow-up test comparisons in the event of a significant interaction. An alpha level of .05 was used for all statistical tests. Partial eta squared (η_p^2) was reported for ANOVA effects and Cohen's *d* and confidence intervals for the t-test (two-tailed). A Bayes Factor analysis was conducted for non-significant effects, and BF10 values of less than 1/3 were considered support for the null hypothesis (Dienes, 2014). All data were analysed using JASP version 0.16.2 (JASP Team, 2023).

3.1.3.2 Data Screening and Exclusion

Eleven participants in total were replaced for the following reasons: two participants failed to follow the experiment instructions (responded 'yes' to all images in the recognition test, although the instructions stated that half of the objects were presented previously and half were new), and nine participants did not produce any items in the CEG test phase.

3.1.3.3 Encoding Phase

The proportion of correct responses and associated response times (RT) in the conceptual and perceptual encoding blocks are summarised in Table *3.2*. In the perceptual encoding block, since the correct answer (upright/tilted) was somewhat subjective, accuracy was calculated based on the majority response by participants. That is, if the majority of participants judged a presented image as tilted, then tilted was considered the correct answer. Data were analysed using a 2 (Age) × 2 (Processing) repeated measures ANOVA. There was a main effect of Processing on accuracy, $F(1, 68) = 160.75$, $p < .001$, $\eta_p^2 = 0.70$, and a significant interaction between Processing × Age, $F(1, 68) = 4.55$, $p < .001$, $\eta_p^2 = 0.06$. However, there was no main effect of Age, $F(1, 68) = 1.50$, $p = .225$, $\eta_p^2 = 0.02$, (BF10 = 0.27) on accuracy. Participants were more accurate in the conceptual encoding condition (Marginal Mean = 90.60%) than the perceptual encoding condition (Marginal Mean = 74.09%). Follow-up tests were conducted to examine the significant interaction in the accuracy data. Paired sample t-tests indicated that young adults performed significantly better in the conceptual encoding condition ($M = 92.94$ %, $SD = 7.78$) than the perceptual encoding condition ($M = 73.65$ %, $SD = 8.48$), $t(34) = 10.27$, $p < .001$, $d = 1.74$, 95% CI [15.47, 23.10], and similarly in older adults, they performed significantly better in the conceptual encoding condition ($M = 88.25$ %, $SD = 6.94$) than the perceptual encoding condition ($M = 74.52$ %, $SD = 10.38$), $t(34) = 7.61$, $p < .001$, $d = 1.29$, 95% CI [10.06,17.40]. An Independent samples t-test showed that accuracy in the conceptual encoding condition was significantly greater in young adults ($M = 92.94$ %, $SD =7.78$) than older adults ($M = 88.25$ %, $SD = 6.94$), $t(68) = 2.66$, $p = .010$, $d = 0.64$., 95% CI [1.17, 8.20]. However, there was no significant difference between groups in the perceptual encoding condition, $t(68) = 0.39$, $p = .701$, $d = 0.09$, 95% CI [-5.39, 3.65],(BF10 = 0.26).

On RTs in the encoding phase, there was a main effect of Processing, $F(1, 68) = 24.92$, $p < .001$, $\eta_p^2 = 0.27$, but no main effect of Age, $F(1, 68) = 1.91$, $p = .172$, $\eta_p^2 = 0.03$, (BF10 = 0.56), and no interaction between Processing × Age, $F(1, 68) = 1.84$, $p = .179$, $\eta_p^2 = 0.03$, (BF10 = 0.29). Participants were quicker to respond in the conceptual encoding condition (Marginal Mean = 838 ms) compared with perceptual encoding condition (Marginal Mean = 1027 ms).

Table 3.2. Performance of Young and Older Adults in the Encoding Phase in Experiment 2

Encoding Phases	**Young Adults** ***M*** **(*SD*)**	**Older Adults** ***M*** **(*SD*)**
Accuracy (%)		
Conceptual Encoding	92.94 (7.78)	88.25 (6.94)
Perceptual Encoding	73.65 (8.48)	74.52 (10.38)
RTs (ms)		
Conceptual Encoding	767 (197)	909 (316)
Perceptual Encoding	1008 (307)	1047 (411)

Note. Standard deviations for all mean values are given in the parenthesis.

3.1.3.4 Recognition

To assess recognition, *d′* was calculated for each participant by subtracting z-transformed hits (proportion of old items judged old) minus z-transformed false alarms (FA; proportion of new items judged old), see Figure 11 and Table *3.3*. The Snodgrass and Corwin (1988) correction was applied to hit and false alarm rates with values of zero or one (i.e. Hit rate = (n Hits + 0.5) / (n old + 1); FA rate = (n FAs + 0.5) / (n new+1) prior to calculating *d'*.

Data were analysed using a repeated measures ANOVA with the within-subjects factor Processing at encoding (conceptual versus perceptual) and between-subject factor Age (younger versus older adult). The results showed no main effect of Processing, *F*(1, 68) = 2.60, *p* = .112, η_p^2 = 0.04, (BF10 = 0.60), and no interaction between Processing × Age, *F*(1, 68) = 0.44, *p* = .512, η_p^2 = 0.01, (BF10 = 0.24). However, there was a main effect of Age, *F*(1, 68) = 12.61, *p* < .001, η_p^2 = 0.16, indicating that young adults (Marginal Mean: d prime = 2.64) produced greater recognition than older adults (Marginal Mean: d prime = 2.17).

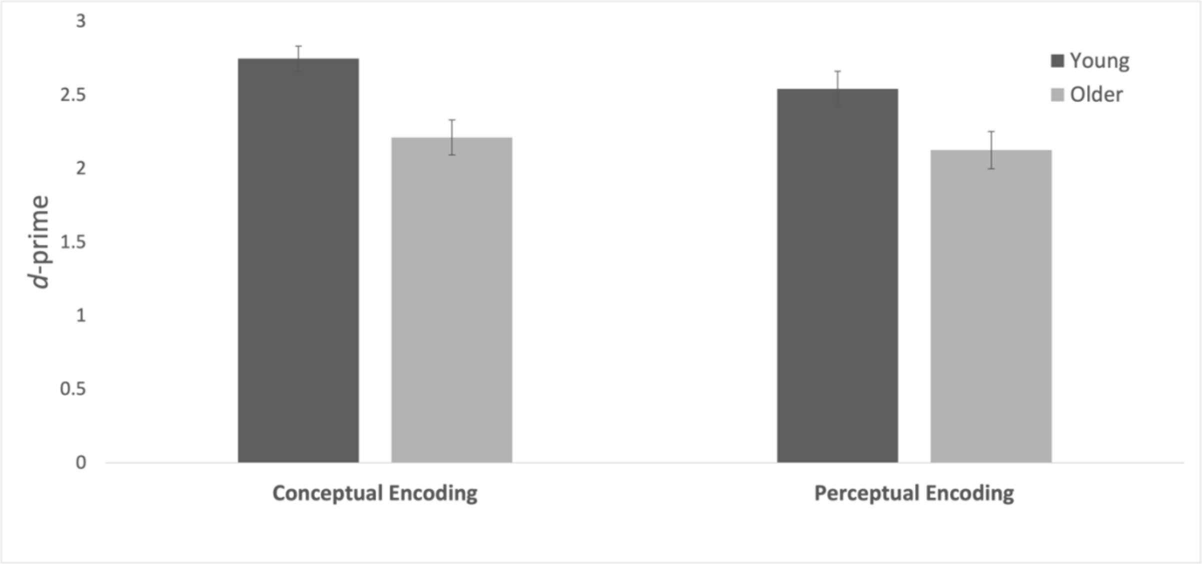

Figure 11. Recognition in Young and Older Adults in the Conceptual and Perceptual Conditions in Experiment 2.

Note. Error bars represent standard error of the mean (SEM).

Table 3.3. Proportion of Hits, Misses, FA, and CR in Experiment 2

Measure	**Conceptual Condition**		**Perceptual Condition**	
	Young	**Older**	**Young**	**Older**
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**
Hits	0.91 (0.09)	0.81 (0.17)	0.86 (0.12)	0.79 (0.17)
Misses	0.06 (0.10)	0.14 (0.13)	0.11 (0.13)	0.20 (0.18)
	Young		**Older**	
FA	0.11 (0.06)		0.13 (0.08)	
CR	0.87 (0.07)		0.85 (0.08)	

Note. Hits: old items correctly judged old; Misses: old items incorrectly judged new; FA: new items judged old; CR: new items correctly judged new. FA stands for false alarms, and CR stands for correct rejection. Standard deviations for all mean values are given in the parentheses.

3.1.3.4.1 Additional Recognition Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether recognition was above zero in each condition. Recognition (Figure 11) in young adults was significantly above zero in the conceptual condition, $t(34)= 31.89$, $p < .001$, $d = 5.39$, 95% CI [2.57, 2.92], and the perceptual condition, $t(34) =$

21.20, $p < .001$, $d = 3.58$, 95% CI [2.30, 2.79]. It was also significantly above zero in older adults in the conceptual condition, $t(34) = 18.57$, $p < .001$, $d = 3.14$, 95% CI [1.97, 2.45], and perceptual condition, $t(34) = 16.74$, $p < .001$, $d = 2.83$, 95% CI [1.87, 2.38].

3.1.3.5 Priming

Any items that participants produced that did not belong to the category were removed prior to calculating priming. Therefore, A total of 19 trials were excluded in the young group, and 28 trials were excluded in the older group. Priming was calculated by subtracting the proportion of previously studied items produced from the proportion of new items produced (see Figure 12 and Table *3.4*). Data were analysed using a repeated measures ANOVA with the within-subjects factor Processing (conceptual versus perceptual encoding) and between-subject factor Age (young versus older adult). The results showed no main effect of Processing, $F(1, 68) = 3.03$, $p = .086$, $\eta_p^2 = 0.04$, (BF10 = 0.65). However, there was a main effect of Age, $F(1, 68) = 21.61$, $p < .001$, $\eta_p^2 = 0.24$, indicating that young adults (Marginal Mean: prop. priming = 23.07) outperformed older adults (Marginal Mean: prop. priming = 17.14), and a significant interaction between Processing × Age, $F(1, 68) = 4.89$, $p = .030$, $\eta_p^2 = 0.07$. Follow-up tests were conducted to examine the significant interaction. Paired sample t-tests indicated that priming in young adults was significantly greater in the perceptual encoding condition ($M = 24.51$, $SD = 6.60$) than the conceptual condition ($M = 21.63$, $SD = 6.08$), $t(34) = 2.58$, $p = .014$, $d = 0.44$, 95% CI [-5.16, -0.62]. However, the paired sample t-tests showed no significant difference in older adults between the perceptual encoding condition ($M = 16.97$, $SD = 6.06$) and conceptual condition ($M = 17.31$, $SD = 5.83$), $t(34) = 0.37$, $p = .718$, $d = 0.06$, 95% CI [-1.57, 2.25], (BF10 = 0.19). An independent samples t-test showed that priming following conceptual encoding was significantly greater in young adults ($M = 21.63$, $SD = 6.08$) than older adults ($M = 17.31$, $SD = 5.83$), $t(68) = 3.03$, $p = .003$, $d = 0.72$, 95% CI [1.47, 7.16], and priming following perceptual encoding was also significantly greater in young adults ($M = 24.51$, $SD = 6.60$) than older adults ($M = 16.97$, $SD = 6.06$), $t(68) = 4.98$, $p < .001$, $d = 1.19$, 95% CI [4.52, 10.56].

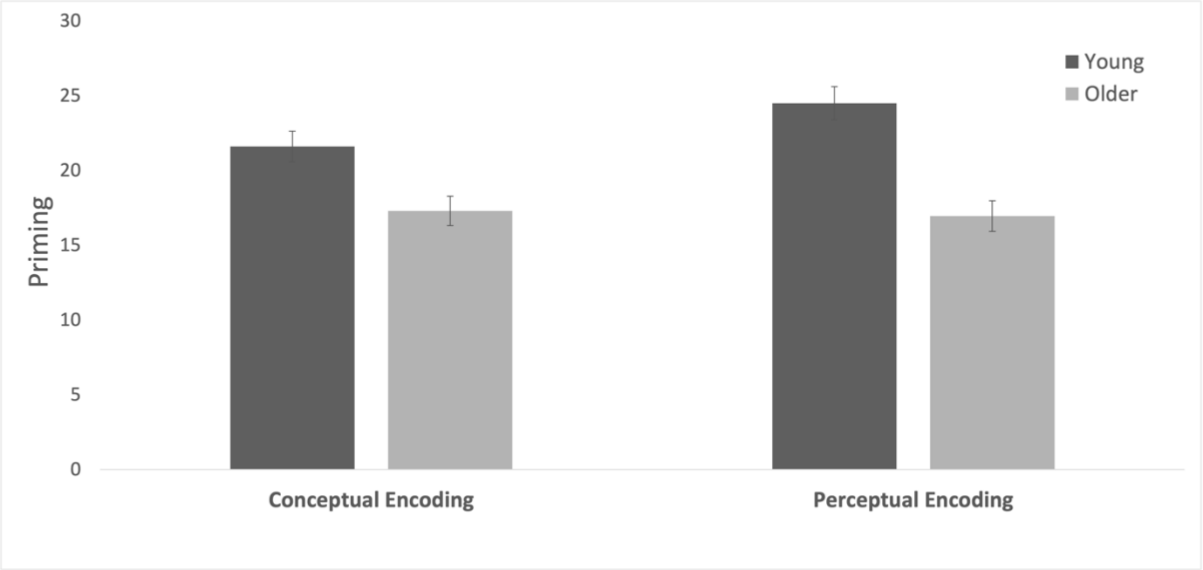

Figure 12. Priming in Young and Older Adults in the Conceptual and Perceptual Conditions in Experiment 2.

Note. Error bars represent standard error of the mean (SEM).

3.1.3.5.1 Additional Priming Analyses (not pre-registered)

One sample t-tests were conducted to examine whether priming was above zero in each condition. Priming (Figure 12) in young adults was significantly above zero in the conceptual condition, $t(34) = 21.03$, $p < .001$, $d = 3.56$, 95% CI [19.54, 23.72], and the perceptual condition, $t(34) = 21.98$, $p < .001$, $d = 3.72$, 95% CI [22.25, 26.87]. Priming was also significantly above zero in older adults in the conceptual condition, $t(34) = 17.59$, $p < .001$, $d = 2.97$, 95% CI [15.31, 19.32], and the perceptual condition, $t(34) = 16.58$, $p < .001$, $d = 2.80$, 95% CI [14.89, 19.05].

3.1.3.6 Awareness Questionnaire

Participants completed a brief awareness questionnaire at the end of the experiment (see section 3.1.2.4), to gauge whether they became aware of the purpose of the CEG task. The test awareness questionnaire revealed that 10 young and three older adults became aware that CEG task was related to memory. However, as so few participants were aware of the purpose of the task, no further analysis was conducted to compare aware versus unaware participants, but the means are presented in Table *3.4*.

Table 3.4 . Priming in Aware and Unaware Participants in Experiment 2

Priming Scores (Prop. Priming)	**Aware** ***M* (*SD*)**	**Unaware** ***M* (*SD*)**
Conceptual Encoding		
Young	20.60 (5.85)	22.04 (6.24)
Older	17.00 (8.72)	17.34 (5.68)
Perceptual Encoding		
Young	24.10 (7.75)	24.68 (6.25)
Older	19.67 (12.86)	16.72 (5.37)

Note. Standard deviations for all mean values are given in the parentheses.

3.1.3.7 Covariate Analysis (not pre-registered)

An Independent samples t-test showed that older adults (*M*= 23.86, *SD* = 4.65) had significantly better performance than young adults (*M* = 20.60, *SD* = 3.91) on the Mill Hill Vocabulary test, *t*(68) = 3.17, *p* = .002, *d* = 0.76, 95% CI [-5.31, -1.21]. However, there were no significant differences between young and older adults on other variables, including years of education, *t(*68) = 1.01, *p* = .318, *d* = 0.24, 95% CI [-0.79, 2.39] (BF10 = 0.38) (see Table *3.1*). As the Mill Hill scores significantly differed between groups, the repeated measure ANOVAs for priming and recognition were repeated with Mill Hill scores entered as a covariate to verify that between-group differences in verbal intelligence did not influence the observed age differences in priming and recognition. The results matched the original analysis in both cases. The ANCOVA on recognition revealed a main effect of Age, *F*(1, 67) = 14.28, $p < .001$, η_p^2 = 0.18, no main effect of Processing, *F*(1, 67) = 0.07, *p* = .797, η_p^2 = 9.99, (BF10 = 0.59), and no interaction between Processing × Age, *F*(1, 67) = 0.39, *p* = .533, η_p^2 = 0.01, (BF10 = 0.30). The Age effect indicated that younger adults (Marginal Mean: d prime = 2.68) outperformed older adults (Marginal Mean: d prime = 2.14). The ANCOVA on priming revealed a main effect of Age, *F*(1, 67) = 8.46 , *p* = .005, η_p^2 = 0.11, a significant interaction between Processing × Age, *F*(1, 67) = 5.42, *p* = .023, η_p^2 = 0.08, and no main effect of Processing, *F*(1, 67) = 2.00, *p* = .162, η_p^2 = 0.03, (BF10 = 33432). The Age effect indicated that younger adults (Marginal Mean: prop. priming = 23.74) outperformed older adults (Marginal Mean: prop. priming = 20.24). The results of ANCOVA showed that age differences in Mill Hill scores did not contribute to the observed age differences on the recognition and priming tasks.

Table 3.5. Summary of Results for Experiment 2

	F-statistic	**p-value**	**Effect size (η_p^2)**
Encoding phase			
(a) Accuracy			
Processing	160.75	<.001	0.70
Age	1.5	.225	0.02
Processing x Age	4.55	<.001	0.06
(b) RT			
Processing	24.92	<.001	0.27
Age	1.91	.172	0.03
Processing x Age	1.84	.179	0.03
Recognition			
Processing	2.6	.112	0.04
Age	12.61	<.001	0.16
Processing x Age	0.44	.512	0.01
Priming			
Processing	3.03	.086	0.04
Age	21.61	<.001	0.24
Processing x Age	4.89	.030	0.07

Note. This table summarised the key results obtained from Experiment 2.

3.1.4 Discussion of Experiment 2

In this study, the effect of ageing on conceptual priming was systematically examined, aiming to determine whether manipulating conceptual and perceptual processing during encoding would interact with age effects. The performance of young (*M age* = 24.40 years, *SD* = 3.74) and older adults (*M age* = 70.57 years, *SD* = 4.35) was compared in a conceptual priming task (CEG) followed by a recognition task to assess explicit memory.

Age effects were evident for explicit memory (recognition) and conceptual implicit memory (priming), and the interaction between (Processing x Age) was significant in priming. Young adults showed greater conceptual priming for perceptually studied items than conceptually studied items, but processing did not influence conceptual priming in older adults. In contrast, priming in Experiment 1A (perceptual priming) was greater following conceptual encoding than perceptual encoding in both young and older adults. It is worth noting that the same conceptual (manmade/natural) and perceptual (upright/tilted) encoding task was repeated in this experiment.

Older adults showed significantly greater accuracy and faster RTs in the conceptual encoding condition (*M* = 88.25%; RT = 909 ms) than the perceptual encoding condition (*M* = 74.52%; RT = 1047 ms), yet their priming on the CEG task was unaffected by the encoding manipulation. This finding was unexpected as it was anticipated that older adults would have greater accuracy and faster reaction times in the perceptual encoding condition, as they are generally impaired in conceptual processing (e.g. Eysenck, 1974; Morcom et al., 2003; Morcom & Rugg, 2004; Rybash, 1996). However, and in general both young and older adults were more accurate and quicker in the conceptual encoding condition and seemed to struggle with the perceptual encoding condition in which they judged if the presented image was upright or tilted. Nevertheless, perceptual encoding led to greater priming in young adults than conceptual encoding.

The age effect on priming using a conceptual implicit task (CEG) was consistent with that of other studies that used the same task (e.g. Jelicic, 1996; Maki et al., 1999; Maki & Knopman, 1996; Stuart et al., 2006). For example, in the study by Jelicic (1996) 24 young (*M* age = 26 years) and 24 older adults (*M* age = 71 years) performed a category production task (same as this study) in which they were given 16 categories and one minute to produce as many exemplars as possible for each category. The findings showed that previously studied words were generated more often than unstudied words, and young participants showed greater priming than the older participants. Furthermore, in another study in which the performance of young and older adults (*n* = 80) on a category exemplar production (CEP) task was compared following conceptual encoding (participants were asked to generate an exemplar for 30 given categorical questions), older adults (*M* age = 62 years) showed less priming than the young adults (*M* age = 22 years) (Stuart et al., 2006). These findings are consistent with the current study as age effect emerged using a conceptual implicit tasks. Furthermore, age differences in implicit memory using the CEG task were consistent with the findings of prior studies that suggested that older adults are impaired in search and selection processes. This can be understood by thinking about the task itself, in situation in which many optional answers can be correct (there are many items that belong to one category) (e.g. Mitchell & Bruss, 2003; Ryan et al., 2001; Toth, 2000), and age-related decline in implicit memory confirmed that search and selection processing is affected by age. In another study by Maki et al. (1999) participants were tested using the CEG task. Participants were given one minute for each category and asked to produce as many exemplars as they could. Priming was reduced in older compared to young adults, but the age differences occurred only in older adults aged 80 years and above. The age differences in CEG reported in Maki et al. (1999) are similar to what was found in this study, though older adults in this study were aged between 65 to 82 years.

Although many studies reported an age effect on the CEG task, many other studies (e.g. Isingrini et al., 1995; Light et al., 2000; Light & Albertson, 1989; Mitchell & Bruss, 2003; Monti et al., 1996) have shown that implicit memory on the CEG task remains intact with aging. Those studies that failed to detect an age effect on implicit memory reported different procedure than this study in a number of respects. For example, Isingrini et al. (1995) allowed two minutes for each category, while Light et al., (2000) allowed 15 seconds for each category. Also, some studies directly asked participants to produce a certain number of exemplars. For example, Light & Albertson (1989) asked participants to produce eight items per category, and Monti et al. (1996) also asked participants to produce eight items per category, and once done they moved to the next category (or after a maximum of 90 seconds). Therefore, procedural differences might be a possible reason for the discrepant findings. Additionally, the age effect that emerged in implicit memory using the CEG task in this experiment suggests that tasks dependent on production processes are sensitive to age (e.g. Light et al., 2000; Rybash, 1996). It has been reported previously that tasks which are based on accuracy measures are sensitive to age effects (e.g. Fleischman, 2007; Light et al., 2000). The general idea is that tasks based on accuracy are more greatly affected by age compared with tasks based on a latency measure. Indeed, the current study showed an age effect on the CEG task, which is based on accuracy and production processes (i.e. generating a response). Although there was a significant age effect on priming in Experiment 1A, the effect size of the age difference in this experiment was greater than the effect size of the age difference in Experiment 1A, respectively (η_p^2 = 0.241, 0.177). Thus, there is some evidence that tasks based on production and accuracy are more sensitive to age differences than tasks based on latency and identification. However, the meta-analysis by La Voie and Light (1994), after reviewing 40 studies based on the response type, showed that there were no differences in the effect size for accuracy or latency measure.

The age difference in priming observed in the conceptual priming task (CEG) was also inconsistent with findings from an earlier study by Ward (2022). Ward (2022) reported an age effect on priming following perceptually studied items only. Further, the study showed that priming did not occur among young and older participants in some conditions (i.e. young participants: conceptual encoding followed by a conceptual test (CC), and perceptual encoding followed by a perceptual test (PP); older participants: conceptual encoding followed by a conceptual test (CC), and perceptual encoding followed by a conceptual test (PC)). However, the present study showed an age difference in conceptual priming but no effect of processing at encoding in priming in older adults. Experiment 1A in contrast showed an age difference in perceptual priming only when followed by conceptual encoding. The differences in the results between this study and Ward (2022) might be related to the different tasks. Their study used a Category Verification Task (CV; an explanation of this task was shown in Figure 3) to capture conceptual priming. Although CEG and CV are both considered as conceptual tasks, the CV task used by Ward (2022) was based on a latency measure. Further, this study confirmed that the CEG task is a robust task for measuring priming, as significant priming occurred in both young and older adults in all conditions in this study.

It is important to note that older adults are known to be slower to respond compared to young adults. Hence, the age effects on priming using the CEG task, where the number of studied items that are produced is compared with the number of unstudied items produced, could reflect that young adults were able to produce more previously studied exemplars in the time given. However, this is not the case in this study, as the allocated time (45 seconds) per category was intended to enable participants to generate a sufficient number of items.

In the present study, age-related decline in explicit memory was tested using a recognition task, where participants were instructed to judge if images were presented previously or not. The findings were consistent with earlier studies showing that young adults perform better than older adults on such explicit tests of memory (e.g. Abbenhuis et al., 1990; Ward, 2018; Ward et al., 2013a, 2020; Wiggs et al., 2006). However, in this experiment there was no effect of processing on explicit memory. It was predicated that greater recognition would emerge following conceptual encoding than perceptual encoding, as conceptual processing typically leads to greater explicit memory performance (e.g. Brown & Mitchell, 1994; Mitchell & Perlmutter, 1986; Monti et al., 1996; Roediger et al., 1992). For example, Mitchell and Perlmutter (1986) showed greater recognition following conceptual than perceptual processing. The present findings do not replicate this effect, nor the observation in Experiment 1A of greater recognition following conceptual processing. The non-significant effect of processing on explicit memory is difficult to explain, but it might be related to the fact that participants were faster in the conceptual encoding block, so they were actually spending less time engaging with items in this condition compared with the perceptual condition, and this might have washed out any effect. However, this interpretation cannot fully explain the non-significant processing effect because participants were also quicker during the conceptual encoding block in Experiment 1A yet processing effects emerged. An alternative explanation is that the lack of processing effects on recognition may be due to the nature of the priming (CEG) task, which in this study was presented in a separate phase prior to the recognition task. It may be possible that the CEG task somehow interfered with the later explicit memory task and washed out the processing effect.

Background tests were administered to young and older adults to understand how they differ in a number of characteristics such as education and pre-morbid intelligence. These factors may interact with memory and affect the magnitude of age effects on priming and recognition. This study revealed a significant difference between the performance of young and older adults in the Mill Hill Vocabulary Test (Raven et al., 1988), with the older participants (*M* = 23.86, *SD* = 4.65) outperforming the younger adults (*M* = 20.60, *SD* = 3.91). The main analysis was therefore repeated with Mill Hill scores included as a covariate to verify if group differences in verbal intelligence explain the age differences in priming and recognition. The results showed that after treating the Mill Hill as a covariate the age effects were still significant on both priming and recognition, as well as the significant interaction between age and processing on priming. Thus, the present age differences in explicit and conceptual implicit memory were not affected by age differences in the verbal intelligence.

It is important to consider the possibility that the age effect on conceptual priming may have emerged due to the usage of explicit memory strategies. This is important since young adults are at more of an advantage when it comes to explicit processing, so if they noticed the connection between the study and test phases, they may have been better able to use an explicit memory strategy to improve their priming score. Furthermore, the nature of the task, which prioritizes accuracy, provides participants with increased opportunities to engage in explicit processing. Prior research using test awareness questionnaires has shown that the number of aware participants is typically higher in young than older adults (e.g. Geraci & Barnhardt, 2010). Also, in this study a conceptual priming (CEG) was used to assess priming and earlier research has suggested that there is a stronger relationship between conceptual processing and test awareness than perceptual processing and test awareness (e.g. Graf et al., 1982; Mace, 2003a, 2003b; Richardson-Klavehn et al., 1994; Toth et al., 1994). For example, Mace (2003b) instructed half of their participants that the priming task was related to memory, while the other half were not informed of this and performed the word-completion test under typical implicit memory instructions. The aim was to understand if being test aware boosted the priming score. The level of processing was also manipulated to understand how this can affect test awareness. Participants performed a conceptual processing and perceptual processing encoding task before recall (explicit) and (WSC) implicit tasks. The results showed that priming in test aware participants was enhanced in the conceptual processing condition as compared to unaware participants. Also, another study using the CEG task reported greater priming for aware than unaware participants in the conceptual condition (Mulligan et al., 1999). Despite these findings, in this study, confidence exists that the age difference in priming remined uninfluenced by explicit contamination because the number of aware participants was generally very low (10 young and three older adults reported awareness that the CEG task was related to memory). This small number of participants represented only 18.5% of the whole sample. Therefore, as the number of aware participants was small, no further analyses were conducted to statistically compare the scores of the aware participants with those who were unaware. It is highly unlikely that there was any explicit contamination in this study, as the majority of participants were unaware that CEG task was related to memory, so they would not have used an explicit strategy to boost their priming.

In ageing studies, it is important to exclude participants with cognitive impairment (e.g. MCI, AD) as including impaired participants may contribute to observed age effects since memory loss occurs during an early stage of AD (e.g. Jahn, 2013). However, and despite the advantages of online testing, there was no cognitive screening test suitable for administration in this study. There was an absence of a suitable online cognitive screening tasks, which is a key limitation of this study and the online mode of testing in general. The decision not to use the EDQ questionnaire (employed in Experiment 1A) was reached following the difficulties reported in Chapter 2. Although the EDQ is suitable for online testing, many older adults scored above the exclusion threshold yet were notably unimpaired. It is extremely important that a suitable and valid cognitive screening test is developed that is capable of being used online to rule out cognitive impairment in samples of older participants. It is worth noting that although there was no formal cognitive screening test in this study, confidence exists in the assertion that the older sample of participants were unimpaired. First, on the information sheet it was made clear that eligibility criteria included no cognitive impairment or dementia. Second, older participants ticked a box on the consent page to confirm that they do not have a clinical diagnosis of cognitive impairment, dementia, or any concerns with their cognitive function. Third, individual performance in the experimental task was normal, whereas impaired participants would have likely struggled, and this would have been visible in the data (e.g. Fleischman & Gabrieli, 1998).

In conclusion, Experiment 2 used a CEG task to measure conceptual priming in young and older adults following processing manipulation at encoding. Both conceptual priming and recognition were reduced in older than young adults, but perceptual/conceptual encoding did not affect priming or recognition. The age difference in priming interacted with processing, but only affecting young adults (greater priming following perceptual than conceptual encoding). The reduced priming in older compared to young adults was observed following both conceptual and perceptual encoding. These findings add to the evidence from Experiment 1A, in which recognition and perceptual priming (on the CID-R task) were also reduced by age, but importantly the age difference in perceptual priming was only significant following conceptual encoding. To shed further light on this, a study that matches or mismatches the processing style at encoding and test (i.e. conceptual encoding followed by conceptual priming task, conceptual encoding followed by a perceptual priming task, etc.) is needed. This will provide a clearer understanding of the role that processing plays on age differences in priming, and this will be the topic of Chapter 4.

Chapter 4: The Effects of Processing During Encoding on Conceptual and Perceptual Implicit Memory, a Repeated Measure Design (Experiment 3).

4.1 Chapter Introduction

The aim of Experiment 3 was to examine the effect of conceptual and perceptual encoding on conceptual and perceptual priming and recognition using a within-subjects design. As in previous experiments reported in this thesis, a recognition task was included to compare the age effects on explicit and implicit memory. In Experiment 3, the category verification with recognition (CV-R) task was used as a conceptual priming measure, and the CID-R task was used as a perceptual priming measure, with a recognition measure captured on each trial. Importantly, these conceptual and perceptual priming tasks were matched as far as possible on all characteristics apart from the type of processing required. Both tasks used a speeded measure with response times (RTs) as the dependent variable, and all aspects were matched as closely as possible (i.e. within-trial, events and durations, etc; see Procedure). Priming tasks (CV vs CID) differs with respect to processing requirements, but the recognition task was the same in both conditions, and therefore, the processing manipulation at test only applied to priming. Experiment 3 was pre-registered on the OSF prior to data collection (https://osf.io/cde6f; under the name of Experiment 4). All pre-registered steps and analyses were followed, and any changes or additional analyses are clearly stated. The raw data and analysis file for the final sample are available on the OSF (https://osf.io/t7b2y).

4.1.1 Hypotheses

The following predictions were made: (a) Main effect of age: It was expected that younger adults would achieve greater priming and recognition than older adults. (b) Main effect of processing: It was expected that there would be greater priming and recognition for conceptually studied items than perceptually studied items. (c) Age x Processing (conceptual/perceptual encoding) x Test (CV-R/CID-R) interaction: It was expected that age differences in priming would be greatest in the conceptual encoding, conceptual test condition, and smallest in the perceptual encoding, perceptual test condition, predicted on the basis of evidence that conceptual processing is affected to a greater extent by ageing than perceptual processing (e.g. Rybash, 1996), and encoding-test processing overlap yields greater priming than processing mismatch (e.g. Roediger & Blaxton, 1987; Roediger & McDermott, 1993). Thus, on the perceptual test greater priming was expected following perceptual than conceptual encoding in both age groups, while on the conceptual test greater priming was expected following conceptual than perceptual encoding in young adults and vice versa in older adults.

4.1.2 Methods

4.1.2.1 Participants

The sample size was estimated using G*Power, with an estimated effect size of 0.15, alpha set at .05, and power at 0.95. This resulted in a total required sample of 96 participants (48 young and 48 older adults). Young participants aged between 18 and 30 years (*M* age = 22.65 years, *SD* = 3.49; 30 females, 17 males, and one unstated) and older adults aged 65 and 86 years (*M* age = 69.19 years, *SD* = 4.79; 20 females, and 28 males) took part in this experiment. Young participants were recruited from the Middlesex University recruitment system (Sona; 16 participants) and Prolific (32 participants). All 48 older participants were recruited from Prolific. All participants were rewarded with course credit or payment at a rate of £9 per hour. Ethical approval was granted from the Middlesex University Research Ethics Committee (Approval code: 19263). Eligibility criteria for participants included that all older participants should be free of dementia, and all participants were fluent in reading and writing in English, had normal/corrected vision, and had received at least a general certificate of secondary education (GCSE). A formal measure of pre-morbid intelligence was taken (the multiple choice of the Mill Hill Vocabulary Test; Raven et al., 1988). For older adults only, additional questions were asked in relation to cognitive function: 1- Have you ever been diagnosed with mild cognitive impairment or dementia? All participants answered no. 2- Do you have difficulty with remembering names / familiar faces? Seven participants answered yes. 3- Do you have difficulty following conversations? All participants answered no. The plan was to exclude participants from the older group who answered yes to all three questions, but as no one answered yes to all questions, no one was excluded based on these additional screening questions. Additional pre-screening restrictions were also included on Prolific, to ensure that only participants without cognitive impairment were included in the sample. The demographic data of the participants can be seen in Table *4.1*.

Table 4.1. Participant Characteristics in Experiment 3

Characteristics	**Young Adults** ***M* (*SD*)** **(*n* = 48)**	**Older Adults** ***M* (*SD*)** **(*n* = 48)**
Age (years)	22.65 (3.49)	69.19 (4.79)
Gender		
(M/F/Unspecified) (*n*)	17/30/1	28/20
Education (years)	16.08 (2.20)	15.85 (3.07)
Highest Qualification (*n*)		
GCSE or equivalent	3	8
A level or equivalent	21	13
Bachelor’s degree	17	13
Master’s degree	7	12
PhD	0	2
Health Status (*n*)		
Excellent	20	4
Good	26	29
Adequate	2	13
Poor	0	2
Extremely Poor	0	0
Trouble of Vision (*n*)		
Yes	0	2
No	48	46
Somewhat	0	0
Mill Hill Vocabulary *	17.46 (5.34)	23.58 (4.02)

Note. Standard deviations for all mean values are given in the parentheses. The multiple-choice part of the Mill Hill Vocabulary Test (Raven et al., 1988), which served as a standard measure of pre-morbid intelligence with a maximum score of 33. * Significant differences between groups, p < .05.

4.1.2.2 Design

Experiment 3 involved a mixed factorial design with Age (young/older adults) as the between-subjects factor, and Processing during encoding (conceptual/perceptual), and Test (conceptual implicit task/perceptual implicit task) as the within-subjects factors. In the conceptual implicit task, priming and recognition were measured using the category verification with recognition (CV-R) task, and in the perceptual implicit task, priming and recognition were measured using the continuous identification with recognition (CID-R) task. In both tasks the priming segment involved the differences in RT between studied and new items. Recognition was calculated based on accuracy measure [*d* prime: z(hits) – z(false alarms)]. This design allowed us to compare the findings in four conditions: perceptual encoding, perceptual test (PP); conceptual encoding, perceptual test (CP); perceptual encoding, conceptual test (PC); conceptual encoding, conceptual test (CC).

4.1.2.3 Stimuli

All visual stimuli were taken from the BOSS (Brodeur et al., 2010, 2014). For example (see Figure 4B in Chapter 2). In total, 160 coloured stimuli (*M* familiarity = 4.33, *SD* = 0.37) were used in this experiment. All stimuli in the encoding and test phases were presented in a new random order for each participant. Eighty items were presented in each block, 40 in the encoding phases and 80 in the test phases (40 previously studied: 20 perceptually studied, 20 conceptually studied, and 40 new). Approximately half of the stimuli were naturally occurring items, and the other half were manufactured items. Stimuli were presented in colour in 320 x 320 pixels in the centre of a white background screen. The priming masked used in the test phase (CID-R task) was black and white 384 x 384 pixel grid. As participants completed the experiment online on their own computers, screen size varied between of 800 x 480 and 1920 x 1080 pixels. Therefore, the exact size of images for any given participant depended on their screen size, but stimuli were automatically configured by the Gorilla software to fit within the confines of the zone.

4.1.2.4 Procedure

The experiment was once again developed and administered using Gorilla.sc, participants performed the task using their own computers (desktop or laptop, not phones or tablets). There were restrictions regarding the browser type that could be used; only the following browsers were allowed: Chrome, Firefox, Safari, and Internet Explorer, and a minimum connection speed of 8 Mbps was required, to ensure that slow internet speed did not affect the presentation of images or recording of RTs. Following informed consent and before the computer task, participant background information was collected including age, sex, years of education, highest qualification level, self-rated vision, and self-reported health. For older participants only, additional questions were asked in relation to cognitive function as reported previously (see section 4.1.2.1), and additional pr-screening was included in Prolific (see section 4.1.2.1). Participants were fully briefed about the nature of their involvement and provided informed consent. They were asked to complete the online study in a quiet room and only when they had ample time, as once they started the study, it could not be paused or resumed at a later time.

4.1.2.4.1 Experimental Task

4.1.2.4.1.1 Encoding Phase

The experiment was broken up into separate encoding and test phases, each containing two blocks. The encoding phase in one block involved conceptual processing of items, and the encoding phase in the other block involved perceptual processing (the order was counterbalanced between participants). Five practice trials were presented in each encoding phase. During each encoding phase a stream of 40 objects was presented. A black fixation cross (‘+’) was presented for 500 ms, followed by an object for 500 ms. On each trial, participants were instructed to judge whether the presented object was natural or manufactured (conceptual condition), or whether the presented object was tilted or upright (perceptual condition). For making a response, participants were instructed to make a keyboard press Z = upright/natural; M = tilted/manmade, and the options remained on the screen until participants made their decision. Speed was emphasised.

4.1.2.4.1.2 Filler Phase

Between the encoding and test phase, there was a brief mental arithmetic filler phase that took three minutes to be completed. The purpose was to provide an unrelated non-verbal task to avoid primacy and recency effects and ensure that all participants have the same duration between the encoding and test phases. In the filler task, participants were presented with random numbers (1-9) and their task was to decide as quickly as possible whether each number was odd or even by selecting an on-screen response option. A fixation cross (‘+’) was presented for 500 ms, followed by a number presented for 5000 ms.

4.1.2.4.1.3 Test Phase – CV-R Task

Following the encoding phases there was a test phase in which participants performed two implicit memory tests with a concurrent recognition judgement: a CV-R task (Figure 13) and CID-R task (order counterbalanced between participants). Four practice trials were presented for each task. In the CV-R task, 80 objects were presented, one at a time (half studied; 20 studied perceptually, 20 studied conceptually, and half new). On each trial, a measure of priming and recognition were captured. A black fixation was presented for 500 ms followed by an object (old/new) and participants were instructed to judge if it matched a given category label by selecting ‘Yes’ or ‘No’ as quickly as possible. For example, an image of an “apple” was presented alongside a category that either matched the item (e.g. “fruit”) or mismatched the item (e.g. “clothing”). On half of the trials the object matched the category. RT was captured when participants made a response by choosing between two boxes which were presented on the screen, one box represent the choice ‘Yes’, and another box represent the choice ‘No’. The object remained on the screen until a response was made, but speed was emphasised. Immediately after response the object was presented again for a recognition judgment, whereby participants were prompted to judge whether or not the object was previously shown in the encoding phase (yes/no). In the instructions, participants were informed that half of the images were presented previously in the encoding phase, and half of the images were new. On a scale of six point, participants responded, where 1 = Sure no, 2 = Think no, 3 = Guess no, 4 = Guess yes, 5 = Think yes, 6 = Sure yes. There was no time limit on the recognition judgment. Following the recognition response, a black fixation cross was presented for 500 ms prior to the next priming trial.

4.1.2.4.1.4 Test Phase – CID-R Task

The CID-R task was identical to that used in Experiment 1A. A total of 80 objects were presented, one at a time (40 studied; 20 studied perceptually, 20 studied conceptually, and 40 new). On each trial, measures of priming and recognition were captured. Participants were informed that on each trial the object would be presented, but it would be behind a mask and difficult to see at first. They were instructed that the object would appear to flash and emerge from behind the mask, gradually becoming clearer. On each trial, the object was initially presented for 16 ms (screen refresh rate) and then immediately masked for 250 ms. The object and mask presentation then alternated with the object's presentation increasing by 16 ms each time and the mask duration decreasing by 16 ms each time, with the effect that the object appears to gradually clarify. Participants were instructed to identify the object as quickly as they could by pressing the 'Space' bar. Upon keypress their identification RT was captured, and they were prompted to type the object name into a box on the screen and then press 'Enter'. In the event that a participant had not identified the object by the time it was fully presented (7000 ms), then the task automatically moved to the recognition judgement. Missed priming trials such as this (i.e. with RTs above 7000 ms) were removed before analysis. Following the priming measure, the same object was presented again for a recognition judgement, whereby participants were prompted to judge whether the object was previously shown in the encoding phase or was new. Participants were informed that half of the objects were presented previously, and half were new. Participants responded on a six-point scale where 1= Sure no, 2= Think no, 3= Guess no, 4= Guess yes, 5= Think yes, 6= Sure yes. There was no time limit on the recognition judgment.

4.1.2.4.1.5 Background Tests

Following the test phase, participants performed a short awareness questionnaire containing five questions adapted from Bowers and Schacter (1990): (1) What do you think was the purpose of the task where you identified objects under the flashing grid? (2) What do you think was the purpose of the task where you judged if objects matched a given category? (3) Did you suspect prior to the start of these test that you would be tested on your memory of the objects? (4) Did you try to use your memory of the pictures to help you in these tasks? (5) If yes, do you think this strategy helped you, and how so? At the end of the experiment, participants completed the multiple-choice component of the Mill Hill vocabulary test (Raven et al., 1988; see Appendix), which served as a brief measure of verbal intelligence as discussed previously, in this test participants were given a total of 33 words and asked to select the correct meaning for each word among six options.

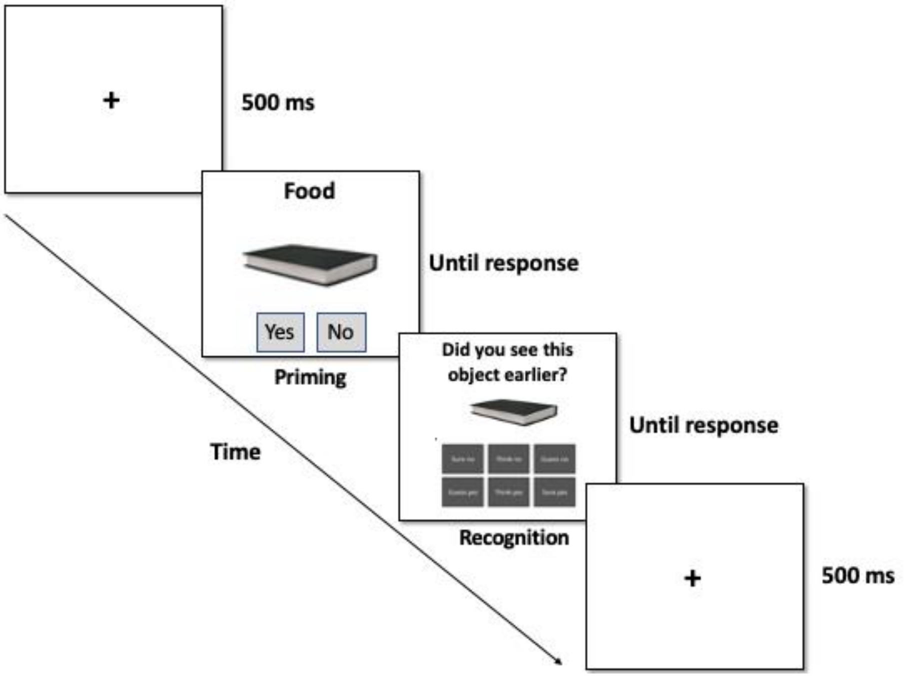

Figure 13. The Category Verification with Recognition (CV-R) Task Used in Experiment 3.

Note. Participants were instructed to decide if the presented image (e.g. book) matched the given category name (e.g. Food) by selecting 'yes' or 'no' as quickly as possible (priming). Following the priming decision, the same image was presented again for a recognition judgment, and participants were instructed to decide whether the object was presented earlier during the encoding phase or not.

4.1.3 Results of Experiment 3

4.1.3.1 Analysis

To examine the hypotheses, the main analysis involved separate 2 Age (young/older) × 2 Processing during encoding (conceptual/perceptual) × 2 Test (conceptual implicit task/perceptual implicit task) repeated measures ANOVAs on priming and recognition, with planned follow-up t tests for any significant interaction. An alpha level of .05 was used for all statistical tests. Partial eta squared (η_p^2) was reported for ANOVA effects and Cohen's *d* and 95% confidence intervals for t-tests. A Bayes Factor analysis was conducted for non-significant effects. BF10 values of less than 1/3 were considered support for the null hypothesis (Dienes, 2014). All data were analysed using JASP version 0.16.2 (JASP Team, 2023).

4.1.3.2 Data Screening and Exclusion

Participants were excluded if they did not meet the eligibility criteria, if they failed to complete the experiment task or follow the instructions, or if they did not meet certain performance thresholds (detailed in the subsections below). In total, 32 participants were excluded, and additional participants were recruited to achieve the required sample size. From the young group, one participant was excluded due to technical issues with response recording, and eight were excluded for failing to follow the instructions (they did not press the 'Space' key as instructed in the CID identification task to identify objects), and four participants were excluded because they performed poorly in the test phase (CID-R). From the older group, eight participants did not follow instructions (did not press the 'Space' key as instructed in the CID identification task), one participant performed poorly in the encoding phase (explained in the encoding phase section below), and 10 participants performed poorly in the priming task (explained in the priming section below).

4.1.3.3 Encoding Phase

In the OSF pre-registration it was stated that participants with <70% correct responses across the two encoding phase blocks would be replaced, however, in practice this was not feasible as the majority of participants scored below this threshold. Therefore, exclusion criteria were applied to participants who demonstrated significant underperformance (i.e. <50%) during the encoding phase (discussed further in the Discussion). Therefore, one older participant was excluded due to low accuracy level in the encoding phase. The correct answer in the perceptual encoding phase block was calculated the same way as in Experiment 1A. That is, since the correct answer (upright/tilted) is somewhat subjective, accuracy was calculated based on the majority response by participants. If the majority of participants judged a presented image as tilted, then tilted was considered the correct answer. Mean accuracy and RTs in the perceptual and conceptual blocks can be found in Table *4.2*.

A 2 (Age) × 2 (Processing) ANOVA on accuracy revealed main effects of Processing $F(1, 94) = 102.66$, $p < .001$, $\eta_p^2 = 0.52$, and Age $F(1, 94) = 5.52$, $p = .021$, $\eta_p^2 = 0.06$, and a significant Processing × Age interaction $F(1, 94) = 40.02$, $p < .001$, $\eta_p^2 = 0.30$. The main effect of Processing indicated that participants showed greater accuracy in the conceptual encoding condition (Marginal Mean = 88.28%) than the perceptual encoding condition (Marginal Mean = 78.02%), and the significant main effect of Age indicated that older adults (Marginal Mean = 84.90%) showed greater accuracy than the young adults (Marginal Mean = 81.41%). Follow-up tests were conducted to examine the significant interaction in the accuracy data. Paired sample t-tests indicated that young adults performed significantly better in the conceptual encoding condition (*M* = 89.74% , *SD* = 6.19) than perceptual encoding condition (*M* = 73.07%, *SD* = 9.54), *t*(47) = 11.04, *p* < .001, *d* = 1.59, 95% CI [13.63, 19.70], and similarly, older adults performed significantly better in the conceptual encoding condition (*M* = 86.82%, *SD*= 9.35) than the perceptual encoding condition (*M* = 82.97%, *SD* = 9.67), *t*(47) = 2.86, *p* = .006, *d* = 0.41, 95% CI [1.14, 6.57]. An independent samples t-test showed that accuracy in the perceptual encoding condition was significantly greater in older adults (*M* = 82.97%, *SD* = 9.67) than young adults (*M* =73.07%, *SD* = 9.54), *t*(94) = 5.05, *p* <.001 , *d* = 1.03, 95% CI [-13.79, -6.00], however, there was no significant differences between young and older adults in the conceptual encoding condition, *t*(94) =1.80, *p* = .075, *d* = 0.37, 95% CI [-0.30, 6.13], (BF10 = 0.89).

A 2 (Age) × 2 (Processing) ANOVA on RTs revealed a main effect of Processing *F*(1, 94) = 35.06, *p* < .001, η_p^2 = 0.27, and a significant interaction between Processing × Age *F*(1, 94) = 11.36, *p* = .001, η_p^2 = .001, but there was no main effect of Age, *F*(1, 94) = 0.65, *p* = .421, η_p^2 = 0.01, (BF10 = 0.38). The main effect of Processing indicated that participants were quicker in the conceptual encoding condition (Marginal Mean = 804 ms) than the perceptual encoding condition (Marginal Mean = 906 ms). Follow-up tests were conducted to examine the significant interaction in the RT data. Paired sample t-tests indicated that young adults were quicker in the conceptual encoding condition (*M* = 792 ms, *SD* = 234) than the perceptual encoding condition (*M* = 953 ms, *SD* = 269), *t*(47) = 5.55, *p* < .001, *d* = 0.80, 95% CI [-218.84, -102.33], and similarly, older adults were quicker in the conceptual encoding condition (*M* = 816 ms, *SD* = 195) than the perceptual encoding condition (*M* = 860 ms, *SD* = 203), *t*(47) = 2.34, *p* = .024, *d* = 0.34, 95% CI [-82.06, -6.10]. An independent samples t-test showed no significant differences between young and older adults in the conceptual encoding condition, *t*(94) = 0.53, *p* = .596, *d* = 0.11, 95% CI [-110.87,64.04], (BF10 = 0.24), and no significant differences between young and older adults in the perceptual encoding condition, *t*(94) = 1.91, *p* = .059, *d* = 0.39, 95% CI [-3.53,189.70], (BF10 = 1.07).

Table 4.2. The Performance of Young and Older Adults in the Encoding Phase in Experiment 3

Encoding Phases	**Young Adults** ***M* (*SD*)**	**Older Adults** ***M* (*SD*)**
Accuracy (%)		
Conceptual Encoding	89.74 (6.19)	86.82 (9.35)
Perceptual Encoding	73.07 (9.54)	82.97 (9.67)
RTs (ms)		
Conceptual Encoding	792 (234)	816 (195)
Perceptual Encoding	953 (269)	860 (203)

Note. Mean accuracy (%) and mean RTs (ms) in the conceptual and perceptual encoding blocks in Experiment 3. Standard deviations for all mean values are given in the parentheses.

4.1.3.4 Recognition

Recognition was captured within the CID-R and CV-R tasks. The number of excluded trials was as follows: for the CID-R test, out of 3384 total trials, 357 were excluded in the young group, and 635 trials in the older group. For the CV-R test, 318 trials were excluded in the young group, and 283 in the older group. Recognition (Figure 14 and Table *4.3*) was calculated the same way as reported in Experiment 1A. That is, *d'* was calculated for each participant by subtracting z-transformed hits (proportion of old items judged old) minus z-transformed FA (proportion of new items judged old). The Snodgrass and Corwin (1988) correction was applied to hit and false alarm rates with values of zero or one (i.e. Hit rate = (n Hits + 0.5) / (n old + 1); FA rate = (n FAs + 0.5) / (n new+1) prior to calculating *d'*.

A 2 (Age) × 2 (Processing) × 2 (Test) ANOVA with the within-subjects factors Processing during encoding (conceptual/perceptual), and Test (CV-R /CID-R), and between-subjects factors Age (young/older adult) was conducted. There were significant main effects of Processing, *F*(1, 94) = 54.95, *p* < .001, η_p^2= 0.37, Test, *F*(1, 94) = 17.22, *p* < .001, η_p^2= 0.16, and a significant interaction between Processing × Test, *F*(1, 94) = 31.17, *p* < .001, η_p^2= 0.25. The main effect of Processing indicated a greater recognition in the conceptual encoding condition (Marginal Mean: d prime = 2.06) than the perceptual encoding condition (Marginal Mean: d prime = 1.70), and the main effect of Test indicated a greater recognition in the conceptual test (CV-R) (Marginal Mean: d prime = 2.07) than the perceptual test (CID-R) (Marginal Mean: d prime = 1.69). The Processing x Test interaction showed that participants had greater recognition following conceptual (Marginal Mean: d prime = 1.98) than perceptual condition (Marginal Mean: d prime = 1.40) on the CID-R, and similarly, participants had greater recognition following conceptual (Marginal Mean: d prime = 2.14) than perceptual (Marginal Mean: d prime = 1.99) condition on the CV-R. However, there was no main effect of Age, *F*(1, 94) = 0.20, *p* = .659, η_p^2= 0.002, (BF10 = 0.25), and no significant interaction between Processing × Age *F*(1, 94) = 1.76, *p* = .188, η_p^2= 0.02, (BF10 = 0.24), Test × Age *F*(1, 94) = 0.60, *p* = .439, η_p^2= 0.01, (BF10 = 0.27), or Processing × Test × Age *F*(1, 94) = 1.53, *p* = .220, η_p^2= 0.02, (BF10 = 0.41).

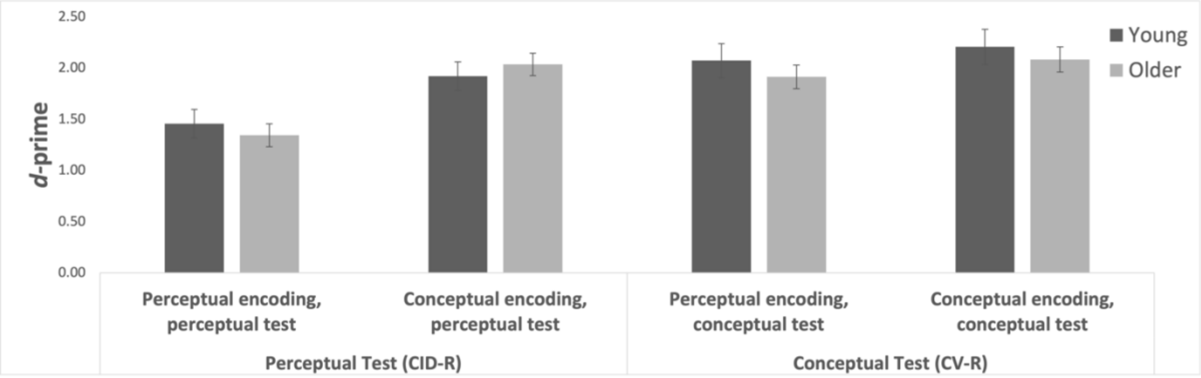

Figure 14. Recognition in Young and Older Adults in Experiment 3.

Note. Recognition task was the same in all conditions (i.e. the perceptual encoding, perceptual test; conceptual encoding, perceptual test; perceptual encoding, conceptual test; and conceptual encoding, conceptual test conditions are actually identical), but the data is represented in the same ways as priming for ease of comparison. PP: perceptual encoding, recognition task; CP: conceptual encoding, recognition task; PC: perceptual encoding, recognition task; CC: conceptual encoding, recognition task. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars represent standard error of the mean (SEM).

Table 4.3. The Proportion of Hits, Misses, FA, and CR in Experiment 3

Test	**Conceptual Encoding (CC)**		**Perceptual Encoding (PC)**	
	Young *M* (*SD*)	**Older *M* (*SD*)**	**Young *M* (*SD*)**	**Older *M* (*SD*)**
CV-R				
Hits	0.81 (0.22)	0.78 (0.19)	0.77 (0.25)	0.74 (0.20)
Misses	0.16 (0.23)	0.22 (0.20)	0.22 (0.26)	0.26 (0.21)
	Young *M* (*SD*)		**Older *M* (*SD*)**	
FA	0.18 (0.24)		0.15 (0.12)	
CR	0.82 (0.24)		0.86 (0.11)	
	Conceptual Encoding (CP)		**Perceptual Encoding (PP)**	
	Young *M* (*SD*)	**Older *M* (*SD*)**	**Young *M* (*SD*)**	**Older *M* (*SD*)**
CID-R				
Hits	0.90 (0.09)	0.82 (0.14)	0.79 (0.18)	0.61 (0.21)
Misses	0.09 (0.10)	0.18 (0.14)	0.21 (0.19)	0.39 (0.21)
	Young *M* (*SD*)		**Older *M* (*SD*)**	
FA	0.32 (0.26)		0.19 (0.15)	
CR	0.67 (0.27)		0.81 (0.15)	

Note. Hits: old items correctly judged old; Misses: old items incorrectly judged new; FA: new items judged old; CR: new items correctly judged new. FA stands for false alarms, and CR stands for correct rejection. CV-R: Category Verification Task with Recognition, CID-R: Continuous Identification Task with Recognition. Standard deviations for all mean values are given in the parentheses.

4.1.3.4.1 Additional Recognition Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether recognition was above zero in each condition. Recognition (Figure 14) in young and older adults was significantly above zero in all conditions: Young adults: conceptual encoding, conceptual test: $t(47) = 12.90$, $p < .001$, $d = 1.86$, 95% CI [1.86, 2.55], perceptual encoding, conceptual test: $t(47) = 12.56$, $p < .001$, $d = 1.81$, 95% CI [1.74, 2.40], conceptual encoding, perceptual test: $t(47) = 13.90$, $p < .001$, $d = 2.01$, 95% CI [1.64, 2.20], perceptual encoding, perceptual test: $t(47) = 10.32$, $p < .001$, $d = 1.49$, 95% CI [1.17, 1.74]. Older adults: conceptual encoding, conceptual test: $t(47) = 16.91$, $p < .001$, $d = 2.44$, 95% CI [1.84, 2.33], perceptual encoding, conceptual test: $t(47) = 16.49$, $p < .001$, $d = 2.38$, 95% CI [1.68, 2.15], conceptual encoding, perceptual test: $t(47) = 18.84$, $p < .001$, $d = 2.72$, 95% CI [1.82, 2.25], perceptual encoding, perceptual test: $t(47) = 12.01$, $p < .001$, $d = 1.73$, 95% CI [1.12, 1.57].

4.1.3.5 Priming

Although it was stated in the OSF that participants scoring below 80% in the test phases would be replaced, once again this was not feasible. In hindsight this threshold was too high as there were many participants who did not reach 80% accuracy. The aim was to keep as many participants as possible, and only excluded those who achieved less than 70% accuracy. A total of four young participants scored below 70%, and 10 older participants scored below 70% in the test phase and were replaced. For each participant, individual trials associated with incorrect object identifications (CID-R task, minor spelling mistakes were permitted), or incorrect category judgements (CV-R task) were removed, as well as any RTs above 7000 milliseconds in both CID-R and CV-R were removed prior to the analysis. Further, trials associated with RTs < 200 milliseconds or > 3SD from the mean (for old/new items separately) were also removed. Although, the CV-R task have no time limit, but any trial with 7000 ms and above was removed to ensure consistency between conceptual (CV-R) and perceptual (CID-R) priming task. The priming mean in the CID-R and CV-R task was then calculated for each participant as the mean RT for new items minus the RT for old items divided by the baseline (new item) RT: (RTnew – RTold) / RTnew, and averaged across participants. For raw RTs, see Table *4.4*.

A 2 (Age) × 2 (Processing during encoding) × 2 (Test) ANOVA revealed only a main effect of Test, *F*(1, 94) = 7.30, *p* = .008, η_p^2= 0.07. There was no main effect of Age, *F*(1, 94) = 2.39, *p* = .125, η_p^2= 0.03, (BF10 = 0.44), or Processing *F*(1, 94) = 1.92, *p* = .169, η_p^2= 0.02, (BF10 = 0.17), and no significant interaction between Processing × Age, *F*(1, 94) = 2.63, *p* = .108, η_p^2= 0.03, (BF10 = 0.26), Test × Age, *F*(1, 94)= 2.01, *p* = .160, η_p^2= 0.02, (BF10= 1.09), Processing × Test, *F*(1, 94) = 0.01, *p* = .931, η_p^2= < .001, (BF10 = 0.22), or Processing × Test × Age, *F*(1, 94)= 0.25, *p* = .618, η_p^2= 0.003, (BF10 = 0.28). The main effect of Test indicated that participants showed greater priming in the perceptual test (Marginal Mean: prop. priming = 0.04) than the conceptual test (Marginal Mean: prop. priming = -0.01). Despite there being no main effect of age, there were clear age differences on the CID-R (perceptual test) priming task visible in **Error! Reference source not found.** while priming in the CV-R task was altogether absent (negative). As such, the decision was made to remove the CV-R test in an exploratory analysis and examine the age difference in a 2 (Age) × 2 (Processing during encoding) ANOVA on the CID-R test only. This revealed a significant main effect of Age, *F(*1, 94) = 6.57, *p* = .012, η_p^2= 0.07, indicating a greater priming in young (Marginal Mean: prop. priming = 0.05) than older adults (Marginal Mean: prop. priming = 0.01). However, there was no effect of Processing, *F*(1, 94) = 0.60, *p* = .442, η_p^2= 0.01, (BF10 = 0.20), and no significant interaction between Processing × Age, *F*(1, 94) = 1.68, *p* = .198, η_p^2= .018, (BF10 = 0.48). Although there was no significant interaction, further exploratory analyses were conducted. There was a significant difference between young and older adults in the conceptual encoding, perceptual test condition (i.e. CP), *t*(94) = 2.58, *p* = .012, *d* = 0.53, 95% CI [0.01, 0.11], indicating that young adults had greater priming than older adults in this condition (conceptual encoding, followed by a perceptual test), but there was no significant Age difference in the perceptual encoding, perceptual test condition, *t*(94) = 1.61, *p* = .111, *d* = 0.33, 95% CI [-0.01, 0.07], (BF10 = 0.67).

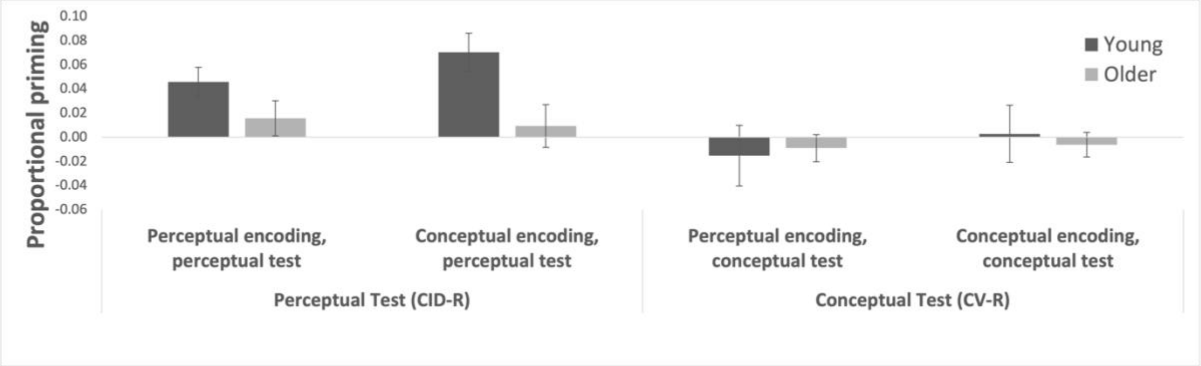

Figure 15. Priming in Young and Older Adults in Experiment 3.

Note. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars represent standard error of the mean (SEM).

Table 4.4. Mean of RTs for Young and Older Adults in Experiment 3

Implicit Memory Tests	**Young Adults *M* (*SD*) (ms)**	**Older Adults *M* (*SD*) (ms)**
CID-R Task		
Perceptual RTs (PP)	3129 (633)	3435 (727)
Conceptual RTs (CP)	3044 (632)	3454 (758)
New	3271 (537)	3494 (677)
CV-R Task		
Perceptual RTs (PC)	1684 (399)	2119 (440)
Conceptual RTs (CC)	1654 (375)	2108 (405)
New	1670 (347)	2100 (403)

Note. CID-R: Continuous Identification with Recognition, PP: perceptual encoding, perceptual test; CP: conceptual encoding, perceptual test; CV-R: Category Verification with Recognition; PC: perceptual encoding, conceptual test; CC: conceptual encoding, conceptual test. Standard deviations for all mean are given in the parenthesis

4.1.3.5.1 Additional Priming Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether priming was above zero in each condition. Priming (Figure 15) in young adults was significantly above zero in all conditions apart from conceptual encoding, conceptual test and perceptual encoding, conceptual test: conceptual encoding, conceptual test: $t(47) = 0.12$, $p = .904$, $d = 0.02$, 95% CI [-0.05, 0.05] (BF10 = 0.16), perceptual encoding, conceptual test: $t(47) = 0.61$, $p = .548$, $d = 0.09$, 95% CI [-0.07, 0.04] (BF10 = 0.19), conceptual encoding, perceptual test: $t(47) = 4.47$, $p < .001$, $d = 0.65$, 95% CI [0.04, 0.10], perceptual encoding, perceptual test: $t(47) = 3.83$, $p < .001$, $d = 0.55$, 95% CI [0.02, 0.07]. However, priming in older adults was not significantly above zero in any condition: conceptual encoding, conceptual test: $t(47) = 0.61$, $p = .545$, $d = 0.09$, 95% CI [-0.03, 0.01], (BF10 = 0.19), perceptual encoding, conceptual test: $t(47) = 0.80$, $p = .429$, $d = 0.12$, 95% CI [-0.03, 0.01],(BF10 = 0.21), conceptual encoding, perceptual test: $t(47) = 0.53$, $p = .599$, $d = 0.08$, 95% CI [-0.03, 0.05] (BF10 = 0.18), perceptual encoding, perceptual test: $t(47) = 1.07$, $p = .291$, $d = 0.15$, 95% CI [-0.01, 0.05] (BF10 = 0.27) (all two-tailed). This indicates that older adults did not exhibit a priming effect in any condition in this experiment.

4.1.3.6 Awareness Questionnaire

The test awareness questionnaire revealed that 19 young and eight older adults became aware that the CID priming task was related to memory. However, only six young and three older adults became aware on the CV priming task. Therefore, further analysis was conducted only on young adults in the CID task, as the percentage of young participants rated as aware was above the pre-registered threshold of 20%. A 2 (Processing at encoding: conceptual /perceptual) × 2 (Awareness: aware/unaware) ANOVA was conducted. There was no main effects of Processing, $F(1, 46) = 1.70$, $p = .199$, $\eta_p^2 = 0.04$, (BF10 = 0.64), or Awareness, $F(1, 46) = 2.95$, $p = .093$, $\eta_p^2 = 0.06$, (BF10 = 0.95), and no significant interaction between Processing × Awareness, $F(1, 46) = 1.63$, $p = .208$, $\eta_p^2 = 0.03$, (BF10 = 0.57), indicating that priming did not differ in aware versus unaware in young adults. This suggests that there was no explicit contamination in the task. The mean proportion of priming for aware versus unaware participants is presented in Table *4.5*.

Table 4.5. Priming in Aware and Unaware Participants in Experiment 3

Priming Scores	**Aware** ***M* (*SD*)**		**Unaware** ***M* (*SD*)**	
	Young	**Older**	**Young**	**Older**
Conceptual Priming (CV)				
CC	-0.06 (0.14)	-0.01 (0.15)	0.01 (0.17)	-0.01 (0.07)
PC	-0.03 (0.08)	-0.01 (0.09)	-0.01 (0.18)	-0.01 (0.08)
Perceptual Priming (CID)				
CP	0.03 (0.10)	-0.03 (0.12)	-0.09 (0.11)	0.02 (0.12)
PP	0.03 (0.08)	-0.03 (0.08)	-0.05 (0.08)	0.02 (0.10)

Note. CC: conceptual encoding, conceptual test; PC: perceptual encoding, conceptual test; CP: conceptual encoding, perceptual test; PP: perceptual encoding, perceptual test. CV: Category Verification, CID: Continuous Identification. Standard deviations for all mean values are given in the parentheses.

4.1.3.7 Covariate Analysis (not pre-registered)

An independent sample t-test showed that older adults (*M* = 23.58, *SD* = 4.02) had significantly better performance than young adults (*M* = 17.46, *SD* = 5.43) on the Mill Hill Vocabulary Test (Raven et al., 1988), *t*(94) = 6.29, *p* < .001, *d* = 1.28, 95% CI [-8.06, -4.19]. However, there were no significant differences between young and older adults in any other variables, including years of education, *t*(94) = 0.42, *p* = .675 *d* = 0.09 , 95% CI [-0.85, 1.31], (BF10 = 0.23). As the Mill Hill scores significantly differed between groups, the 2 (Age) × 2 (Processing during encoding) ANOVA was repeated for priming with the Mill Hill scores entered as a covariate to examine whether differences in Mill Hill scores contributed to the significant age difference. There was no main effect of Processing, *F*(1, 93) = 2.07, *p* = .154 , η_p^2= 0.02, (BF10 = 0.41), or Age *F*(1, 93) = 0.21 , *p* = .648, η_p^2= 0.003, (BF10 = 0.35), and no significant interaction between Processing × Age, *F*(1, 93) = 0.03, *p* = .861 , η_p^2= 3.31, (BF10 = 0.29). Thus, the age effect which emerged in the CID-R priming task appears to have been influenced by differences between young and older adults in the vocabulary test.

4.1.3.8 Further Additional Analysis (not pre-registered)

Age differences in priming and recognition were not clear in this experiment. Thus, a median split analysis was conducted to investigate priming and recognition among the youngest and oldest participants (see Figure 16 and Figure 17). Participants from each age group were split into two groups based on the median age, giving four different age groups as follows: youngest (*n* = 27): 18-22 years, young (*n* = 21): 23-30 years, older (*n* = 25): 65-67 years, and oldest (*n* = 23): 68-86 years.

A 4 (Age) × 2 (Processing) × 2 (Test) ANOVA on recognition showed significant main effects of Processing, *F*(1, 92) = 53.58, *p* < .001, η_p^2= 0.37, Test *F*(1, 92) = 19.41 *p* < .001, η_p^2= 0.17, and Age, *F*(3, 92) = 3.72, *p* = .014, η_p^2= 0.11, and a significant interaction between Processing × Test, *F*(1, 92) = 33.16, *p* < .001, η_p^2= 0.27. However, the interaction between Processing × Age, *F*(3, 92) = 1.00, *p* =.397, η_p^2= 0.03, (BF10 = 0.05), Test × Age, *F*(3, 92) = 1.88, *p* = .138, η_p^2= 0.06, (BF10 = 2.33), and Processing × Test × Age, *F*(3, 92) = 2.07, *p* = .109, η_p^2= 0.06, (BF10 = 0.14) were non-significant. The effect of Processing indicating a greater recognition in the conceptual condition (Marginal Mean: d prime = 2.08) than the perceptual condition (Marginal Mean: d prime = 1.72), and the effect of Test indicating a greater recognition in the conceptual test (Marginal Mean: d prime = 2.10) than the perceptual test (Marginal Mean: d prime = 1.70), and Age effect indicated that young participants (Marginal Mean: d prime = 2.31) had greater recognition compared to oldest (Marginal Mean: d prime = 1.88), older (Marginal Mean: d prime = 1.81), and youngest (Marginal Mean: d prime = 1.60). Follow up tests were conducted to examine the significant age effect. Post hoc comparisons using the Tukey test showed Age differences between the youngest and young participants in the perceptual encoding, conceptual test condition, *t* = 3.97, *p* = .010, *d* = 1.15, 95% CI [-2.01, -0.10], indicating that young participants (23-30 years) had greater recognition than the youngest participants (18-22 years) in the perceptual encoding, conceptual test condition. There were no other significant differences.

The 4 (Age) × 2 (Processing) ANOVA on priming (CID-R task only given no priming in the CV-R task) showed no main effect of Processing, *F*(1, 92) = 0.41, *p* = .524, η_p^2= 0.004, (BF10 = 0.20), and no interaction between Processing × Age, *F*(3, 92) = 1.25, *p* = .298, η_p^2= 0.04, (BF10 = 0.23). However, there was a marginal main effect of Age, *F*(3, 92) = 2.63, *p* = .055, η_p^2= 0.08, (BF10 = 1.11).The Age effect indicated that youngest participants (Marginal Mean: prop. priming = 0.07) had greater priming compared to young (Marginal Mean: prop. priming = 0.04), older (Marginal Mean: prop. priming = 0.02), and oldest (Marginal Mean: prop. priming = 0.01).

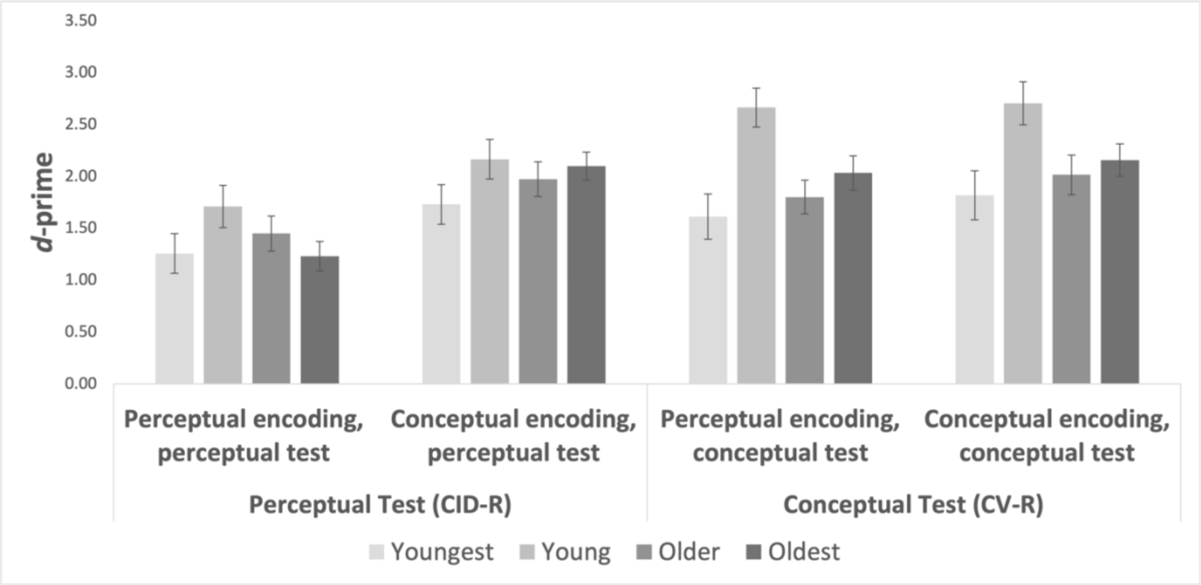

Figure 16. Recognition in the Four Age Groups (Median Split Analysis) in Experiment 3.

Note. Youngest = 18-22 years; young = 23-30 years; older = 65-67 years; oldest 68-86 years. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars indicate standard error of the mean (SEM).

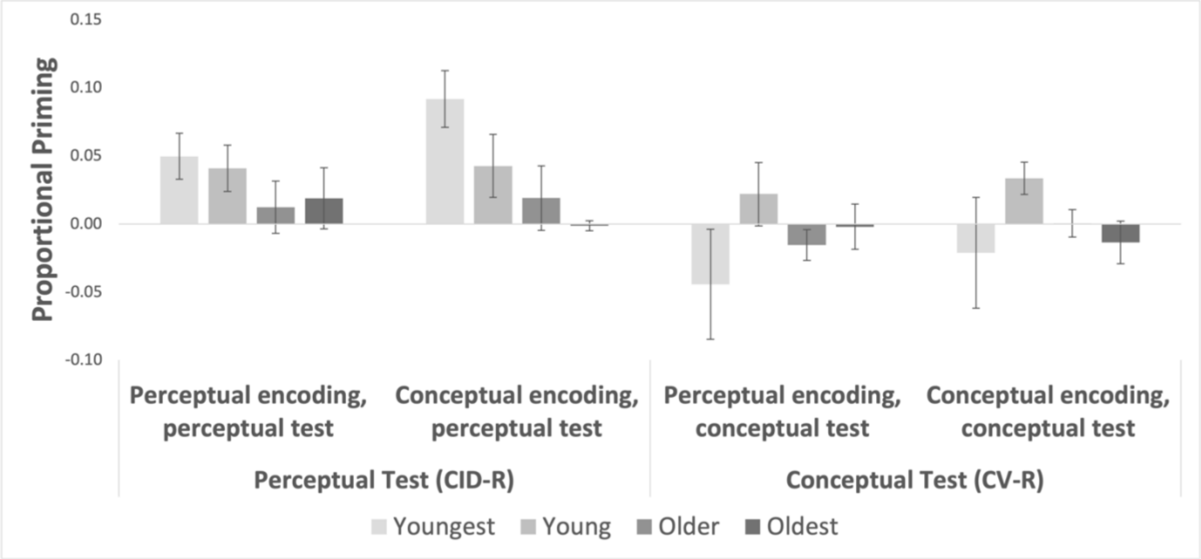

Figure 17. Priming in the Four Age Groups (Median Split Analysis) in Experiment 3.

Note. Youngest = 18-22 years; young = 23-30 years; older = 65-67 years; oldest 68-86 years. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars indicate standard error of the mean (SEM).

Table 4.6. Summary of Results for Experiment 3

	F-statistic	**p-value**	**Effect size (η_p^2)**
Encoding phase			
(a) Accuracy			
Processing	102.66	<.001	0.52
Age	5.52	.021	0.06
Processing x Age	40.02	<.001	0.3
(b) RT			
Processing	35.06	<.001	0.27
Age	0.65	0.421	0.01
Processing x Age	11.36	0.001	0.001
Recognition			
Processing	54.95	<.001	0.37
Test	17.22	<.001	0.16
Processing x Test	31.17	<.001	0.25
Age	0.2	.659	0.002
Processing x Age	1.76	.188	0.02
Test x Age	0.6	.439	0.01
Processing x Test x Age	1.53	.220	0.02
Priming			
Processing	1.92	.169	0.02
Test	7.30	.008	0.07
Processing x Test	0.01	.931	<.001
Age	2.39	.125	0.03
Processing x Age	2.63	.108	0.03
Test x Age	2.01	.160	0.02
Processing x Test x Age	0.25	.618	0.003

Note. This table summarizes the key results obtained from Experiment 3.

4.1.4 Discussion of Experiment 3

This experiment systemically manipulated processing (conceptual/perceptual) in the encoding phase prior to conducting conceptual (CV-R) and perceptual (CID-R) priming tasks. The conceptual and perceptual priming tasks used in this study were very comparable except for the type of processing. Both tasks were based on latency measure (speed), using the same type and number of stimuli, and the duration of events within both tasks were consistent. Also, for consistency between both tasks any RTs above 7000 ms were removed before the analysis. These similarities made both tasks very comparable except for the processing style required (CV- conceptual, CID- perceptual).

For priming, only a main effect of the test emerged in the initial analysis, indicating greater perceptual priming (CID) than conceptual priming (CV). There was no priming on the CV-R task in either group (negative), yet the CID-R task was sensitive to priming, suggesting that this task is a robust tool for assessing implicit memory, while the CV-R task is less sensitive. This may be because repetition priming is itself a very robust phenomenon (e.g. Berry et al., 2012; experiment 1). The significant effect of test indicates greater priming on the perceptual implicit test (CID) than the conceptual implicit test (CV), which is consistent with Ward (2022), which showed greater priming following a perceptual implicit than conceptual implicit task. This finding is important as this is the only other study, to my knowledge, that manipulated processing type at both encoding and test using a within-subject design.

After excluding the CV-R test from the analysis given the lack of priming, a reliable age difference emerged, indicating that priming is greater in young than older adults when encoding is conceptual, and the test is perceptual (i.e. CP). This is consistent with observations in Experiment 1A, suggesting that age differences may be a function of processing requirements at encoding and test. These findings replicate a previous study by Small et al. (1999), which recruited 403 participants using a within-subjects design. They found an age differences in perceptual priming (stem completion task) but no age differences in the conceptual priming (fact completion). Similarly to the present study, their encoding phase involved conceptual processing, where participants decided if the presented word was an English word or non-English word. Ward (2022) also showed an age difference on CID and CV priming tasks, however, this was only the case following perceptual encoding. It is important to remark that the Ward (2022) study was identical to this experiment, except that her study did not include a recognition task. The test awareness data in this experiment showed no differences between aware and unaware participants, suggesting that there was no explicit contamination, but given the different findings between this study and that of Ward (2022), it is possible that priming effects may be sensitive to the inclusion of a concurrent recognition task. It is also worth noting that the age difference in priming were abolished in the present study when group differences in verbal intelligence were ruled out. Older adults performed better than young adults on the Mill Hill test, which is consistent with earlier experiments reported in this thesis. Therefore, the main analysis was repeated with Mill Hill scores included as a covariate to examine whether this difference explains the age difference in implicit memory. After including the Mill Hill scores, the age effect on implicit memory disappeared. This suggests that the age difference in priming in the conceptual encoding, perceptual test condition is somehow affected by differences between young and older adults in verbal intelligence. This finding is not comparable with the results obtained in Experiment 1A and Experiment 2, where Mill Hill scores did not explain age differences in priming. Following the median split analysis, the age effect on priming was very close to significance ($p = .055$), and the Bayesian analysis indicated greater support for the alternative hypothesis of an age difference (BF10 = 1.11). However, it is possible that power was reduced by splitting participants into four age groups.

The significant interaction between Processing × Test in implicit memory was not significant, although based on previous study that matching the processing type during the encoding and test phase will lead to greater priming effect (e.g. Roediger & Blaxton, 1987; Roediger & McDermott, 1993). This was not evident in this study; however, the insensitivity of the conceptual priming task (CV) did not allow for obtaining a greater priming effect in the conceptual encoding, conceptual test condition for example. But also, when comparing the priming effect in the (CID) task, priming was greater in the conceptual encoding, perceptual test than the perceptual encoding, perceptual test condition.

In this study there were main effects of both processing and test and a significant Processing × Test interaction on recognition. The significant effect of processing on explicit memory was excepted, as prior studies suggest that conceptual processing leads to greater recognition (e.g. Brown & Mitchell, 1994; Mitchell & Perlmutter, 1986; Monti et al., 1996). However, there was no main effect of age, which is an odd observation and inconsistent with numerous studies that have found a clear age-related decline in explicit memory (e.g. Jelicic, 1996; Nilsson, 2003; Ward, 2018; Ward et al., 2013a, 2013b, 2020), as well as longitudinal studies showing a progressive decline in explicit memory with advancing age (e.g. Davis et al., 2001; Fleischman et al., 2004; Hultsch et al., 1992). The predication was that age differences in recognition would be observed regardless of the condition, as observed in earlier experiments presented in this thesis. For example, clear age differences in explicit memory were found in Experiment 1A and Experiment 2. However, it is important to state that several studies have documented that recognition task are less sensitive than recall tasks (Schugens et al., 1997), perhaps an age difference in explicit memory would have been more apparent if a recall task had been used. Recall requires self-initiated search of memory, whereas recognition tasks offer more retrieval signals from the environment in the form of a cue (Craik & McDowd, 1987). Although this may at least partially explain the lack of an age difference in explicit memory in this study, there is also a belief that it might be related to the nature of online testing. Some of the participants might not have engaged as expected, for example, if young participants did not perform the task as instructed, this may have abolished the age difference. This has been discussed briefly in a recent paper that compared online and in person studies, claiming that age effects that have been found in laboratory settings do not always replicate in the online world and this may be related to the online sample itself. An example was given that when the young adult group have a higher percentage of low-effort participants, this results in diminishing the age effect (see Greene & Naveh-Benjamin, 2022).

The significant interaction between Processing × Test was also an unexpected finding, indicating greater recognition following conceptual than perceptual encoding on CID-R and CV-R tests. This result was unexpected because the recognition task was actually identical in all conditions – that is, only the priming tasks differed with respect to processing at test. The only interpretation that comes to mind is that the implicit memory tasks (CV and CID) may have somehow had an effect on the concurrent recognition judgement. That is, the recognition judgement might have been affected by whatever priming decision came before it – whether it was perceptual or conceptual. The absence of age differences in explicit memory was odd, therefore, an exploratory median split analysis was conducted. An age effect on recognition emerged comparing the four age groups. However, follow-up analysis showed that young participants (23-30 years) produced greater recognition than the youngest participants (18-22 years) in the perceptual encoding, conceptual test condition. There were no other significant age differences. Thus, although there was an age effect on explicit memory following the median split analysis, this was not between the youngest and oldest groups as expected, and it is unclear why age differences only occurred between the young and youngest groups.

In relation to the encoding phase, there was a significant interaction between Age × Processing in the accuracy data, indicted that both ageing groups performed better in the conceptual encoding condition than the perceptual encoding condition, unexpectedly, older adults performed significantly better than young adults in the perceptual encoding condition only, where participants need to decide if the presented objects was upright or titled. There was a significant interaction between Age × Processing in the RT data as well. The interaction indicted that young and older adults were quicker in the conceptual encoding condition compared with the perceptual encoding condition. However, there was no difference between young and older adults in the conceptual and perceptual encoding phases. This is inconsistent with the notion that older adults are more impaired in the conceptual than perceptual encoding (Eysenck, 1974; Morcom et al., 2003; Morcom & Rugg, 2004; Ward et al., 2017), and also inconsistent with the processing deficit hypothesis that indicted that young adults were in more advantage in the conceptual processing (e.g. Eysenck, 1974; Mason, 1979; Simon, 1979).

As has been stated previously in this thesis, it is important to pre-screen older participants to ensure that they meet the eligibility criteria. In this study, there was an additional pre-screening method. First, on the background questionnaire where participants were asked to rate their health status, there was a clear note stating "NOTE: this research is on healthy ageing, and it is an eligibility requirement that participants are free of cognitive impairment", and additional questions were asked: 1- Have you ever been diagnosed with mild cognitive impairment or dementia? (all participants answered no), 2- Do you have difficulty with remembering names/ familiar faces? 3- Do you have difficulty following conversations? Finally, in this experiment, advantage of the pre-screening applied directly in Prolific, which prevented any participants who have been diagnosed with MCI or dementia from taking part. This is an important step to confirm that older participants are healthy, as accidently including participants with MCI or AD may contaminate the results as in AD the first domain that can be affected is memory (Bäckman et al., 2005; Jahn, 2013), and this would affect the ability to understand the effect of normal ageing on implicit memory.

Finally, although there is evidence that the CID-R task is immune to explicit contamination (e.g. Brown et al., 1991, 1996; MacLeod, 2008; Ward et al., 2013b), it was necessary to conduct further analyses to explore whether priming in the CID and CV tasks were affected by awareness, as some previous studies have shown a relationship between priming and awareness (e.g. Geraci & Barnhardt, 2010) In the current study, more young participants were rated as aware (CV: 6, CID: 19) than older participants (CV: 3, CID: 8), which is consistent with previous studies showing that the proportion of younger adults rated as aware tends to be higher than the proportion of older adults. For example, in a study by Geraci (2006), more than half of the younger adults were rated as aware compared with only three from the older group. In the current experiment, there was no main effect of awareness on young adults in the CID-R task. Priming was numerically greater for aware participants than unaware participants only in the conceptual encoding, perceptual test and in the perceptual encoding, perceptual test conditions (i.e. in the perceptual implicit task - CID). Since priming was not affected by awareness, confidence remains that priming was not affected by explicit contamination.

To conclude, the primary goal of this experiment was to systemically manipulate processing (conceptual/perceptual) during encoding prior to matched conceptual and perceptual priming tasks in a within-subjects design. While Experiments 1A (conceptual/perceptual encoding manipulation followed by a perceptual priming task – CID) and 2 (conceptual/perceptual encoding manipulation followed by a conceptual priming task – CEG) together gave the same combination of conditions as in the current study. In the present study, only a direct comparison of perceptual encoding, perceptual test (PP), perceptual encoding, conceptual test (PC), and conceptual encoding, conceptual test (CC) conditions in a within-subject design was feasible, utilizing closely matched tests. Matching the perceptual and conceptual priming tasks and using a within-subjects design is an important step to ensure that any age differences on the perceptual and conceptual priming tasks as a function of encoding are only due to difference in processing. Overall, however, there was no effect of age on recognition, and while there was an age difference in priming in the conceptual encoding, perceptual test condition, this disappeared following the covariate analysis. The lack of an age difference in recognition was unexpected, and possible limitations with the online testing environment and other explanations were discussed. A follow-up in-person study is needed to ensure a more controlled environment, which will also allow the use of a cognitive screening test to rule out impairment in older adults.

Chapter 5: The Effects of Processing During Encoding on Conceptual and Perceptual Implicit Memory, An In-person Experiment (Experiment 4)

5.1 Chapter Introduction

The aim of Experiment 4 was to replicate Experiment 3 in-person in a laboratory environment. The replication was conducted in a controlled lab environment following the easing of COVID-19 restrictions in the UK, which was only possible in the final year of the PhD. The replication was conducted to understand if (1) the findings of Experiment 3 can be replicated, and (2) if the online mode of testing produces different effects than lab environment. The aim was to examine the effect of conceptual and perceptual encoding on conceptual and perceptual priming and recognition using a within-subjects design. Once again, the CV-R task was used as a conceptual priming measure, and the CID-R task was used as a perceptual priming measure, and both were matched as far as possible on all characteristics apart from processing (see details in Chapter 4). Experiment 4 was pre-registered on the OSF prior to data collection (https://osf.io/yd9bw). All pre-registered steps and analyses were followed, and any changes or additional analyses are clearly stated. The raw data and analysis file for the final sample are available in the OSF (https://osf.io/t7b2y). The experiment presented in this chapter was presented at the Aging and Cognition conference in Leuven (April 2023): Al-Abdulla, M.A., & Ward, E.V. (2023). *Effects of ageing and processing on perceptual and conceptual priming and recognition*. Poster presented at the Aging & Cognition Conference, Leuven, Belgium, April.

5.1.1 Hypotheses

The following predictions were made: (a) Main effect of age: It was expected that younger adults would achieve greater priming and recognition than older adults. (b) Main effect of processing: It was expected that greater priming and recognition will emerge for conceptually studied items than perceptually studied items. (c) Age × Processing (conceptual/perceptual encoding) × Test (CV-R/CID-R) interaction: It was expected that age differences in priming would be greatest in the conceptual encoding, conceptual test condition, and smallest in the perceptual encoding, perceptual test condition, predicted on the basis of evidence that conceptual processing is affected to a greater extent by ageing than perceptual processing (e.g. Rybash, 1996), and encoding-test processing overlap yields greater priming than processing mismatch (e.g. Roediger & Blaxton, 1987; Roediger & McDermott, 1993). Thus, on the perceptual test greater priming was expected following perceptual than conceptual encoding in both age groups, while on the conceptual test greater priming was expected following conceptual than perceptual encoding in young adults and vice versa in older adults.

5.1.2 Methods

5.1.2.1 Participants

The sample size was estimated using G*Power, with an estimated effect size of 0.15, alpha set at .05, and power at 0.95. This resulted in a total required sample of 96 participants (48 young and 48 older adults). Young participants aged between 18 and 31 years (*M* age = 22.17 years, *SD* = 3.28; 39 females, and nine males), and older adults aged between 67 years and 90 years (*M* age = 76.29 years, *SD* = 5.12; 33 females, and 15 males) took part in this experiment. Young participants were recruited from the Middlesex University recruitment system (Sona), flyers, and an existing database (Jones, Silas & Ward lab; https://jswlab.co.uk), and older participants were recruited through the supervisors' existing partnership with the University of Third Age (U3A; https://www.u3a.org.uk). All participants were rewarded with course credit (1.5 credits) or a payment of £10 in the form of an Amazon voucher. Ethical approval was granted from the Middlesex University Research Ethics Committee (Approval code: 19263). Eligibility criteria included that all older participants should be free of dementia, and all participants were fluent in reading and writing in English, had normal/corrected vision. The demographic data of the participants can be seen in Table *5.1*.

Table 5.1. Participant Characteristics in Experiment 4

Characteristics		**Young Adults** ***M* (*SD*)** **(*n* = 48)**	**Older Adults** ***M* (*SD*)** **(*n* = 48)**
Age (years)		22.17 (3.28)	76.29 (5.12)
Gender (M/F) (*n*)		9/39	15/33
Education (years)		16.21 (2.36)	16.33 (3.06)
Highest Qualification (*n*)			
	GCSE or equivalent	6	10
	A level or equivalent	27	5
	Bachelor's degree	9	22
	Master's degree	4	9
	PhD	2	2
Health Status (*n*)			
	Excellent	22	12
	Good	25	33
	Adequate	1	3
	Poor	0	0
	Extremely Poor	0	0
Trouble of Vision (*n*)			
	Yes	2	0
	No	46	46
	Somewhat	0	2
Near Vision Test Card (inch)*		34.67 (6.25)	51.92 (31.39)
WAIS-III Digit Symbol (Processing Speed) *		78.02 (16.29)	60.44 (10.66)
Wechsler Test of Adult Reading (WTAR) *		43.23 (5.99)	48.54 (2.08)
Mini Mental State Exam (MMSE)		-	28.23 (1.59)

Note. Standard deviations for all mean values are given in the parentheses. Visual acuity was measured using the Near Vision Test card (Schneider, 2002). The WAIS-III Digit Symbol Substitution Test (Wechsler, 1997) was used to measure processing speed. The WTAR (Wechsler, 2001) involved reading list of 50 English words and was used to measure pre-morbid intellectual functioning. MMSE (Folstein et al., 1975) is a cognitive screening test for cognitive impairment, administered on older adults only. *Significant difference between groups, p < .05.

5.1.2.2 Design

Experiment 4 involved a mixed factorial design with Age (young/older adults) as the between-subjects factor, Processing during encoding (conceptual/perceptual), and Test (conceptual implicit task/perceptual implicit task) as within-subjects factors. Conceptual priming was measured using the category verification with recognition (CV-R) task, and perceptual priming was once again measured using the continuous identification with recognition (CID-R) task. In both tasks there was a recognition judgement after each priming trial. As in Experiment 3, the design allowed for the comparison of four conditions: perceptual encoding, perceptual test (PP); conceptual encoding, perceptual test (CP); perceptual encoding, conceptual test (PC); conceptual encoding, conceptual test (CC).

5.1.2.3 Stimuli

All visual stimuli (everyday objects) were once again taken from the BOSS (Brodeur et al., 2010, 2014). For example, see Figure 4. In total, 160 coloured stimuli (*M* familiarity = 4.34, *SD* = 0.37) were used in this experiment. All stimuli in the encoding and test phases were presented in a new random order for each participant. Eighty items were presented in each block, 40 in the encoding phases and 80 in the test phases (40 previously studied: 20 perceptually studied, 20 conceptually studied, and 40 new). Approximately half of the stimuli were naturally occurring items, and the other half were manufactured. The correct answer for the encoding phase (perceptual encoding) was decided based on the decision of 12 participants, where they completed an online study on Gorilla to rate if the images was rounded or angular, and based on the results there were two images (zebra and ostrich) that participants did not agree whether they are rounded or angular, and therefore, those two images were replaced. In this experiment, stimuli were presented in the centre of a white background screen, and the priming mask used in the CID-R task was changed to a colourful grid (Figure 18). A colourful mask was used in this experiment as using the same mask (black and white; see Figure 4) that was used in previous experiments did not produce the desired effect – images in the perceptual identification task were too easily identified behind the mask from the first gaze. This may be due to the different programming tools used and different computer.

Figure 18. Colourful Mask Used in Experiment 4.

5.1.2.4 Procedure

The experiment was developed using E-prime 2.0, a psychology software tool for designing and running psychology lab experiments. Participants performed the task at the Middlesex University campus in a private, sound dampened cubicle. The experiment was presented on Dell desktop computer, and the screen size was 52 × 36 cm with a display resolution of 1920 × 1080 pixels. Viewing distance was approximately 63 cm. Before the experimental task, participants were asked to read the information sheet and sign the consent form. Where they agree that they read and understood the information sheet, confirmed that the meet the eligibility criteria including no clinical diagnosis of dementia, aged between 18-30 years for young or 65 years and above for older, fluent in reading and writing in English, and have normal vision (corrected with glasses is fine). Then participant background details, including age, sex, health status, and education background were collected. Visual acuity was measured using the Near Vision Test Card (Schneider, 2002; see Appendix), in which participants were asked to hold a card at a distance of 16 inches (40 cm) and read the smallest line of letters that they could comfortably see (scores range from 16 to 160 inches). All other background tests were conducted at the end after the experiment task discussed below.

5.1.2.4.1 Experimental Task

5.1.2.4.1.1 Encoding Phase

The experimental task was broken up into separate phases for encoding and test, each containing two blocks. The encoding phase in one block involved the conceptual processing of items, and the study phase in the other block involved perceptual processing (the order was counterbalanced between participants). Five practice trials were presented in each encoding phase. During the encoding phase there was a steam of 40 objects presented, a black fixation was presented for 500 ms, followed by an object presented for 500 ms. On each trial, participants were instructed to judge whether the presented object was natural or manmade (conceptual condition), or whether the presented object was angular or rounded (perceptual condition). To response participants were instructed to make a keyboard press where ‘Z’ = angular/natural; ‘M’ = rounded/manmade, and the instructions remained on the screen until participants made their decision. Speed was emphasised. It is important to note that the perceptual judgment was changed in this experiment from upright/titled in Experiments 1A, 2, and 3 to angular/rounded in this experiment. This decision was reached as participants in the earlier experiments seemed to struggle with the perceptual decision, and therefore in this experiment the angular/rounded decision was chosen. Deciding whether images are angular/rounded is arguably easier and less subjective than deciding whether they are upright/tilted, and thus participants are more likely to be able to follow instructions. Indeed, in the online version, participants encountered challenges with the perceptual encoding block, resulting in low accuracy. Consequently, more participants had to be replaced than initially anticipated.

5.1.2.4.2 Filler Phase

Between the encoding and test phases, there was a brief mental arithmetic filler phase that took three minutes to be completed. The purpose was to provide an unrelated non-verbal task to avoid primacy and recency effects and ensure that all participants had the same duration between the encoding and test phases. In the filler phase, participants were presented with random numbers (1-9), and their task was to decide as quickly as possible whether each number was odd or even by pressing ‘1’ for odd and ‘2’ for even on the keyboard. A black fixation was presented for 500 ms, followed by a number presented until a response was made.

5.1.2.4.3 Test Phase – CV-R Task

Following the encoding phase and filler task, participants completed the test phase. During this phase, participants performed two implicit memory tests: a category verification with recognition (CV-R) task, and a continuous identification with recognition (CID-R) task (the order of tests was counterbalanced between participants). Four practice trials were presented for each task. In the CV-R task, 80 objects were presented, one at a time (half studied; 20 studied perceptually, 20 studied conceptually, and half new). On each trial, a measure of priming and recognition was captured. A black fixation was presented for 500 ms followed by an object (old/new), and participants were instructed to judge if the presented object matched the given category label by selecting ‘Yes’ or ‘No’ as quickly as possible (RT captured upon keypress). For making a response, participants were asked to press ‘Z’ for Yes, and ‘M’ for No using the keyboard. On half of the trials, the object matched the category. Immediately after response, the object was presented again for a recognition judgment, whereby participants were prompted to judge whether or not the object was previously shown in the encoding phase. Participants were informed that half of the objects were presented previously, and half were new. The participants responded on a six-point scale, where 1 =

Sure no, 2 = Think no, 3 = Guess no, 4 = Guess yes, 5 = Think yes, 6 = Sure yes. No time limit was imposed on recognition judgments.

5.1.2.4.4 Test Phase – CID-R Task

In the CID-R task, a total of 80 objects appeared on the screen, one at a time (half studied; 20 studied perceptually, 20 studied conceptually, and half new), and on each trial, a measure of priming and then recognition was captured. An object was initially presented for 16 ms (screen refresh) and immediately masked for 250 ms. The object and mask presentations were then alternated with the object presentation increasing by 16 ms each time and the mask decrease by 16 ms each time. The effect is that the object appears to gradually clarify. Participants were instructed to identify the object as quickly as they could by pressing the 'Enter' key. At this point, their RT was captured, the object disappeared, and they were prompted to type the object name into a box on the screen. If participant was slow and did not response until the image was fully presented without the mask (7000 ms) the following message was shown on the screen: "You were too slow, please try to be quicker next time. Press 'Space' to continue". Immediately after identification, the same object was presented again for the recognition judgment (explained above). Participants were informed that half of the objects were presented previously, and half are new, and no time limit was imposed on recognition judgments.

5.1.2.5 Background Tests

Following the experiment participants filled out a short awareness questionnaire containing five questions adapted from Bowers and Schacter (1990): (1) What do you think was the purpose of the task where you identified objects under the flashing grid? (2) What do you think was the purpose of the task where you judged if objects matched a given category? (3) Did you suspect prior to the start of these test that you would be tested on your memory of the objects? (4) Did you try to use your memory of the pictures to help you in these tasks? (5) If yes, do you think this strategy helped you, and how so? At the end of the session participants also completed a few other tests. Older adults completed The Mini-Mental State Examination (MMSE; Folstein et al., 1975; see Appendix) as a screening test for cognitive impairment. The MMSE questionnaire contains 11 questions to assess orientation, comprehension, and memory. It is administered by the researcher (maximum score = 30), and participants scoring below 24 are considered as impaired. However, in this experiment no older participants scored below this threshold (*M* = 28.23, *SD* = 1.59). Following that both young and older adults completed the Digit Symbol Substitution subtest of the WAIS III as a standardised measure of processing speed (Wechsler, 1997; see Appendix). In this test participants are given two minutes to complete as many numbered empty boxes as possible with the correct symbol that matches the number as given in a key (maximum score = 133). Finally, young and older adults completed the Wechsler Test of Adult Reading (WTAR) as a measure of pre-morbid intelligence (Wechsler, 2001; see Appendix). In this test, participants are presented with a list of 50 uncommon English words and asked to pronounce them correctly, while the researcher keeps score (maximum score = 50).

5.1.3 Results of Experiment 4

5.1.3.1 Analysis

To examine the hypotheses, the main analysis involved separate 2 Age (young/older) × 2 Processing at encoding (conceptual/perceptual) × 2 Test (conceptual implicit task/perceptual implicit task) mixed ANOVAs on priming and recognition, and follow-up test comparisons in the event of any significant interactions. An alpha level of .05 was used for all statistical tests. Partial eta squared (η_p^2) effect size was reported for ANOVA effects and Cohen's *d* and confidence interval for t-tests. Bayes factor analysis was conducted for any non-significant effects, with BF10 values of less than 1/3 considered support for the null hypothesis (Dienes, 2014). All data were analysed using JASP version 0.16.2 (JASP Team, 2023).

5.1.3.2 Encoding Phase

In the OSF it was stated that participants with <60% correct response across the encoding phases would be replaced, however, in practice and due to time constraints this was not possible. In-person recruitment and testing were very time consuming, and although six participants scored below 60% accuracy, they were not replaced. The correct answer for the encoding phase, whether the presented image was rounded or angular was calculated by recruiting 12 participants (friends and fellow lab members) and asking them to complete a short online study on Gorilla in which they rated images as rounded or angular discussed in section 5.1.2.3.

Mean accuracy scores and RTs in the perceptual and conceptual blocks can be found in Table *5.2*. A 2 (Age) × 2 (Processing) ANOVA on accuracy revealed main effects of Processing, *F*(1, 94) = 295.94, *p* < .001, η_p^2 = 0.76, and Age, *F*(1, 94) = 20.07, *p* < .001, η_p^2 = 0.18, however, there was no interaction between Processing × Age, *F*(1, 94) = 0.49, *p* = .487, η_p^2 = 0.01 (BF10 = 0.28). Participants were generally more accurate in the conceptual encoding condition (Marginal Mean = 92.01%) than the perceptual encoding condition (Marginal Mean = 61.22%), and young adults were generally more accurate (Marginal Mean = 80.23%) than older adults (Marginal Mean = 73.00%).

On RTs there were also main effects of Processing, *F*(1, 94) = 4.68, *p* = .033, η_p^2 = 0.05, and Age, *F*(1, 94) = 6.10, *p* = .015, η_p^2 = 0.06, however, there was no interaction between Processing × Age, *F*(1, 94) = 3.70, *p* = .058 , η_p^2= 0.04 (BF10 = 1.09). Participants were generally quicker in the conceptual encoding condition (Marginal Mean = 1026 ms) than the perceptual encoding condition (Marginal

Mean = 1135 ms), and younger adults were generally slower (Marginal Mean = 1159 ms) than older adults (Marginal Mean = 1002 ms).

Table 5.2. Performance of Young and Older Adults in The Encoding Phase in Experiment 4

Encoding Phases	**Young Adults** ***M*** **(*SD*)**	**Older Adults** ***M*** **(*SD*)**
Accuracy (%)		
Conceptual Encoding	96.25 (4.19)	87.76 (8.82)
Perceptual Encoding	64.22 (15.98)	58.23 (14.40)
RTs (ms)		
Conceptual Encoding	1057 (282)	996 (410)
Perceptual Encoding	1262 (409)	1008 (467)

Note. Mean accuracy (%) and mean RTs (ms) in the conceptual and perceptual encoding blocks in Experiment 4. Standard deviations for all mean values are given in the parentheses.

5.1.3.3 Recognition

The total number of excluded trials in the CID-R and CV-R tasks was as follows: for the CID-R test, out of 3384 total trials, 203 trials were excluded in the young group, and 321 trials in the older group. For the CV-R test, 114 trials were excluded in the young group, and 205 in the older group. To assess recognition (Figure 19 and Table *5.3*) *d'* was calculated as described previously, where *d'* was calculated for each participant by subtracting z-transformed hits (proportion of old items judged old) minus z-transformed FA (proportion of new items judged old). The Snodgrass and Corwin (1988) correction was once again applied to hit and false alarm (FA) rates with values of zero or one prior to calculating *d'*.

A 2 (Age) × 2 (Processing at encoding) × 2 (Test) ANOVA revealed a main effect of Age, *F*(1, 94)= 21.61, *p* < .001, η_p^2= 0.19, showing that young adults (Marginal Mean: d prime = 2.42) had greater recognition than older adults (Marginal Mean: d prime = 1.82). However, there were no main effects of Processing, *F*(1, 94)= 0.79, *p* = .375, η_p^2= 0.01, (BF10 = 0.15), or Test *F*(1, 94) = 0.97, *p* = .327, η_p^2= 0.01, (BF10 = 0.28), and no interaction between Processing × Age, *F*(1, 94)= 1.43, *p* = .235, η_p^2= 0.02, (BF10 = 0.26), Test × Age, *F*(1, 94)= 1.60, *p* = .210, η_p^2= 0.02, (BF10 = 0.54), Processing × Test, *F*(1, 94)= 1.45, *p*= .231, η_p^2= 0.02 (BF10 = 0.23) , and Processing × Test × Age, *F*(1, 94)= 2.76, *p*= .100, η_p^2= 0.03, (BF10 = 0.47).

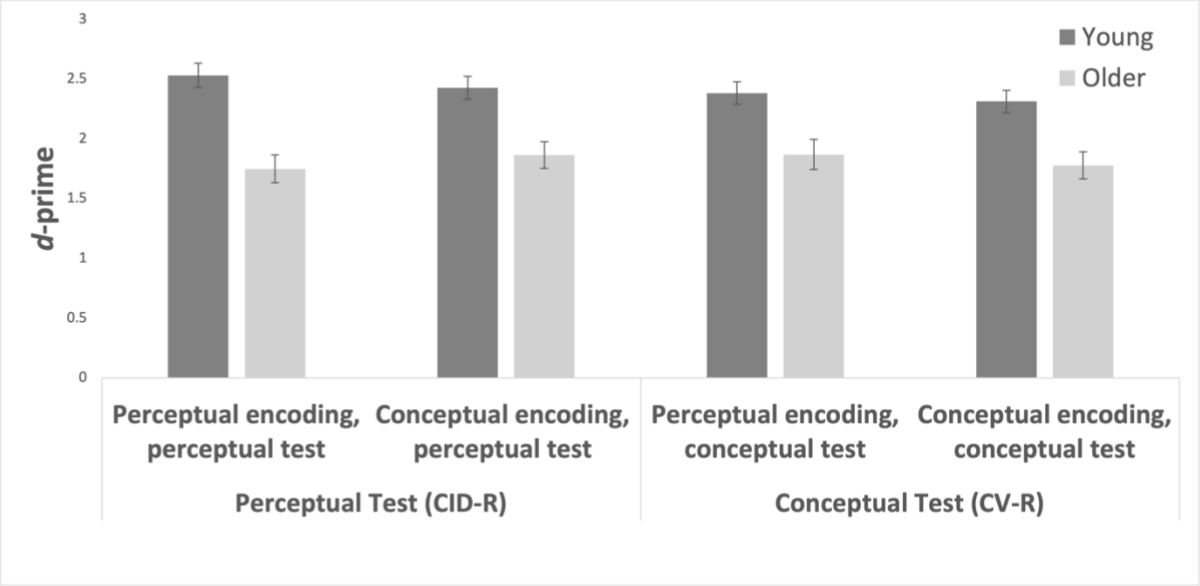

Figure 19. Recognition in Young and Older Adults in Experiment 4.

Note. Recognition task was the same in all conditions (i.e. the perceptual encoding, perceptual test; and conceptual encoding, perceptual test; and perceptual encoding, conceptual test; and conceptual encoding, conceptual test conditions are actually identical), but the data is represented in the same ways as priming for ease of comparison. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars represent standard error of the mean (SEM).

Table 5.3. The Proportion of Hits, Misses, FA, and CR in Experiment 4

Tests	**Conceptual Encoding (CC)**		**Perceptual Encoding (PC)**	
	Young *M* (*SD*)	**Older *M* (*SD*)**	**Young *M* (*SD*)**	**Older *M* (*SD*)**
CV-R Test				
Hits	0.84 (0.11)	0.74 (0.19)	0.86 (0.09)	0.76 (0.21)
Misses	0.16 (0.11)	0.26 (0.19)	0.14 (0.10)	0.24 (0.21)
	Young *M* (*SD*)		**Older *M* (*SD*)**	
FA	0.15 (0.11)		0.19 (0.19)	
CR	0.85 (0.11)		0.82 (0.20)	
	Conceptual Encoding (CP)		**Perceptual Encoding (PP)**	
	Young *M* (*SD*)	**Older *M* (*SD*)**	**Young *M* (*SD*)**	**Older *M* (*SD*)**
CID-R Test				
Hits	0.86 (0.11)	0.74 (0.22)	0.87 (0.14)	0.71 (0.22)
Misses	0.14 (0.11)	0.26 (0.22)	0.13 (0.14)	0.29 (0.22)
	Young *M* (*SD*)		**Older *M* (*SD*)**	
FA	0.14 (0.12)		0.17 (0.15)	
CR	0.85 (0.12)		0.83 (0.15)	

Note. Hits: old items correctly judged old; Misses: old items incorrectly judged new; FA: new items judged old; CR: new items correctly judged new. FA = false alarms; CR = correct rejection. CC: conceptual encoding; conceptual test; PC: perceptual encoding, conceptual test; CP: conceptual encoding; perceptual test; PP: perceptual encoding; perceptual test. Standard deviations for all mean values are given in the parentheses.

5.1.3.3.1 Additional Recognition Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether recognition was above zero in each condition. Recognition (Figure 19) in young and older adults was significantly above zero in all conditions: Young adults: perceptual encoding, conceptual test: $t(47)= 25.46$, $p < .001$, $d= 3.68$, conceptual encoding, conceptual test: $t(47)= 24.68$, $p <. 001$, $d = 3.56$, PP: $t(47) = 25.08$, $p < . 002$, $d = 3.62$, conceptual encoding, perceptual test: $t(47) = 25.43$, $p <.001$, $d = 3.67$. The same was true for older adults: perceptual encoding, conceptual test: $t(47) = 14.84$, $p < .001$, $d= 2.14$, conceptual encoding, conceptual test: $\mathrm{t}(47)= 15.64$, $p <.001$, $d= 2.26$, perceptual encoding, perceptual test: $t(47) = 14.95$, $p <.001$, $d = 2.16$, conceptual encoding, perceptual test: $t(47) = 16.63$, $p < .001$, $d = 2.40$.

5.1.3.4 Priming

Although it was stated in the OSF that participants scoring below 80% accuracy in the test phases would be replaced, this was not feasible in practice as 13 participants failed to meet this threshold (lowest score was 54.75%) and there was not time to replace this volume of participants during the PhD, as in-person testing was very time consuming. Therefore, no participants were excluded. For each individual participant, trials associated with incorrect object identifications (CID-R task), or incorrect category judgements (CV-R task) were removed, and any RTs above 7000 ms in the CV-R and CID-R were also removed. Further, trials associated with RTs < 200 ms or > 3SD from the mean (for old/new items separately) were also removed (applies to both CV-R and CID-R). The priming mean in the CID-R and CV-R tasks was calculated for each participant as the mean RT for new items minus the RT for old items divided by the baseline (new item) RT: (RTnew – RTold)/RTnew and averaged across participants (Figure 20 and Table *5.4*). Priming in the conceptual test conditions was once again negative (i.e. the perceptual encoding, conceptual test and conceptual encoding, conceptual test conditions), and therefore the CV-R test was not included in the planned analysis. A 2 (Age) × 2 (Processing) ANOVA revealed no main effect of Processing, $F(1, 94) = 2.19$, $p = .142$, $\eta_p^2 = 0.02$, (BF10 = 0.52), or Age $F(1, 94) = 3.77$, $p = .055$, $\eta_p^2 = 0.04$, (BF10 = 1.13), and no interaction between Processing × Age, $F(1, 94) = 2.03$, $p = .158$, $\eta_p^2 = 0.02$, (BF10 = 0.52). However, Bayesian analysis provided greater support for the alternative hypothesis of an age difference (BF10 = 1.13), and *p* value for age effect was close to the significance level $p = .055$. The number of priming events for the entire sample under each condition are display in Table *5.5*. In general, priming was more prevalent among young participants than older participants, and it was more prevalent when the test was perceptual (CID-R) than conceptual (CV-R).

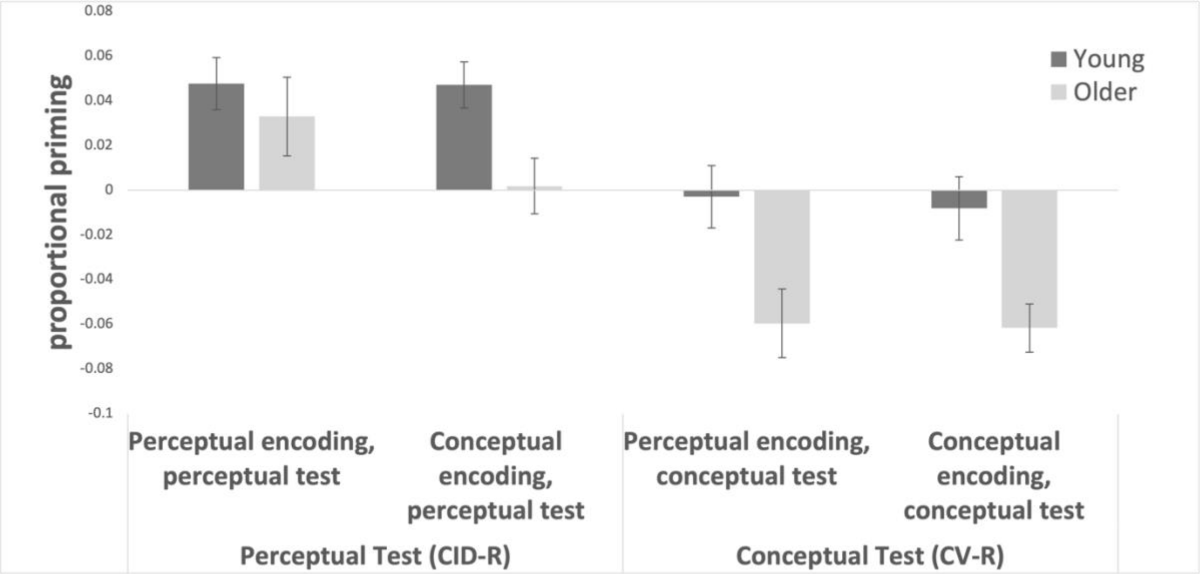

Figure 20. Priming in Young and Older Adults in Experiment 4.

Note. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars represent standard error of the mean (SEM).

Table 5.4. Mean RTs in Young and Older Adults in Experiment 4

Implicit Memory Tests	**Young Adults *M* (*SD*) (ms)**	**Older Adults *M* (*SD*) (ms)**
CID-R Test		
Perceptual RTs (PP)	1799 (358)	2373 (550)
Conceptual RTs (CP)	1806 (378)	2453 (547)
New	1897 (379)	2453 (455)
CV-R Test		
Perceptual RTs (PC)	1666 (543)	2773 (643)
Conceptual RTs (CC)	1673 (536)	2785 (655)
New	1674 (562)	2626 (593)

Note. CID-R: continuous identification with recognition, PP: perceptual encoding, perceptual test; CP: conceptual encoding, perceptual test; CV-R: category verification with recognition; PC: perceptual encoding, conceptual test; CC: conceptual encoding, conceptual test. Standard deviations for all mean values are given in the parentheses.

Table 5.5. The Occurrence of Priming (N) Across Conditions

Age Group/Conditions	**PP**	**CP**	**PC**	**CC**
Young Adults (*n*)	32	38	26	20
Older Adults (*n*)	30	24	15	12
Total (*n*)	62	62	41	32

Note. PP: perceptual encoding, perceptual test; CP: conceptual encoding, perceptual test; PC: perceptual encoding, conceptual test; CC: conceptual encoding, conceptual test.

5.1.3.4.1 Additional Priming Analyses (not pre-registered)

One sample t-tests were conducted to confirm whether priming was above zero in each condition. Priming (Figure 20) was above zero in two conditions only in young adults: the perceptual encoding, perceptual test and conceptual encoding, perceptual test conditions. Young adults: perceptual encoding, perceptual test: *t*(47) = 4.12, *p* < . 001, *d* = 0.59, 95% CI [0.02, 0.07], conceptual encoding, perceptual test: *t*(47) = 4.55, *p* < .001, *d* = 0.66, 95% CI [0.02, 0.07], perceptual encoding, conceptual test: t(47) = 0.21, *p* = .835, *d* = 0.03, 95% CI [-0.03, 0.03], (BF10 = 0.16), conceptual encoding, conceptual test : t(47) = 0.57, *p* = .570, *d* = 0.08, 95% CI [-0.04, 0.02], (BF10 = 0.18). For older adults priming in all conditions was below zero, significant only in the conceptual encoding, conceptual test and perceptual encoding, conceptual test conditions: perceptual encoding, perceptual test: *t*(47) = 1.87, *p* = .068, *d* = 0.27, 95% CI [-0.00, 0.07], (BF10 = 0.78), conceptual encoding, perceptual test: *t*(47) = 0.15, *p* = .883, *d* = 0.02, 95% CI [-0.02, 0.03], (BF10 = 0.16), conceptual encoding, conceptual test: *t*(47) = 5.72, *p* < .001, *d* = 0.83 , 95% CI [-0.08, -0.04], perceptual encoding, conceptual test: *t*(47) = 3.89, *p* < .001, *d* = 0.56, 95% CI [-0.09, -0.03].

5.1.3.4.2 Exploratory Analysis

Priming in the conceptual encoding, perceptual test condition (Figure 20) appeared to be greater in young than older adults. Therefore, an independent t-test was conducted as an exploratory analysis to check if this difference was significant (since this was observed in Experiments 1A and 3). The analysis showed a significant Age difference in the conceptual encoding, perceptual test condition, *t*(94) = 2.79, *p* = .006, *d* = 0.57, 95% CI [0.01, 0.08], indicated that young adults had greater priming than older adults in this condition.

5.1.3.5 Awareness Questionnaire

The test awareness questionnaire for the CID-R test revealed that 11 young and four older adults became aware that the perceptual identification task was related to memory, and for the CV-R test eight young and four older were aware that the task was related to memory. As the percentage of aware participants was low in both tasks (CID-R: 15.63%, CV-R: 12.50%) no further analysis was conducted. The pre-registered threshold for analysis of awareness data was that at least one group had 20% aware participants. The proportion of priming in aware versus unaware participants is presented in Table *5.6*.

Table 5.6. Priming in Aware and Unaware Participants in Experiment 4

Priming Scores	**Aware** ***M* (*SD*)**		**Unaware** ***M* (*SD*)**	
	Young	**Older**	**Young**	**Older**
Conceptual Priming (CV)				
CC	-0.03 (0.10)	0.01 (0.06)	-0.00 (0.10)	-0.07 (0.07)
PC	0.01 (0.08)	-0.02 (0.05)	-0.01 (0.10)	-0.06 (0.11)
Perceptual Priming (CID)				
CP	0.04 (0.10)	-0.02 (0.15)	0.05 (0.06)	0.00 (0.08)
PP	0.04 (0.08)	0.05 (0.11)	0.05 (0.08)	0.03 (0.12)

Note. Standard deviations for all mean values are given in the parentheses. CC: conceptual encoding, conceptual test; PC: perceptual encoding, conceptual test; CP: conceptual encoding, perceptual test; PP: perceptual encoding, perceptual test.

5.1.3.6 Covariate Analysis (not pre-registered)

Independent sample t-test were conducted showing significant differences between young and older adults in WTAR test scores, $t(94) = 5.81$, $p < .001$, $d = 1.19$, 95% CI [-7.13, -3.50], Digit Symbol Substitution scores (processing speed), $t(94) = 6.26$, $p < .001$, $d = 1.28$, 95% CI [12.00, 23.16], and vision scores, $t(94) = 3.73$, $p < .001$, $d = 0.76$, 95% CI [-26.42, -8.08]. However, there was no significant differences between groups in years of education, $t(94) = 0.22$, $p = .823$, $d = 0.05$, 95% CI [-1.23, 0.98] (BF10 = 0.22). For the exploratory analysis, the plan was to include variables that significantly differed between groups in an ANCOVA to check if the main effect of age in the analysis of recognition was influenced by the differences in these variables. Pearson’s correlations were conducted to verify the assumption of uncorrelation among covariates. The correlation analysis showed no correlation between the three tests (WTAR, processing speed, and vision test, all $p > .05$). Therefore, the main ANOVA analysis on recognition was repeated with these factors entered as covariates, to examine whether the age effect was influenced by age differences in these factors. Note that the ANCOVA was not applied to the priming data since there was no main effect of age in the main analysis. The ANCOVA showed a marginal main effect of Test, $F(1, 93) = 3.94$, $p = .050$, $\eta_p^2 =$

0.04, and a main effect of Age, *F*(1, 93) = 10.38, *p* = .002, η_p^2= 0.10. The Test effect indicated a greater recognition in the perceptual test (Marginal Mean: d prime = 2.56) than the conceptual test (Marginal Mean: d prime = 2.51), and the Age effect indicated a greater recognition in young (Marginal Mean: d prime = 2.78) than the older (Marginal Mean: d prime = 2.29). However, there was no main effect of Processing, and the interaction between Processing × Age, Test × Age, Processing × Test, and Processing × Test × Age were all non-significant (all *p* > .05). Therefore, it can be concluded that the age effect on recognition was not affected by differences between young and older participants in these background tests.

5.1.3.7 Further Additional Analysis (Median Split; not pre-registered)

Once again, a median split analysis was conducted to examine priming and recognition in the youngest and oldest participants. Figure 20 and Figure 21 show priming and recognition, respectively, in the four age groups after conducting a median split: youngest (*n* = 31): 18-22 years, young (*n* = 17): 23-31 years, older (*n* = 25): 67-76 years, and oldest (*n* = 23): 77-90 years. A 4 (Age) × 2 (Processing at encoding) × 2 (Test) repeated measures ANOVA on recognition showed a significant main effect of Age only, *F*(3, 92) = 7.41, *p* < .001, η_p^2= 0.20, young participants (Marginal Mean: d prime = 2.52) had higher recognition compared to youngest (Marginal Mean: d prime = 2.36), older (Marginal Mean: d prime = 1.85), and oldest (Marginal Mean: d prime = 1.78). However, there were no main effects of Processing, *F*(1, 92) = 0.83, *p* = .366, η_p^2= 0.01, (BF10 = 0.15), Test *F*(1, 92) = 1.08, *p* = .301, η_p^2= 0.01, (BF10 = 0.23), and no interaction between Processing × Age, *F*(3, 92) = 0.51, *p* = .679, η_p^2= 0.02, (BF10 = 0.04), Test × Age, *F*(3, 92) = 0.58, *p* = .630, η_p^2= 0.02, (BF10 = 0.08), Processing × Test, *F*(1, 92) = 1.34, *p* = .251, η_p^2= 0.01, (BF10 = 0.23), or Processing × Test × Age, *F*(3, 92) = 1.42, *p* = .242, η_p^2= 0.04, (BF10 = 0.14). Tukey post hoc test showed that Age differences emerged between the youngest and oldest participants in the perceptual encoding, perceptual test condition, *t* = 3.69, *p* = .026, *d* = 1.02, indicated greater recognition in the youngest than the oldest participants. Also, in the perceptual encoding, perceptual test condition there was a significant Age difference between young participants and older participants, *t* = 3.72, *p* = 0.02, *d* = 1.17, indicating greater recognition in young than older adults. Finally, recognition was greater in young participants than the oldest participants in the perceptual encoding, perceptual test condition, *t* = 4.12, *p* = .006, *d* = 1.32. A 4 (Age) × 2 (Processing at encoding) repeated measures ANOVA on priming showed no main effects of Processing, *F*(1, 92) = 2.39, *p* = .126, η_p^2= 0.03, (BF10 = 0.42), or Age, *F*(3, 92) = 1.61, *p* = .192, η_p^2= 0.05, (BF10 = 0.31), and no interaction between Processing × Age, *F*(3, 92) = 0.77, *p* = .516, η_p^2= 0.02, (BF10 = 0.14).

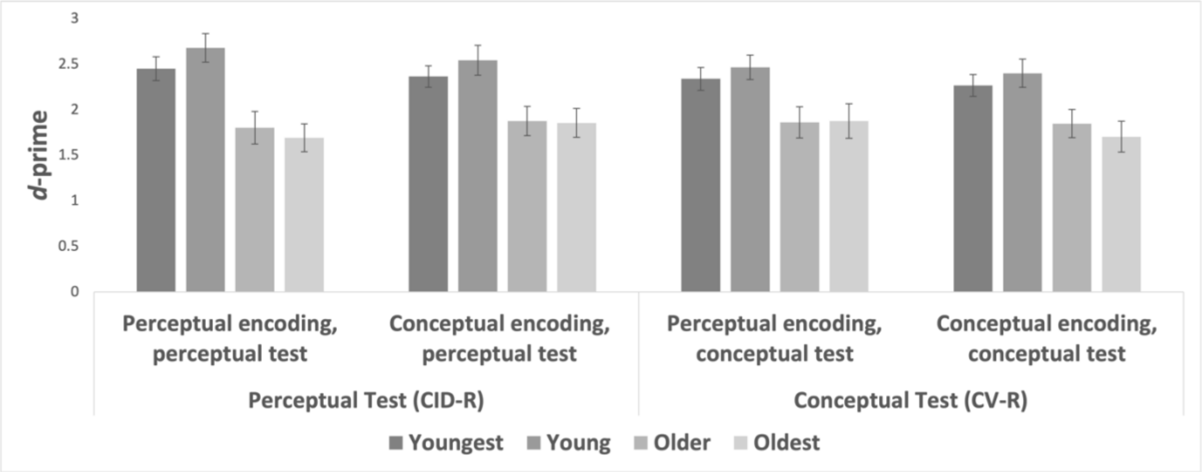

Figure 21. Recognition in the Four Age Groups (Median Split Analysis) in Experiment 4.

Note. Youngest = 18-22 years; Young = 23-31 years; older = 67-76 years; oldest = 77-90 years. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars indicated standard error of the mean (SEM).

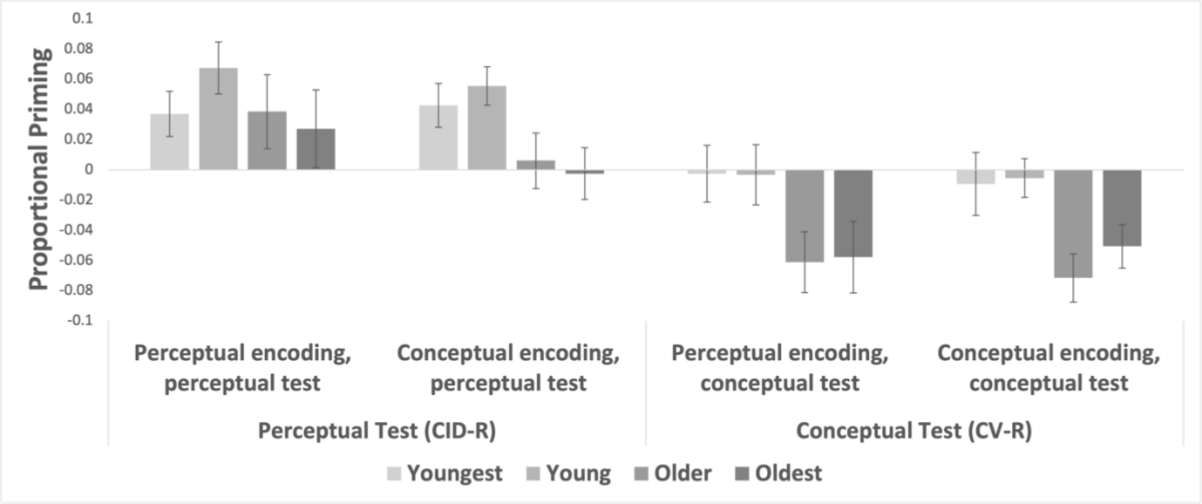

Figure 22. Priming in the Four Age Groups (Median Split Analysis) in Experiment 4.

Note. Youngest = 18-22 years; Young = 23-31 years; older = 67-76 years; oldest = 77-90 years. CID-R: Continuous Identification Task with Recognition, CV-R: Category Verification Task with Recognition. Error bars indicated standard error of the mean (SEM).

Table 5.7. Summary of Results for Experiment 4

	F-statistic	**p-value**	**Effect size (η_p^2)**
Encoding phase			
(a) Accuracy			
Processing	295.94	<.001	0.76
Age	20.07	<.001	0.18
Processing x Age	0.49	.487	0.01
(b) RT			
Processing	4.68	.033	0.05
Age	6.10	.015	0.06
Processing x Age	3.70	.058	0.04
Recognition			
Processing	0.79	.375	0.01
Test	0.97	.327	0.01
Processing x Test	1.45	.231	0.02
Age	21.61	<.001	0.19
Processing x Age	1.43	.235	0.02
Test x Age	1.60	.210	0.02
Processing x Test x Age	2.760	.100	0.03
Priming			
Processing	2.19	.142	0.02
Age	3.77	.055	0.04
Processing x Age	2.03	.158	0.02

Note. This table summarizes the key results obtained from Experiment 4.

5.1.4 Discussion of Experiment 4

In this experiment, which was an in-person replication of Experiment 3, processing (conceptual /perceptual) was manipulated during encoding prior to conceptual (CV-R) and perceptual (CID-R) priming tasks in a within-subjects design. This experiment was conducted in person following the easing of COVID-19 restrictions, allowing for greater control over the environment and the conditions in which participants performed the task, but also to directly compare the findings of the online versus laboratory versions of the experiment.

The data of Experiment 4 showed an age effect on recognition. Young participants (*M* age = 22.17 years; *SD* = 3.28) were correctly able to judge if presented images were shown previously at a greater level than older adults (*M* age = 76.29 years; *SD* = 5.12). This was inconsistent with what was reported in Experiment 3, where there were no age effects on explicit memory in the online version. However, the present experiment was procedurally identical to Experiment 3. This inconsistency may be due to the mode of testing; it was observed in this experiment that there was greater accuracy and engagement during the encoding phase, which may have led to greater accuracy in the recognition test phase. Also by comparing recognition in Figure 14 (Experiment 3) and Figure 19 (current experiment), it can be seen that recognition was greater generally in this experiment, suggesting more engagement with the task when study was conducted in person. It might be that the researcher's presence affected participants' motivation. In a recent paper by Gagné and Franzen (2023), the authors explored the impact of the experimenter's physical presence on participants' task performance. They found that conducting in-person testing with the researcher present resulted in a stronger sense of social pressure, which lead to improved task performance compared to online testing. The age difference in explicit memory, as seen in the current experiment, was expected, and replicates many previous studies showing an age difference in recognition (e.g. Abbenhuis et al., 1990; Light et al., 2000; Ward, 2018; Ward et al., 2013a, 2013b, 2020). As noted in the discussion of Experiment 3, some studies show that recognition tasks produce smaller age differences than recall tasks when assessing explicit memory. For example, a meta-analysis reported an effect size of 0.50 for recognition and 0.97 for recall (La Voie & Light, 1994). However, this study was able to detect age differences in recognition. Additionally, the exploratory median split analysis revealed age differences between groups in explicit memory, with significant differences in the perceptual encoding, perceptual test condition (i.e. PP) between the youngest and oldest participants, young and older participants, and young and oldest participants.

Young and older participants performed a number of background tests in this study in order to examine age differences in a range of factors that may affect memory. Participants performed the WTAR test as a measure of pre-morbid intelligence, a near vision test, and a processing speed test. Other background information such as years of education was also collected. Analysis showed that young and older adults significantly differed on all of the formal tests. Since an age effect emerged in explicit memory, the main analysis was repeated with these tests treated as a covariate to confirm whether the age difference in recognition was influenced by differences in background variables. The results showed that the age difference in explicit memory remained significant when these factors were partialed out, indicating that the difference in recognition between young and older adults was not affected by these variables.

Age differences in priming were non-significant on the CID-R task and priming in the CV-R task was once again negative. The negative priming in the CV-R task is consistent with the online version (Experiment 3) and suggests that the CV-R task may not be sensitive to priming, and therefore this task was not included in the main analysis. One possibility is that the lack of priming effect in the CV-R task may be connected to the combination of a latency measurement and using an implicit task that is based on conceptual processing. That is, trying to be quick when processing items conceptually may wash out the priming effect and lead to the observed negative priming values. It was predicted that age differences in priming would be greatest in the conceptual encoding, conceptual test condition (i.e. CC), as older adults are impaired in conceptual processing (e.g. Rybash, 1996), and also according to the processing deficit hypothesis young adults are at more of an advantage than older adults when conceptual processing is involved (e.g. Eysenck, 1974). Similarly, It was predicted that age differences in priming would be smallest in the perceptual encoding, perceptual test condition (i.e. PP). However, this observation did not even occur numerically. One explanation, as touched on above, might be that the conceptual priming task (CV-R) is either not sensitive to age differences or did not work as expected given that there were no priming effects, it is worth noting that the prior study by Ward (2022) also reported a non-significant interaction between Age × Processing × Test. Furthermore, this interaction was non-significant in Experiment 3.

It is worth noting that the p value in CID-R task for the main effect of age was borderline significant (*p* = .055), and Bayesian analysis provided evidence in favour of the alternative hypothesis of an age difference in priming (BF10 = 1.13). When looking at **Error! Reference source not found.**, there was a clear age difference in the conceptual encoding, perceptual test condition (i.e. CP). Therefore, an exploratory analysis was conducted to compare priming in young and older adults in this condition, which revealed a significant difference: young adults showed greater priming in the conceptual encoding, perceptual test condition than older adults. It is also important to note that the priming effect in the CID-R task was only significantly above zero in young adults only. Thus, the results indicated a general decline in perceptual priming with age given that priming was completely absent in older adults. The age difference in the conceptual encoding, perceptual test condition was identical with what was observed in Experiment 1A and also the age effect appeared in the same condition in Experiment 3, but the effect disappeared following the covariate analysis. The present findings are consistent with previous studies that used a perceptual identification task and reported an age effect on implicit memory (e.g. Ward et al., 2020), and Small et al. (1995) used another type of perceptual implicit task (stem completion) and reported an age effect when test was perceptual followed by a conceptual encoding condition. Also, the findings were similar to Stuart et al. (2006) as this study showed an age effect in the perceptual encoding, perceptual test condition, however, they did not have a conceptual encoding, perceptual test condition in their study. The present observations are not consistent with Ward (2022), which showed an age effect only in the perceptual encoding, perceptual test condition.

The lack of sensitivity that has been found in the CV task in this experiment and Experiment 3 was inconsistent with previous studies. For example, Light et al. (2000) Experiment 2 showed a priming effect only in young adults and not older adults, and Ward (2022) showed priming in older adults was evident only in their conceptual encoding, perceptual test condition. One of the studies featured in this thesis, utilizing a different conceptual priming task (CEG; Experiment 2), successfully identified age differences in priming following conceptual and perceptual encoding. The present findings are also inconsistent with the earlier study by Light et al. (2000); Experiment 2, which reported an age effect on a CV task. In their study 36 young and 36 older participants were asked to decide if a presented item belonged to a given category name as quickly as possible (conceptual processing), and the results showed that older adults were slower (1193 ms) compared with young adults (967 ms), that is, they produced greater priming. This would be the equivalent to the present conceptual encoding, conceptual test condition.

Accuracy data in the encoding phase showed age and processing effects. Young adults were generally more accurate than older adults in both conditions (conceptual and perceptual encoding conditions), and both groups were more accurate in the conceptual than the perceptual condition. The greater accuracy in the conceptual than perceptual encoding condition for older adults was surprising as the general assumption is suggesting that older adults are impaired in conceptual processing (e.g. Eysenck, 1974; Morcom et al., 2003; Morcom & Rugg, 2004; Rybash, 1996). In relation to the RT data during the encoding phase, young adults (Marginal Mean = 1159 ms) were slower than older adults (Marginal Mean = 1002 ms) in the conceptual and perceptual encoding conditions, which is also unexpected. However, taken together the greater accuracy (in both conditions) for young adults may explain their slower response times. That is, people may need a longer time to produce the correct answer.

The expected effect of processing on priming and recognition in this study did not reach significance. Greater priming and recognition were anticipated for conceptually studied items than perceptually studied items. Previous studies show that recognition is enhanced following conceptual processing. For example, Monti et al. (1996) showed that deep/conceptual processing enhanced explicit memory as measured by recall (*M* = 30.1%) compared to perceptual encoding (*M* = 9.5%). Further, the meta-analysis conducted by Brown and Mitchell (1994), showed that 133 studies reported greater priming following conceptual processing, compared with 32 studies that found greater priming following perceptual processing, and four reported equivalent priming in the conceptual and perceptual processing. The latter observation is consistent with the findings of this study, as both priming and recognition for conceptually and perceptually studied items were equivalent. This finding was inconsistent with Experiment 3, where processing affected explicit memory. The non-significant effect of processing is consistent with Ward et al. (2020), whose study showed no effect of processing on explicit and implicit memory. However, the researchers argued that the processing manipulation in their study did not work. As processing did not produce the expected effects in this experiment it seems possible that the altered decision in the encoding phase (from upright/tilted in Exp. 3 to rounded/angular in Exp. 4) may explain this, as this is the only difference between this experiment and Experiment 3. Therefore, more experiments are needed to employ a range of decisions with different processing requirements to fully understand how this affects the priming and recognition.

The awareness questionnaire that participants completed following the experimental task revealed that only 11 young and four older participants were aware that CID task was related to memory, and eight young and four older participants were aware that the CV task was related to memory. As the proportion of aware participants was low in both tasks (below the pre-registered 20% threshold), no follow-up test was conducted to examine whether being aware had an effect on priming. In general, as most participants were unaware, confidence exists that priming was not affected by explicit contamination. Also, it is important to state that CID-R task is immune to explicit contamination as suggested by earlier research (e.g. MacLeod, 2008; Ward et al., 2013b). It has been argued that participants in speeded tests are generally unable to engage in explicit strategies as there is not time to do so (e.g. Brown et al., 1991, 1996; MacLeod, 2008). It was clear in this experiment that participants were engaging and trying to complete the trials as quickly as they could, as instructed, so there was no time to think about the prior encoding phase in an attempt to boost priming – if anything, this would have probably slowed participants down and reduced priming further.

In this study, one of the most widely used cognitive screening tools was employed – the MMSE. The MMSE was used instead of the EDQ that was employed in Experiment 1A, which was associated with some issues (discussed previously). The MMSE was not able to be used in previous experiments as they were all conducted online given Covid-19 restrictions, and the MMSE requires researcher administration. The MMSE is a robust, validated, and widely used tool for screening older adults for cognitive impairment. It is often used in both research and clinical practice to detect early signs of mild cognitive impairment (MCI) and dementia (Liu & Chang, 2021). The MMSE was very effective in this study, allowing for quick and efficient assessment of cognitive functions in various areas: orientation, attention, memory, language, calculation, and visual constructions (Sheehan, 2012). Additionally, the use of the MMSE offers advantages as this test is generally short and can be completed quickly, saving time for both the participant and the researcher. Therefore, using the MMSE while planning to exclude any participants scored below 24 (cutoff threshold for normal function), confidence was held that the sample of older participants represented a healthy population.

Finally, although some findings were replicated in this experiment and consistent with Experiment 3, there are other findings that were inconsistent between the online and in-person versions of the study. Briefly, age differences in explicit memory emerged in this study, but not in Experiment 3. An age effect on implicit memory (conceptual encoding, perceptual test; CP) was evident in both this experiment and Experiment 3, but in Experiment 3 this disappeared when differences between young and older adults in the vocabulary test were controlled for. The results in the encoding phase also showed some inconsistencies between the online and in-person versions, there was an interaction between age and processing in Experiment 3, but there was no such interaction in this study. But in general, the results of Experiment 3 and this experiment were comparable, particularly the age effect on implicit memory in the conceptual encoding, perceptual test condition. This may suggest that the online method was just as valid as the in-person experiment. The minor differences between the two experiments were related to the level of engagement; it is likely that engagement and effort were greater when the study was conducted in person.

In conclusion, the primary goal of this experiment was to replicate Experiment 3 in a controlled laboratory environment. The experiment systematically manipulated processing (conceptual/perceptual) during encoding prior to closely matched conceptual and perceptual priming tasks in a within-subjects design. Overall, there was an age effect on recognition but no age effect on priming in the main analysis. However, given that priming was altogether absent in older adults and significant in young adults only on the perceptual test, the findings point to a general reduction in perceptual priming with age. The lack of priming on the CV-R task in either group may suggest a lack of sensitivity of this measure.

Chapter 6: General Discussion

This thesis aimed to overcome inconsistencies in the literature and examine whether there is evidence of age-related decline in implicit memory. The ambiguity regarding whether implicit memory remains intact or declines with age is the result of many differences among previous studies, including participant characteristics, statistical power, task reliability, explicit contamination, and processing requirements. The latter has not been thoroughly investigated in the past and was the main focus in this thesis. Age effects on implicit memory may be influenced by the type of processing employed at encoding and/or in the implicit memory task. This is important as numerous studies have suggested that older adults have impaired conceptual processing, whereas perceptual processing remains intact with normal ageing (e.g. Fleischman & Gabrieli, 1998; Geraci & Hamilton, 2009; Rybash, 1996). Nevertheless, the manipulation of processing during encoding and test phase has not been taken into consideration very thoroughly in prior studies. Therefore, in the research presented in this thesis, processing (conceptual/perceptual) was manipulated at encoding, and multiple types of implicit memory tasks differing in either conceptual or perceptual processing were used in order to provide insight into how processing style interacts influences age differences in implicit memory. Although the literature has uncovered clear age effects on explicit memory (reviewed in Ward & Shanks, 2018), an explicit memory (recognition) task was included in all experiments in the present research to compare age effects on explicit and implicit memory. The results suggest that explicit and implicit memory are both affected by age, and implicit memory was sensitive to the manipulation of processing at encoding and test – specifically, priming was reduced by age when processing at encoding was conceptual and processing at test was perceptual. For a summary of the results of each experiment, please refer to Table 6.1 below.

Table 6.1. Summary of Results for All Experiments

Experiment	Recognition	Priming
1A	• Main effect of Age with greater recognition in young than older adults. • Main effect of Processing with greater recognition following conceptual than perceptual encoding. • Interaction between Age and Processing: both young and older adults showed greater recognition in the conceptual than the perceptual condition, and young adults outperformed older adults in the conceptual but not the perceptual condition.	• Main effect of Age with greater priming in young than older adults. • Main effect of Processing with greater priming following conceptual than perceptual encoding. • Interaction between Age and Processing, with greater priming in young than older adults in the conceptual but not the perceptual condition.
1B	• Main effect of Age with greater recognition in older than young adults. • Main effect of Processing with greater recognition following conceptual than perceptual encoding.	• Main effect of Processing with greater priming following conceptual than perceptual encoding.
2	• Main effect of Age with greater recognition in young than older adults.	• Main effect of Age with greater priming in young than older adults. • Interaction between Age and Processing: priming in young adults was greater in the perceptual than the conceptual condition, but there was no difference between the conditions for older adults.
3	• Main effect of Processing with greater recognition following conceptual than perceptual encoding. • Main effect of Test with greater recognition following conceptual than perceptual test. • Interaction between Processing and Test: recognition was greater following conceptual than perceptual condition on CID-R and CV-R tests.	• Main effect of Test with greater priming following the perceptual than the conceptual test. • Following exploratory analysis an Age effect emerged in the conceptual encoding, perceptual test condition.
4	• Main effect of Age with greater recognition in young than older adults.	• Following exploratory analysis: an Age effect emerged in the conceptual encoding, perceptual test condition.

6.1 Implicit Memory in Normal Ageing and the Effect of Processing.

As reported in this thesis, a series of experiments showed a decline in implicit memory (priming) as an effect of normal ageing, and in most cases this interacted with processing. In Experiment 1A, age effects emerged when participants encoded conceptually followed by a perceptual implicit test (CID-R)[1]. In Experiment 2, age effects emerged on a conceptual implicit test (CEG) regardless of the type of processing used during the encoding phase. In Experiment 3, age effects emerged following conceptual encoding on a perceptual implicit test (CP), consistent with the findings of Experiment 1A. However, an ANCOVA suggested that the age effect was influenced by differences between young and older adults in vocabulary level. Finally, in Experiment 4, the main effect of age was close to significance (*p* = .055), and following an exploratory analysis an age effect emerged again when data was processed conceptually and followed by a perceptual test (CP condition), as in Experiment 1A and Experiment 3. Thus, several experiments reported in this thesis provide evidence that implicit memory is sensitive to advancing age when a perceptual implicit test is used and stimuli are processed conceptually during encoding. This supports the notion that older adults are impaired in processing data conceptually (Jelicic, 1995; Rybash, 1996), in line with the processing deficit hypothesis that claims that older adults are at less of an advantage when data are processed conceptually (Eysenck, 1974).

The CEG task used in Experiment 2, which served as conceptual implicit task was capable of producing a priming effect, and was sensitive to age differences in implicit memory. However, as the instructions of the CEG task are to produce exemplars, it is possible that participants may have engaged in explicit processing to fulfil this goal. That is, participants may have though back to the previously studied items to help them come up with exemplars for the various categories. This is perhaps more likely than on speeded tasks such as the CID-R task. However, it should be noted that only a small number of participants were actually aware of the relationship between the study and test phases, so it is still unlikely that explicit contamination was much of an issue. In Experiment 3 and 4, a conceptual implicit task that was more comparable to the perceptual implicit task (CID) was desired. Therefore, the CV-R task was chosen as a replacement of the CEG. Both CID-R and CV-R are based on RT and were matched as closely as possible in various characteristics. However, the CV-R task used in Experiment 3 and 4 was not effective. This task exhibited certain limitations, notably being unable to detect a priming effect in various conditions, it suggests that when combined with conceptual processing at test and latency measure (RT), it might obscure the priming effect, as there was a negative priming effect for both age groups, as explained previously processing items

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[1] In this chapter, the findings of Experiment 1B are not considered given the very small sample size and low statistical power, meaning that they are not representative.

conceptually might wash out the priming effect. This may highlight a deficiency in this type of conceptual implicit memory task. Therefore, the insensitivity of the CV-R task did not allow for a deep understanding of the effect of using a conceptual priming task, and it would be beneficial for future research to investigate further using other conceptual priming tasks. Finally, after using multiple tasks to assess implicit memory, and exclusively employing a single perceptual priming task, namely CID. The results undeniably indicate that the CID task is an optimal choice for evaluating the performance contrast between young and older adults. Consequently, it can be confidently asserted that the CID task exhibits reliability as an assessment tool for implicit memory. In future studies, it may be worthwhile to explore alternative perceptual tests to ascertain whether age-related effects persist under similar conditions which is conceptual encoding followed by a perceptual test (CP). Furthermore, the CID-R task, recognized for its speeded nature, has been argued to be immune to explicit contamination (e.g. Brown et al., 1991, 1996).

Although not a key feature of the present thesis, differences between production and identification processing represent another topic to consider when examining age differences in implicit memory (reviewed in Prull, 2004). According to previous research, ageing has little or no effect on tasks involving identification processing, while production processes are impacted by age (e.g. Fleischman & Gabrieli, 1998; Gabrieli et al., 1999; Light et al., 2000; Rybash, 1996). Examples of production tasks include word stem completion (WSC) and CEG, where participants have to generate or produce a response in response to a cue, such as completing a word stem or producing exemplars in response to a category name. Winocur et al. (1996) showed that an age effect emerged on a WSC task (production), but there was no age effect on a word fragment completion (identification) task. However, the WFC task is rather an ambiguous case as it requires production processes if there is a single solution, but requires identification if there are more than one solution, and participants need to identify the patterns of letters while producing words (Light et al., 2000). However, in this thesis, age effects on implicit memory emerged using tasks relying on both identification (CID) and production (CEG), suggesting that more research needs to be done to examine how different types of response affect the observed age differences in implicit memory.

Additionally, when studying priming, it is important to consider the type of measurement employed in the implicit memory task (reviewed in Fleischman, 2007; Light et al., 2000). Previous research has indicated that tasks based on RT and accuracy are not equally affected by age. For example, Light et al. (2000), after reviewing several priming tasks based on a latency measure and other types of responses, reported a significant difference in effect sizes between the tasks. However, the meta-analysis of La Voie and Light (1994) showed no differences in effect sizes. In this thesis various priming tasks were used, some based on accuracy and others on latency (reaction time). In Experiment 1A, the CID-R task was based on latency measure, and an age effect emerged. In Experiment 2, a CEG task based on accuracy was used, and there was an age effect regardless of the encoding condition. In Experiment 3, the CV-R and CID-R tasks, both based on latency, were used, and an age effect on implicit memory emerged in the CID-R task following the conceptual encoding condition; however, following further analysis, the age effect on implicit memory was shown to be influenced by other variables. Finally, in Experiment 4, exploratory analysis revealed an age effect in the conceptual encoding followed by a perceptual test condition. The key message here is that age effects emerged regardless of the type of response: the CEG (accuracy) and the CID (latency) tasks were both affected by ageing, and the age effect in the CID-R task was inconsistent with some earlier studies that reported no age effect when using a task involving a latency measure (e.g. Light et al., 2000; Mitchell, 1993). Therefore, more research is needed to clarify how different type of measurement in implicit memory tasks can contribute to ageing effects. Additionally, when employing tasks which are based on RT, the longer baseline for older compare with young adults may mask age differences (e.g. Salthouse, 1985), this is because longer baseline RTs may exaggerate priming in older adults and may wash out age differences. However, this thesis addresses the issue by employing the proportion transformation, which is widely considered as the best technique to measure priming. This technique has been used in prior studies (e.g. Chapman et al., 1994; Faust et al., 1999; Ward et al., 2013b, 2020).

It is also important to consider the findings of previous studies that have suggested that perceptual processing in general is sensitive to changes in stimuli in the encoding and test phases (e.g. changing from pictures to words between phases, known as a cross modality). Specifically, modality changes in implicit tasks generally lead to a reduction in priming (Jacoby & Hayman, 1987; McAndrews & Moscovitch, 1990; Park & Gabrieli, 1995; Roediger & Blaxton, 1987; Srinivas, 1993). In this thesis, a CID-R task was utilized as a perceptual implicit task, and in all cases the stimuli (images) were used in the encoding and test phases. Therefore, the above stated issue was not a concern. However, this is another factor that may need to be examined further in future studies where age effects are concerned – how changes in stimuli between phases and the way in which they are processed affects age differences in priming. Concerning the use of images as stimuli, the tasks described in this thesis relied on the presentation of images (except the CEG task in which participants produced exemplar words in the test phase following the presentation of images at encoding). According to previous research, images produce a greater priming effect than words, this is known as the picture superiority effect (e.g. Weldon & Roediger, 1987). However, in this thesis, there was no direct comparison between using word/images as stimuli and therefore there was no clear conclusion about this issue. But this is an important issue to be considered in future research.

Research has also suggested that matching the processing type during the encoding and test phases yields a greater priming effect (Transfer Appropriate Processing; Roediger & Blaxton, 1987; Roediger & McDermott, 1993; Ward, 2022). For example, processing items in a perceptual manner at encoding is thought to lead to greater priming on a perceptual task (and similarly for conceptual encoding and conceptual testing), while a processing mismatch would reduce priming. However, in this thesis, no evidence of this was found. In Experiment 1A, the priming effect was not larger when a perceptual implicit test followed the perceptual encoding condition, and in Experiment 2, no significant effects of processing were found. Additionally, in Experiment 3, the processing effects or the interaction between processing and test were not found to be significant; similarly, in Experiment 4, there was no effect of processing. However, the insensitivity of the CV (conceptual) task may have hindered the ability to examine and compare true priming effects in the perceptual encoding, conceptual test and conceptual encoding, conceptual test conditions.

Moreover, it has been suggested that using familiar stimuli (e.g. the word BICYCLE as stimulus or an image of a bicycle) produces greater priming effects (Bowers & Schacter, 1993; Squire, 1992) compared with unfamiliar or novel stimuli (e.g. non-words [POWCHED] or novel geometric shapes). In the research presented in this thesis, familiar objects were used in all the experiments, but a priming effect did not emerge in all experiments. It would be interesting for future research to contrast the findings using novel/unfamiliar stimuli.

On the whole, the age effect on conceptual implicit memory reported in Experiment 2 is consistent with several studies that have found an age effect in different conceptual implicit tasks including category exemplar production/generation (e.g. Jelicic, 1996; Maki et al., 1999; Stuart et al., 2006), and category verification (e.g. Light et al., 2000; Ward, 2022). The age effect on perceptual implicit memory reported in Experiment 1A and 4 is consistent with several studies that have reported an age effect in different perceptual implicit tasks including perceptual identification (Abbenhuis et al., 1990; Russo & Parkin, 1993; Ward, 2018, 2022; Ward et al., 2013b, 2020), and word stem completion (e.g. Hultsch et al., 1991; Small et al., 1995), and contradicts Mitchell and Bruss's (2003) conclusion that implicit memory mostly remains intact as a person ages.

Finally, the conceptual encoding, perceptual test condition yielded the most significant age differences. This can be attributed to the impairment in the conceptual encoding experienced by older adults when combined with perceptual processing during the test phase, creating as processing mismatch that results in lower performance among older adults.

6.1.1 Explicit Contamination in Implicit Memory

Implicit memory was examined in the experiments in this thesis without telling participants that memory was being tested. Even when priming was measured concurrently with recognition, the purpose of the implicit portion was disguised as much as possible. That is, participants were instructed to, for example, identify objects as quickly as possible. Despite this, there was a concern that participants may become aware of the connection between the encoding and test phases and the fact that previously studied items were represented at test, and somehow use an explicit strategy to perform the implicit task (reviewed in Ramos et al., 2017). This is important as young adults would have an advantage in using an explicit strategy, which may increase their priming in comparison to older adults. However, research has suggested that speeded tasks are immune to explicit contamination as participants do not have ample time to employ an implicit strategy even if they become aware (e.g. Brown et al., 1991, 1996). For example, previous research has demonstrated that the CID-R task is not affected by explicit contamination (MacLeod, 2008; Ward et al., 2013b). For example, Ward et al. (2013b) found no differences in priming when implicit memory was tested separately (CID task) compared with when it was tested concurrently with explicit memory (CID-R task), additionally, it demonstrated no improvement in priming when participants were informed which items were old and which items were new.

Despite this, in the research reported in this thesis, efforts were made to control for possible explicit contamination and to monitor the effect of explicit contamination on conceptual implicit tasks where there has not been as much research. That is, although there is good evidence that the CID-R task is unaffected by explicit contamination, it is unknown whether this may be an issue on conceptual implicit tasks. An awareness questionnaire was given to participants at the end of each experiment to gauge whether they were aware of the purpose of implicit memory task. There was no intention to exclude aware participants but, instead, to compare priming in aware versus unaware individuals. The results of the awareness questionnaire in Experiment 1A indicated that only 13 participants out of 70 were aware of the purpose of the perceptual identification task (CID-R). Similarly, in Experiment 2, 13 participants out of 70 were aware that the CEG task was used to assess memory. In Experiment 3, 27 participants were aware of the purpose of the CID-R task. However, there were only nine participants rated as aware of the purpose of the CV-R task. As the percentage of aware young participants was greater than 20% on the CID-R task in this experiment (pre-registered threshold), further analysis was conducted to understand if there was an effect of awareness, but the results showed no effect of awareness on priming in young participants, suggesting that explicit contamination did not boost their priming on this task. Finally, in Experiment 4, 15 participants were aware of the purpose of the CID-R task, and 12 participants were aware in the CV-R task. This did not reach the pre-registered threshold for statistical comparison of aware and unaware participants, but means suggested that priming was numerically greater in aware compared with unaware participants only in young adults in the perceptual encoding, conceptual test condition and older adults in the conceptual encoding, conceptual test and perceptual encoding, perceptual test conditions. Overall, priming was not statistically affected by awareness in young adults on the CID-R task (Experiment 3), replicating the prior studies mentioned above, and in general the number of participants who could be considered aware was very low in other experiments. Therefore, explicit contamination did not affect priming in the experiments in this thesis or contribute to the age effect on implicit memory. This also provides new evidence that conceptual tests, like perceptual tests, do not appear to be affected by explicit contamination, and in fact the level of awareness seems to be even lower on these tasks.

6.2 Explicit Memory, Processing, and Normal Ageing

Based on the findings of previous studies, age differences in recognition are typically smaller in recognition than the recall tasks (e.g. Craik & McDowd, 1987; Danckert & Craik, 2013; Light & La Voie, 1993; Moscovitch & Winocur, 1992; Naveh-Benjamin & Craik, 1995; Nyberg et al., 2003; Schugens et al., 1997; Whiting & Smith, 1997). However, in this thesis, age effects on explicit memory (recognition) emerged, replicating prior findings (e.g. Howe, 1988; Jelicic, 1996; Ward et al., 2013b, 2020; Wiggs et al., 2006). This was the case in all experiments except Experiment 3, which surprisingly showed no difference in recognition between young and older adults (also reported by Schugens et al., 1997; Naveh-Benjamin & Craik, 1995). Numerically, the young adults outperformed older adults in three conditions in Experiment 3 (perceptual encoding, perceptual test (PP), perceptual encoding, conceptual test (PC), and conceptual encoding, conceptual test (CC)), so it is possible that this trend did not reach significance. The finding of no age difference in recognition contradicts many prior studies, and possibly emerged because of the online testing format, as there was less engagement in Experiment 3. This may be why the recognition score was smaller in Experiment 3 compared with Experiment 4 even though both experiments were identical except of the mode of testing. As a replication of Experiment 3, Experiment 4 was conducted in the lab to allow comparison of in-person with data collected online. In Experiment 4, consistent with earlier experiments in this thesis, an age-related decline in explicit memory was found. Overall, the findings presented in this thesis align with prior research indicating a decline in explicit memory (reviewed in Light, 1991; Ward & Shanks, 2018). This suggests that both explicit and implicit memory decline with age, and that memory is generally and globally affected by normal ageing. These results further lend support to the notion that explicit and implicit memory share a common underlying memory system (Berry et al., 2008b, 2008a; Buchner & Wippich, 2000; Nosofsky et al., 2012). Regarding the processing effect on explicit memory, in Experiment 1A conceptual processing led to greater recognition as was expected. In Experiment 2, there was no effect of processing, but numerically conceptual processing led to greater recognition. In Experiment 3, conceptual processing during encoding resulted in greater recognition on both tests (CID-R and CV-R; note that the recognition tasks following CID and CV were identical and only the priming task differed). Finally, the results of Experiment 4, which was identical to Experiment 3 but conducted in person, showed no effect of processing. Numerically, recognition was enhanced following conceptual encoding but only for older adults on the CID-R task. Therefore, the results overall were consistent with previous studies that uncovered greater recognition following conceptual processing (e.g. Brown & Mitchell, 1994; Craik & Lockhart, 1972; Graf & Mandler, 1984; Mitchell & Perlmutter, 1986; Monti et al., 1996).

6.3 Critical Evaluation

A key strength of this thesis is in overcoming many methodological issues found in the literature that have caused discrepancies in the field, especially concerning the type of processing and how it interacts with age. In this thesis, multiple types of implicit memory tasks (CID, CV, CEG) were employed to investigate whether age-related decline is evident in implicit memory across a range of processing modalities. Further, all experiments conducted for this thesis were properly powered (except for Experiment 1B, which unfortunately did not work as expected). Ensuring adequate power is crucial as conducting a study with insufficient power can result in a failure to detect a true effect (Dorey, 2011), while ensuring sufficient power reduces the possibility of Type II errors and increases the likelihood of detecting a difference when one is present (Biau et al., 2008).

Additionally, all experiments were pre-registered on the OSF prior to data collection. In the past, this practice was not widely used. According to Simmons et al. (2021), ten years ago, in psychology approximately zero research were pre-registered. However, pre-registration is fast becoming a trend in science. Pre-registration involves planning and registering the methods and analysis before any data are collected (e.g. Moore, 2016; Nosek et al., 2018; van ’t Veer & Giner-Sorolla, 2016), which is important to allow transparency, replication, and most critically the prevention of p-hacking. Pre-registration has proven to be a valuable practice in providing the researcher with a clear roadmap for post-data collection steps. However, there were instances where strict adherence to the pre-registered plan was challenging. For instance, in Experiment 1A, the initial intention was to exclude older adults scoring above 7 on the EDQ questionnaire. Yet, this approach proved unfeasible as it would have resulted in the exclusion of the majority of participants when this was not necessary, and it was found that the general instructions on the EDQ questionnaire were problematic. Moreover, in other experiments, some pre-registered thresholds were also adjusted to ensure the retention of a significant portion of participants.

Due to the global Covid-19 pandemic, all experiments in this thesis except Experiment 4 had to be conducted online. Online testing offers many potential advantages, such as the speed of recruiting participants compared with lab testing and the diversity of the recruited sample. It has also been suggested that older adults who participate in lab studies are not always representative of the ageing population, as only older adults with good physical health can travel to the lab (Golomb et al., 2012). However, at the same time there are other issues related to older adults who do not have the technical knowledge or access to internet in order to perform an online study (Gagné & Franzen, 2023). There is growing evidence that data from online studies are comparable to that conducted in laboratory (e.g. Anwyl-Irvine et al., 2019; Germine et al., 2012; Greene et al., 2022; Greene & Naveh-Benjamin, 2022; Sauter et al., 2022; Semmelmann & Weigelt, 2018). However, conducting online studies prevents one from having a controlled environment, which can easily be found in a lab. For example, differences between the device/screen for each participant may affect the quality of stimuli presentation and reaction times (reviewed in Gagné & Franzen, 2023), meaning that data could be noisier. Hence, to exert some control, the range of permissible browsers, device types, and connection speeds employed across all online experiments was restricted.

Conducting online and in-person studies was an advantageous in this thesis, facilitating the comparison of differences between testing modes. Differences in participants motivation between online and laboratory studies were noted. As addressed in the discussion in Chapter 5, there was more engagement in Experiment 4 (in-person) compared to Experiment 3 (online), although both experiments were identical. Given their identical nature, the boredom factor can be excluded, leading to less engagement with the task. Therefore, the main reason might be related to people's concern about how they appear to the experimenter, whereas in online studies, there is no physical meeting between the participant and the experimenter (e.g. Belletier et al., 2015; Belletier & Camos, 2018), and therefore it is likely that the lack of engagements in online studies is due to the lack of presence of the experimenter. However, these results differ from those of a previous study that observed higher scores when data were collected at home compared to in a lab (Cyr et al., 2021), and they are similar to the results of another study by Belletier and Camos (2018) that showed evidence of greater working memory when participating in a study alone compared to in the presence of the experimenter. Another study also found the same level of motivation in online and lab samples (Gosling et al., 2004).

In addition, when comparing years of education between the online (Experiment 1A, 2 and 3) and in-person (Experiment 4) experiments, the participants' years of education were higher in the in-persons experiment for both young (*M* = 16.21) and older (*M* = 16.33) adults compared with the online experiments (young *M* = 15.89; older *M* = 15.67; aggregated mean). The higher level of education in Experiment 4 (in-person) may be related to the source of the sample (U3A) for older adults. Differences in the level of education have been raised as an issue when recruiting young adults (i.e. university students), compared with older adults from the general public. This is supported by research showing that higher education may protect somewhat against cognitive decline in older adults (Albert et al., 1995; Andel et al., 2006). However, this was not the case in the present research as the participants' level of education did not differ between the young and older adults. In many cases, the sample of older adults in the studies conducted was diverse; some older adults were recruited from Prolific (recruitment services), and others were recruited from U3A, which is an organisation of retirees, and members of U3A are always engaging in educational workshops and different activities, making them high functioning.

Moreover, when comparing online versus lab testing, it is important to acknowledge the effort and preparation required of the researcher. When an online study is ready to be performed, the researcher can relax and wait to obtain the data, but when a study is performed in the lab, significant preparation is required. When Experiment 4 was conducted in-person, initial arrangements had to be made before testing each participant. For example, as some older participants could not walk long distances or use public transportation to travel to campus, booking a parking space on campus was one of the initial arrangements that the researcher needed to make. Additionally, time differences were among the main differences as testing in the lab took months to complete, whereas online testing was much shorter. Another noteworthy aspect of testing in the laboratory concerns when a participant does not appear for their allocated time slot. This issue slows the process as the researcher cannot arrange for another participant to fill the slot. In contrast, the online environment offers advantages as many participants can take part in the experiment simultaneously.

Of all the potential limitations associated with online testing, perhaps the main weakness is the lack of neuropsychological assessments that can be used online. When cognitive ageing studies are conducted in a lab, there are many cognitive screening tests that can be used to pre-screen older participants such as The Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), The Mini-Mental State Examination (MMSE; Folstein et al., 1975), Abbreviated Mental Test, Clock drawing, Mini-Cog, 6-CIT, Test Your Memory, General Practitioner Assessment of Cognition (GPCOG), Memory Impairment screen, and Addenbrookes Cognitive Assessment (reviewed in Ismail et al., 2010). Using a cognitive screening test is essential when conducting an experiment that attempts to understand normal age-related changes in memory and cognitive functioning. Specifically, it is important to ensure that older adults are healthy and do not suffer from MCI, dementia, or any other cognitive dysfunction, as such impairments can influence the results. For example, since memory is usually the first domain to be affected by AD (e.g. Bäckman et al., 2005), unknowingly including participants with MCI and/or AD in healthy ageing studies can invalidate the results. In general, cognitive screening tests that can be used online and without supervision are scarce, and this is why the EDQ

(Arabi et al., 2013) was used in the initial experiments. Although this test was quick and easy to conduct, it was quickly apparent that it has several limitations. The EDQ has fairly generic instructions and because of that many older participants scored above the cutoff, and therefore the decision was made to abandon it. Only the validated MMSE was used in the final experiment, which was conducted in person. This was one of the main limitations in this thesis, and it underlines the importance of developing cognitive screening tests that can be used online and without the researcher's supervision.

Although there were limitations in the screening of older participants due to the testing method employed (i.e., online), there are compelling reasons to believe that these participants were indeed healthy and free of dementia. This belief is supported by the notion that a decline in explicit memory often marks the onset of Alzheimer's disease (AD) (Terry & Katzman, 1983; Welsh et al., 1992). In all experiments, an explicit memory task (recognition) was included, and there were no particular outliers that gave cause for concern in terms of participants having cognitive impairment/AD. Many prior studies have demonstrated the inability of AD patients to perform such tasks effectively (e.g. Abbenhuis et al., 1990; experiment 1; Kessels et al., 2005). Furthermore, it is worth noting that most cognitive screening tests, including MMSE and MoCA, incorporate a recognition task. Therefore, if any participants in the older adults group were indeed impaired, it is reasonable to assume that they would likely have difficulty performing the recognition task and would have been easily identifiable for exclusion.

In a systematic review published by Tsoy et al. (2021), the authors reviewed self-administered studies to detect MCI and AD such as (C-TOC; Cognitive Testing on Computer). One of the important criteria that this systemic review considered was the level of experimenter involvement in conducting the screening test. The researchers differentiated between the instruments that can be used online/computerised and the instruments that can be employed without any level of supervision (for full details see Table 2, Table 3, and Table 4 in Tsoy et al., 2021). This is important because, a review of the literature examining cognitive screening tests showed that there are numerous tests that can be administrated via a computer, but some of them require the presence of the experimenter/researcher such as, MoCA and Cogstate Brief Battery (reviewed in De Roeck et al., 2019). During the pandemic, looking for cognitive screening tests that can be administered online without the presence of the researcher became a priority. After reviewing many instruments in the systematic review, there were only two tests that could be self-administered to detect MCI and AD – namely, the CNSVS; CNS vital Signs (Gualtieri & Johnson, 2006; Gualtieri & Johnson, 2005), and the COGSelfTest; Computerized Self-Test (Dougherty et al., 2010). However, the CNSVS test was quite long, requiring about 30 minutes to complete. This may have increased the possibility of drop out, and also increase the payment cost for participants. Overall, finding a suitable and valid cognitive screening test to detect MCI and AD that can be self-administrated, without any level of supervision, was extremely difficult. It is important to note that the lack of online screening tests in the field was due to the fact that many researchers have attempted to create online screening tests for different purposes, such as early diagnostic tests, accessibility to a large population, and cost saving when tests are scored automatically. However, in this project and because of the pandemic, the main aim was to find a suitable instrument that can be used without any level of researcher involvement due to the social distancing rule during the pandemic.

While writing this thesis, a paper was published showing the adaptation of a cognitive screening test as an extension of previous work (Tagliabue et al., 2022) – that is, the Self-Administered Task Uncovering Risk of Neurodegeneration (SATURN; maximum score = 29). A total of 346 older adults aged 65-75 years (*M* age = 68.4 years) completed SATURN online to assess MCI and dementia. This test can be administered online and without supervision. The score is obtained based on 19 brief tasks that assess seven cognitive domains including: attention, incidental, orientation, maths, recall, spatial, and executive. Participants were satisfied and reported that the instructions were clear (Tagliabue et al., 2023), and the results of the previous paper that validate SATURN showed that the SATURN and MoCA (Montreal Cognitive Assessment) were highly correlated (r = 0.90; Bissig et al., 2020; for information about the test visit https://doi.org/10.5061/dryad.02v6wwpzr). Therefore, in future online ageing studies, the SATURN assessment might be considered as a useful cognitive screening test. Another instrument that might be useful in future studies to screen elderly participants is the Telephone Interview for Cognitive Status (TICs), develop by Brandt et al. (1988). This instrument offers a non-face-to-face method of screening. It comprises 11 items, including word list memory, orientation, attention, repetition, conceptual knowledge, and nonverbal praxis, with a maximum score of 41 points. Sample items include asking the participants for their full name, today's date, their location at the time of testing, and to count backward from 20 to 1. Several studies have demonstrated the reliability and validity of the TICs (e.g. Welsh et al., 1993). Therefore, this instrument might be considered as well in future online studies.

Another aspect to consider (touched on in the discussion of Experiment 1A) is the potential confound between exposure time to stimuli in the encoding phase and the processing manipulation. That is, memory for visual stimuli increases as study duration increases (e.g. Berry et al., 2017), but in a design manipulating the type of cognitive processing one must ensure that the exposure duration is (1) long enough to allow for conceptual encoding in the conceptual/deep processing conditions, and (2) brief enough to not encourage this such processing in the perceptual/shallow condition. Based on previous studies, in all experiments participants were exposed to stimuli for 500 ms in the encoding phase, and asked to determine whether the presented object was upright/tilted (Experiment 1A, 2, and 3, shallow processing), angular/rounded (Experiment 4; shallow processing) or natural/manmade (all Experiments, deep processing). Thus, in this thesis the type of decision was varied in order to manipulate the type of processing and exposure time to stimuli was held constant. This was deemed the 'cleanest' design. However, one cannot rule out the possibility that participants did not processing conceptually even in the perceptual conditions. This is unlikely because in the processing manipulation in most cases led to a significant effect on priming and recognition – that is, memory was greater following conceptual than perceptual processing. Thus, it can be concluded that processing was 'deeper' in the conceptual conditions and the manipulation was successful. Nevertheless, it will be interesting for future studies to manipulate both the type of processing decision and the exposure duration in an orthogonal design to remove this potential confound and more clearly understand the effect of processing on priming and recognition.

Additionally, while the primary focus of this thesis was not on age differences in executive function (EF), it is essential to consider this when comparing the performance of young and elderly participants. A recent previous study by Idowu and Szameitat, (2023) demonstrated that older adults (*M* age = 71.56 years) exhibit declines in four key aspects of EF: inhibition, shifting, updating, and dual-tasking, in comparison to young participants (*M* age = 21.18 years). Particularly noteworthy is the greater decline observed in inhibition (e.g. Idowu & Szameitat, 2023). Therefore, when considering the present study, it is worth noting that the ability of older adults to effectively switch between tasks may have been worse than that of older adults, affecting their performance and later memory. For example, the encoding phases in each experiment were 'blocked', and participants were required to make one type of decision (conceptual or perceptual) in the first block and this was switched in the second block. Older participants in particular may have struggled with this switch. They may have continued in the second block with whatever decision was required in the first block, and/or their responses may have been slowed by the switch. This was not something that was directly examined here, but it worth bearing in mind and investigating in the future. However, it is believed that the potential effects of this issue would have been minor because clear and specific instructions were displayed on the screen throughout the tasks, serving as reminders and aids for older participants to ensure they performed the tasks accurately.

Another aspect to consider, which may differ between age groups (young versus older adults), is the level of category fluency. Prior studies have shown that advancing age decreases the number of words produced in category fluency task (e.g. Rodriguez-Aranda & Martinussen, 2006; Troyer, 2000). This such decline may have affected the results in Experiment 1A, 1B, 3, and 4, where participants were required to name stimuli flashing under a mask in the perceptual priming task, or in Experiment 2, where participants were given a category name (e.g. Animals) and asked to generate as many items as possible (e.g. cat, dog). However, this is not considered a major issue in this thesis because a vocabulary test (The Multiple-Choice part of the Mill Hill Vocabulary Test [Experiments 1-3], and The Wechsler Test of Adults reading [WTAR, Experiment 4]) was administrated as a background test revealing that older participants in all experiments had a larger vocabulary compared to young adults.

Another factor that is important to consider, which may differentially impact young and older adults, is test anxiety and familiarity with the use of computers. An essential consideration regarding test anxiety is that it may vary among participants based on their familiarity with the environment. For instance, younger participants often have a strong familiarity with the campus environment due to their regular presence at the university. Conversely, older adults, who may not frequent the campus as often, could experience greater anxiety due to their unfamiliarity with the surroundings. Of course, this only applies to in-person experiment (Experiment 4). In other words, it is possible that older adults may be more anxious during experimental tasks, especially when they are required to come to campus to take part in an experiment, compared to young adults (especially psychology students) who may be more familiar with such tasks and being on university campus. Secondly, older adults generally exhibit lower computer usage rates compared to younger adults (Czaja et al., 2006), partially due to differences in life stage and responsibilities. However, it is important to note that computer usage among older adults can vary based on their living circumstances. In developing countries, where many older adults live independently, reliance on technology for tasks like bill payments and appointment scheduling is more common. Test anxiety has been shown to significantly influence cognitive assessment task outcomes (e.g. Clarke & MacLeod, 2013; O'Toole & Pedersen, 2011). However, some research also suggests that mild anxiety may actually enhance performance (Eysenck, 1982). Anxiety levels and computer familiarity were not directly assessed in the experiments in this project, so it is possible that this may have impacted older adults. In future studies data could be collected specifically in relation to anxiety and familiarity with computers in order to partial out any unwanted effects. However, it is deemed unlikely to have been a major concern in this study. Participants in the first few experiments completed the tasks online, so (1) all participants were in the comfort of their own home, and (2) all participants would have needed to be at least reasonably confident with using computers in order to even attempt the study. Further, in the final experiment older participants were primarily recruited from the U3A – a group of typically high functioning individuals engaged in lifelong learning. Many of them have taken part in experiments before (even at Middlesex) and were familiar with the use of computers as scheduling took part via email. Nevertheless, test anxiety and familiarity with computers are two very important factors that should be considered in other studies where older participants may be less familiar with taking part in experiments.

In all studies in this thesis age was treated as a categorical variable. Participants were either placed into a young participant group (18-30 years) or older participant group (+65). This is a very common and convenient method of examining age differences in memory (and not only memory). The vast majority of prior studies have also segregated young and older adults into separate groups for comparison. However, there are inherent issues with this method. For example, grouping older adults assumes homogeneity in age-related characteristics, yet differences may exist between, for instance, those aged 65-80 and 85-90, leading to loss of data precision. Treating age as a continuous variable would enhance precision. Sometimes it is challenging to achieve this because recruiting participants through random selection or advertising for an experiment does not allow the researcher to control or intervene in selecting the age of each participant. However, this was demonstrated in a previous study involving a large sample of participants (*n* = 1072), revealing that explicit memory (recognition) showed an increase up to mid-young adulthood (25-34 years) followed by a sharp decline (Ward et al., 2020). Another even more sensitive approach would be to treating age as a continuous variable by following participants over time and examining changes in memory through the use of a longitudinal design. Only by using this type of design would one be able to actually quantify changes in memory.

A final concern to mention when conducting an online study is older adults' experience in using technology. Previous research has suggested that the experience of technology among older adults compared to younger adults may affect their performance on the task itself (Cyr et al., 2021). Although lab-based research is typically also done using technology, it is perhaps more demanding when participants perform a task at home by themselves. This issue was observed in Experiment 1A, as certain older participants encountered difficulties downloading the EDQ instrument onto their devices, completing it, and returning it.

6.4 Implications and Future Directions

This thesis uncovered new evidence of an age effect on both explicit and implicit memory. There has been ongoing debate as to whether implicit memory declines or remains stable with age, but the present findings suggest that whether age differences emerge depends on the type of cognitive processing at encoding and test. The theoretical implication is that this suggests that ageing affects memory globally. This may be taken as support for the notion that a single memory system driving both explicit and implicit memory is subject to decline with advancing age (i.e., single-system models of memory, Berry et al., 2008b, 2008a; Buchner & Wippich, 2000; Nosofsky et al., 2012). Memory systems frameworks attribute dissociations between explicit and implicit memory (i.e. where a factor produces different outcomes on the two) to the reliance on distinct memory systems (e.g. Gabrieli, 1998, 1999; Mitchell, 1989; Mitchell et al., 1990; Schacter, 1987; Schacter & Tulving, 1994; Squire, 1994, 2004, 2009; Tulving & Schacter, 1990. In relation to ageing, the argument may be that a selective deficit to explicit memory with age, with preserved implicit memory, is evidence that the two are driven by separate memory systems. This, of course, does not fit with the present data. However, one may also argue that that the present findings do not necessarily rule out the multiple-systems perspective – it is possible that declines in both explicit and implicit memory with age represent parallel decline of two separate systems. To further complicate the matter, in addition to systems approaches processing theories attribute dissociation between explicit and implicit memory to the engagement in different types of processing (e.g. the processing modes framework, see Cabeza & Moscovitch, 2013). The primary theory is the conceptual-perceptual theory, arguing that different types of cognitive processing give rise to differential effects on explicit and implicit memory. The present data is more in support of this such theory, suggesting that age effects on implicit memory are moderated by the manner of cognitive processing. Lastly, the component process framework explains dissociations as stemming from the involvement of numerous processing components, each associated with different brain regions. Within this framework, dissociations are contingent upon specific brain regions; for example, the hippocampus mediates relational memory irrespective of whether the task is explicit or implicit, conceptual or perceptual (for more details see Cabeza & Moscovitch, 2013). While the purpose of the present thesis was not to input on these systems versus processes arguments, the data are relevant. From a systems perspective, the data may be viewed as supporting a single-system model, but this is not conclusive and this topic has been the subject of debate for several decades. Future studies involving neuroimaging and/or computational modelling may be able to shed further light on the operations of explicit and implicit memory.

There are also key practical implications of finding a decline in priming with age. The decline in priming appears to be smaller than that on explicit memory, so perhaps there are ways that implicit memory can be used to boost explicit function. For example, in everyday life, whether studying a list of information or preparing for an exam, employing implicit memory strategies may enhance your ability to recall information later on. For instance, utilizing techniques like flashcard or visualization not only aids in initial learning but also strengthens memory retrieval pathways. By actively engaging these methods, you are effectively priming you brain to more efficiently access and recall the learned material when needed. Indeed there is evidence that some types of learning strategies mediated by implicit memory may help older adults with everyday memory, such as remembering new face–name pairings (Haslam et al., 2011). This should be examined in future studies. Further, given the evidence that both explicit and implicit memory decline with age, there is an apparent need to design centres (in person or virtual) that offer continuous education and /or training for older adults to support them, as engaging in a continuous education may reduce the severity of problems related to cognitive decline in normal ageing. Additionally, as this thesis demonstrates that implicit memory declines in normal aging, it can assist government officials and other relevant decision-makers in workforce planning and retirement, particularly by identifying jobs that do not rely heavily on implicit memory for individuals above the age of 65.

This project has raised many important questions in need of further investigation. First, new and better conceptual implicit tasks are needed to be developed as the CV-R task in Experiment 3 and 4 did not work as expected and there was no priming effect. Second, a cognitive screening test that can be used online and without any experimenter involvement is also needed. Anticipated trends suggest an increase in online studies given their ease of administration and comparability to lab studies, but several questions remain unanswered and more studies comparing in-lab and online testing are needed.

6.5 Conclusion

In conclusion, improved methodologies and recruitment of sufficiently large samples are needed to understand the effect of age on implicit memory and to resolve existing discrepancies in the field. In this thesis, an age effect on implicit memory was evident in most experiments, and it was affected by processing type: In most experiments, the age effect on implicit memory emerged when data were processed conceptually at encoding and tested using a perceptual implicit task. The results of the online experiments (1A, 2, 3) were largely comparable with those obtained from in-person testing (Experiment 4), which is consistent with previous studies that showed no effect between a task undertaken in the lab with supervision or at home unsupervised (Assmann et al., 2016; Back et al., 2020; Cyr et al., 2021). However, more research is needed to compare the performance in the lab and online, especially in the field of cognitive ageing. Taken together the overall findings presented in this thesis add significantly to the field and suggest that implicit memory is not resistant to age-related decline.

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Appendix

Early Dementia Questionnaire (EDQ)

Thank you for your interest in taking part in this questionnaire.

For each question, please choose the answer that best applies to you and put a tick in the relevant box (Never, Seldom, Sometimes, Always).

		In a week (in the last 2 years)			
		Never (0)	**Seldom (1)**	**Sometimes (2)**	**Always (3)**
1.	**A. Memory** Require check list as memory support				
2.	Difficulty in remembering events that took place in the past 1 week (recent memory)				
3.	Unable to find kept item				
4.	Difficulty in remembering names / familiar faces				
5.	Difficulty in remembering familiar road directions				
6.	**B. Concentration** Difficulty in following conversation				
7.	Difficulty understanding reading				
8.	Difficulty following stories on television				
9.	Repetitive questioning				
10.	**C. Physical Symptoms** Difficulty carrying out daily house chores / work / hobby				
11.	Difficulty in taking care of self / personal hygiene or using the toilet				
12.	Disrupted movement (physical restlessness)				

13.	**D. Emotion** Unsuitable reaction towards external stimuli (example: telephone ringing - emotional outburst)				
14.	Obsession towards emotional event, although it has taken place long time ago (example: death of family member or friend)				
15.	Apathy / no passion / not interested in surroundings				
16.	Looking for support / assurance from partner				
17.	**E. Sleep** Night-day rhythm disruption				
18.	Restlessness at night				
19.	**F. Others** Confusion after moving houses / in a new environment				
20.	Outsiders aware of changes in term of behaviour / appearance				

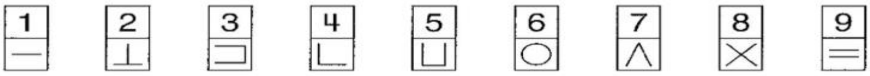
The Multiple Choice of The Mill Hill Vocabulary Test

Word	Response A	Response B	Response C	Response D	Response E	Response F	Correct Response
Fascinated	ill-treated	poisoned	frightened	modelled	charmed	copied	E
Liberty	freedom	rich	forest	worry	serviette	cheerful	A
Stubborn	steady	obstinate	orderly	hopeful	hollow	slack	B
Precise	natural	faulty	stupid	exact	grand	small	D
Resemblance	memory	assemble	attendance	fondness	repose	likeness	F
Anonymous	applicable	insulting	nameless	magnificent	fictitious	untrue	C
Elevate	raise	revolve	waver	move	work	disperse	A
Task	horn	trap	problem	game	jail	job	F
Courteous	dreadful	polite	curtsy	proud	short	truthful	B
Prosper	imagine	succeed	punish	propose	beseech	trespass	B
Lavish	unaccountable	romantic	extravagant	selfish	lawful	praise	C
Immerse	frequent	reverse	rise	hug	dip	show	E
Conciliate	congregate	pacify	compress	reverse	radiate	strengthen	B
Envisage	enfeeble	surround	activate	contemplate	estrange	regress	D
Amulet	cameo	flirtation	charm	jacket	crest	savoury	C
Garrulous	talkative	massive	ridiculous	daring	ugly	fast	A
Libertine	profligate	farrago	regicide	rescuer	canard	missionary	A
Bombastic	democratic	bickering	destructive	anxious	cautious	pompous	F
Levity	parsimony	salutary	alacrity	frivolity	velleity	tariff	D
Whim	complain	tonic	wind	noise	fancy	rush	E

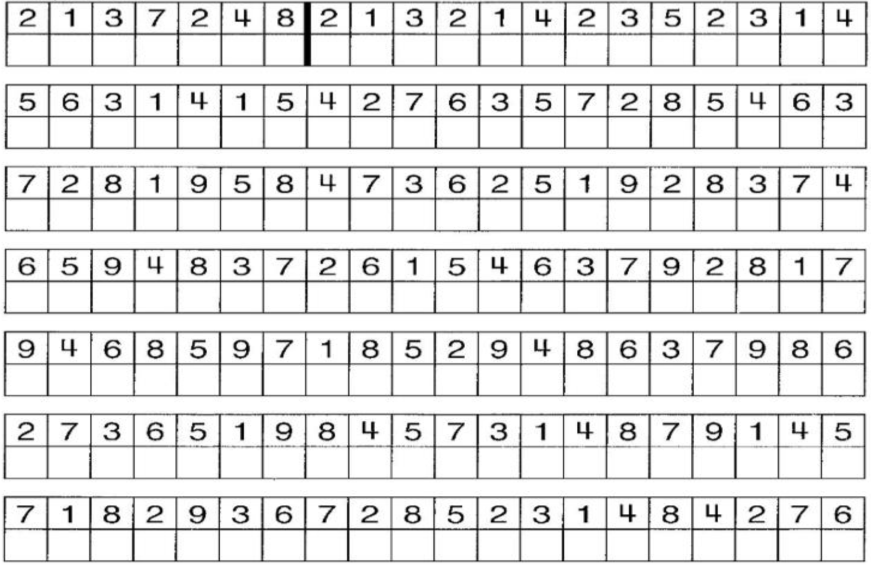
Ruse	limb	trick	colour	paste	burn	rude	B
Recumbent	fugitive	unwieldy	penitent	cumbersome	repelling	reclining	F
Querulous	astringent	petulant	inquiring	fearful	curious	spurious	B
Temerity	impermanence	nervousness	punctuality	rashness	stability	submissiveness	D
Fecund	esculent	profound	sublime	optative	prolific	salic	E
Abnegate	contradict	renounce	belie	decry	execute	assemble	B
Traduce	challenge	suspend	misrepresent	attenuate	establish	conclude	C
Vagary	vagabond	obscurity	evasion	caprice	vulgarity	fallacy	D
Specious	fallacious	palatial	nutritious	coeval	typical	flexible	A
Sedulous	rebellious	complaisant	seductive	dilatory	diligent	credulous	E
Nugatory	inimitable	sublime	numismatic	adamant	contrary	trifling	F
Adumbrate	foreshadow	detect	elaborate	protect	eradicate	approach	A
Minatory	implacable	belittling	depository	diminutive	quiescent	threatening	F

WAIS-III Digit Symbol (Processing Speed)

Digit Symbol—Coding



Sample Items



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5	6	3	1	4	1	5	4	2	7	6	3	5	7	2	8	5	4	6	3

7	2	8	1	9	5	8	4	7	3	6	2	5	1	9	2	8	3	7	4

6	5	9	4	8	3	7	2	6	1	5	4	6	3	7	9	2	8	1	7

9	4	6	8	5	9	7	1	8	5	2	9	4	8	6	3	7	9	8	6

2	7	3	6	5	1	9	8	4	5	7	3	1	4	8	7	9	1	4	5

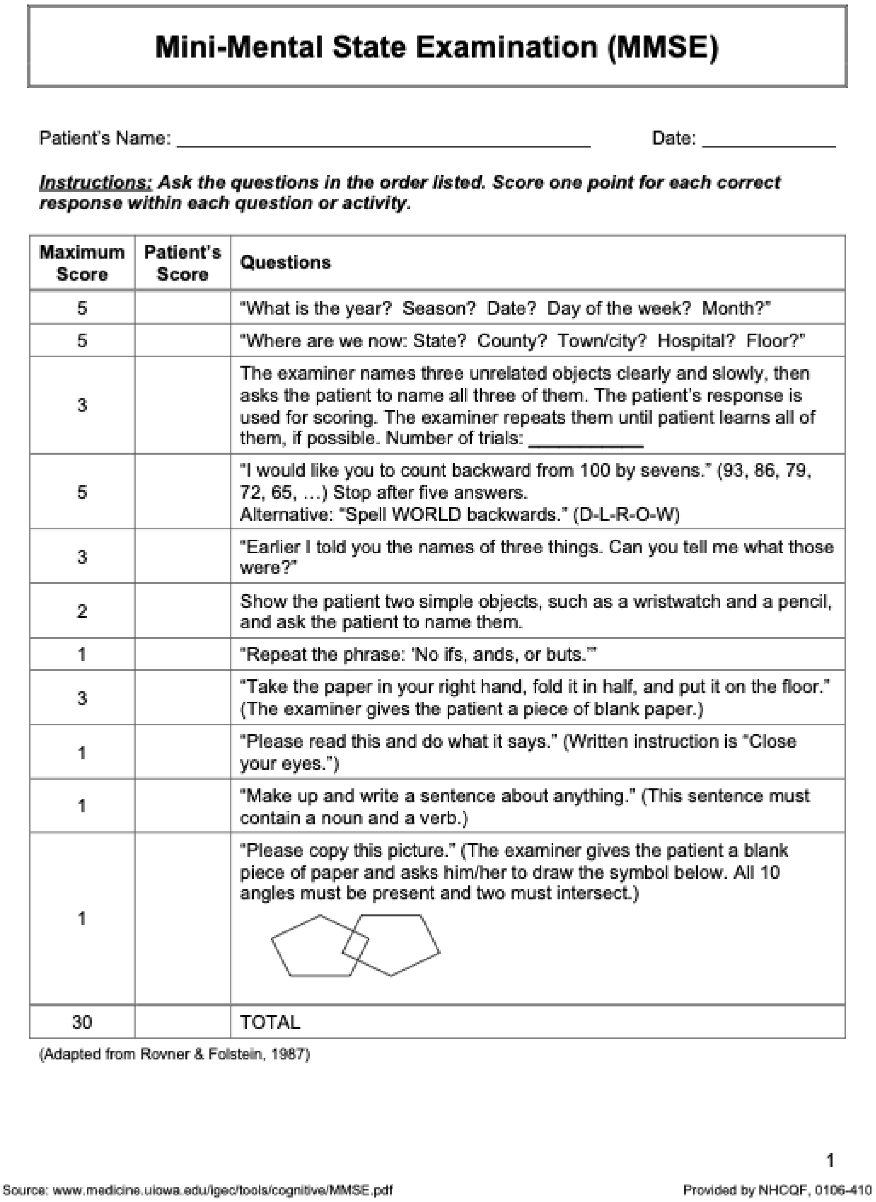
7	1	8	2	9	3	6	7	2	8	5	2	3	1	4	8	4	2	7	6

Wechsler Test of Adult Reading (WTAR)

WTAR WORD CARD

1. again
2. address
3. cough
4. preview
5. although
6. most
7. excitement
8. know
9. plumb
10. decorate.
11. fierce
12. knead
13. aisle
14. vengeance
15. prestigious
16. wreath
17. gnat
18. amphitheatre
19. lieu
20. grotesque
21. iridescent
22. ballet
23. equestrian
24. porpoise
25. aesthetic
26. conscientious
27. homily
28. malady
29. subtle
30. fecund
31. palatable
32. menagerie
33. obfuscate
34. liaison
35. exigency
36. xenophobia
37. ogre
38. scurrilous
39. ethereal
40. paradigm
41. perspicuity
42. plethora
43. lugubrious
44. treatise
45. dilettante
46. vertiginous
47. ubiquitous
48. hyperbole
49. insouciant
50. hegemony

Mini-Mental State Exam (MMSE)



Mini-Mental State Examination (MMSE)

Patient's Name: ____ Date: _____________

Instructions: ***Ask the questions in the order listed. Score one point for each correct response within each question or activity.***

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: ___________
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.)
30		TOTAL

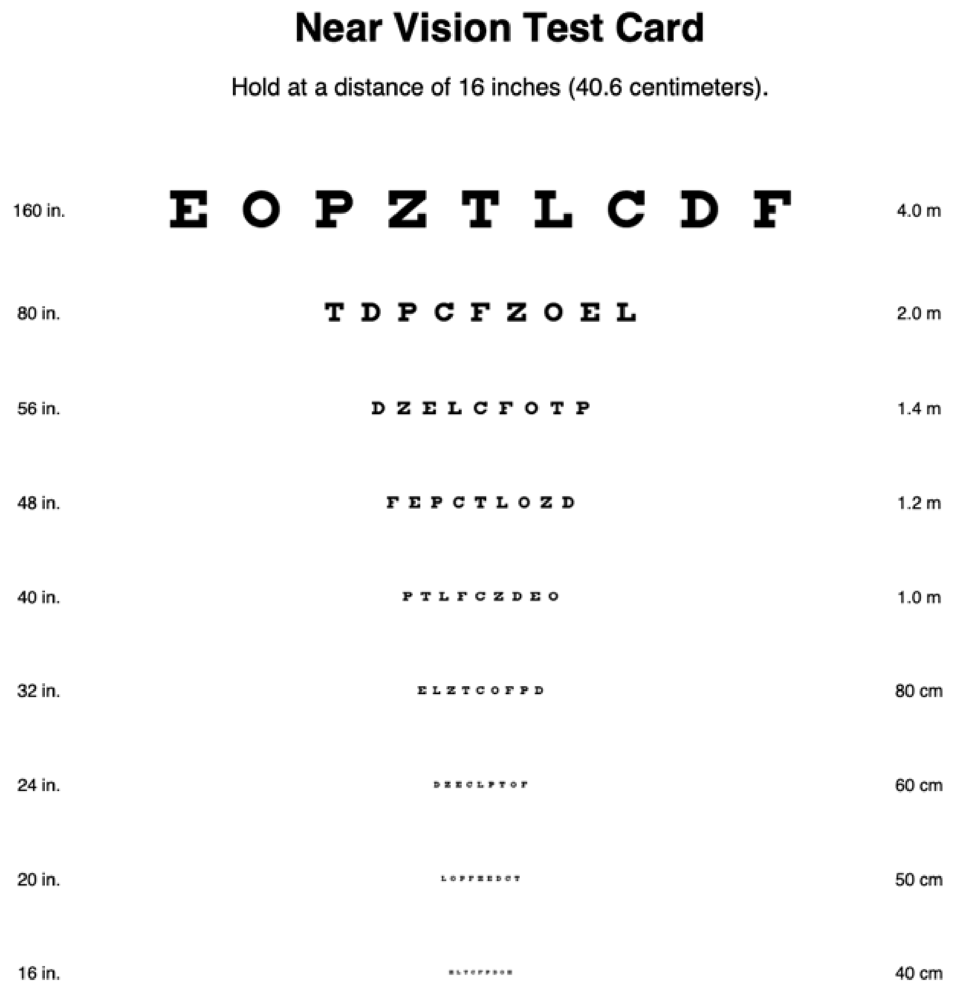
(Adapted from Rovner & Folstein, 1987)

1

Source: www.medicine.uiowa.edu/igec/tools/cognitive/MMSE.pdf

Provided by NHCQF, 0106-410

Near Vision Test Card



Near Vision Test Card

Hold at a distance of 16 inches (40.6 centimeters).

160 in.	E O P Z T L C D F	4.0 m
80 in.	T D P C F Z O E L	2.0 m
56 in.	D Z E L C F O T P	1.4 m
48 in.	F E P C T L O Z D	1.2 m
40 in.	P T L F C Z D E O	1.0 m
32 in.	E L Z T C O F P D	80 cm
24 in.	[illegible]	60 cm
20 in.	[illegible]	50 cm
16 in.	[illegible]	40 cm