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**Age Differences in Prospective Memory: Is There More to be Explained by  
Reminders and Metacognition?**

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## Abstract

The purpose of the current research was to examine if older adults perform better than younger adults at prospective memory (PM) tasks in a naturalistic environment due to better use of reminders. Specifically, it was predicted that (in line with previous research) older adults would outperform younger adults on the naturalistic PM task. It was also predicted that older adults would support their prospective remembering more effectively than younger adults through superior metacognitive awareness. Beyond confirming previous findings, this study sought to create and validate new methods for investigating the relationship between reminder use and PM. To examine reminder use and PM, a web-based app containing an A and a B button was given to 69 participants (N = 36 younger adults, N= 33 older adults) across Australia and New Zealand to press 21 times in a week with a required four-hour wait between presses. Upon completing the task, two surveys then comprehensively examined how participants completed the task and how participants use reminders in everyday life outside of the task. None of the original hypotheses were supported. However, in line with previous findings, the results from this study indicated that even when older adults used fewer reminders on average than younger adults ( $p < .05$ ), there was still no significant age-related declines in PM performance ( $p > .05$ ). An intriguing finding came through investigating metacognitive awareness. The results implied that older adults who 'actively manage' their remembering do much better with PM tasks (22.5% of PM performance variance explained by metacognitive awareness). However, the same effect is absent in younger adults (<1% variance explained). The current study showed that more sophisticated and considered methods for investigating reminder use in PM is in order and discusses how these might be implemented in future research.

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## Chapter One

### Introduction

A 2016 paper by Kliegla et al. explains recent methodological advancements, conceptual advancements, and neuroscientific advancements for prospective memory (PM) specifically related to ageing. The purpose of this thesis is to attempt to further these advancements to method and theory alike by examining how a person's environment may be structured, their familiarity with different reminders, and how their management of reminder use may act to support PM performance in different age cohorts. The advancements in method come from exploring different ways to measure reminder use and its associated variables (in addition to examining reminder use through typical methods). This exploratory approach to reminder use and PM may offer greater insight into previous data or reveal new variables for future studies. A problem that first presented itself when examining PM and reminder use was that in studies such as Schnitzphan et al. (2012), external reminders were only used by 14.9% and 12.8% in younger and older adults, respectively. So, the challenge was to encourage reminder use without explicit prompting that may skew participants natural reminder use behaviours. The solution came via a paper by Masumoto et al. (2011) that found one of their four task conditions led to internal memory strategies being used by 74% of participants and external reminders being used by 65% of participants. The condition was called week-based output monitoring (WBO); where participants were asked to call the experimenters 21 times through the week with a minimum of four hours in between calls. Instead of keeping track of three calls to experimenters in a day or being given regular times to make calls (e.g., 8am, 1pm, 7pm) where only three PM tasks need to be tracked; the WBO condition required the monitoring of much more information. Therefore, the WBO created a lot more room for error without reminders or some structured approach. Ultimately, the WBO method meant that naturalistic reminder use could be examined without explicitly instructing participants to use reminders, while still keeping a high reminder use rate.

An article by Drayson and Clark (2018) provides this thesis with a conceptual framework to explain how older and younger age cohorts may use reminders differently in prospective remembering. In their article, they discuss ideas around extended and embodied cognition, which relates to cognitive ageing and disability as well as a different way to think about the cognitive systems in older and younger adults. As a basic summary, Drayson and Clark (2018) explain through the concepts of extended and embodied cognition that cognition is not just within the brain; rather cognition is distributed across and between the brain, the body, and the environment. From this perspective, it makes sense to examine prospective remembering from a naturalistic perspective as it encompasses the full composition of a person's cognition. This unique framework means this thesis will examine reminders as a component of cognition and prospective remembering, rather than reminders being compensatory or supplementary to cognition.

Research has indicated that in a naturalistic setting, older adults may have a greater or equal performance on PM tasks when compared to younger adults (Henry et al., 2004). Concurrently, Levy et al. (2002) has shown that older adults with positive perceptions of ageing lived on average 7.5 years longer than those with less positive self-perceptions of cognitive ageing. Given how threatening cognitive decline can be for older adults and the unique situation of potential cognitive superiority (or even equivalency) in PM for older adults, this thesis also hopes to provide a possible framework for reframing the negative views often found around cognitive ageing.

The literature review for this thesis is structured as follows: first cognitive ageing, the ageing population crisis, and ageism will be introduced to provide the social context for this thesis. After the social context, the basics of cognitive ageing and possible neurological mechanisms for superior PM performance in older adults will be explained. Following an explanation of cognitive ageing, the conceptual framework for the thesis of embodied and extended cognition will be explained in-depth as it relates to ageing and reminder use within cognitive systems. Subsequently, PM will be explained regarding its essential components and fundamental theories; which will then be

examined as they relate to ageing. After explaining PM and ageing effects, reminder use will be covered extensively, including a critique on lacking modern research.

## **Chapter Two**

### **Embodied and Extended Cognition, Ageing-Populations and Ageism**

#### ***2.1.1 Ageing Population***

Globally the population is ageing as a result of decreasing fertility and increasing longevity (life expectancy). By 2050 one in six people will be over 65, where it was one in 11 in 2019. In 2018 for the first time in history, people aged 65 or over outnumbered children under the age of five globally (United Nations, 2019). In particular, New Zealand is estimated to have an even greater ageing population with one in 4.5 adults over 65 by 2036 and close to one in three by 2061. Further, this demographic shift is not just a bulge that will pass with time but rather a new norm. In 2002 the UN adopted a plan calling for changes in attitudes, policies and practices at all levels to help deal with this massive shift in population composition ("Ageing", 2020). With evermore outdated social constructs such as retirement and largely problematic perceptions of ageing in Western culture, there is an ever-increasing need for a proactive approach to ensure desirable outcomes in the face of these ongoing demographic shifts.

#### ***2.1.2 Ageism***

Recognising the older adult population's growth, the 1992 Human Rights Commission Amendment Act (HRCA act) outlawed age-based discrimination in New Zealand. Despite this act, age-based discrimination needs further conversation. Nelson (2005) explains that when walking down the street and glancing at other individuals, automatic categorisation of race, gender, and age occurs. Research has extensively focused on discrimination and bias of the first two; however, we barely see ageism as an "-ism" like sexism or racism (Nelson, 2016). In fact, age-based discrimination and bias is often condoned or even promoted in Western society. As examples of this, a shared joke

is for people to reference "senior moments". Further, when searching google images for "birthday cards for 65-year-olds" the first card says "65 is the new... what was I saying?". Moreover, the term dementia, used to diagnose these cognitive issues comes from a derogatory Latin origin of the words *de* and *ment*, separately meaning "without" and "mind" together meaning "madness". Equally important is how this age bias is often carried into employment. Employer perceptions of older workers are largely of being physically and mentally less capable than their younger counterparts; as well as untrainable (e.g., can't teach an old dog new tricks) (Nelson, 2016). Workplace bias functions as a self-fulfilling prophecy as negative stereotypes affect older adults' motivation and dedication to their workplace (Kooij and Zacher, 2016). Given the increasing proportion of the elderly population, a challenging problem for our time is how do we combat and mitigate issues of ageism? A start may be to challenge some of the old notions and conceptions around cognitive ageing. Specifically, because prospective memory is a type of memory which (as seen above) is often the primary cognitive domain stigmatised (Harada et al., 2013), superior or equal prospective remembering in older adults may provide a conversational starting point, both to reassure older adults and to combat ageist conversation.

### **2.1.3 Cognitive Ageing**

As people age, so too does the brain. Importantly, cognitive ageing is part of the ageing process and not a pathology. While the risk of dementia doubles every 5-6 years, until age 90, only about 30% of over 85's are affected by dementia, leaving about 70% with either mild cognitive impairment, or normal functioning (Qiu & Fratiglioni, 2018). When looking specifically at memory, it seems that episodic memory (what did I eat for lunch?), source memory (where did I see that fact?) and flashbulb memory (where were you on 15 March 2019 during the Christchurch mosque shootings?) decline the most. By contrast, long term procedural memory (riding a bike) and semantic memory (facts, concepts and vocab) remain intact ("Memory Changes in Older Adults", 2006). When it comes to memory in older adults, there are theoretically substantial long-term memory stores, the

constraint on recall is more about accessibility than availability (Hedden & Gabrieli, 2004). As the brain changes structurally (2% volume reduction per decade from the fifth decade of life), losses primarily occur in white matter, the hippocampus, and the brain's prefrontal region (Leatham, 2019). These regions are related to complex attention, executive function, and affect short-term/working memory by decreasing the ability to deal with interference, affecting encoding into long term memory; with slower processing also hurting retrieval (Leatham, 2019). A result of the changes described is that crystallised abilities that develop over the lifespan through exposure to life events (education, culture, socialising) tend to remain stable with age. However, fluid abilities, like processing speed and problem solving, become particularly susceptible to decline with normal ageing (Salthouse, 2019). Prospective memory and ageing specifically are expanded on in more detail later in this thesis. However, in short, PM and cognitive ageing are related to several fluid components of cognition. Theoretically, this makes PM particularly susceptible to age-related cognitive decline.

#### ***2.1.4 The Malleability of Adult Cognition***

Part of the stigma of cognitive ageing may be informed by outdated scientific views around the adult brain's malleability. As neural imaging has improved over the years, the old view of limited neural plasticity in adults has changed drastically. An article by Zeiler et al. (2016) highlights the possibility of enhanced adaptive neural functioning after strokes through optimal stimulation of the post-stroke neuroplastic period. More directly, Colangelo et al. (2019) highlight the so-called "perennial" tissue in 'mature' brains is actually surrounded by areas of neural precursor stem cells, allowing for both neurogenesis (new neurons) and neural plasticity. Further, the main loss of brain matter in older adults is in white matter (myelinated neurons), which are neurons that are electrically insulated allowing for faster transmission of nerve impulses (hence why cognitive ageing is often associated with slowing cognitive abilities). The white matter generation process is called myelination and allows for more robust and faster neural connection. When the motor pathways are

myelinated (occurs around 15), this area of the brain is said to be matured, implying our brains are 'grown' and are to be maintained and eventually degraded. However, there is significant evidence that myelination continues to happen in the adult brain, strengthening the neural circuits through learning (Williamson & Lyons, 2018). While it is more significant in younger adults, myelination appears to remain present and stable throughout adulthood. Additionally, different methods of interacting and learning can further enhance this process of myelination (Coyle, 2010). The adult brain is not just a settled and declining version of its younger counterpart as previously thought. The recently recognised malleability of adult brains towards neurogenesis and away from neurodegeneration offers two avenues to protect against neurological ageing. Practically, the malleability of adult brains not only speaks to the learning abilities of older adults, which are often incorrectly thought to be very limited (especially in a workplace; Nelson, 2016); but also allows for the possibility for pre-compensation with cognitive decline. Pre-compensation for cognitive decline is where adults may pre-emptively build more cognitive resources and abilities so that they stay above the threshold of disability for longer after cognition starts declining.

In this section we have seen how ageism functions as a problem within our society and how cognitive ageing occurs, both in how it declines and how this decline may not necessarily be as linear and homogenous as previously thought. This section provides part of the neurological picture involved with reframing cognitive ageing. The next section initially extends on these neurological components that will be particularly relevant to prospective remembering. Following this the ideas of embodied and extended cognition will be explained providing a way to conceptualise the use of reminders in prospective remembering as integral components of a cognitive system rather than external crutches for cognitive deficits.

## **2.2 Embodied, Extended and Distributed Cognition**

### ***2.2.1 Cognitive Load and Working Memory***

How difficult is it to find your socks, to change the oil in your car, or to remember your mother's birthday? It depends. A good way of thinking about how difficult tasks are is to think about the cognitive load they impart. Cognitive load is strongly related to working memory and how information can be held and later stored in long-term memory. When the cognitive load is too high, working memory is overloaded, and information can be lost or not processed. Cognitive Load Theory (Sweller, 1994) breaks down cognitive load into three components: intrinsic cognitive load, which is the inherent difficulty or complexity of the new information; extraneous cognitive load, which is how the information is presented (influencing/distracting working memory from processing new information); and germane cognitive load, which involves the deep processing of the new information to integrate it with previous knowledge/learning. Intrinsic cognitive load cannot be altered, whereas extraneous and germane cognitive loads can. For example, in describing a square, the intrinsic complexity of a square is constant regardless of how it is described. However, presenting a verbal representation of a square to a child versus showing them a picture and describing it changes the extraneous load. Further, germane load in the square example above is less when the child already has knowledge or schemas (patterns of behaviours or thoughts organised into categories and their relationships with other information) about shapes. If the child had never heard of shapes and is shown a square consolidating that information into a schema would mean constructing a category of shapes and searching for related information (increasing working memory demands). If the child knew of shapes, the information is easily linked with other shapes and their schemas, consolidating the learning process. In older adults, as stated above, fluid cognitive resources, including working memory, are reduced. Decreased working memory means that the relative cognitive load associated with new tasks or problems is higher.

One way to combat this decrease in working memory capacity/resources is what is known as chunking (Gilchrist et al., 2008). Cowan (2001) highlights that working memory can hold three to four unitary items or 'chunks'. More information can be recalled when it is organised into superordinate groups (through schemas). This process is known as chunking. A nice example of this

is with language, when given a list of letters that are nonsensical such as "afkjhsiuoe" a person will remember a small number perhaps the magical seven plus or minus two (Miller, 1956). However, when linked with language and meaning people can quite easily chunk the letter information into superordinate categories of words, and further sentences. For example, common phrases "you can't judge a book by its cover" "there is no such thing as a free lunch" and "you can't have your cake and eat it to" contain over 85 letters, yet they can quite easily be remembered and relayed back. In general, older adults' lower working memory capacity has access to fewer chunks at a given time; however, the degree of chunking (quality/size of superordinate categories) does not appear to be compromised (Gilchrist et al., 2008). Because chunking and LTM are not compromised as much as fluid processes like working memory in older adults, increasing schema complexity through combining lower level schemas into higher level schemas (by increasing germane load without exceeding working memory limits) can aid in the storage and organisation of information, effectively reducing working memory load (Kirschner, 2002). In PM, working memory is an integral part of successful performance (Smith & Bayen, 2005), if older adults have spent time through their life enhancing schema complexity for relevant PM tasks, this could theoretically compensate for the decreased functional capacity of working memory.

### ***2.2.2 Extended and Embodied Cognition***

Chunking is a cognitive strategy for remembering more information, but remembering, according to hypotheses of extended and embodied cognition, can be more than just what is occurring inside the brain. Instead, extended and embodied cognition proposes that remembering can be distributed across varying systems combining neural, bodily, social and technological resources (Michaelian & Sutton, 2013). Drayson and Clark (2018) explain that embodied cognition is about sensory and motor processes (e.g., head tilting in response to rotated text) aiding or shifting the cognitive processes and/or resources required to complete a task. Extended cognition contends that the environment can be an extra-neural contributor to our cognitive abilities, that is, the

environment essentially acts to achieve the same function (e.g., memory storage) as what would be done by brain-based cognitive processes. Additionally, proponents of extended cognition claim there is no important difference between information stored in non-biological structures and the biological brain. These concepts have a deep philosophical basis, and as such, it is possible to get bogged down in the ontological arguments. The purpose of this section is not to advocate for any ontological viewpoints; instead, it is to offer these concepts as possible schemas to explain and reframe cognitive ageing as well as how reminders and the environment may be used as part of a cognitive system aiding in prospective remembering.

### ***2.2.3 Embodied Cognition***

Embodied cognition fits with an embedded thesis which is that extra-neural conditions can increase a person's cognitive capacity (Pouw et al., 2014). What this is saying is that the cognitive system uses the environment to decrease the cognitive load, which can allow for better performance than through purely internal brain-based cognition. An example by Drayson and Clark (2018) shows that when situated within the environment, acting in different fashions within that environment can mediate the need for high-level thought. In their chapter, they give an example of a baseball outfielder trying to catch a fly ball successfully. From a brain-based view, the outfielder could look at the ball and using the visual input, calculate (perhaps unconsciously) the trajectory of the ball to estimate where it will land. The visual information followed by cognitively complex computation allows the outfielder to estimate where – and how fast to run to make the catch. An embodied view shows there is a lower cost strategy that does not require complex internal brain-based computation. The outfielder need only move laterally to be in line with the ball and run in a way that makes the ball appear to have a constant velocity. In this case, the outfielder will end up in the same place as the ball when it lands using only basic sensory and motor capabilities. This example highlights that it should not be assumed that abstract reasoning and calculation is always what explains our abilities. Additionally, Pouw et al. (2014) explain that people can also use gestures

as a slightly more natural process of reducing computational load. While we don't conclusively know how the cognitive system trades external with internal cognitive resources; it seems likely that when cognitive demands are high (either due to high cognitive load or low cognitive ability) the cognitive system may be more likely to opt for external or embodied computational strategies (Pouw et al., 2014). Alternatively, with greater exposure and practice in various tasks, such as gesturing, older adults by chance come into more and more of these embodied actions; which become favoured through their low demand on cognitive resources.

#### **2.2.4 Extended Cognition**

Extended cognition relates to the extended mind thesis where non-biological structures are constitutive of cognition. Here, the best example is the Otto and Inga thought experiment from Clark and Chalmers' (1998). In this thought experiment, Otto and Inga both become aware of an exhibition occurring at the Museum of Modern Art (MoMA) in New York. Inga thinks about the location of MoMA for a moment, recalling it is on 53rd St and sets off. Otto has mild Alzheimer's, but he always has his notebook with him, writing any useful new information inside. Upon hearing of the MoMA, he retrieves the museum's address from his notebook (where he had previously written it down) and sets off. Here, both Otto and Inga have the dispositional belief (a belief that exists as stored knowledge but is not being considered by the mind) that MoMA is on 53rd street for Inga that is before she recalls the location from her memory and for Otto this is before he consults his notebook. Occurrent beliefs (a belief that is currently considered by the mind) then occur after Inga's retrieval of information from long term memory stores and after Otto consults his notebook, leading them both to head to 53rd street. Here Inga's memory and Otto's notebook play very similar roles for storage and retrieval; the difference obviously being, Inga's process is done entirely neurologically, where Otto's process is extended beyond his brain, including the notebook. The extended thesis argues that we accept both of these processes as cognitive processes through the 'Parity Principle'.

Parity Principle (PP): If, as we confront some task, a part of the world functions as a process which, were it to go on in the head, we would have no hesitation in accepting as part of the cognitive process, then that part of the world is (for that time) part of the cognitive process. (Clark and Chalmers 1998)

This principle is not for any external information, just specific instances where extended processes are functionally equivalent to intracranial cognitive processes. Again, when examining the parity principle, there is a possibility of getting bogged down in philosophical arguments (e.g., Wheeler, 2010); however, Drayson and Clark (2018) interestingly relate this concept to cognitive impairment, cognitive reserve, and cognitive disability that provide an attractive way to view cognition for this thesis.

### **2.2.5 A Schema for Rehabilitation, Disability, and Cognitive Reserve**

The classical view of cognition has been termed neurocentrism where the brain is the central and almost exclusive mechanism of cognition, ignoring the interactions of the brain, body, and environment (Gallagher, 2018). Neurocentrism has led to several normed societal views of cognitive ageing, disability, and rehabilitation that carry stigma and negative affect. First, let's examine the effects of the neurocentric view on rehabilitation perceptions through its two intervention mechanisms. The first type of intervention is *restorative*, referring to the repair of neural circuitry. The second type of intervention is *compensatory*, which are interventions not focused on changing the brain. The neurocentric view creates a hierarchy where the goal is to first try restorative interventions, with compensatory interventions as a backup plan, leaving patients with long-term deficits. Drayson and Clark (2018) illustrate, within the example of ideomotor apraxia, some of the issues with the neurocentric view. With ideomotor apraxia, patients lack the ability to pantomime, including brushing their teeth. From a neurocentric view, a patient has a deficit – they cannot mime brushing their teeth. However, given a toothbrush in hand (an environmental change) this miming function and the literal function of brushing their teeth is often restored. From a neurocentric view,

the toothbrush is compensatory, and restorative intervention would involve trying to repair the circuitry that allows for pantomime. Because full-restorative circuit repair is not possible, the neurocentric view would see the patient as still having a deficit and compensating for it; generating a sense of a sub-optimal fix (from a treatment involving compensation strategies) and unnecessary stigma. In the embodied/extended view, the addition of a toothbrush means that the distributed cognitive system no longer contains a deficit (as both miming and brushing their teeth actions can be performed once again); therefore cognition is 'restored' and the patient, as a result, may have a more positive perception of rehabilitation's outcomes.

Next, we may examine disability and the use of external aids. The standardised neurocentric way of thinking appears to have informed an anti-environmental support prejudice within society. Older adults can be so worried about how they appear to others (concerning their possible cognitive frailties) that they may avoid health care involving external aids for fear they may appear reliant on such devices and incapable of independence (Spafford et al., 2010). Moreover, Gaffney (2010) shows that assistive devices such as the wheelchair carry the associated 'sick role' making assistive devices both enabling and simultaneously wounding. The embodied/extended view means that people can see external aids and the environment as more critical than just patches or compensatory props. Instead, the embodied/extended view implies that patients no longer have deficits (and their associated stigmas) given the right environmental conditions; meaning that the extended/embodied view sees disability as a relational condition (i.e., related to the changing distribution of the cognitive system involving the brain, body, and world) rather than intrinsic to the individual. As a result, embodied/extended cognition also fits with a social model of disability and reframes the meaning of cognitive reserves. To illustrate this, consider an older adult who suffers a stroke and now cannot remember to feed themselves (a very basic PM task). As Drayson and Clark (2018) explain, a neurocentric view would see that person having a disability. However, when applying the social model of disability, this situation only results in an apparent disability in a society where people live

alone and are expected to feed themselves. In a multigenerational household, where a family lives and eats together, forgetting to feed oneself becomes much less of a disability.

Additionally, extended/embodied cognition can be used to reframe cognitive reserve. In an article by Archer et al. (2005) they explain the story of a man who maintained a high functioning and independent lifestyle but was found post-mortem to have severe Alzheimer's Disease which would usually result in high levels of impairment, making autonomy extremely unlikely. Despite his severe Alzheimers, the man maintained his house and finances, retained his personality and language abilities, and only noticed a shift from the ability to thinking seven moves ahead in chess to three or four. Here, the resources this man had in abundance may have been both neural and environmental. As his cognitive abilities lessened, he appears to have become more reliant on environmental scaffolding, body movements such as counting on his fingers, putting memory demands on lists, automating payments, and so on. With complex and demanding lives, individuals may develop ways to offload some cognitive tasks on to the environment, the interactions with the environment, and the body. People who already rely on these external mechanisms may find it easier to adapt to brain damage/decline, slowly shifting their reliance more and more onto these external mechanisms. Here again, cognitive reserve is not just neurological, but a relational property depending on the environment.

Furthermore, it seems that society holds young capabilities as the norm against which younger and older adult's cognition is evaluated. An embodied/extended cognition view would instead evaluate different distributed cognitive systems on whether or not they can achieve a goal instead of evaluating the brain-based component of the cognitive system. An example of this is that children are better at remembering verbatim details and are therefore less vulnerable to some kinds of false memory manipulations (Brainerd et al., 2002). However, adults can use external resources (e.g., video recording) to 'compensate' for their greater susceptibility to memory manipulation. Rather than evaluating only cognition (the ability to remember information verbatim in this

example), complete agent-environment systems could be evaluated. Children's distributed cognitive systems are heavily brain-based, with minimal environmental input; where older adults have a mix of brain-based cognition and moderate environmental input. With the embodied/extended view, the system's quality is based upon how well the system achieves the desired goal (e.g., accurate court testimony or performance on a recall test assessing false memory). It is important to note that the extended/embodied cognition concept is not perfect. Extended/embodied cognition does not resolve or even address specific issues around consciousness, rationality, personhood, agency that are generally considered part of the mind (Drayson & Clark, 2018). However, it offers a new way of looking at cognitive ageing, especially related to this thesis and how older adults may use their environment in prospective remembering. As mentioned earlier in this thesis positive perceptions of ageing significantly benefit lifespan (Levy et al., 2002); if older adults did happen to use calendars more, and were more engaged socially to achieve superior or equal PM performance to younger adults, why should there be an anti-environmental support prejudice and shame for doing so? Especially if it reduces the life expectancy of older adults. The goal-based evaluation of distributed cognitive systems means that we can look past 'compensatory' mechanisms or brain-based cognitive deficits and start to respect the outcomes of the different cognitive systems, reducing stigma and possibly the prominence of ageism in society.

This section outlines the issues of the ageing population crisis. It emphasises why current ageist views around cognition are problematic and offers several arguments towards a more functional way to conceptualise human cognition. Prospective memory and reminder use in PM work together to provide a perfect example of these arguments in a real and meaningful way, with scientific backing. The next section explains what prospective memory is, its theories, related cognitive processes, and the effect age appears to have on prospective remembering in different contexts.

## Chapter Three

### Memory: Prospective, Retrospective, Influences, Paradoxes, and Meta-Cognition

#### 3.1 Prospective and Retrospective Memory

Remembering to pay back a friend, getting shopping on the way home, and taking medication are all examples of prospective memory (PM) tasks. Put simply, PM tasks involve remembering to do an action after a delay; it must be self-initiated, and to be effective, must come about within a specific window of time (Uttl, 2008). The process of PM requires encoding (the term used for forming future intentions) and retrieval. *Encoding* involves encoding into memory the cue or stimulus that will trigger an intended behaviour as a response, as well as the response itself, and linking them cognitively. *Retrieval* is the act of later encountering the PM cue (which may be internal, like a thought or feeling) and then recognising it as an opportunity to enact a response. More often than not PM tasks require an internal cue (a thought or feeling coming to mind) rather than having some explicit prompt (e.g., someone telling you that you're supposed to be doing something), as such it is often referred to as 'remembering to remember' (Kvavilashvili et al., 2009). Historically within research, the focus has been on the retrospective component of memory (Kristiansson, 2011); unsurprising when you think how individuals often conceptualise memory as retrieving or revisiting something from the past. Retrospective memory (RM) involves the memory of people, words, and events encountered or experienced in the past; often cued by external events. For example, being asked when your birthday is or where you first went to school. This type of memory (retrospective) is classically broken down into declarative and non-declarative memory (Kristiansson, 2011). Declarative RM can help with the recall of facts or past personal events. Non-declarative RM involves info such as how a person may perform a forehand in tennis or the procedural habit of smoking when they are stressed (amongst other things – all kinds of habits, conditioning etc. are covered by the term non-declarative). Uttl et al. (2008) explain that like RM, prospective memory can also be broken down into different subcomponents; such as

*vigilance/monitoring* (RM equivalent would be short-term/working-memory) which could involve monitoring food to make sure it doesn't burn. *Proper PM* is what people typically mean when using the term prospective memory. Proper PM is where awareness is brought back to previously formed plans or intentions at the right place and time, such as intending to post a letter after work. The plan is not consciously maintained at work but then later retrieved when seeing a cue (e.g. a post-box), which then relies on retrospective memory to retrieve the plan's content (e.g. post a letter). Lastly, *habitual PM* is a long-term prospective memory that becomes patterned, such as remembering to take medication regularly. Distinguishing these components of PM is as important as distinguishing between short-term memory, long-term declarative memory, and long-term non-declarative memory; however, as will be shown later, these distinctions and their importance are often neglected within PM research.

Prospective memory and retrospective memory are not wholly independent components of memory; often, they are interrelated. If someone finds themselves able to remember that a task needs to be done, they also need to remember what it is. For example, once you remember that you were supposed to do a task on the way home, you must remember what that task is (e.g., go to the supermarket to get groceries). The retrospective component is usually minimal; it involves recognising the cue, then recalling the information/action that cue is meant for (usually something short like 'post a letter'). PM, however, is one of the most frequent everyday memory challenges as it requires an *actionable window*, which is a window of time and space where remembering to do an intention is useful (e.g., remembering to take medication won't be useful unless you are in a place with your medication and it is the correct time to take the medication). Additionally, it requires *monitoring*, which is the allocation of attentional resources to hold the prospective memory task in mind. Lastly, PM requires *delayed intent* where information must leave the conscious mind to come back later. The extent that PM is challenging is illustrated in a recent paper by Haas et al. (2020) who systematically investigated the natural occurrence of PM errors and how often they occurred relative to other cognitive errors in younger and older adults. Haas et al. (2020) confirmed

previous research (Crovitiz & Daniel, 1984; Unsworth et al., 2012) that the majority of daily cognitive errors (>50%) are linked to PM in both younger and older adults.

Both PM and RM are related to executive functions. Executive function is a term for different higher-order cognitive mechanisms such as monitoring, selection, set-switching, control of attention and inhibition, and coordination (Kristiansson, 2011). These mechanisms are strongly related to memory and the task of future and past remembering as they allocate the mental resources and controls the internal strategic processes for successful memory performance (Kliegal et al., 2016). Martin et al. (2003) highlight that executive function is increasingly important as PM tasks become more complex and also may act as a crucial mediator of age effects as executive resources diminish with age.

Another integral part of prospective remembering are cues. In any task, a cue is what triggers the prospective remembering; it is both an act of recognition and allows the participant to recall what they should be doing. With PM there is always some sort of ongoing activity referred to as the *ongoing task* (Guynn et al., 1998); this fills the time between the initial intent and the realisation, which needs to be interrupted (by a cue) for successful PM performance. Further, cues can be recognised either spontaneously or through active monitoring. Here researchers have referred to these tasks in which a cue can occur as either *time-based* or *event-based* tasks. An example of a time-based task may be “I must attend the 4 pm meeting”, these tasks are said to involve more self-initiated retrieval as you may need some constant awareness of the time (though a watched clock will change this). Event-based tasks have no specific time such as “I must post this letter when passing a mailbox” which in contrast may seem to be less self-initiated as there is an external cue, in the above example, a mailbox (Einstein & McDaniel, 1990). The research also defines focal and non-focal cues, as well as conjunction cues. *Cue focality* describes whether or not the cue is related to the task; for example, a focal cue may be circling the word *John* when doing a task of naming celebrities (the name component is processed as part of the task). A non-focal cue in a

similar example would be having a target of seeing a face with glasses while doing the same celebrity naming task; here the cue is not involved in the same cognitive process as the ongoing task and is therefore non-focal. *Conjunction cues* are cues coinciding with the prospective memory task; for example, needing to take a pill in the evening could be synchronised with having dinner; synchronising this regular activity with pill-taking allows it to act as a conjunction cue.

Within prospective remembering there are also several different types of load that affect the difficulty of PM tasks. These loads are ongoing task load, prospective memory load, prospective load, and retrospective load, which can be manipulated in different ways to effect prospective memory performance (Meier & Zimmermann, 2015).

1. *Ongoing task load* refers to the demands of the task around which the prospective memory task is occurring (Einstein et al., 2005). This could be going about daily processes such as shopping or cleaning or could involve high demand tasks such as complex arithmetic.
2. *Prospective memory load* refers to the additional demands that occur as a result of adding a PM task to an ongoing task (e.g., needing to send a message to a partner after work, which requires encoding processes and retrieval processes).
3. *Prospective load* refers to the number of prospective memory targets; for example, remembering to send a message after work (one PM task), compared to needing to send a message, get groceries, and post a letter (three PM tasks).
4. *Retrospective load* is the amount of information that must be remembered as a result of a PM task, whether a person must remember one action (e.g., in 10 minutes ask for a blue pen), or much more (e.g., in 10 minutes write down the time, using a blue pen, and hand the researcher a penny from the left drawer).

Within retrospective load is also what is known as output monitoring, which is particularly relevant to this thesis. *Output monitoring* is whether individuals remember prior PM tasks, which has been

shown to impact retrieval of retrospective components of the task (i.e., remembering the action required, such as handing over the blue pen; Meier & Zimmermann, 2015). In this thesis output monitoring is used to influence reminder and strategy use and retrospective load is minimal. Additionally, the prospective load in this thesis are relatively low with three PM tasks per day as an average which is less than the average number of daily tasks reported in diary-based studies (which due to self-report – an effortful process, is likely an substantial underestimate of actual PM frequency; Ihle et al., 2012; Schnitzspahn et al., 2016).

### **3.2 An Alternative to Current PM Categorisation**

While the event- and time-based categories of cue and PM task are widely discussed and clearly defined above; It could be argued that these categories may act to hinder the theoretical understanding of PM. These widespread categories came from McDaniel and Einstein (2000) with similar categorical conceptualisations from researchers such as Harris (1984), and Kvavilashvili and Ellis (1996). It seems that because McDaniel and Einstein were the best-known PM researchers at the time, their categories propagated throughout PM literature to become the two normed categories for distinguishing tasks or cues. The main argument for the distinction is that event-cues and time-cues are underpinned by different cognitive mechanisms. However, Utzl (2008) points out that time-based cues are frequently seen as or translated into event-based cues. In people's lives time cues are frequently accompanied by event-cues, for example 5pm is often associated with finishing work, 7:30pm is accompanied by a sunset. Even looking at the time functionally makes a time-cue an event-cue (seeing 8:00 pm on your watch is an event). To contrast, an event-cue is almost impossible to convert to a time cue (as you don't know when the event will occur). Because of this Utzl (2008) argues a time cue may be a less invasive event cue, and that the cognitive mechanisms are unlikely to be substantially different.

When looking at event cues as they relate to functional autonomy or independence for older adults (a primary reason prospective memory study is important; Kvavilashvili et al., 2013) in a naturalistic setting an event-cue is only an event-cue if there is no time within which it needs to be completed; which does not contribute to important daily functions. If it needed to be completed by a time, then it would be stated as such. For example, if a person needed to post a letter upon seeing a mail box (an event based PM task) there would have to be some time window to post that letter, if there wasn't a time window, it would not matter if the task was done, and the letter would not be important (except, in extremely uncommon circumstances). If the letter was important and needed to be posted before Wednesday and the post box was cleared at 5pm Tuesday, the task would need to be done by 5pm Tuesday. This example is not the same as a specific time-based task where an appointment is at 4:30pm for example, but would still typically be defined as a TBPM task in diary-based PM studies as it involves monitoring time. This is shown in diary-based studies where people very rarely report an event-based task (less than 1% of the time; Niedźwieńska & Barzykowski, 2012; Schnitzspahn et al., 2016; Schnitzspahn et al., 2018). Schnitzspahn et al. (2018) also points out the above, questioning the usefulness of the distinction of time- and event-based PM tasks in everyday life. They state that these two distinctions do not capture the range of situations people encounter in their everyday life, making categorisation difficult, prompting further research to verify the types of PM tasks people encounter. Schnitzspahn et al. (2018) suggest that time-based tasks should have variants involving temporal specificity (e.g., appointments vs posting a letter before someone's birthday), regularity (e.g., regular bill payments like power or water, vs irregular bill payments such as one off repair costs), or length of delay (e.g., remembering to check when the kettle is boiled, vs groceries on the way home, vs dental appointment in 3 months). These alternative ways of looking at naturalistic PM allow researchers to track how well participants' PM functions within specific task types, e.g., PM abilities regarding highly specified tasks, PM abilities for deadlines, and PM abilities for short or longer delay intervals. This approach seems more practical as it allows researchers to understand where individuals PM may be lacking in an applied context. The applied context could be

used to see if an older adult needs help with specific types of tasks in particular to maintain independence such as functioning in a work context, managing their health by taking medication and getting to appointments, able to pay their bills on time etc. The focus on time components such as length of delay could also help researchers readily communicate subdomains of PM like vigilance PM and task regularity could be related to habitual PM (explained below).

Early research into habitual PM exemplifies the importance of identifying subdomains in prospective memory research as opposed to the current EBPM and TBPM. As described above habitual PM is where long-term PM becomes patterned as part of a routine or in conjunction with other actions. This patterned prospective remembering may occur in tasks such as regular medication taking or regular appointments (both of which can be incredibly important for health). In 2000, McDaniel and Einstein theorised that habitual PM likely functions differently from PM proper by being more reliant on associative memory and action scripts. Subsequent neurological evidence has supported this claim with Meier et al. (2014) showing that the event-related potentials (ERPs) of habitual PM are different from those involved in PM proper, with low resolution brain electromagnetic tomography analysis showing that they involve recruitment from different neural circuits (less frontal and greater parieto-occipital activity in habitual PM compared to episodic PM or PM proper). Additionally, Meier et al. (2014) found that this process of recruitment from different areas was continuous rather than categorical as a PM task becomes more habitual. This means PM proper does not just become habitual PM after a certain time period, but rather develops as a PM task is repeated. Given that different neural recruitment mechanisms are used in these different PM subdomains, these findings offer a large potential confound in PM research when comparing tasks done more frequently to those done less frequently, even if only over a short period of time (e.g. three to seven days). Despite the potential confound, the change in performance or neural mechanisms over time has not been examined over very large intervals, for example, Cavuto et al. (2017) when examining habitual PM only did their study over two weeks. Research such as Rendell and Thompson (1993), a meta-analysis by Uttil (2008), and a more recent study by Cavuto et al.

(2017) have all highlighted importance habitual PM research. Instead of distinguishing so strongly between EBPM and TBPM, researchers should focus more these sorts of subdomains which show greater promise at furthering PM understanding even with a comparatively scarce literature base.

### **3.3 Multi-Process Theory of PM**

The dominant theory of prospective remembering is the Multi-process Theory by McDaniel & Einstein (2000). This theory states that there are two mechanisms for prospective remembering – monitoring and spontaneous retrieval. *Monitoring* refers to the deliberate cognitive allocation of attentional resources to facilitate the search for cues that signal prospective memory action; this results in a performance cost to the ongoing task (Smith, 2010). Spontaneous retrieval is the probabilistic process where the prospective memory intention suddenly moves into (or ‘pops up’ in) consciousness in response to processing a retrieval cue. Unlike monitoring there is a significantly lower performance cost (though this should not be equated to fully automatised prospective memory responding as there is a small amount of processing; McDaniel & Scullin, 2010). These processes were demonstrated in a series of experiments by Einstein et al. (2005). The experiments varied cue focality, instruction, number of focal targets etc. What they found is that when, for example, a cue is not focal or participants were given high emphasis instruction (PM task was given high emphasis relative to the ongoing task), there would be a significant cost to ongoing tasks suggesting monitoring. Participants in the study could also have a focal cue with low emphasis on the PM task and get similar PM performance with no cost to the ongoing task, providing evidence for spontaneous retrieval. The experiment highlighted that, depending on the condition, people will rely on multiple processes (monitoring or spontaneous retrieval) in prospective remembering, hence multi-processing theory.

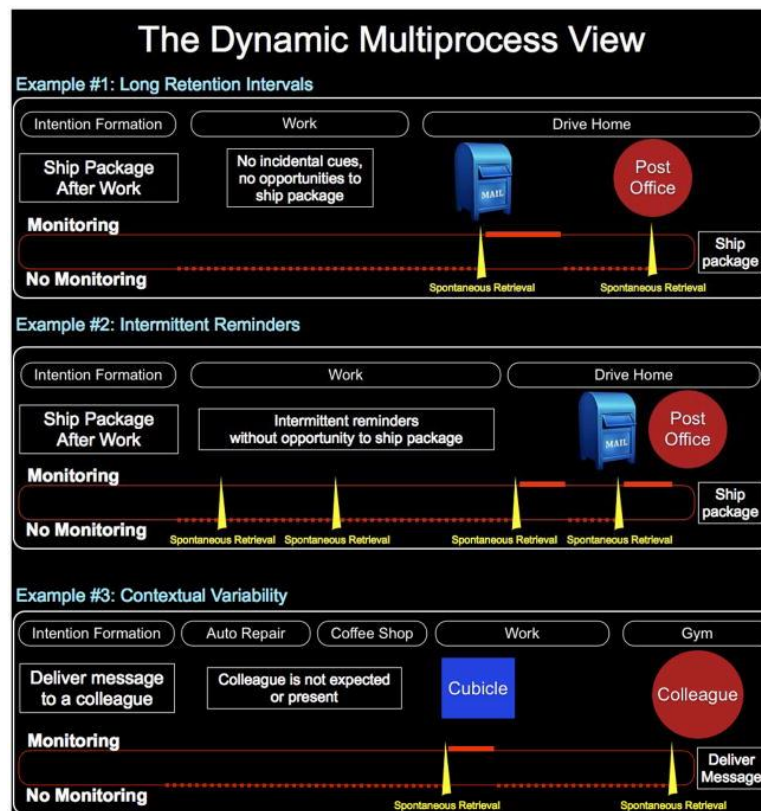
In a 2005 paper by Einstein et al., the discussion highlighted that participants may ‘sneak in’ some monitoring as a possible explanation for some of their results where they failed to find significant ongoing task costs in the moderate emphasis on PM group. However, they then went on

to refute this claim as lower levels of monitoring would theoretically result in lower PM performance. A 2013 paper by Scullin et al. further examined monitoring and spontaneous retrieval. In their study, younger adults showed a dynamic approach to resource allocation; for example, engaging more in monitoring after successful PM retrieval and less monitoring before the first cue or in a situations where PM cues were unlikely to appear. This finding led Scullin and colleagues (2013) to conclude that there is a dynamic interplay between monitoring and spontaneous retrieval, in contrast to Einstein et al. (2005) dismissing this possibility. In the original multi-process theory (McDaniel & Einstein, 2000), individuals either monitor or rely on spontaneous retrieval rather than alternating between the two. In a monitoring-only view; participants are supporting prospective memory by monitoring for cues, for which ongoing task costs should always be apparent. In spontaneous-retrieval-only, participants are purely relying on spontaneous retrieval and ongoing task costs will not be observed. The dynamic multiprocessing framework, as outlined in the Scullin et al. (2013) study suggests a more 'complex' dynamic framework where people can flexibility engage and disengage monitoring as situations require it. This makes sense as prolonged monitoring for infrequent or absent prospective memory cues would be a waste of cognitive resources. Secondly, spontaneous retrieval allows for the conscious re-emergence of an intention without many cognitive resources to hold that intention in mind being used, if this comes about in a time where the task is actionable within a near but not immediate timeframe, the cued intention may be forgotten and the conscious re-emergence of this intention would be wasted. Instead it makes sense to engage monitoring in response to spontaneous retrieval and evaluate if it is worth sustaining that monitoring or disengaging it. As an example consider sending a letter after work. While at work an individual may get several cues that generate spontaneous retrieval, however the person will not be able to send the letter, so monitoring is not engaged. Then on the drive home another cue generates spontaneous retrieval, in this case if the person drives past a post office or post box, then they may act on the task resulting in successful PM performance. So, while driving, if an individual is spontaneously cued then the individual can have a period of monitoring to look for further

prospective cues as they are relevant to the context. This incorporation of contextual variability allows for much clearer understandings of the data in the study of PM and its influencing factors (as described above). Other examples of contextual variability and a clearer picture of this situation can be seen in figure 1.

**Figure 1**

*The Dynamic Multiprocess Framework*



*Note.* This figure was produced by Scullin et al. in 2013, it includes different situations in which there is a dynamic interplay between contexts, monitoring and spontaneous retrieval. From "The Dynamic Multiprocess Framework: Evidence from prospective memory with contextual variability", by M. Scullin, M. McDaniel and J. Shelton, 2013, *Cognitive psychology*, 67(1-2), p.62.

### 3.4 Ageing and Prospective Memory

#### 3.4.1 Brain-Based Cognitive Capacity and PM

First, it is important to more fully understand the cognitive components involved in the different phases of prospective remembering. While the exact cognitive resources for PM decline are somewhat contentious, generally declines are seen to be predominantly linked to the lesser

amount of attentional resources available and a decrease in cognitive control (i.e., higher-order, fluid domains of cognition such as working memory and executive control; Hering et al., 2014). As stated previously components of executive function which decline with cognitive ageing are related to declines in PM performance, particularly inhibition (of the ongoing task) and task shifting. In addition, there are also significant episodic and semantic memory demands (as PM actions will require remembering both autobiographical and factual memory). Cognitive demands for PM depend on which of the four phases of prospective remembering a person is in (Kliegel et al., 2002). The first phase *intention formation* relies on encoding and planning, this is dependent on working memory capacity as to how well the task is encoded. The *intention retention* phase then relies on the storage of the information in long-term memory, particularly this would be related to episodic memory which is a form of long-term memory associated with relatively steady age related declines, and to a lesser extent semantic memory which is associated more with later life decline (Harada et al., 2013). Lastly there is *initiation intention* which is detecting the PM cue and *intention execution* which is acting upon the cue. Intention initiation relies on monitoring to detect the appropriate situation by noticing cues, cognitive flexibility or task shifting to switch between the ongoing task and the PM task, and inhibition to inhibit the ongoing activity. Intention execution relies also on cognitive flexibility as well as retrospective memory to enact the correct action. Fluid abilities such as working memory capacity and controlled attention/executive function as well as some retrospective processes such as encoding, and retrieval all have age related declines especially as adults approach their 60's (Harada et al., 2013). However, each component will contribute to different stages of prospective memory, meaning deficits will depend on the way in which the PM tasks are set out. If the task is more frequent, there will be a greater demand on executive function/controlled attention; if the task is infrequent, but requires complex actions upon execution, there are greater retrospective memory and encoding demands, as the intention retention phase is longer and the PM action requires remembering more information.

### **3.4.2 The Age-PM Paradox**

Early prospective memory researchers came up with a conceptualisation of PM tasks that is well contrasted with the reminder use and environmental influence ideas presented in this thesis. Craik (1987) suggested that typical PM tasks have low environmental support, with high demand on self-initiated processes (e.g., planning, encoding, inhibition). Given that ageing comes with a decrease in recruitment abilities for self-initiated processes, it was initially argued that PM performance should decrease in response to ageing (Einstein & McDaniel, 1990). This hypothesis is relatively consistent with the laboratory-based assessment of prospective memory which has shown that age-related decline in PM is relatively minor until about 60 years old. After 60, the decline is accelerated (seemingly in concordance with other cognitive declines; Niedźwieńska & Barzykowski, 2012; Uttl, 2008). In 2004, Henry et al. conducted the first meta-analytic review of age-effects on PM, found that older adults, on average, performed worse than younger adults in lab-based tasks. In contrast to the laboratory findings, numerous studies later found that in naturalistic settings that older adults outperformed their younger counterparts (Rendell & Thomson, 1999; Einstein & McDaniel, 1990; Bailey et al., 2010; Schnitzspahn et al. 2011); highlighting a positive age effect (improvement with age) for PM performance. This inverse relationship of age effects in response to task setting is termed the age-PM paradox (Rendell & Craik, 2000).

Theoretically, the age-PM paradox is not supported by the original multi-process theory put forward by McDaniel and Einstein (2000). The theory assumes that PM performance is mediated by automatic and strategic monitoring processes (depending on the situation). As put forward by McDaniel and Einstein (2000) Environmental supports and compensatory strategies can allow for automatic retrieval processes to be mediated in PM tasks (e.g., by an alarm, or enhanced through a distinct object within the environment); however, in situations where monitoring is likely (e.g., focal task, high importance instruction) environmental supports and compensatory strategies would not increase the cognitive resources of older adults required to initiate the strategic processes required for successful prospective remembering. Thus, naturalistic environments with environmental/compensatory supports would still be carry some deficits for older adults as strategic

monitoring processes are not helped. However, assuming that most real-life tasks require the intention retention phase of PM to be over long periods such as hours or days (making most PM tasks reliant on spontaneous retrieval processes, rather than monitoring intensive as is seen in the shorter lab tasks) the theory would still predict no age effects, not positive ageing effects.

Placed in the context of the dynamic multiprocessing framework by Scullin et al. (2013), there is an extra component that may benefit PM through more strategic switching between monitoring and spontaneous retrieval. Hypothetically, environmental and compensatory supports could be better utilised by older adults to allow for a more adaptive switching between spontaneous retrieval and monitoring. More adaptive switching could allow PM to be spared in a naturalistic setting, even when cognitive processes such as inhibition or set switching decrease with age. This hypothesis of PM being spared or even enhanced while other cognitive processes decline still requires further systematic testing (Kliegal et al., 2016).

Highlighted initially by the Uttl (2008) there are several systematic problems in the investigation of the age-PM paradox. As discussed above instead of TBPM and EBPM it may be better to examine task type (e.g. high specificity PM tasks vs low specificity PM tasks), though most of the PM research focuses exclusively on distinguishing time- and event-based PM tasks. Additionally, Schnitzspahn et al. (2018) point out that when investigating the age-PM paradox, the tasks used inside the lab and outside the lab are not comparable. This is because differing tasks and cue types may give rise to uncontrolled confounds. Further, subdomains of prospective memory are often not well distinguished or categorised within PM studies. Kvavilashvill and Fischer (2007) highlighted that laboratory-based assessment of PM usually has time intervals of 10-15min, as opposed to hours or days, qualifying it to be more reflective of vigilance/monitoring PM as opposed to proper PM.

More fundamental research issues also exist within the ageing and PM literature. Firstly, there are often ceiling effects (e.g., Altgassen et al., 2010; Niedźwieńska & Barzykowski, 2012;

Masumoto et al., 2011). Ceiling effects can be quite significant, with no age-decline present as both age groups get perfect or near-perfect scores (Uttl, 2008). Secondly, most PM studies assessing differences between younger and older adults have approximately 20 participants per group, resulting in meagre statistical power for the majority of studies (Uttl, 2008). Lastly, Uttl highlights effects of age confounds such as researchers making the ongoing task easier for older adults, or not accounting for IQ or number of years in education (intelligence is correlated with better PM performance; Cherry & LeCompte, 1999). Schnitzspahn et al. (2018) also point out that there are very few within-subject design studies for age-PM paradox that examine the same group in both a laboratory and naturalistic setting, leaving the majority of between-subject studies with several of the methodological issues stated above. With many of these concerns not picked up by Henry et al. (2004) in the original meta-analysis, and with little correction in many studies since, Uttl (2008) and Schnitzspahn et al. (2018) both call into question the authenticity of the presumed age-PM paradox. However, in their study Schnitzspahn et al. (2018) did end up replicating the age-PM paradox, finding that older adults performed better in naturalistic time-based tasks (statistically significant) and achieved an overall higher (though not statistically significant) scores in the event-based task, while doing significantly worse on event-based laboratory tasks (though approximately equal on the time-based task).

Outside of moderating factors discussed earlier, such as ongoing task absorption (i.e., degree of attentional resources invested in ongoing task), cue focality, or cue distinctiveness; there are also separate contextual and emotional mechanisms that may mediate or moderate the age-PM paradox. Excluding the use of reminders, which will be elaborated on later in this thesis, the next section will elaborate on some of these alternative influences on PM between age groups.

### ***3.4.3 Emotional Mechanisms in Age-Related PM***

There are two ways in which emotion is examined as a variable contributing to PM performance. The first way is through manipulating cue valence, giving either positively or negatively

valenced cues. The second way is to examine how the mood states of participants alter their PM performance. Previous literature has shown that emotion can improve attentional resource allocation and visual processing (Pessoa, 2008); older adults in particular show enhanced memory and attention with positive stimuli (Mather & Carstensen, 2005). Concurrently, as shown by Blair et al. (2007), emotion can also disrupt task performance and reduce individuals' ability to perform goal-directed tasks (which are common in prospective remembering, Penningroth & Scott, 2013). Early evidence from Schnitzspahn et al. (2012) indicated that older, but not younger adults benefitted from valenced cues; though, later meta-analytic review by Hostler et al. (2018) revealed this not to be the case. In their meta-analytic review Hostler et al. (2018) examined several potential moderators for the emotion-PM relationship, including cue focality, arousal, and age. When looking at the effects of age on cue valence, negative cues did not affect PM performance regardless of age, and positive cues appeared to confer a benefit to older adults; however, the effect was not statistically significant.

Concerning mood and PM related to older and younger adults, the primary study explicitly looking at this relationship as it relates to age is by Schnitzspahn et al. (2014) which found mood states (both positive and negative) negatively affected the PM performance of younger but not older adults. This finding was useful for early conceptual understandings of what may be going on within the dynamic process of monitoring and spontaneous retrieval as it relates to mood and emotionality. However, like most laboratory-based tasks, the method reflects the vigilance/monitoring PM subdomain rather than prospective memory proper. The study did identify some potential confounds around task difficulty potentially affecting affective states in PM tasks. For example, older adults had significantly lower PM scores which could reflect lower motivation, resulting in lower task-related stress and lesser changes in affective states (as they are unlikely to get stressed or emotional if they do not care about the task). While PM and mood generally have been covered in other articles (e.g., Knight et al. 2015) it seems that no subsequent research following Schnitzspahn et al. (2014) has been conducted with mood and PM as it relates to differential ageing effects.

#### **3.4.4 Motivation and Task Importance in Age-Related PM**

Another confounding effect of the age-PM paradox is motivation and task importance. Regarding motivation, many studies have looked at the influence of task importance as it relates to PM performance (e.g. Ihle et al., 2012; Smith & Hunt, 2014). Other studies, such as Alberle et al. (2010) looked at manipulating task importance through monetary incentives. In a review by Walter and Meier (2014) they looked at varying types of motivation in PM research and how it related to the mechanisms. In their review, they found relative importance manipulations (where you increase the relative importance of PM when two tasks are important, i.e. ongoing task and PM task) enhanced PM usually at the cost of the ongoing task. However, in Altgassen et al. (2010), they showed that increasing social importance (by asking participants to do the experimenter a favour) had a greater effect on older adults and did not result in this same ongoing task cost. Walter and Meier (2014) found that in line with the multi-process theory and given the lack of ongoing task cost in the social importance condition, that spontaneous retrieval may be enhanced through a more significant association between the PM target and the PM task. When relating these concepts to components of motivation, it appears social motives are related to intrinsic motivation and a reward on top of that, such as monetary incentives, or the pressure from increasing task importance, provides extrinsic motivation. Supporting neuropsychological evidence highlight the extrinsic rewards are related to increased prefrontal activation, which actively maintains task-goal association enhancing strategic monitoring. Further, accounting for the differential age effects Walter and Meier (2014) highlight that older adults may be more prone to intrinsic motivation giving them a performance advantage and closer to their maximum performance in naturalistic studies. Younger adults appear to be less motivated to contribute their full potential to PM research, meaning perhaps that they may work at a deficit unless rewarded; hence having greater benefits from extrinsic motivation such as in Alberle et al. (2010).

#### **3.4.5 Metacognitive Awareness in Age-Related PM**

Related and separate to the above is the contextual influence of metacognitive awareness. Metacognitive awareness in PM refers to a person's ability to predict their PM performance on a task before they have completed that task. The logic behind metacognitive awareness is that if people are better able to estimate their performance, they can allocate appropriate resources and strategies (Gilbert, 2015). When predicting PM performance in naturalistic tasks, it follows that older adults have more experience with these tasks and may better be able to predict their performance, with the reverse being true for younger adults in a laboratory-setting (as most younger adults in PM research are university students; Ihle et al., 2012). Schnitzspahn et al. (2011) systematically tested this assumption, finding that older adults do indeed benefit from better meta-cognitive awareness in naturalistic contexts. Cauvin et al. (2019) looked at younger adults finding that they significantly overestimate their performance in naturalistic tasks. Devolder et al. (1990) also highlight that it may be that negative stereotypes around memory lead older adults to chronically underestimate their ability, which could increase motivation, greater use of aids/strategy, and greater reflection on their cognitive ability. Metacognitive strategies are associated with brain areas involved with spontaneous retrieval and less with monitoring creating less cognitive demand for older adults (Walter & Meier, 2014). Perhaps increased metacognitive awareness is favoured in older age as a result of the decreased cognitive resources as it allows for enhanced spontaneous retrieval, placing less demand on resource-intensive processes such as monitoring. This relationship of metacognitive awareness and its relationship with task importance and motivation still needs further systematic study. However, these contextual components offer promising and exciting avenues for investigating the age-PM paradox, especially as it relates to the paradox's cognitive mechanisms.

Scullin et al. (2013) showed that younger adults seemed to be more cognitively flexible and adaptive in their use of spontaneous retrieval and monitoring as it related to PM performance in a laboratory context. As shown by the above contextual factors and emotional factors; it seems that instead of executive function mechanisms such as set switching or inhibition, older adults may use processes such as regulated emotionality, or increased intrinsic motivation to more successfully rely

on spontaneous retrieval. While research offers many exciting avenues to pursue, there are many methodological kinks to be worked out. As stated by Schnitzspahn et al. (2018), while there are substantial theoretical and practical implications of age-PM paradox research, research in this area is still in its infancy. While it is difficult pragmatically, sample sizes need to increase; subdomains need to be more widely distinguished, and lab and naturalistic task assessment methods need further investigation. At this stage, however, it does appear the literature has given some credence to Craik's (1987) first finding of the age-PM paradox.

## Chapter Four

### Reminders

#### 4.1 Reminder Types

To remember what we need to make the dinners for the week, we may write a grocery list in advance. To remember if we posted a letter, we may retrace the places we have visited and the activities we did. To remember to take medications, we may plan to take them with breakfast in the morning. These activities all demonstrate the use of different reminders or memory aids, which are devices or strategies used to deliberately enhance memory (Intons-Peterson & Fournier, 1986). Guynn et al. (1998) expand on what information reminders can contain in a prospective memory context: a target, an action, and a context. A *target* refers to what it is that one should remember (you should do something on the way home from work), an *action* refers to the specific action one should carry out (buy groceries), and *context* refers to the reason the task is being performed (you're buying groceries as you have guests coming over). Reminders can also be a cue which is a stimulus or combination of stimuli in the external environment, or an internal event such as a thought or state (Dismukes & Nowinski, 2007). A cue is more likely to be effective if it is presented when the prospective memory task can be acted upon.

At a basic level external reminders are a type of reminder that use resources outside of the brain including other people (i.e., asking them to remind you), items in the environment, the environment itself (e.g., the layout of a bedroom). Internal reminders are aids that rely on memory and cognitive tools used deliberately to aid in the retrieval or retention of information including mnemonics such as the use of rhyme or acronyms. Combined reminders, often neglected by the literature, are when the reminder used relies on the external environment to strengthen internal processes such as writing out imagined parts of information to see if it sparks a memory, or using daily activities such as meal times to be linked internally with another behaviour like pill taking. These definitions, however, are far less clear cut than they may appear at first glance. The obstacles in defining each will be highlighted below.

Reminders, as described above, play a significant role within our daily lives. Much of the older scientific research examined differences between internal and external reminder use (e.g., Harris, 1980; Intons-Peterson & Fournier, 1986). However, for this thesis the additional category of combined reminder use will also be added. This chapter will illustrate the difficulties in distinguishing the different kinds of reminders and elaborate on the study of digital reminders. Following this cognitive offloading research examining the function and cognitive implications of reminder use will be described. Lastly, reminder types, digital reminder use, and cognitive offloading will be contrasted with how current age-PM paradox research has investigated reminder use.

#### **4.1.1 Internal Reminders**

As can be seen in the section on ageism, society tends to fixate on improving brain-based cognition and steers away from external 'crutches'; as such, most experimental psychology researchers focus on internal remembering methods over external ones (Kristansson, 2011). Internal remembering methods include low demand techniques such as mental retracing where, in their head, a person retraces locations they have visited and the activities they have done to remember if they posted a letter. Then, there are much more demanding techniques like a memory palace where

the user creates unique associations in an imagined space. To generate these unique associations in the imagined space a person must spend time and effort practicing the skill of constructing a memory palace, and each construction is a mentally effortful process. The use of higher demand strategies is not only demanding to encode, but also require an effortful and time-consuming learning process (to first understand what a memory palace is and how/why a memory palace works); effectively limiting both their practicality and accessibility to much of the population (Conderman, 2020).

While high and low demand internal strategies are somewhat easily distinguished, categorising what counts as an internal memory strategy and what does not is a bit more complicated. Harris (1980) highlights that the use of chunking to enhance in the recall of word lists is often a spontaneous and automatic strategy, making chunking a normal memory process and therefore not a mnemonic or internal memory aid. This normal memory process vs mnemonic/internal memory aid example makes the operationalisation of internal memory aids a difficult process. Firstly, everyone can implicitly or explicitly learn strategies; as an example, some people when trying to remember the name of someone they met, will go through the alphabet to try to 'feel' which letter resonates with the start of the forgotten name. Other people may never engage in the above strategy, known as alphabetic searching, unless explicitly taught it as a strategy. Additionally, once learnt, alphabetic searching will be used less consciously over time as the processing of this strategy becomes more automatic. Further, as highlighted by Kristansson (2011), people may find internal memory aids obscured by other concurrent mental processes (e.g., while driving, attentional processes may mean mental focus is predominantly on the road and other drivers, this could obscure a separate mental process of thinking of a story that is linking items or memories together, which is an internal memory aid known as the story method), increasing the likelihood that individuals would be unaware that an internal memory aid is being used. As illustrated by these examples, what is or isn't an internal remembering method by Harris's (1980) definition varies person to person. Part of the focus of this thesis is to examine how older and

younger adults are differentially aware of different internal remembering methods. We also aim to examine how participant's internal reminder use profiles (what sort of reminders they use and how frequently) affect PM performance. In examining internal methods further and looking at their qualitative and quantitative features, this thesis may help further our understanding of appropriate ways for researchers to differentiate between normal memory processes and internal memory strategies.

#### **4.1.2 Combined Reminders**

Another reminder category with fuzzy edge cases is the in-between reminder category of combined reminders. Researchers such as Intons-Peterson and Fournier (1986) have argued that some memory aids include a combination of internal and external resources that deserve their own category. Henry et al. (2012) also believed some reminders did not fit cleanly into internal or external categories which he labelled conjunction reminders (i.e., conjunction cues, discussed in section 3.1). Given conjunction reminders fit the definition of combined reminders given in the introduction, this thesis also labels them as combined reminders. To understand this idea of combining internal and external resources take the example of the combined reminder 'reminder through association' where the intent is to create a distinct cue (such as a red ribbon) that is out of place in the environment, such as an office. The ribbon is an external component of the memory system. However, it does not function to cue attention in an actionable window (i.e., a period where completing the prospective memory action is possible). Further, the ribbon does not provide any retrospective information (the ribbon has no natural relation or information relevant to the task, other than the meaning the person assigns to it). Moreover, the ribbon is primarily bolstering the internal processes of motivation through repeated reminding (though it may have the opposite of the desired effect), and cognitive shifting (conscious change in attention) by shifting their attention from their ongoing task to the prospective memory task. Therefore, the ribbon functions as neither an external or internal aid specifically, but instead as a combination of the two.

While some researchers support this third category of combined reminders, other researchers such as Kristansson (2011) have stated that there is not necessarily a solid distinction between external reminders and combined reminders; this is because some external aids could be argued to be more internalised depending on the structure of the external environment. In support of this similar effects to the 'reminder through association' strategy given in the example above with a red ribbon, could occur by simply glancing at, but not reading, a calendar. If the calendar was distinct or put in an odd place it would function like the ribbon but would likely be recorded as an external reminder (as it contains retrospective information and is often defined outright as an external reminder by researchers; Intons-Peterson & Fournier, 1986). However, this lack of distinction doesn't mean we should discard the category of combined reminders; rather it can help strengthen our definition of external reminders. External reminders will exist on a continuum and if you can determine that the main function is to replace internal processes as opposed to strengthen them then you could label the reminder as external. For example, Otto's notebook functions mainly as external information storage given his compromised brain-based cognition; on the other hand, a person may use a notebook like Otto to write things down, but unlike Otto, not consult the notebook again. Note-taking literature (Burack & Lachman, 1996) shows that the process of writing things down can increase recall even when the notes are not referred back to. While in both cases a notebook is used, the definition above means that Otto's notebook would be considered an external reminder (replacing the cognitive function of information storage and altering retrieval), while the other person who took notes, without consulting them again, would functionally use the notebook as a combined reminder. The example above provides an argument for the utility of a combined reminder type as these reminders are distinctly different from external aids in that they predominantly rely on bolstering internal methods, and distinct from internal methods as they rely on external or environmental aids.

#### **4.1.3 Reminder Contexts**

Both external and internal reminders can enhance retrieval, encoding, and storage of information both inside and outside of the brain. However, the effectiveness of the enhancement depends on the context of the situation. Intons-Peterson (1993) illustrates the different contexts where external reminders may have greater utility over internal methods of remembering. Firstly, when there is an important ongoing task that needs attention, such as cooking a chicken in the oven, external aids like an alarm clock can be relied upon to reduce the need for monitoring. They also allow for accurate information storage when there is limited time for encoding, rehearsal, or for mnemonics to be used. This accurate storage also helps when tasks require working with complex information that may not be able to be sufficiently processed in the moment. Tasks that require long temporal intervals also are well suited to external reminders, such as making an appointment several months in advance. Intons-Peterson and Fournier (1986) shows there are also different contexts where an internal method would be preferable. Firstly, people may not wish to rely on external prompts, such as when giving a public speech. Secondly, external reminders may be difficult to prepare (e.g., when no phone, pen or paper are available) or hard to use. Thirdly, when the interval between learning and recall is short enough that external aids would presumably not be needed (e.g., remembering a short message that will be relayed once off the phone). Additionally, external aids may also be less preferable as they can be inconvenient, for example having to carry a notebook, timers, photographs etc. around with you may be a nuisance. And lastly, generating external aids may interfere with the ongoing task.

The above shows where either external or internal reminders may be useful; however, there are also several areas of daily life where reminders as they currently exist are insufficient. Brewer et al. (2017) looked at highly specified time- and event-based intentions, intentions that are upcoming but not fully formed as actionable tasks, and persistent goals which generally carry throughout a person's day to day life. Of these, external reminders may be useful for highly specific time-based intentions (e.g., an alarm will be very useful for a future appointment) and combined reminder strategies may assist with event-based tasks (e.g., a red ribbon on your desk can help cue an action

upon getting to work). However, it is often very difficult to generate effective reminders for event-based intentions, vague intentions, or persistent goals. In their study Brewer et al. (2017) found that methods such as calendar notification could not serve as reminders if the person does not turn on the device with the calendar notifications or use the application, or if the person ignores notifications. Additionally, if the calendar notification for example said to 'meditate before bed' and was scheduled at 10pm (the person's regular bed-time), then that person gets held up by a late night phone call the notification may be forgotten about or ignored. The challenge for reminders like the example above is not only to be delivered in a timely way, but also in a way that avoids habituation or irritation. Reminders may develop to overcome some of these challenges, for example smart assistants such as Cortana can allow users to generate a grocery list and an associated grocery store location, and using location tracking, the digital assistant can remind someone of the list upon entering the store. However, many of the issues for reminders found in certain event-based intentions, vague intentions, and goals are yet to be solved. Accordingly, it is important to recognise prospective memory performance required for independent living encompasses many situations in which reminders may not be useful, or even potentially act as a hindrance.

#### **4.2 Digital Reminder Use and PM**

As highlighted by Roser and Ritchie (2013), our technological advancement, including the development of computer technology and increasing quality relative to cost, is growing at an exponential rate. Further, in New Zealand, over 80% of the population had at least one smartphone as of 2019 (Hughes, 2019). Digital reminders have gone from specialised physical devices like pagers and non-smartphone PDA's given exclusively to brain-injured or cognitively impaired patients, to apps that can collectively feature on any individual's smartphone, often for free. This increased accessibility has led to some mass adoption of digital reminders (e.g., Outlook Reminders or Google Calendar) which, in addition to acting as a planner and calendar, can set alarms, synchronise data across multiple devices, and passively notify us in the background of other tasks. Further, digital

reminders are starting to use location data, motion detection, and artificial intelligence to prompt more accessible reminders which could substantially improve their effectiveness (Brewer et al., 2017).

Digital versions of previously analogue reminders offer a different mode of interaction, and different methods of encoding (e.g., cranking a timer to set an alarm versus pressing a button on a phone). These different encoding methods may impact memory and reminder use behaviours and are yet to be systematically studied. While it may seem like greater functionality and practicality belongs in the digital reminder camp, especially as we progress into the future, analogue reminders will always offer unique benefits. Firstly, analogue reminders can provide a useful type of friction. For example, taking notes requires an individual to get a notebook and a pen and handwrite, which requires more effort than retrieving a smartphone from your pocket and typing, making the encoding threshold higher. This higher encoding threshold can deliberately force more meaningful task setting (associated with better PM performance in younger and older adults; Ihle et al., 2012). Secondly, Analogue reminders also present us with less possible distraction; as highlighted by Kuniecki et al. (2015) digital reminders are often made to siphon our attention; for example, most digital notifications are deliberately red as this colour captures our attention through its emotional valence. Also, refreshing a social media feed with a pull down or opening of an app functions similar to a casinos slot machines; even if there wasn't something interesting in the feed, you feel like there almost was something good, like getting two out of three cherries on a slot machine. This almost winning situation results in the 'near-miss effect' where reward circuits are stimulated in a near-miss event even though you are technically losing. This mean refreshing social media feeds, regardless of the content, conditions users to keep visiting, drawing their regular attention, and altering their behaviour (Wu, 2017). Consequently, digital reminders may require cognitive resources to resist conditioned behaviours interfering with the use of the reminder in the first place. Additionally, analogue reminders are often more accessible (not requiring technology) and unlike digital

reminders, do not produce flickering light waves that can disrupt our vision or circadian rhythms (Blume et al., 2019).

### 4.3 Older Adults and Digital Technology Barriers

As everyone comes to adopt the use of more digital reminders, it is important to understand how the adoption process is different for older and younger adults. Firstly, Schreurs et al. (2017) highlight that older adults tend to lag behind younger adults in their adoption of digital technology. One hurdle inhibiting the adoption of digital devices in the older adult population is digital literacy, which is inherent in those brought up with technology but can be challenging to learn for older adults (Guner & Acarturk, 2020). A study by Nygård and Starkhammar (2007) mapped some of the hinderances to attaining digital literacy in older adults. They found three main categories of interference:

1. *Conditions of context and the person.* Digital reminder use for older adults requires learning, which involves cognitive load and fluid abilities which are more impacted by ageing than other cognitive domains. Specifically, older adults mentioned difficulty attending to multiple aspects of the new technology, memory deficits, stress sensitivity, and pressure from the external environment as hindrances.
2. *Limited knowledge of technology and its potential.* Limited knowledge leads to uncertainty about functional aspects of technology or its applied relevance to one's life, hindering the perceived efficacy and depth of use.
3. *Difficulties communicating problems with technology use.* Learning and understanding what components of technology are going wrong involves earlier steps of knowing what operating system they're on, what device they have (e.g., iPhone or Android), the difference between native apps and websites, and much more. Essentially, digital technology has its own language that older adults need to understand to get help in the first place.

The issues above have come from examining everyday technology use in older adults with cognitive impairment; however, these issues likely carry to a lesser or equal extent to those with normal age-related decline in cognition. Furthermore, representations of older adults and technology use in media and social discourse create added socio-emotional challenges, including self-doubt and concerns of further marginalisation, in addition to the cognitive challenges shown above. Because of the above digital literacy issues and socio-emotional challenges, if digital reminders are the available memory aid a lack of competency (or a perceived lack of competency) could negatively impact the decision to offload, as well as the depth to which they are able to encode information. The gap in digital reminder use frequency, as well as digital literacy is termed the 'grey divide' (Schruers et al., 2017).

Age-PM paradox research in the past has avoided electronic aids and smartphone applications because of the 'grey divide' influences mentioned above (e.g., Ellis & Kvavilashvili, 2000; Schnitzspahn et al., 2016). "To avoid technical and compliance issues for older adults" is the reason given by Schnitzspahn et al. (2016). While the grey divide may perhaps aid younger adults relative to their older counterparts in PM performance; the counterargument is that due to the novelty of a smartphone older adults may pay more attention to the device and subsequently it is older rather than younger adults that see a benefit in their PM performance (Randall, 2016). A study by Niedźwieńska & Barzykowski (2012) found older adults outperformed younger adults in a PM task when using mobile phones to assess naturalistic PM, showing that either older adults do benefit from technology or if technological differences do impair PM performance the effect is likely small. Randall (2016) investigated the impacts of smartphones on older and younger adult PM performance and subsequently found that familiarity with smartphones did not seem to differentially affect younger or older adult PM performance. This thesis not only to uses a smartphone-based PM task, but also investigates digital reminder use, and everyday preference and use of technology. As such, this thesis may be able to add further insight to the use of electronic aids and smartphones within age-based PM research.

#### **4.4 Cognitive Offloading**

A specific concept, with its own separate literature that integrates and expands on much of the above involving extended/embodied cognition, metacognition, and reminders, is that of cognitive offloading. Cognitive offloading is defined as the use of physical action in order to reduce the cognitive demands of everyday tasks (Boldt & Gilbert, 2019). A simple example of cognitive offloading is external normalisation. If someone sees a page tilted sideways, they will often tilt their head to read the information as a way of normalising the orientation of the text. This behaviour avoids the need for internal normalisation where an internal transformation (mentally rotating the letters) is performed to form a representation of the page in memory. This external normalisation can reduce the cognitive demand on brain-based resources (Risko & Gilbert, 2016). Cognitive offloading research has two primary questions: what are the mechanisms that trigger cognitive offloading? And what are the cognitive consequences of this behaviour? For example, if a person like Inga was to use a notebook as a memory storage device like Otto, how would this change their memory ability? And what might guide their decision to use the notebook in the first place?

##### ***4.4.1 Cognitive Consequences of Offloading: Transactive Memory Systems***

One way this research has examined the cognitive consequences of offloading is through research on 'transactive memory systems'. Transactive memory systems (TMS) involve sharing cognitive labour with respect to the encoding, storage, retrieval, and communication of information from multiple domains (Lewis & Herndon, 2011; Wegner et al., 1985). For example, one person could know about finding food, while another person knows how to prepare it; the information required by someone involved in TMS shifts from remembering 'what' to remember to remembering 'where' (Risko & Gilbert., 2016). Initially, investigations into TMS examined social relationships, with research suggesting the older adults could use social collaboration to compensate for age-related cognitive declines in memory (Johansson et al., 2000). Later research into TMS in older adults found

that while memory errors were reduced, adults remembering separately could remember more than those who worked together (Ross et al., 2004).

The above transactive memory system is known as an 'agent-agent' system; more recently, research has expanded the social agent-agent basis of TMS research to include agent-technology TMS. As our interaction with technology increases, we become progressively more reliant on computers and the internet. We are so integrated with smartphones and the internet that people have been shown to mistake access to the information on the internet for their own personal understanding of the information (Fisher et al., 2015). How this affects memory is proving (like social research in TMS) to be complicated. For example, knowing information will not be stored can enhance recall when examining trivia statements (Sparrow et al., 2011). However, when examining list generation, offloading an initial list into storage can enhance memory on a second list; hypothetically this occurs through reduced proactive interference (less encoding interference from the first list as it is known to be saved; Storm & Stone, 2015). This means that how individuals offload, as well as their perceptions of offloading, will likely influence their prospective and retrospective memory abilities.

#### ***4.4.2 Metacognition and Cognitive Offloading***

Another essential question of prospective remembering and reminders is: what causes people to use reminders in the first place? Boldt and Gilbert (2019) demonstrate that cognitive offloading is determined by the metacognitive evaluation of the difficulty of the task. Metacognitive awareness discussed in the previous chapter refers explicitly to one's knowledge about their prospective memory performance on a given task. Metacognitive awareness is influenced by a subjective process of monitoring ones believed cognitive abilities (metacognitive monitoring). Also, there is metacognitive control which can be defined as the process of using a person's own judgement to guide behaviour (Risko & Dunn, 2015). So, a persons perceived effectiveness of specific memory aids and their perceived ability for a task combines with their ability to enact behaviours based on

judgement to determine offloading (onto external reminders) or strategy use (use of internal or combine remembering methods). As an example, if a person perceives memory aids, such as an alarm, to be very useful (their degree metacognitive monitoring will determine the accuracy of this belief) and believes their ability to complete a given PM task is abysmal (again determined by metacognitive monitoring), they may offload the retrieval part of the task onto an alarm. However, this offloading only occurs if their judgement allows them to override the encoding costs involved in setting the alarm (i.e. if their metacognitive control is sufficient to guide behaviour in this context).

To examine how metacognitive monitoring and control are influenced, researchers have investigated task difficulty, metacognitive beliefs, age, task instructions, practice-trial difficulty (practice trial of PM task is made harder or easier than the actual task to yield some contrast that may bias offloading) and previous experience with cognitive offloading (Scarampi & Gilbert, 2020).

Noteworthy effects for this thesis are:

1. that individuals have a bias to reuse prior strategies if they are used successfully (Scarampi & Gilbert, 2020).
2. Reminders are set more frequently if the task has a higher memory load or a more significant number of distractions (Gilbert, 2015).
3. Gilbert (2015) also found a positive but non-significant effect of age on offloading intentions (older adults intended to offload more frequently), but this area needs more direct investigation.
4. The decision to offload is independent of an individual's objective unaided prospective memory ability or working memory capacity; instead, it is based on their perception of their memory abilities (Boldt & Gilbert, 2019; Morrison & Richmond, 2020; Simon & Schmitter-Edgecombe, 2016).

#### **4.5 Age-Prospective Memory Research and Reminders**

After examining all the details in different reminder types, different situations of reminder use, and different influences and consequences of cognitive offloading, this last section examines how the age-PM paradox literature has examined the use of reminders. The most popular explanation in the literature for the age-PM paradox is that older adults have greater naturalistic PM performance due to greater use of reminders and environmental aid. However, researchers have highlighted that there is little empirical support for this claim (Alberle et al., 2010; Aronov et al., 2015; Ihle et al., 2012; Phillips et al., 2008; Rendell & Craik, 2000). There is often no difference in reminder use (Ihle et al. 2012); greater use by younger adults (Rendell & Thomas, 1999); or participants can be explicitly instructed to not use reminders in naturalistic tasks and older adults will still perform better (Rendell & Craik, 2000).

The general approach of studying reminders in prospective memory is as an adjunct to other confounding variables, such as motivation, activity absorption, metacognitive awareness, or social importance. For example, Ihle et al. (2012) examined stress and personal task importance in addition to reminder use. Their study, when examining reminder use, had a brief post-hoc interview that examined the number of reminders used on experimenter-given tasks per day. The aggregate of reminder use was then correlated with PM performance. The results from Ihle et al. (2012) found that reminder use was correlated with PM performance but the performance benefit was the same across groups and did not contribute to age-related PM performance differences. Ihle et al. (2012) is an example of a simple adjunct to an age-PM paradox study of “how many reminders did you use to complete the task?” in order to examine an extra variable. Other studies, like Masumoto et al. (2011), looked at specific types of external reminders and internal reminders. They took a binary approach to analysis, comparing, for example, those who used external reminders to those who did not. They found that external but not internal reminders improved PM performance. However, they asked whether or not participants had used an internal reminder and to specify the type if they had. As stated above in section 4.1.1, conscious awareness of the use of internal strategies may be obscured by concurrent mental processes or by a lack of explicit awareness that they are using a

specific technique. All of the studies mentioned above have examined other variables, often unrelated to reminder use. Within these studies, without a specific and dedicated focus on reminders, the research appears to neglect the complexity associated with reminder use.

the studies mention previously in this section suggests that reminders do not explain the age-PM paradox. Older adults in a naturalistic setting do not seem to use more reminders, and greater use of external reminders doesn't seem to benefit them. However, as can be seen above, there are many interacting factors that aren't examined. Below is a list of important considerations when examining reminder use in PM:

1. A reminder may be used to help with the retrospective or prospective component on a PM task. Notably, a person may use many reminders to assist in retrospective remembering while still failing to execute prospective memory actions.
2. Reminder usefulness is dependent on the context: external reminders are better for tasks completed over long intervals, with higher ongoing task demands etc. Internal reminders can be useful in shorter retention intervals and when external reminders aren't practical. Using an internal or external reminder in an inappropriate context may result in worse performance.
3. How reminders are used can change their function: in agent-agent TMS (a form of external or combined reminder) working with someone collaboratively will contribute to fewer errors, while working with someone separately will result in a more information being retained. This is also true for simpler items such as a notepad which may hold information or could be used to bolster encoding processes.
4. Reminders are not made equal. External cues may contain a cue, a cue + an action, or a cue + an action + a context (i.e., an external aid may just say you need to do task A, or they may tell you what task A is and why you're doing it). Internal cues may also be high demand

learned strategies (e.g., memory palace) or passive low demand strategies (e.g., mental rehearsing).

5. Reminder categories (internal, external, and combined reminder use) can contain substantial variance between participants. For example, when looking at internal memory aids an individual using several mnemonics and visual encoding techniques would be said to be using internal memory aids, as would someone who used mental retracing once.
6. Digital reminders may provide an additional barrier for older adults depending on their fluency with technology. Additionally, digital reminders may impede reminder use in older and younger adults through their levels of distraction from the PM task (i.e., increasing ongoing task load).
7. Reminders must be used within an actionable window to be effective for prospective remembering (appropriate time and place).
8. People may not be aware of the internal strategies used and may forget several external strategies they have used if asked to recall in a post-hoc interview (Harris, 1980).
9. Reminders can be used in conjunction with one another; if a person uses both external memory aids and internal memory aids at the same time, there will be some interaction effects. To examine them separately from a person who has used both is ignoring the influence reminders may have on one another.

Additionally, there is always an internal component of external memory and vice versa. Where an external reminder replaces an internal process such as the notebook for Otto above, he will still need a semantic memory system to make sense of the notebook writings. Internalised concepts such as time cues for 6 p.m., as highlighted by Uttl (2008), always coincide with some sort of event or external cue, like a sunset or a clock displaying 6 p.m. (as stated in section 3.2, looking at the time makes it an event cue). People in a naturalistic environment are always scaffolded and integrated

with the environment around them. When looking at reminders superficially, as is often done in naturalistic components of age-PM paradox research, a lot of the nuance and complexity of reminder-use investigation is lost. In this space, this thesis seeks to question some of the underlying methods and hopefully add greater depth to conceptualisations of how reminders are studied in age-PM paradox research.

## Chapter Five

### Method

#### 5.1 Introduction

Previous evidence for naturalistic PM performance suggests that older adults should either have similar performance or greater performance than their younger counterparts, despite the opposite outcomes in a lab-based setting of PM. A simple explanation given by early researchers was that the naturalistic advantages seen in older adults are explained by greater reminder use (compared to younger adults), though subsequent research has shown this is not the case (Alberle et al., 2010; Aronov et al., 2015; Ihle et al., 2012; Phillips et al., 2008; Rendell & Craik, 2000). The purpose of this thesis is to replicate previous research showing comparable or greater naturalistic PM performance in older adults, as well as validating previous findings of the effects of reminder use in older and younger adults naturalistic PM performance. Research on naturalistic PM and reminder use in younger and older adults is also usually done as an adjunct to other confounding variables such as motivation. So, in addition to validating previous research, this study looks to explore *how* reminders are examined and used in younger and older adults' prospective remembering.

Previous research has shown that external memory aids, but not internal memory strategies, enhance PM performance, particularly in older adults (Aronov et al. 2015, Masumoto et al. 2011; Scarampia & Gilbert, 2019). Also identified in previous research is that older adults prefer, and more frequently use, external over internal memory strategies (Aronov et al., 2015). It is hypothesised that older adults prefer external memory strategies due to their reduced cognitive resources. Specifically, it is hard for older adults to execute high effort, self-initiated encoding and retrieval processes involved in internal memory strategies due to reduced cognitive resources (Anderson & Craik, 2000, as cited by Aronov et al., 2015). Further, a study by Masumoto et al. (2011) also found older adults

substantially lacking in their use of electronic devices as memory aids within external memory aid use.

There has been little research on combined reminders in PM research, with only a few studies mentioning conjunction reminders (a sub-component of combined reminders). An early study by Maylor (1990) highlighted that subjects had the best PM performance when PM tasks were done in conjunction with another routine event. The week-based output method used in this thesis allows for flexibility within participants lives, needing to be done on average 3 times per day for 7 days. This should allow for easy synchronisation of the task within routine activities such as waking, lunch break, and going to sleep or in conjunction with regular mealtimes.

Metacognitive factors have also been examined as a potential influence on the age-PM paradox. Metacognition is particularly relevant to PM and reminder use, as perceptions on the likelihood of successful PM performance will presumably influence the extent to which individuals engage in planning or elaborate encoding for a PM task. Their perceptions of task difficulty, encoding ability and likely success will also influence their perceived need to rely on external methods. Current research suggests that older adults have greater metacognitive awareness than younger adults and that this translates to better prospective memory performance in a naturalistic setting (Schnitzspahn et al., 2011). As such, the relationship between metacognitive abilities (awareness), reminder use, and subsequent PM performance will be examined.

In conclusion, the hypotheses for this study are presented below.

## **5.2 Hypotheses**

1a. Assuming current PM reminder research holds around external reminders, it is predicted that external reminders will be more strongly associated with better PM performance than other reminder strategies.

- 1b. The WBO method's flexibility may lend itself most strongly to combined reminders. If this is the case, then combined reminder use will be more strongly associated with better PM performance than other reminder strategies.
2. Older people will have better PM performance than younger people (because this is a naturalistic setting for PM use).
3. Older people will have better metacognitive awareness (their predicted PM score will be closer to their actual PM score) than younger people.

### **5.3 Exploratory Analyses**

In an article by Tukey (1980), he explained how we need both exploratory and confirmatory analyses to further scientific understanding. This thesis's hypotheses are based on confirmatory analyses. However, as mentioned in the reminder use chapter (Chapter Three) of the literature review, reminder use in PM research is often examined in an overly simplified manner. There are several ways in which reminder use has not yet been examined to influence the age-PM paradox. As such, a large component of this thesis will look to uncover new questions and methods for examining the age-PM paradox in a naturalistic setting.

Initially, as per previous research (Aronov et al., 2015), reminder frequency will also be compared to PM performance. Reminder frequency in this thesis refers to a total frequency with which reminders are used. Given 21 PM opportunities, a survey assessed how often reminders were used on a 5-point Likert scale. The ordinal scores of 19 possible reminders (seven external, six internal, six combined) will be combined to give a total reminder frequency (scoring between 0-95). While examining reminder frequency is more in depth than the binary use/no use method of investigating reminder use's effects on PM performance; examining reminder frequency still neglect several components of reminder use that will be addressed below.

Firstly, digital versus analogue comparisons of reminder use are often neglected in studies of reminder use in prospective memory (Randall, 2016). As digital reminders become more commonplace, it seems relevant to check their use and effects on PM performance between the different age groups. As such within the first follow up survey (see Appendix A), reminders with common digital and analogue options (e.g., using a paper calendar seems similarly popular to using a digital calendar like google calendar) will be examined. Further, the second follow up survey (see Appendix B) will examine digital versus analogue preference and everyday use of different analogue and digital memory aids.

Another component is that in the naturalistic study of reminder use, reminders types (external, internal, combined) are often treated as separate entities used in isolation (e.g., Ihle et al., 2012; Masumoto et al., 2011). However, presumably how they are used together will also influence their effectiveness. For example, tying to life events, a combined reminder, and writing notes, an external reminder, will likely complement each other. This combination of complimentary reminders would likely benefit PM performance more than the sum of the reminders' individual benefits. To examine reminder category interactions, reminder use profiles will be constructed. To create a reminder use profile, reminder use will be split into high or low use (used more or less than sample mean) in each category (external, internal, combined). Having high or low use for the three categories will generate eight possible profiles (e.g., high external use, low internal use, low combined use) which will then be compared to PM performance.

Another possibly important variable in examining reminder use is the subjective utility of the reminders. How useful reminders are perceived to be would likely influence how the reminders are used. For example, if a reminder is perceived as useful, presumably, a person will use that reminder more. Further, suppose older and younger adults have different interpretations of what reminders are more or less useful. In that case, this may bias the use of less useful reminders and therefore impact PM performance (or represent a difference in objective utility for some reminders). Lastly, it

may be the case that believing reminders are more or less useful may impact how useful those reminders are.

Reminder utility will first be examined to see if it influences the frequency with which people use reminders. Secondly, reminder utility will be compared to PM performance. In comparing utility to PM performance, there are several confounds. First of all, creating a sum of utility will be influenced by the number of reminders used. Another problem arises when accounting for the number of reminders used by creating a mean utility score. There will still be an influence of reminder frequency; a reminder used for one button press will contribute as much to mean utility as a reminder used for all 21 button presses. To account for this a reminder utility profile will be constructed, where the mean utility will be artificially split into a dichotomous variable of high or low utility (mean of 2 or less is low, more than 2 is high), as will reminder frequency (higher or lower than the mean reminder frequency for the sample) giving four possible reminder utility profiles.

Following the examination of experimental data for the PM task, data from a separate reminder capacity survey will be used to explore more possible variables contributing to the effects of reminder use in PM performance. Using simple techniques, the reminder capacity survey will examine how participants use reminders in everyday life. Specifically, this examines participants' familiarity with different reminder types, how they feel about digital and analogue reminders, how frequently they use different reminders, how their environment is organised, how much they remember for others, and how collaborative they are in their remembering. The reminder capacity survey will not only be useful in helping to make sense of this studies' results but may also provide some insight into the external validity of the results, seeing if the reminder use in this study is comparable with reminder use outside of the study.

#### **5.4 Participants**

Participants were 69 people from across New Zealand and Australia. Participants were recruited via Facebook community pages, posters in local malls, libraries, retirement homes, and

word of mouth. Participants were required to be between the ages of 19 and 30 or 60 and 75 years of age and to have a smartphone. Additionally, participants were not allowed to participate if they had been diagnosed with dementia, mild cognitive impairment, or had a history of neurological issues that may affect cognition such as a stroke or serious TBI (traumatic brain injury). There were 36 participants for the younger adult group made up of 21 (58.3%) females and 15 (41.7%) males. The average age for this group was 24.6 years old ( $SD = 2.30$  years). For the older adult group, there were 33 participants made up of 28 (84.8%) females and 5 (15.2%) males. The average age for this group was 64.8 years old ( $SD = 4.10$  years). The average number in years of education was 14.42 ( $SD = 2.67$  years) and 16.74 ( $SD = 1.84$  years) for older and younger adults respectively, this difference was statistically significant ( $p < .001$ ). Participants were given a \$10 GiftPay voucher as compensation for completing the study. Prior to the commencement of data collection, a low-risk ethics notification was created that addressed potential ethical issues and how they would be managed. This was then peer-reviewed by an independent reviewer. Afterwards, A low-risk notification was submitted to the Research Ethics Office at Massey University, which was approved prior to data collection. Consent forms were asked to be completed prior to participants starting the experiment. However, a number forgot and gave verbal consent prior to commencement, and later sent through consent forms. This study was also pre-registered on the Open Science Framework ([https://osf.io/d4bzc/?view\\_only=72aa7369986a4491985266c13db925d4](https://osf.io/d4bzc/?view_only=72aa7369986a4491985266c13db925d4)).

There was an initial sign up number of 109 participants who completed the entry survey giving their personal details and indicating their interest in the study. This was supposed to stop at 95 participants as per the pre-registration. However, the data collection occurred over six weeks, and the first two weeks saw 6 participants drop out of 22 people (5 of which were older adults), so more participants were recruited. Some participants found the task to be seemingly too difficult, felt anxious about participating and dropped out, some became busy and felt that they could not prioritise the task and dropped out. This meant that 76 participants went through and completed the task, however, 5 of these participants did not meet the desired cut off PM score of 12. One

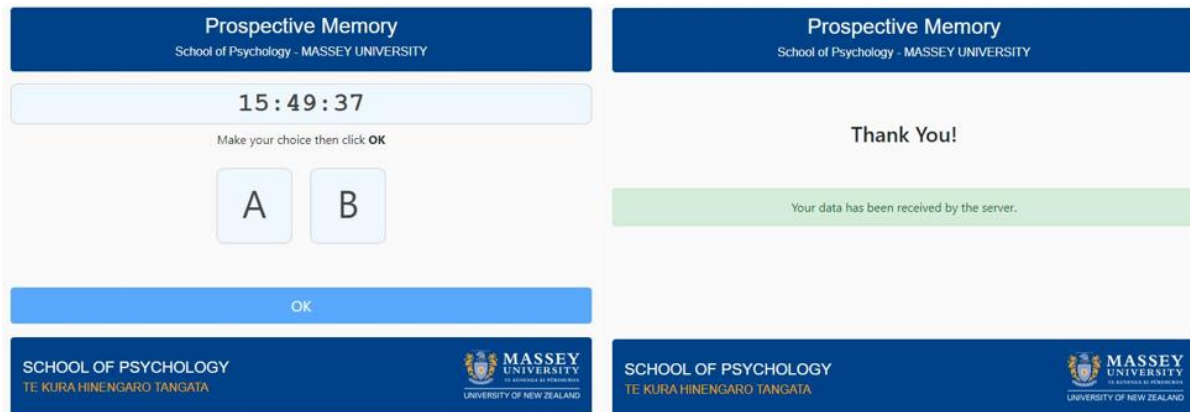
participant also found that her button presses didn't register on the server and one participant forgot to alternate presses and was selectively excluded (this was not specified in the original pre-registration). Ultimately, this left 69 participants. The older adult group was also required to do a cognitive screen called the Test Your Memory (TYM) test during the follow-up call after completing the PM task. To do the TYM tests, after an initial set up call that got their postal address, paper copies of the TYM test were mailed to participants that had instructions telling them to not open the envelope until the organised follow-up call. The cut-off score was set at 42/50 as per the original validation study (Brown et al., 2009) which found this cut off point to have a sensitivity of 93% and a specificity of 86% for detecting mild dementia. All older adults who completed the PM task got a score of 42 or higher. As such, no older adults were excluded from the analysis as a result of the cognitive screen.

## **5.5 Materials**

An online application was created to be accessed via a mobile phone web browser. The task was to press a button on their phone, in the created application, that was either an A or a B, 21 times in the week. The button presses were required to be four hours apart and had to alternate between the A button and the B button (see figure 2). Participants were instructed to use any strategy they wanted, including no strategy, to complete the task outside of having someone else do it for them. Also, if participants accidentally pushed either the wrong button (e.g., A instead of B) or pressed a button too soon, they were told to ignore the press as if it did not happen.

**Figure 2**

*Screenshot of the Web App Interface*



To assess metacognitive awareness, participants estimated their PM performance on a digitised slider that went from 1 through to 21. This estimation was based on the score they may get following the scoring rules described above. The slider given to participants after having the rules explained to them over the phone and reading the information sheet.

The participants also completed two surveys over the phone, a 'reminder use' survey and a 'reminder capacity' survey (see Appendix A and B for full surveys). The reminder use survey consisted of 21 questions that involved first asking for their name and whether they had used any strategy to complete their task other than just expecting to remember when necessary. Following this, participants were asked about the items used in completing a task from a comprehensive list of all the different possible strategies they could use to complete the task. The list was based on Intons-Peterson & Fournier's (1986) categorised memory aid list. This gave six possible external reminders, five possible internal reminders, and 5 possible combined reminders. Each category had an additional 'other' option for reminders that may not be listed. Each question asked how frequently they used each memory reminder, e.g. alarm use, based on a 5-point Likert scale of 0 times, 1-3 times, 4-6 times, 7-12 times, 12-21 times. If the reminder was used, they would also respond to how useful the reminder was on a 4-point Likert scale of not useful, of low usefulness,

moderately useful, highly useful. The 'Reminder Capacity' had 10 different questions examining how they use reminders in everyday life, how organised their spaces are, and whether participants engage in collaborative remembering.

The TYM test cognitive screening tool was guided over the phone. Participants were instructed to open their envelope containing the TYM test, and then place it face up with section asking for their name under the TYM test title. Participants were then given the general guidelines for completing the TYM test over the phone (e.g., answer the questions at your own pace). An additional instruction to the standard procedure was that participants were to notify me before turning over the page. Upon completion, participants were asked to take a photo of both sides of the TYM test and send it through via text or email for scoring.

## **5.6 Procedure**

Data collection was done over six weeks, and the date for setting up the experiment was always on a Saturday. The set-up was done over the phone. Participants would be given their login for a web application that would register which button they pressed (A or B) and the time of the participant's press. Additionally, in the set-up phone call participants would be instructed through a survey getting more personal information (postal address for older adults, if they were going to complete the study in a familiar environment, and the number of years in education) and an estimated score for the task of a total 21 correct button presses (after excluding time errors and AB errors). In addition to verbal instruction and an information sheet, participants were also sent a text with bullet points of essential information for the task after completing the first call. The task then ran from 12:01 a.m. Sunday through till 11:59 p.m. Saturday the following week. Participants were notified that they would not be contacted until the following Sunday morning for a follow-up session, but they may reach out with questions regarding the task.

On Sunday, a follow-up call would consist of two follow-up surveys, one on reminder use and one on reminder capacity. Participants were guided through these surveys over the phone.

Older adults also did the TYM cognitive screen on the Sunday call after completing the first two surveys. During the last three weeks of data collection, the researcher filled out the reminder use survey (instead of the participants filling out the reminder use survey themselves), where each reminder item was read aloud. Participants had pictures of the two response scales (frequency and utility Likert scales, see Appendix A) in front of them and were asked to respond how frequently they used each item (e.g. an alarm) based on the five response options. If they used an item, they were also asked how useful it was from four possible response options. During the first three weeks, the reminder use survey was done by participants while being guided over the phone about the response options. This meant that 24 (72.3%) older adults and 18 (50%) younger adults had a researcher filled out survey. The reminder capacity survey was entirely done by the participants while being guided over the phone. It consisted of 10 questions to further explore participants reminder use, particularly in their everyday life.

Finally, after all the data was collected participants were sent their GiftPay vouchers and asked if they would like to receive a summary of the thesis results.

## Chapter Six

### Results

#### 6.1 Introduction

The current research focuses primarily on contrasting age groups and their reminder use in a digital naturalistic prospective memory (PM) task. The first set of analyses aims to confirm previous research findings about reminder use and metacognition in a naturalistic prospective memory task for younger and older adults. Following initial confirmatory analyses, a series of exploratory analyses, which explore novel ways of studying reminder use for PM tasks, are described. Finally, to help expand further on findings from the confirmatory analyses and previous research, the contents of a separate reminder capacity survey will be analysed. The data were analysed using the Statistical Package for the Social Sciences (SPSS; version 27) software programme.

#### 6.2 Initial Analyses

The use of Multiple Regression analyses requires that certain assumptions are met (Williams et al., 2013). To ensure these assumptions were met a series of analyses were carried out in addition to the multiple regression analyses to ensure multiple regression was a suitable technique to use for the data.

##### 6.2.1 Linearity

The first assumption is that the relationships between the independent variables (IVs) and depend variables (DVs) are linear. To assess this, scatterplots were created for each individual variable in each of the sections in which multiple regression analyses were used. Section 6.3.2 of this section had only binary variables in the analysis and as such already meet the assumption of linearity. Section 6.4.2 had scatterplots of total reminder use, total alarm use frequency, total note-taking use frequency, and total tying to even frequency against PM performance for each group

(older and younger adults) and as a whole sample. All 12 scatter plots appeared to show linear relationships or at least have no obvious curvilinear relationships. Section 6.3.5 also appeared to have linear distributions with each of the variables (External, internal, and combined utility against reminder frequency for sample as a whole and between age groups).

### **6.2.3 Multicollinearity**

The second assumption is that there is no multicollinearity in the data. Multicollinearity is when the independent variables have large correlations between them, which, when present, increases the standard error of the regression coefficients and decreases the  $P$  values (Miles, 2014). The variance inflation factor ( $VIF$ ) and tolerance statistic were used to diagnose for possible collinearity violations. The rule of thumb recommended and used in this analysis was that  $VIF$  was to be not greater than 10 and tolerance should not be less than 0.2 (The Open University, 2021). The assumption of multicollinearity will be discussed in the appropriate sections only if the assumption is violated.

### **6.2.4 Independent Residuals**

The third assumption is that the values of the residuals are independent. To examine if the residuals are independent a Durban-Watson test was used. A Durban-Watson statistic of 2 indicates there is no autocorrelation (autocorrelation occurs when residuals are not independent), generally a Durban-Watson statistic of less than 1 or more than 3 indicate that this assumption is violated and there is an autocorrelation between residuals (The Open University, 2021). Like with multicollinearity this assumption will only be discussed in the appropriate sections if the assumption is violated.

### **6.2.5 Homoscedasticity**

The fourth assumption for the multiple regression analyses is that the variance of the error terms are similar across the values of the independent variables. To assess if this assumption was

violated a plot of standardised residuals against standard predicted values was created and looked at for possible funnelling. If significant signs of funnelling are present on the plot, then the assumption of homoscedasticity is assumed to not be met. This assumption will be discussed in the appropriate sections if violated.

### ***6.2.6 Normality of the Residuals***

The fifth assumption is that the value of the residuals are normally distributed. This was examined through a P-P plot for the models of each multiple regression analysis. Normality was assumed if most of the dots laid close to the diagonal line on the P-P plot. This assumption will be discussed in the appropriate sections if violated.

### ***6.2.7 No Influential Cases Biasing the Model***

The final assumption for the multiple regression analyses was that there were no significant outliers in the analyses that would place undue influence on the models. To examine for any outliers the Cook's Distance statistic was used for each participant. To determine if any data point violated that assumption, it would have to have a Cook's Distance value of greater than 1. This assumption will be discussed in the appropriate sections if violated.

## **6.3 Confirmatory Analyses**

### ***6.3.1 Zero Order Correlations***

To explore the relationships PM performance had with the predictors of age, reminder use, and the use of digital (as opposed to analogue) external reminders, point biserial correlation analyses were carried out. The categorical variables were age group (younger or older age group), external use (external reminder used/no external reminder used), internal use (internal/no internal), combined use (combined/no combined), and digital reminder use (digital reminder/no digital reminder). The analysis of zero order correlations found no statistically significant relationships (see Table 1). Thus, no evidence was found for H1a which predicted a significant relationship between

external reminder use and PM performance with a correlation of  $r(69) = 0.05$  ( $p = .66$ ). Additionally, H1b predicted a significant relationship between combined reminder use and PM performance; again this hypothesis was not supported,  $r(69) = -0.021$  ( $p = .87$ ). There was also no evidence to support H2 which would predict a negative relationship between age group and PM performance,  $r(69) = 0.013$  ( $p = .92$ ).

Digital reminder use did not predict PM performance as can be seen in Table 1 ( $r[69] = .004$ ,  $p = .972$ ). Interestingly, 58% of older adults used digital reminders compared to only 42% of younger adults. It is worth noting, however, that digital reminder use was only assessed for taking notes, calendar use, or if they had another type of external reminder that was digital such as using screenshots, or a reminder app. Digital reminder use was not assessed for alarm usage; this was because there is not a commonly used analogue alarm (analogue here would refer to an alarm without a digital interface), unlike calendars or note taking where both digital and analogue versions are widely used.

Additionally, when looking at zero-order correlations within the age groups separately there was no relationship between reminder use (external/ no external, internal/ no internal, comb/no comb) and PM performance.

**Table 1**

*Zero-order Correlations Between Prospective Memory, Reminder Use, Age Group, and Digital Reminder Use in a Naturalistic PM Task. (Pre-registered)*

|                      | PM Score | Age Group | External Use | Internal Use | Combined Use | Digital Y/N |
|----------------------|----------|-----------|--------------|--------------|--------------|-------------|
| PM Score             | 1        |           |              |              |              |             |
| Age Group            | .013     | 1         |              |              |              |             |
| External Use         | .054     | -.165     | 1            |              |              |             |
| Internal Use         | -.023    | .189      | -.107        | 1            |              |             |
| Combined Use         | -.021    | .100      | -.071        | .023         | 1            |             |
| Digital Reminder Use | .004     | .159      | -.170        | -.024        | .006         | 1           |

\* $p < .05$ .

### 6.3.2 The Effects of Age and Reminder Use on PM Performance

To further examine if either age or reminder use could be used to explain some of the variance in PM performance a two-stage hierarchical multiple regression analysis was conducted in addition to the previous correlation analysis (see Table 2). The two step hierarchical multiple regression analysis shows that age as a predictor of PM performance was negligible ( $R^2 = .015$   $p = .92$ ) with the addition of reminder type (external, internal, combined) also proving to be negligible predictors of PM performance ( $R^2 = .058$ ,  $p = .97$ ). These results show that age cannot explain any of the variance in PM performance, and neither can the use of internal, external, or combined reminder use. As a result, this data further supports the null hypothesis for hypotheses 1a, 1b, and hypothesis two.

**Table 2**

*Hierarchical Multiple Regression Analysis of Age and Reminder Use as Predictors of PM Performance (Pre-registered)*

| Model                                | R    | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics |          |     |     |               |
|--------------------------------------|------|----------|-------------------|----------------------------|-------------------|----------|-----|-----|---------------|
|                                      |      |          |                   |                            | R Square Change   | F Change | df1 | df2 | Sig. F Change |
| 1. Age                               | .013 | .000     | -.015             | 2.509                      | .000              | .011     | 1   | 67  | .917          |
| 2. Age, External, internal, Combined | .065 | .004     | -.058             | 2.562                      | .004              | .088     | 3   | 64  | .967          |

(Constant) = Dependent Variable: PM score

### 6.3.3 The Effects of Age on Metacognitive Performance

Metacognitive awareness can influence a person's ability to allocate appropriate resources making it highly relevant to both reminder use and PM performance. To examine the differences in metacognitive awareness a 'metacognitive accuracy' score was calculated by taking their actual

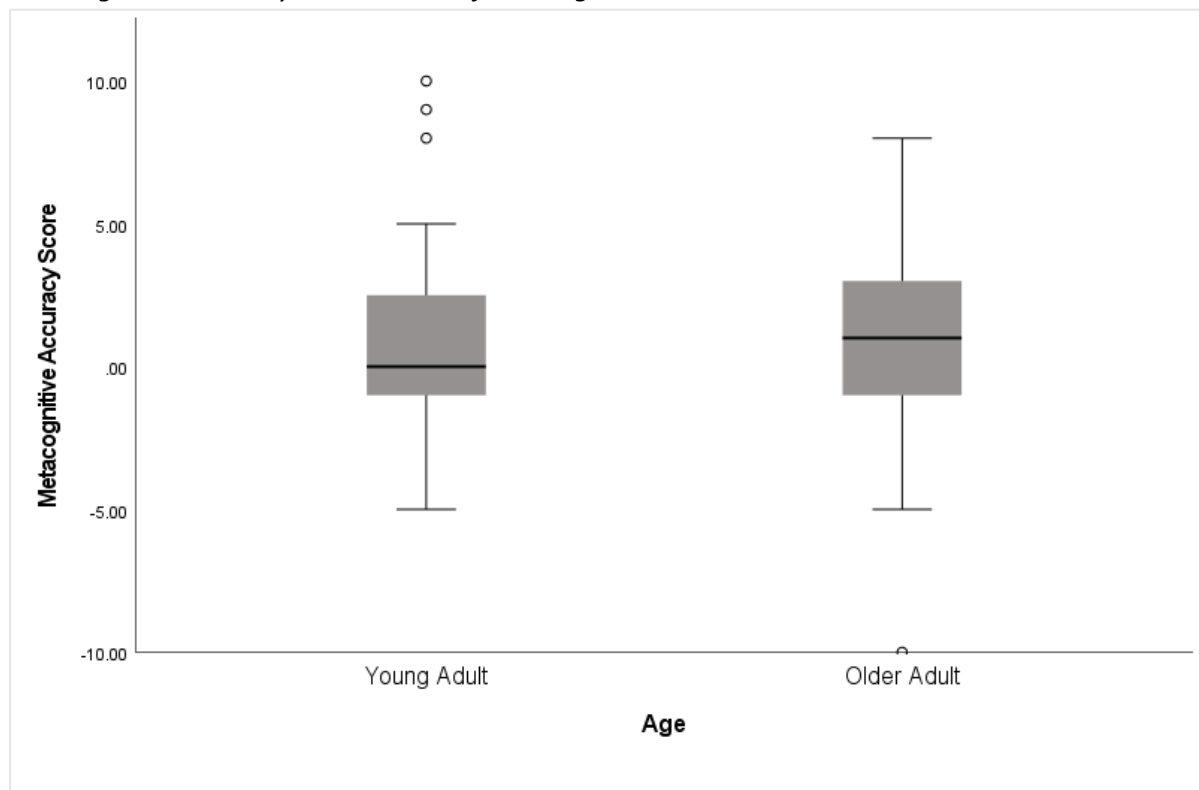
score and subtracting their predicted score (so a positive score indicates underestimation of performance and a negative score indicates overestimation of performance). Both groups on average skewed towards underestimating their performance on the task (younger adults and older adults had a mean metacognitive accuracy score of  $0.75 \pm SD 3.40$  and  $0.52 \pm SD 3.77$  respectively), with only 28% and 36% of younger and older adults respectively overestimating their PM performance. Interestingly exactly one third of the younger adult group perfectly predicted their PM score, with three outlier participants who substantially underestimated their performance. The older adults on the other hand had 24.24% of the participants perfectly predict their PM score and one outlier who overestimated PM performance (see figure 3.). Outliers were included as the participants met the criteria for inclusion as set out in the pre-registration. To determine the difference between older and younger adults' metacognitive awareness an independent means  $t$ -test<sup>1</sup> was carried out. The independent  $t$ -test showed that the metacognitive awareness difference between the age groups was not significant ( $t_{67} = .272, p = .786$ ). Therefore, hypothesis three which predicted that older adults would have superior metacognitive awareness to younger adults was not supported.

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<sup>1</sup> In the pre-registration this test was mistakenly labelled as being a dependent means  $t$ -test.

**Figure 3**

*Metacognitive Accuracy Score Box Plot for Younger and Older Adults*



### **6.3.4 Metacognitive Awareness and Offloading**

To examine if metacognitive awareness may affect offloading, three linear regression analyses were carried out comparing total reminder use frequency with the metacognitive awareness of sample (for the whole sample, for younger adults only, and for older adults only). The results of these regression analyses (see Appendix D) shows that for the sample as a whole, metacognitive awareness did not explain any of the variance,  $R^2 = .015$ ,  $F(1, 67) = 2.06$ ,  $p = .156$ . For younger adults metacognitive awareness did not explain any of the variance in reminder use frequency  $R^2 = -.027$ ,  $F(1, 34) = .088$ ,  $p = .769$ . For older adults metacognitive awareness explained 8.6% of the variance in reminder use frequency,  $R^2 = .086$ ,  $F(1, 31) = 4.01$ ,  $p = .054$ . According to Becker (2000) an  $R^2$  of .086 is the equivalent to between a medium and large effect size (equivalent

to a Cohen's  $d$  of just above 0.6). Despite the effect size of metacognitive awareness influencing offloading in older adults, none of the regression analyses reached statistical significance ( $p < .05$ ). So, while nothing can be said conclusively about the effect of metacognitive awareness on offloading for older adults, these results do provide support for future studies with larger sample sizes to investigate this potential relationship.

### **6.3.5 Metacognitive Awareness and PM Performance**

Theoretically, older adults may find greater benefit than younger adults from metacognitive abilities because metacognitive strategies are associated with greater activation of brain areas involved in spontaneous retrieval, decreasing the demand on the more limited cognitive resources of older adults performing PM tasks (Walter & Meier, 2014). To determine if there were age-related effects for the relationship between metacognition and PM performance, two regression analyses were carried out comparing metacognitive accuracy scores and PM performance (see Appendix D). In line with the theory explained above, metacognitive awareness scores in older adults explained 22.5% of the variance in PM performance,  $R^2 = .225$ ,  $F(1, 31) = 10.31$ ,  $p = .003$ . In comparison, younger adult's metacognitive awareness scores predicted less than 1% of the variance,  $R^2 = .003$ ,  $F(1, 34) = 0.12$ ,  $p = .732$ . This result means that while older adults' metacognitive abilities may not be better than younger adults, metacognitive awareness in older adults is substantially more important for successful PM performance. According to Becker (2000) an  $R^2$  of .225 is the equivalent to a Cohen's  $d$  of approximately 1.1 (the exact  $R^2$  for a Cohen's  $d$  of 1.1 is .232) which is above a large effect size (which would be a Cohen's  $d$  of 0.8). Effect sizes this large are extremely uncommon in psychological research, to a point where this result should be interpreted cautiously (Funder & Ozer, 2019). However, the size of this effect also offers lots of promise for understanding PM and the age-PM paradox in future research.

## 6.4 Reminder Use

### 6.4.1 Reminder Use Descriptive Statistics

The number of different types of reminder (out of a possible 19) as well as the total frequency with which those reminders were used (totalled from 5-point Likert scale per reminder) are displayed in Table 3. Independent *t*-tests found that the only statistically significant difference between younger and older adults was the total number of different types of reminders used (younger adults,  $M = 5.00$ ,  $SD = 1.67$ , older adults  $M = 4.18$ ,  $SD = 1.49$ ,  $t_{67} = 2.138$ ,  $p = .036$ ). As an average, there was 0.818 more reminders used by younger adults when compared to older adults (i.e., younger adults in this sample used approximately 20% more types of reminder). However, independent *t*-tests comparing total reminder use frequency were not significantly different ( $t_{67} = .750$ ,  $p = .456$ ) indicating that while more types of reminder were used by younger adults ( $M = 19.53$ ,  $SD = 6.05$ ), they were used fewer times than the reminders used by older adults ( $M = 18.36$ ,  $SD = 6.84$ ), so the total frequency with which reminders were used was not significantly different between younger and older adults.

**Table 3***Descriptive Statistics for Reminders Used by Younger and Older Adults in Naturalistic PM Task*

|                                   | Younger Adult |                | Older Adult |                | Total |                |
|-----------------------------------|---------------|----------------|-------------|----------------|-------|----------------|
|                                   | Mean          | Std. Deviation | Mean        | Std. Deviation | Mean  | Std. Deviation |
| Total Reminder Frequency          | 19.53         | 6.05           | 18.36       | 6.84           | 18.97 | 6.42           |
| Total External Reminder Frequency | 8.44          | 3.18           | 9.39        | 4.42           | 8.90  | 3.82           |
| Total Internal Reminder Frequency | 4.94          | 3.60           | 4.03        | 3.85           | 4.51  | 3.72           |
| Total Combined Reminder Frequency | 6.14          | 3.58           | 4.94        | 3.53           | 5.57  | 3.58           |
| Number of Reminders               | 5.00          | 1.67           | 4.18        | 1.49           | 4.61  | 1.63           |
| Popular reminders used            |               |                |             |                |       |                |
| Frequency of Alarm Use            | 2.92          | 1.86           | 3.27        | 1.96           | 3.09  | 1.90           |
| Frequency of Note taking          | 3.22          | 1.85           | 3.52        | 1.91           | 3.36  | 1.87           |
| Frequency of Tying to Event       | 3.19          | 1.65           | 3.06        | 1.92           | 3.13  | 1.77           |

*Note.* The reminder frequency is based on the sum of ordinal responses in the reminder use survey asking about the frequency of reminders use (see Appendix A) from 1 – not used, through to 5 – 21+ times used. This was averaged across participants for popular reminders and averaged across reminder categories for each type (external, internal, combined) which included seven possible external reminders, six possible internal reminders, and six possible combined reminders.

**6.4.2 Reminder Use and PM Performance**

The confirmatory section of this result section, in line with previous research (e.g. Masumoto et al., 2011), examined reminder use and PM performance by making the use of reminder types a dichotomous variable (used or not used). To examine this relationship between reminder use and PM performance further three multiple regression analyses were carried out looking at how the of frequency of reminder use impacted PM performance (for older adults, younger adults and the sample as a whole). Additionally, to see if some specific reminders impacted PM performance three of the most popular reminders (alarm use, note taking, tying to events) were

also compared to PM performance in the same multiple regression analysis. As can be seen in Table 4, there were no significant relationships (for model summaries see Appendix C). This means that frequency of reminder use and the frequency with which the most popular reminders were used does not significantly predict PM performance. The analysis was going to use both the frequency and also the number of reminders used (see Table 4 for descriptives). However, having both of these measures together in the analysis violated the assumption that there is no multicollinearity in the data. As such the number of reminders was excluded as it is the less accurate measure of reminder use frequency.

**Table 4**

*Simultaneous Regression Analysis of Reminder Use Against PM Performance for the Whole Sample, Younger Adults, and Older Adults*

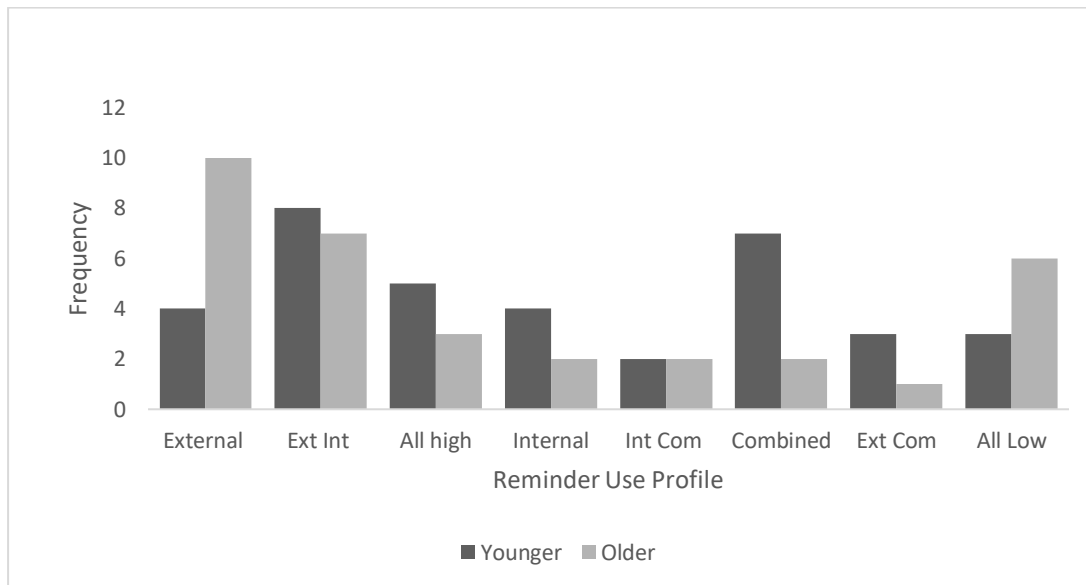
|                       | Unstandardized Coefficients |            | Standardized Coefficients |        | 95.0% Confidence Interval for B |             |             |
|-----------------------|-----------------------------|------------|---------------------------|--------|---------------------------------|-------------|-------------|
|                       | B                           | Std. Error | Beta                      | t      | Sig.                            | Lower Bound | Upper Bound |
| <b>Both Groups</b>    |                             |            |                           |        |                                 |             |             |
| (Constant)            | 19.409                      | 1.032      |                           | 18.809 | .000                            | 17.347      | 21.470      |
| Total Reminder Use    | .022                        | .055       | .057                      | .403   | .688                            | -.088       | .133        |
| Alarm Use             | -.409                       | .645       | -.082                     | -.635  | .528                            | -1.698      | .879        |
| Note-Taking           | -.111                       | .657       | -.022                     | -.169  | .866                            | -1.423      | 1.201       |
| Tying to Event        | -1.254                      | .722       | -.244                     | -1.736 | .087                            | -2.697      | .189        |
| <b>Younger Adults</b> |                             |            |                           |        |                                 |             |             |
| (Constant)            | 18.793                      | 1.533      |                           | 12.256 | .000                            | 15.734      | 21.986      |
| Young Total RU        | .036                        | .084       | .089                      | .428   | .672                            | -.153       | .544        |
| Young Alarm           | -.640                       | .891       | -.132                     | .531   | .478                            | -2.505      | 1.129       |
| Young Note-Taking     | .456                        | .858       | .094                      | -.953  | .599                            | -1.260      | 2.237       |
| Young Tying to Event  | -1.027                      | 1.078      | -.197                     | 12.256 | .348                            | -3.047      | 1.418       |
| <b>Older Adults</b>   |                             |            |                           |        |                                 |             |             |
| (Constant)            | 20.141                      | 1.592      |                           | 12.651 | .000                            | 16.880      | 23.402      |
| Old Total RU          | .053                        | .088       | .140                      | .597   | .555                            | -.128       | .234        |
| Old Alarm             | -.759                       | 1.155      | -.146                     | -.890  | .516                            | -3.124      | 1.606       |
| Old Note-Taking       | -1.178                      | 1.323      | -.218                     | -1.708 | .381                            | -3.889      | 1.532       |
| Old Tying to Event    | -1.923                      | 1.126      | -.373                     | 12.651 | .099                            | -4.228      | .383        |

### **6.4.3 Reminder Use Profiles**

As an alternative to the standard method of analysing reminder use and PM performance (through frequency, number of reminders used, or reminder categories), reminder use profiles were constructed by splitting the sample into high use or low use for each of the three reminder use types (for a more detailed explanation see section 5.3). Reminder use profiles, unlike standard methods of analysis, examines participant reminder use as a whole (meaning interaction effects between reminder categories are not neglected). Because of the subsequent distribution of profiles and the sample size of this study, there was insufficient data to carry out inferential statistics as per pre-registration (for descriptive statistics, see Appendix E). While the relationship between the reminder use profiles and PM could not be examined, the distribution of the reminder use profiles between younger and older adults is displayed in Figure 4. This distribution shows while comparable for the most part, older adults tended to be higher in external reminder use with less aid from internal and combined reminders than younger adults. Where younger adults were high in combined reminder use and low in external and internal reminder use compared to older adults.

**Figure 4**

*Reminder Use Profile Distribution Between Younger and Older Adults*



*Note.* The labels given to the reminder use profile on the X-axis are stating what reminder was of above average use for the category based on reported frequency (the other reminder types will be below average if not listed). Additionally, ext means external, int means internal, and com means combined reminders.

## 6.5 Reminder Utility

Reminder utility is how useful the participants found the reminders that they used. This has not been investigated before in age-PM paradox research but may influence PM performance both generally and within age groups. To calculate the average utility for each of the groups, those that used reminders had their reminder utility total for each category averaged. Regarding the total mean utility rating, this was the average utility of the categories that were used (45 participants used all three categories, 21 participants used only two reminder categories, and 3 participants only used one category of reminders).

### 6.5.1 Age Differences in Reminder Utility

To examine the effects of age on the perceived utility of reminders independent *t*-tests were carried out to establish whether there were age group differences in the average utilities for reminders and reminder types (external, internal, combined). Of the differences displayed below in

Table 5 none were found to be significant at  $p < .05$  (see Appendix F). This means that younger and older adults did not differ in their perceptions about how useful reminders were.

**Table 5**

*Perceived Utility of Reminders Descriptive Statistics for Younger and Older Adults*

|                  | Group       | N  | Mean | Std. Deviation |
|------------------|-------------|----|------|----------------|
| Mean utility     | Young Adult | 36 | 3.18 | 0.54           |
|                  | Older Adult | 33 | 3.37 | 0.64           |
| External utility | Young Adult | 35 | 3.52 | 0.56           |
|                  | Older Adult | 32 | 3.50 | 0.66           |
| Internal utility | Young Adult | 29 | 2.71 | 0.93           |
|                  | Older Adult | 22 | 3.11 | 1.00           |
| Combined utility | Young Adult | 32 | 3.39 | 0.64           |
|                  | Older Adult | 27 | 3.38 | 0.83           |

**6.5.2 Reminder Utility and Reminder Frequency**

The effects of reminder utility on the frequency of reminders were analysed using multiple regression analyses. The results indicated that there are no significant relationships between the utility of reminders and the frequency with which they are subsequently used (See Appendix F). This means that for the whole sample, as well as for the individual age groups, the subjective utility of reminders generally does not significantly predict reminder use frequency. In the older adult multiple regression analysis, there was a violation in the assumption that the values of the residuals are independent. The Durban-Watson statistic for the older adult reminder use against external, internal, and combined utility was 0.88 indicating a positive autocorrelation. As such results from that section of the analysis (bottom section of Table F1 in Appendix F) should be interpreted with caution.

**6.5.3 Reminder Utility and PM Performance**

The effects of perceived utility of reminders on PM performance was also explored in a simple correlation analysis between groups, as well as within groups. There was no correlation between PM performance and reminder utility found in the sample as a whole or within the younger adult group (see Appendix F). However, there was a significant negative correlation ( $r(33) = -.470, p = .027$ ) for the older adult group between perceptions of internal utility and PM performance, suggesting that the less older adults perceived internal reminders to be useful, the greater their PM performance. This is the only value of significance within the older adult group (see Table 6); mean utility was not correlated with PM performance.

**Table 6**

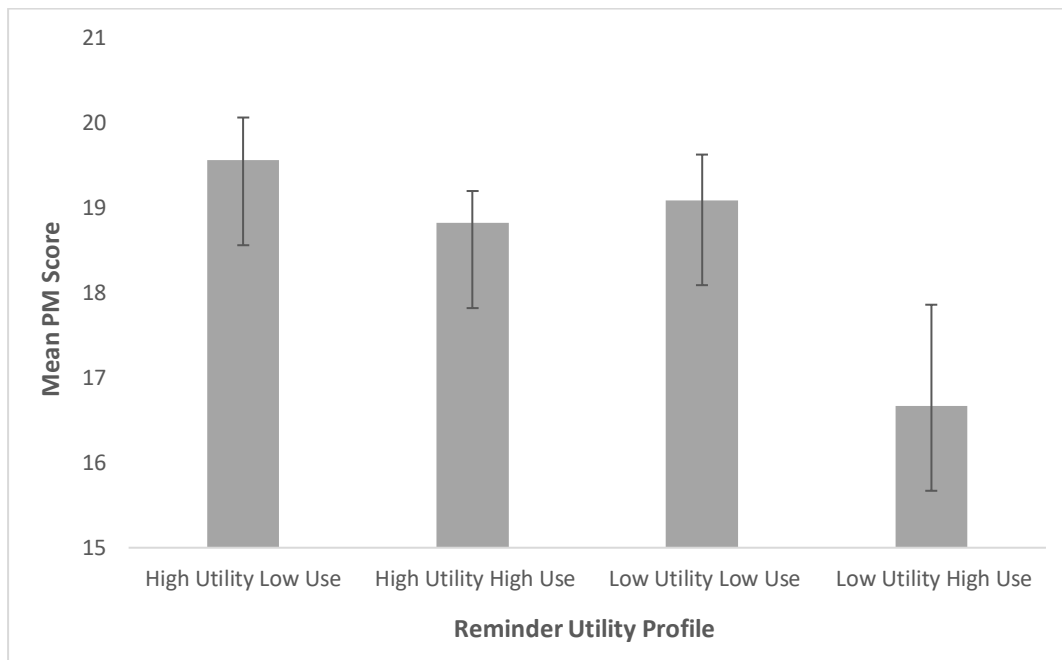
*Older Adult Correlations Between PM Performance and the Utility of Reminder Types*

|                            |                                   | Old external utility | Old internal utility | Old combined utility | Old mean utility |
|----------------------------|-----------------------------------|----------------------|----------------------|----------------------|------------------|
| Older Adult PM Performance | Pearson Correlation               | -.140                | -.470*               | .111                 | -.170            |
|                            | Sig. (2-tailed)                   | .444                 | .027                 | .581                 | .352             |
|                            | Sum of Squares and Cross-products | -7.500               | -29.106              | 6.611                | -8.211           |
|                            | Covariance                        | -.242                | -1.386               | .254                 | -.265            |
|                            | N                                 | 32                   | 22                   | 27                   | 32               |

#### **6.5.4 Reminder Utility Profiles and PM Performance**

As discussed in section 5.3, a reminder used for one button press will contribute as much to mean utility as a reminder used for all 21 button presses; meaning that reminder use frequency confounds with reminder utility. To account for this groups were split into high or low use based on whether they used more or less than the mean frequency of reminders in the sample (reminder frequency greater than 18.97). Then, groups were split into high or low utility. The utility scale (see Appendix A) went, 1 – not useful, 2 – of low usefulness, 3 – moderately useful, and 4 – highly useful. The sample had a mean utility was 2.83 indicating a possible bias (e.g., social desirability bias

towards saying reminders were useful to seem more competent in their choice of reminders) and a negative skew of the data. A clear rationale for the high/low utility split was that options 1 and 2 on the utility scale were saying a reminder was below average usefulness, and options 3 and 4 were saying reminders were above average usefulness. However, when splitting the low category as equal to or less than 2 (as per pre-registration), the negatively skewed mean utility distribution resulted in only two participants that met the criteria for the 'low utility high reminder use' category. To spread participants more evenly between the groups (reminder utility profiles) the high/low utility categories were done like reminder frequency and based off being higher or lower than the sample mean of 2.83. Notably this is why the analysis is different to what was suggested in the pre-registration. Further, the initial analysis declared in the pre-registration was a one-way ANOVA; however, a Levene's test for assessing the homogeneity of variance was carried out and showed that the variances between reminder utility profile groups were not equal,  $F(3,65) = 5.34, p = .002$ . So, instead of a one-way ANOVA a Kruskal-Wallis H test was carried out. The Kruskal-Wallis H test showed that there was not a statistically significant difference in PM scores between the different external reminder use groups in everyday life,  $\chi^2(3) = 4.774, p = .189$ . In Figure 5 the data appears to show that the 'Low Utility High Use' group has the worst PM performance with a mean substantially less than the other groups ( $M = 16.67$  compare to  $M = 19.56$  for High Utility Low Use,  $M = 18.82$  for High Utility High Use, and  $M = 19.09$  for Low Utility Low Use). However, it is important to note this difference in mean scores was not significant ( $p > .05$ ).

**Figure 5***Mean PM Scores for Reminder Utility Profiles*

## 6.6 Reminder Capacity Survey Results

The reminder capacity survey (see Appendix B) looked at reminder use in the everyday life of participants outside of the experiment. The survey allows for comparisons between naturalistic reminder use in the assessment of PM and real-life reminder use; allowing for some insight into the ecological validity of examining reminder use through the WBO method used in this study. Additionally, the reminder capacity survey investigates components beyond reminder use such as the organisation of people's spaces which may further explain some of the patterns of data presented above.

### 6.6.1 Everyday Use of External Reminders

The first question on the reminder capacity survey examined how frequently people used external reminders in their everyday life, the 5-point ordinal scale was broken into: never, 1-2 times per month, 1-3 times per week, 1-2 times per day, or 3+ times per day. A Kruskal-Wallis H test showed that there was not a statistically significant difference in PM score between the different

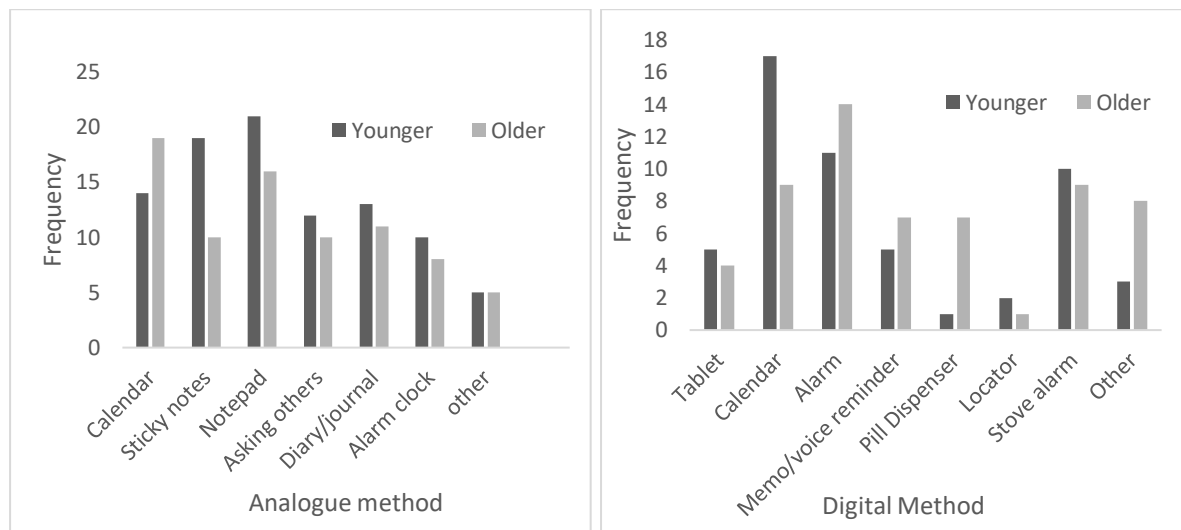
external reminder use groups in everyday life,  $\chi^2(3) = .632, p = .889$ . This means that how often people tend to use external reminders in real life does not impact their naturalistic PM performance. Interestingly, when doing another Kruskal-Wallis H test for comparing everyday external reminder use frequency and experimental external reminder use frequency there was also no significant difference,  $\chi^2(3) = 4.95, p = .175$ . This result means that how frequently someone tended to use external reminders in an everyday setting does not appear to affect reminder use frequency in experimental PM tasks. However, it should be noted that the mean of the responses on this question was 3.94 on a 5-point scale ( $SD = 1.03$ ), with no person in the sample responding with never, and only six people stating they use reminders 1-2 times per month. Because of the negative skew in the distribution in response to this question, conclusions should be made cautiously.

### **6.6.2 Digital and Analogue Preference and Everyday Use**

Question 2a on the reminder capacity survey examined what participants preferred method of external reminder was, either digital or analogue. For older adults 42.4% preferred analogue methods and 57.6% preferred digital. For younger adults 13.9% preferred analogue and 86.1% preferred digital. Subsequently question 2b asked how satisfied they were with the preferred method of reminder on a 4-point Likert scale from not satisfied through to very satisfied. Older adults ( $M = 3.55 \pm 0.56$ ) responded similarly to younger adults ( $M = 3.41 \pm 0.65$ ) showing both groups were between moderately and very satisfied with their preferred reminders.

**Figure 6**

*Self-Reported Frequency of Analogue and Digital Reminder Use in Everyday Living for Younger and Older Adults*



*Note.* Smart phone was excluded as a digital method of reminder use as all participants in both groups had used a smart phone as a reminder.

Question three on the reminder capacity survey asked what analogue reminder methods participants use regularly. The results of question three were that younger adults said that they regularly used more forms of analogue reminders than older adults, though this difference was not statistically significant ( $M = 2.61$   $SD = 1.74$  and  $M = 2.33$ ,  $SD = 1.24$  respectively,  $p = .453$ ). Additionally, results from question six found that on average older adults had used slightly more digital reminder devices than younger adults, again this result was not statistically significant ( $M = 2.73$ ,  $SD = 1.376$  for older adults, and  $M = 2.47$ ,  $SD = 1.320$  for younger adults,  $p = .435$ ). Both results are surprising given the grey divide in digital technology use and the stated preference of only 13.9% of younger adults preferring analogue reminders compared to 42.4% in older adults. For the comparative distribution of analogue and digital reminder use in younger and older adults see Figure 6. Additionally, Table 7 shows that the frequency with which younger and older adults use these reminders does not correlate with their PM performance on the naturalistic PM task.

### **6.6.3 Collaborative Remembering and PM**

Question five examined collaborative remembering, finding that 27.78% of younger adults had someone that aided regularly in prospective remembering; in the older adult group this percentage was 45.45%. To compare PM performance for those who engage in collaborative remembering with those who do not an independent  $t$ -test was carried out which found no significant difference in PM performance between the groups ( $t(67) = -.79, p = .432$ ). When it came to remembering tasks and events for others the scale was scored on a 5-point Likert scale from never, 1-2 times per month, 1-3 times per week, 1-2 times per day, 3+ times per day. Younger and older adults had means of  $3.25 \pm 1.25$  and  $3.06 \pm 1.12$  respectively which was not a significant difference ( $p = .511$ ). On average both younger and older adults remembered tasks or events for others approximately 1-3 times per week. A Kruskal-Wallis H test showed that there was not a statistically significant difference in PM score for those who remember more or less for other people ( $\chi^2(2) = 1.324, p = .857$ ).

#### **6.6.4 Knowledge of Internal Remembering Methods**

Question 7a and 7b presented a series of internal reminders (see Appendix B) in which participants would first respond to whether or not they had heard of these internal remembering methods (question 7a), followed by whether they had practiced and previously used these methods (question 7b). Younger adults in the sample were aware of and used more internal remembering methods than older adults (aware of,  $M = 6.50, SD = 1.72$  compared to older adults  $M = 5.88, SD = 2.03$ , and used  $M = 4.667, SD = 1.64$  for younger adults compared to  $M = 4.18, SD = 1.53$ ) though this difference was not statistically significant (aware of,  $t_{67} = 1.27, p = .173$ , used,  $t_{67} = 1.38, p = .210$ ).

#### **6.6.5 Organisation of Personal Spaces and PM**

Question nine of the reminder capacity survey assessed how organised participants were (i.e., how much structure and thought goes into organising the personal aspects of their spaces). When spaces are more organised, they may ease the complexity usually associated with interacting within that environment and can provide external mechanisms to ease cognitive load. There was no difference between younger and older adults organisational scores ( $M = 9.83$ ,  $SD = 1.66$  and  $M = 9.91$ ,  $SD = 1.26$  respectively) totalled from three 4-point Likert scales asking how organised their house, workspace, and bedroom are. When compared to PM performance, total organisation standardised regression coefficient  $\beta = .21$ , was not significant ( $p = .087$ ).

**Table 7**

*Simultaneous Regression Analysis of Reminder Capacity Survey Data Against Prospective Memory Performance*

|                       | Unstandardised Coefficients |            | Standardised Coefficients<br>Beta | t      | Sig. | 95.0% Confidence Interval for B |             |
|-----------------------|-----------------------------|------------|-----------------------------------|--------|------|---------------------------------|-------------|
|                       | B                           | Std. Error |                                   |        |      | Lower Bound                     | Upper Bound |
| (Constant)            | 14.978                      | 2.299      |                                   | 6.514  | .000 | 10.386                          | 19.570      |
| Total organisation    | .359                        | .206       | .212                              | 1.737  | .087 | -.054                           | .771        |
| Everyday analogue use | -.237                       | .199       | -.145                             | -1.190 | .238 | -.634                           | .161        |
| Everyday digital use  | .306                        | .230       | .165                              | 1.332  | .188 | -.153                           | .766        |

## Chapter Seven

### Discussion

To reiterate previous chapters, past research suggests that either external or combined reminder use, and not internal remembering strategies improves PM performance (Maylor, 1990; Masumoto et al., 2011). In line with previous age-PM paradox research, older adults should have superior PM performance on the task, given the naturalistic setting in which the experimental task occurred (Niedźwieńska et al., 2013; Schnitzspahn et al., 2018). As a possible contributor to the superior performance in PM (potentially through greater reminder use), it was also predicted that older adults would have superior metacognitive awareness (Schnitzspahn et al., 2011). None of these hypotheses were supported. Reminder categories did not predict and of the variance in PM scores, older adults had similar PM performance to younger adults, and metacognitive awareness was equal between both age groups.

While confirming previous research is important, this thesis also sought to do exploratory data analysis within the domain of reminder use and prospective memory. The method used to explore reminder use in PM is based on that used by Masumoto et al. (2011).

Harris (1980) found that when participants responded to a list of external memory aids they reported extensive use of address books, telephone books, and birthday books, but when openly asked how they remember birthdays or addresses, very few responded that they used these reminders at all. Resultantly, Harris (1980) stated that there is significant retrieval failure in the recall of memory tools when openly asking what aids were used. So, to ascertain all possible reminders and memory aids used in this study, participants filled out a comprehensive list of possible reminders for the task. This list was based on Intons-Peterson and Fournier's (1986) memory aid list and adapted to the task because of its superior detail when compared to the categories listed in

Masumoto et al. (2011). In addition to enumerating the reminders used to confirm previous findings in age-PM paradox research (such as Ihle et al., 2012), this study assessed the frequency of reminder use. Further, this study also assessed metacognitive awareness. In addition to previous reminder use measures, new variables were also explored, and participants were asked how useful the reminders they used were. To look for other possible patterns or explanations related to reminder use and to relate findings from the reminder use survey (Appendix A) in greater depth to the extended and embodied cognition, everyday components of reminder use were also examined. This examination included questions on organisation, reminder preferences, collaborative remembering, and everyday use of various digital and analogue methods.

This chapter examines the findings of the current study related to previous research involving metacognition, reminders, and the age-PM paradox. After examining the data using traditional methods, alternate methods of investigating reminder use in PM will then be reviewed in the order they are presented in the previous section. Finally, this discussion will cover the limitations of the current research and recommendations for future research.

## **7.1 Discussion of Confirmatory Analyses**

### ***7.1.1 Age Differences in Naturalistic PM Performance***

The confirmatory analyses were examined in two parts, and both analyses indicate that older and younger adults do not differ in naturalistic PM performance in this task. General laboratory results for PM indicate that performance decreases sharply after 60 years of age (Uttl, 2008); the purpose of using an older adult group that was older than 60 was to show that despite the age-related decline in brain-based cognitive resources, a naturalistic context shows that PM as a memory domain may be spared. Finding no significant difference between age groups is not quite as significant as positive ageing effects as it is in line with the original multi-process theory as put forward by McDaniel and Einstein (2000) and does not contribute to the possibility of older adults using environmental and compensatory supports to enhance switching between monitoring and

spontaneous retrieval (as per the dynamic multiprocess model by Scullin et al., 2013). Further, older adults may have been disadvantaged due to the method using an experimenter-generated PM task, which have been reported less frequently as having positive age effects compared to real-life self-assigned PM tasks (Schnitzspahn et al., 2018). This disadvantage for older adults in experimenter-generated PM tasks may be due to the increased requirements for brain-based cognitive resources used in adapting to a novel task which would lessen as a task becomes more habitual (Meier et al., 2014). However, the finding from this study still functions to support the theory that age-related declines in PM performance may be spared in older adults through a distributed cognitive system.

### ***7.1.2 Reminder Types as Predictors of PM Performance***

Previous studies have looked to see if memory aids are beneficial for PM performance and if so, what type of memory aid (usually broken into only internal or external categories, e.g., Masumoto et al., 2011) may be most beneficial for PM performance. This study found that none of the reminder types predicted PM performance. At a basic level, this finding is significant as it does not support previous findings that external strategies are related to greater PM performance (Aronov et al. 2015, Masumoto et al. 2011; Scarpia & Gilbert, 2019), or Maylor's (1990) findings that supported combined reminder use as a predictor of greater PM performance. However, these findings may be argued to be inconsequential as the confirmatory method of analysis used (involving a categorical comparison of reminder types and PM performance) does not consider several intricacies involved in the complex relationship reminder use has with PM as highlighted in Chapter Four of this thesis. For example, this method does not take into account how extensively used the memory aids were - using external reminders could constitute a participant using an alarm once, or a participant could use a note-taking system, a calendar, alarms, and ask someone else to remind them for each of the 21 presses. Additionally, this method of examination ignores interaction effects between reminder use categories and the contextual appropriateness of individual reminders for the

specific task (i.e., external reminders may better suit some PM tasks than internal reminders, but this may not be the case in other PM tasks).

### **7.1.3 Metacognitive Awareness**

Analysis two found that there were no significant differences in metacognitive awareness between younger and older adults. This finding is not in line with previous evidence, which indicated that older adults have greater metacognitive awareness in a naturalistic context (Schnitzspahn et al., 2011). This finding is especially important as Schnitzspahn et al. (2011) is the only other study comparing younger and older adults' metacognitive awareness in a naturalistic setting. Furthermore, both age groups in this study were quite accurate. As an average, both group's estimations were within one point of their PM score with a slight bias towards underestimating their performance on the task (though only by a mean score difference of 0.75 and 0.52 for younger and older adults respectively between the groups estimated and actual PM scores). However, at an individual level, both groups had participants who greatly under- or over-estimated their scores (see Figure 3). Cauvin et al. (2019) did examine the predictions of younger adults in a naturalistic setting and found that they tended to be overconfident in a naturalistic setting in contrast to the current study. Conversely, Devolder et al. (1990) show that older adults tend to underestimate their abilities. When relating this to theory, there are a few points to note: firstly the current task was a digital PM task done on a smartphone, which may have influenced the perception of certain older adults who did not feel confident in their digital literacy<sup>2</sup>. Secondly, this task was quite high demand with a higher prospective load when compared to Schnitzspahn et al. (2011), which had six PM opportunities compared to the 21 in this study. This higher demand may have biased participants towards under confidence. Thirdly, this was an experimenter given task, which may seem foreign when compared real-life naturalistic PM tasks (where older adults have more experience, which may contribute to

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<sup>2</sup> Several older adults explicitly mentioned (in passing) that they were not very capable or confident with digital technology.

previous findings of greater metacognitive awareness in this group compared to younger adults). Lastly, the metacognitive score was assessed as a post-error score (number of presses minus any incorrect presses), which means the retrospective component of remembering the correct button (A or B) may also be factored into evaluating their performance. These factors listed may account for the lack of difference in metacognitive abilities in younger and older adults.

#### ***7.1.4 Metacognitive Awareness and PM performance***

The most substantial finding of this study came when looking for age-based effects of metacognitive awareness in naturalistic PM performance. Discussed previously in Section 3.4.5 of this thesis, it was assumed based on previous evidence discussed by Walter and Meier (2014) that greater metacognitive awareness would be present in older adults as it allows for enhanced spontaneous retrieval and less monitoring (which is cognitively demanding). However, it was not the case, as shown above that metacognitive awareness was favoured in older adults. Instead, there was an age-based effect where metacognitive awareness predicted PM performance in older but not younger adults. This result's strength was quite impressive with 22.5% of the variance in PM performance explained by older adults' metacognitive awareness, and .3% of the variance in PM performance explained by younger adults' metacognitive awareness. This result implies that older adults who more actively manage their remembering benefit significantly in naturalistic PM performance. By contrast, it may also be possible that younger adults because of their greater brain-based cognitive resources have a PM performance that is less contingent on how much effort or attention they place into it. So, while the results are consistent with Walter and Meier's (2014) estimation that metacognitive awareness would reduce the cognitive demand, it does not seem like older adults automatically adapt greater metacognitive awareness to compensate for their declining brain-based cognitive abilities.

## **7.2 Exploration of Reminder Use and PM**

Prior research has investigated reminders to explain why older adults may have greater PM performance in naturalistic settings. Increased reminder use is assumed to provide greater PM performance, especially in older adults, as it encourages more spontaneous retrieval and less monitoring (reducing the demand for cognitive resources required for prospective remembering). In the current study, neither the frequency with which participants used reminders nor the number of different reminders used significantly predicted PM performance. Additionally, the frequency with which each individual reminder type (external, internal, combined) was used also did not predict PM performance for either age group or the sample as a whole. Further, in line with previous research (Rendall & Thomas, 1999) younger adults used a greater number of reminders than older adults. Thus, the current findings further affirm, in line with previous research (Randall, 2016; Ihle et al., 2012; Rendall & Thomas, 1999), that equal (or superior) naturalistic PM performance in older adults is not due to the use of more memory aids (or greater frequency of use) when compared to younger adults. To examine the possibility that some reminders may be more effective than others, the three most popular reminders were also examined to see if they predicted PM performance. The most popular reminders were alarms, taking notes, and tying to events. Noticeably, these types of reminders are considerably different in their contribution and function within prospective remembering - alarms may be useful for prospective memory cueing, taking notes is useful for retrospective accessing of information, and tying to events is a conjunction cue which may be a more effective version of alarms as it provides an event-based cue which is more flexible (though not guaranteed to be noticed like an alarm). Despite their promise, none of the three popular reminder types significantly predicted PM performance.

### ***7.2.1 Reminder Use Profiles***

To understand reminder use better within the domain prospective remembering, an alternate method analysing different ratios of reminder use was constructed in the form of a 'reminder use profile'. As it currently stands when external reminders are examined, for example in

the studies by Aronov et al. (2015), and Masumoto et al. (2011), researchers examine whether external reminder use by itself may contribute to PM performance. Looking at reminder types individually rather than the combination of reminders a person may use ignores interaction effects that specific reminders may have with one another. Interaction effects here refer to the interactions reminders may have that make two reminders together better than the sum of their individual benefits. For example, asking someone to remind you (an external reminder) and trying to specific times (a combined reminder) each have their own utility and may benefit PM performance. However, if you ask someone to remind you and you've informed them of the specific times, instead of getting non-specific reminders to do a task, you now have two people engaged in prospective remembering and monitoring the time (or spontaneously retrieving the time cue) in order to complete the PM task. The use of these two reminders together creates a strategy that has benefits beyond what either individual reminder brings to the participant. It could be that older adults combine reminders in a way that benefits their prospective memory better than younger adults even if they use the same or fewer reminders (as is shown in Ihle et al., 2012; Rendell & Thomas, 1999). What can be seen in Figure 4 is that high external reminder use with low reminder use in other categories is more common in older adults, and high combined reminder use with low use in other categories is more common in younger adults. This difference in reminder use profiles highlights that there may be different ways in which older and younger adults combine reminders that may explain why older adults have equal or greater performance in naturalistic PM tasks than younger adults despite older adults' brain-based cognitive deficits. Unfortunately, reminder use profiles could not be statistically analysed through a one-way ANOVA due to small sample sizes (see Appendix E). An attempt was made to condense the profiles into fewer categories (down from eight initial categories); however, this could not be done in any logical or consistent manner. Despite being unable to analyse this data, it can still be argued that this presents a possible new variable that may explain naturalistic PM performance differences between younger and older adults. A reminder use profile creates a more comprehensive picture of reminder use than is currently typical of PM

research (which examines reminder use components in isolation). Reminder use profiles may even offer benefits for those with difficulty in prospective remembering by identifying patterns of internal, external, and combined reminder use that is most beneficial for different age groups (assuming that different profiles may be better suited to different age groups, otherwise profiles could offer a general concept for an optimal reminder type combination).

### **7.2.2 Reminder Utility and PM**

Reminder utility is defined in this thesis as how useful a reminder is perceived to be by the person using it for successful PM performance. Previous studies such as Gilbert (2015) and Schnitzspahn et al. (2011) have discussed how individual awareness of prospective remembering abilities affects the allocation of resources and strategies. However, in the PM literature no one has yet discussed how the awareness of those resource's abilities to affect PM performance moderates PM performance or the subsequent ways in which the resources may continue to be used. The utility of reminders can be used to answer questions such as "if a person believes, or is aware that, a reminder is useful for a PM task, does that mean that they will use that reminder more frequently?" And "if another person is not aware of the utility of reminders, and subsequently uses reminders as a matter of convenience instead of selecting what they find more useful, will that in-turn affect PM performance?" Additionally, results in a previous study by Simon and Schmitter-Edgecombe (2016) indicated that a person's perception of their PM was more important than their actual PM abilities in determining whether a person uses reminders. Similarly, it may be the case that the perception of a reminder's utility could be more important than the reminder's objective utility in determining a reminder's repeated use or effectiveness. Further, it is possible that the effects of utility on subsequent reminder use and PM performance may vary with age given the differences in cognitive resources, culture, perceptions, and environments of older and younger adults. The current section gives an initial exploratory look at reminder utility as a potential new variable to account for PM performance differences and in explaining part of the age-PM paradox.

Interestingly, older and younger adults did not differ in how they perceived reminder usefulness as an average across and between reminder use categories (i.e., internal, external, and combined reminders types and reminder usefulness generally did not differ for the two age groups). As an alternative to reminder categories, individual reminders could be examined to see if certain reminders contained age differences in how useful they are perceived to be. Unfortunately, due to a small sample size individual reminder examination was not possible. So, while future studies may be able to investigate age differences in reminder utility further, the current study suggests that age does not contribute to different perceptions in the utility of reminders.

### ***7.2.3 Reminder Utility and Reminder Use Frequency***

Previous research by Scarampi and Gilbert (2020) found that individuals are biased to reuse prior strategies if they are successful. It is important to note that reminder utility was assessed in the reminder use survey (Appendix A) after completing the week of the PM task. In a naturalistic task like this, where participants can roughly know how well they have done but may not be certain of their precise score because they cannot see the errors that were possibly made (e.g., may have accidentally pressed sooner than four hours apart, or pressed A instead of B), their estimation of successful reminder use is likely going to be primarily based off how useful they felt the reminder was in this task and previous beliefs about how useful different kinds of reminders are. To examine if the bias of reusing strategies affected the two age groups differently, the relationship between reminder utility and reminder use frequency was analysed. Because the task was novel and participants had 21 opportunities to remember, a successful reminder on one day is likely to be useful for the next day, thus increasing the frequency of use throughout the week (as per Scarampi & Gilbert, 2020). While some of the data approached statistical significance, reminder utility had no significant relationships with reminder use frequency.

### ***7.2.4 Reminder Utility and PM Performance***

Beyond reminder frequency, reminder utility may also be correlated with PM performance. Reminder utility and PM performance was examined using both a simple correlation between mean utility and PM performance – and through a Kruskal-Wallis H test with reminder utility profiles and PM performance. While the profiles were created to account for confounding on reminder use frequency (see section 5.3 for more detail), the created profiles create two artificially dichotomous variables, which, according to MacCallum et al. (2002), reduces resultant effect sizes and increases the chance of finding spurious effects. To get more insight into the data, both forms of analysis were done keeping in mind their unique problems. First utility and PM performance were correlated for older and younger adults separately and for the sample as a whole. While the sample as a whole and the younger adult group had no significant relationships between PM performance and utility, older adults had a significant negative correlation between perceptions of internal utility and PM performance. This negative correlation meant that the less older adults perceived internal reminders to be useful, the greater their PM performance. Interestingly, reminder utility for the internal remembering methods is probably the most objectively varied reminder use category regarding reminder effectiveness. Internal reminders like mental rehearsing having little to no objective utility (in that they offer little to no benefit to retrospective or prospective remembering), while cognitively demanding methods such as memory palaces and task-specific methods such as the odd number strategy have higher utility (as they have evidence of aiding components of prospective memory; McDaniel & Bugg, 2012). What this could mean is that older adults who hold a higher standard for the utility of reminders such as mental rehearsing or retracing (17 of 22 older adults who used internal reminders used mental rehearsing or retracing, which made up 63% of internal remembering methods used by frequency) could be considered more sophisticated rememberers as they more accurately interpret the objective utility of specific reminders (i.e., they accurately perceive reminders that are bad at assisting in remembering as bad reminders). Less sophisticated rememberers may be less likely to accurately evaluate the usefulness of reminders and therefore not be able to adapt to the use of more effective reminders (i.e., they will not adopt the use of more

effective reminders as they will not be perceived as useful). It may also be the case that less sophisticated rememberers could say they already have a method they are happy with, so they will not try new methods, or if a new method is used, they may not stick with it because they remain attached to their old less useful method. Because less sophisticated rememberers (who will rate non-useful methods as useful) then use fewer effective reminders, they will likely be outperformed on the PM task, hence judgements of lower internal utility being significantly correlated with higher PM performance.

### **7.2.5 Reminder Utility Profiles and PM Performance**

To further explore this relationship between reminder utility and PM performance while partially accounting for the confound of reminder use frequency, four categories were created that combined both reminder utility and reminder frequency together (for more see sections 5.3 and 6.5.4). These categories then meant that different questions around reminder use could be examined such as:

1. is it better to use lots reminders that are of low usefulness when compared to a few highly useful reminders?
2. Is it better to use a few highly useful reminders or lots of highly useful reminders?
3. If reminders are of low usefulness is it better to use more or less of them?

Results from a Kruskal-Wallis H test show that there was no significant difference in PM performance between reminder use profiles. When comparing means for the groups it appears that the 'Low Utility High Use' group had a substantially worse score than the other profiles. This result would suggest that if you have several reminders that aren't perceived to be useful, it is likely better to use fewer reminders. Using reminders requires cognitive resources and if the return on these resources is less than the input (as is likely if the reminder is perceived to be of low usefulness), then more reminders would mean less available cognitive resources for the PM task and therefore decrease PM performance. However, these differences were not statistically significant. Future

research with a greater sample size may be able to find an answer to the questions above and be able to carry out a one-way ANOVA as declared in the pre-registration to find how utility contributes to PM performance at different reminder use frequencies. Further, future research may also be able to examine possible age effects within reminder utility profiles.

This early investigation of reminder utility has yielded some interesting results. The results of this study suggest that older adults who are more accurate in assessing the utility of internal reminders may have enhanced PM abilities. Despite no significant differences being found in the reminder utility profiles, it still seems plausible that future research may yet investigate and uncover significant effects between these groups of high/low utility, and high/low frequency of reminder use. It also remains, as mentioned previously, that the investigation of reminder use in prospective remembering research has been overly simplistic. As such research into reminder use and PM in the future should further investigate reminder utility in its relationship with offloading and modifying prospective remembering abilities.

### **7.3 Reminder Capacity Survey**

The reminder capacity survey aimed to add detail to the results through a greater everyday understanding of the participant's lives. The first question asked how frequently participants used external reminders in their everyday lives outside of the experiment. This could speak to a participant's prior experience with external reminders that may inform both the utility (regarding how much these reminders contribute to PM performance) and the frequency of external reminders in the PM task. The results indicated that different frequencies with which people used external reminders in everyday life did not result in significantly different PM performance. Additionally, differing everyday external reminder use did not result in significant differences in experimental external reminder use. The non-significant relationship of everyday reminder use and PM performance could be expected given that more direct experimental use of external reminders in the task was not significantly correlated to PM performance either. The non-significant relationship

between external reminder use (everyday-life versus experimenter-given) could mean comparing naturalistic diary-based studies such as Schnitzspahn et al. (2016) and experimenter given naturalistic studies like in this experiment are problematic as the reminder use by participants is distinctly different. For example, when trying to determine reminder use profiles in older and younger adults (like those shown in section 6.4.3) the evidence from an experimenter-given study may not be comparable to a diary-based study. However, this is very minor evidence that experimenter-given and everyday-life external reminder use differs, and the appropriateness of comparisons between external reminder use in these contexts still remains unclear.

### **7.3.1 Digital Reminder Use**

Digital and analogue preference and everyday use of digital and analogue reminders were used to examine the extent of the 'grey divide' in this study. What was found was mostly as expected for the digital/analogue preference. More older adults than younger adults preferred analogue reminders, though interestingly, most older and younger adults preferred digital reminders. This digital preference was somewhat in contrast to the experimental PM task findings of analogue and digital reminder use, where despite having approximately 30% fewer older adults who preferred digital memory aids, as a percentage more older adults used digital reminders in the PM task than did younger adults. Further, though not a statistically significant difference, older adults said that they used fewer analogue methods regularly and had used a greater variety of digital memory aids than younger adults. So, while preferences followed what would be typical for the age groups (given the presence of the grey divide), the actual use of digital reminders was the opposite. Younger adults used more analogue reminders, and older adults used more digital reminders, which occurred in the experimental task and real life. Prior research into prospective remembering has avoided digital technology (by opting out of any digital technology use in PM research where possible) for fears that unfamiliarity with technology would differentially impair PM performance (Ellis & Kvavilashvili, 2000; Schnitzspahn et al., 2016). However, Randall (2016) found in their study

that a lack of familiarity with smartphones did not appear to affect PM performance between younger and older adults differentially. Additionally, older adults' PM performance and digital reminder use in the experimental task, combined with how they responded to survey questions indicates that the digital divide is not what it used to be. These results give further support of Randall's (2016) claim that there is no need for the current aversion towards technology in investigating the age-PM paradox.

### **7.3.2 Collaborative Remembering**

Another component of the reminder capacity survey looked at collaborative remembering in older and younger adults. Older adults were more frequently aided by others in remembering tasks when compared to younger adults (45.45% compared to 27.78%). Given most of this regular collaborative remembering would come from close relationships like a partner or parent and the average age of marriage or civil union is around 30 years old ("Marriages, civil unions, and divorces", 2018) and the majority of younger adults in this study had moved out of home, this sort of discrepancy would be expected between these age groups. Additionally, this age difference in collaborative remembering may have impacted the results more if more participants had engaged in collaborative remembering strategies, but only 8.6% of the sample used collaborative remembering as a memory aid in the experimental task. Regarding remembering for others, there was a non-significant relationship of age and the frequency with which tasks or events were remembered for others (see question 10 in Appendix B). How frequently people remember for others was not observed to be related to PM performance in the PM task. Previous research has stated that social collaboration (agent-agent systems) may compensate for age-related cognitive declines in memory (Johansson et al., 2000). However, asking people how frequently they engage in collaborative remembering and how often they remember for others are rather vague and simplistic ways of examining collaborative remembering and agent-agent systems. This was meant to be done as a further exploratory contribution to PM research and age effects as very little research has been done

into collaboration or transactive memory systems in PM comparatively between younger and older adults (only 4 studies have examined PM in the social context; Altgassen et al., 2021). More in-depth research is required regarding collaborative remembering, age effects, and prospective remembering.

### **7.3.3 Internal Remembering Knowledge**

The more internal remembering methods participants know, the more they can tailor appropriate methods to the task. Question 7a and 7b (see Appendix B) both asked if older or younger adults may know or use more internal remembering methods. The list of internal remembering methods came from Intons-Peterson and Fournier (1986), with some of the descriptions and labels modified. There were no statistically significant age effects for either how many methods were known or used. Additionally, much like external reminder use within both groups, internal reminder use and knowledge measured by question 7a and 7b did not correlate with the experimental internal reminder use frequency. These findings are in-line with previous research in memory training where greater general knowledge and use of internal remembering methods does not generalise across many tasks and is often only useful in highly specific circumstances (Rebok et al., 2007).

### **7.3.4 Organisation and PM Performance**

The last part of the reminder capacity survey examined people's organisation of spaces and how that organisation is linked to prospective memory performance. As stated previously, extended/embodied cognition views people's minds as partially constituted of non-neural components, such as notebooks or a person's structured personal environment. To first determine if a person could generate a structure within their environment, participants were asked if the experiment would be carried out in a place they had lived in for more than three months, all participants responded with yes. Additionally, question nine of the reminder capacity survey asked how organised the personal aspect of their spaces were, including their house, workplace, and

bedroom. The result from this question was that the total organisation (as a combined score of their house, workplace, and bedroom on a Likert scale of 1-4, see Appendix B) between older and younger adults was very comparable ( $M = 9.83$  and  $9.91$ , for younger and older adults respectively) and had a standardised regression coefficient  $\beta = .21$ , that was not significant ( $p = .087$ ). This result provides some tentative evidence of the possibility of organisation influencing prospective remembering. Participants were guided through question nine in the survey, and each participant was told what each of the response options on the 4-point Likert scale meant:

1. 'not organised' spoke to no structure.
2. 'not very organised' spoke to a slight structure to the space.
3. 'slightly organised' spoke to a moderate level of organisation or some systematising.
4. 'highly organised' spoke to a comprehensive system of organisation with some reasoning (e.g., colour coated and spatially optimised desk items).

Unfortunately, there was both a possible social desirability bias of wanting to seem organised and a general flawed interpretation of response options (even after clarification was given), with statements like "It looks messy but my space functions as I know where everything is, so I would say I am slightly organised" or "I suppose I would like to think I am slightly organised". As a result, the data tended to skew towards a high subjective rating of organisation with an average organisational score of 9.87 of a maximum 12. Further, the distribution of Responses was also very peaked with little variation. The result is from a negatively skewed and narrowed range of responses and is still almost statistically significant, while this result should not be over-interpreted, organisation as a contributor to PM performance seems an exciting and promising area for future research.

#### **7.4 Limitations of the Current Study and Future Research**

A significant limitation for the current study was that observed PM performance was high, with approximately one-third of participants attaining a perfect PM score. This performance resulted in a

ceiling effect, with a negatively skewed PM score distribution. Ceiling effects were anticipated as the Masumoto et al. (2011) study that inspired this study's method had 50% of their participants achieve a perfect PM score. To increase difficulty without making the task too demanding an extra step of alternating between A and B when executing the PM task was added (see Section 5.6), successfully decreasing the number of participants with a perfect score by approximately 15% compared to Masumoto et al. (2011). However, ceiling effects still exist which reduce data variability (Vogt & Johnson, 2011) making it more difficult to find significant effects of independent variables (the most important being age) on PM performance. Several different manipulations could be done to increase the retrospective memory load (e.g., increasing encoding costs by adding more information to be retained). However, it is challenging to make the prospective memory component of this task harder in a naturalistic context as increasing the frequency of button presses in the week isn't translatable to any real task requiring PM (not many real-life prospective memory tasks occur more than three times per day).

An important component of this study was to show that reminder use should be investigated in ways that it has not been previously. Either by showing that new methods of examining reminder use in PM (i.e., reminder use profiles and reminder utility profiles) can return significant results where classic methods (i.e., dichotomous used/not used reminder types and reminder use frequency) could not, or by showing stronger relationships between new variables of reminder use and PM when compared to old variables. Further, as mentioned above, several analyses in this study were unable to be performed due to the limited sample size. The initial sample size required as per the pre-registration for the confirmatory analyses was 77 for a power of 0.8 and to detect an effect with a Cohen's  $f^2$  of 0.15 (a medium effect size; Cohen, 1988); however, the sample size for many of the other analyses in the exploratory section of this thesis would need to be substantially larger. Because of the limited sample sizes and assumption violations two important one-way ANOVAs analyses (pre-registered) could not be performed. The first ANOVA was examining reminder use profiles, which included as few as four participants in some of the groups. Reminder use profiles

could have indicated whether reminders need to be examined as a collective instead of being examined in their individual parts (as well as answering other questions mentioned above in Section 7.2.1). The second ANOVA could have allowed for a more comprehensive understanding to be gathered from reminder utility which is a variable previously unexamined in PM and reminder use. Despite an inability to investigate these variables as desired, the initial justifications to examine these concepts further (mentioned in Section 4.5 and Section 5.3) still stand. Both the interaction effects between reminders as they contribute as a whole towards PM performance, and the utility of reminders impacting offloading or PM may be beneficial to study together or in isolation in future research.

The exploratory component of this thesis also leaves many questions for further research. For example, the reminder capacity survey offers explorative insight in questions such as:

1. How translatable is experimenter-given task reminder use to everyday reminder use?
2. How do the effects of collaborative remembering differ with age?
3. How does knowledge of internal remembering methods affect PM performance?
4. How does the organisation of one's spaces contribute to their ability to complete PM tasks?

The reminder capacity survey was meant to give a brief insight into participants' lives outside of the experimental task. However, future research should investigate some of the reminder capacity section components in greater detail, especially the organisation of spaces, the translation of experimenter given task reminder use and everyday reminder use, and knowledge of different internal/combined remembering strategies.

Further, PM research needs greater investigation of the habitual prospective memory subdomain (as argued in Section 3.2 of this thesis). Future research could look to replicate this study, comparing several weeks of week-based output monitoring to examine how PM performance shifts over time and examine how reminder use changes over time between younger and older adults.

The measure of PM in this study is an attempt to simulate tasks such as regular food intake or medication taking, but the generalisability to everyday PM required for independent living is unclear. This study's week-based output monitoring component may limit the generalisability of the results (as this degree of output monitoring is not normal in everyday PM tasks) but was used as Masumoto et al. (2011) found this method increased the frequency of reminder use. Future studies with larger sample sizes may be able to examine reminder use through similar methodology within a more externally valid measure of PM performance in a naturalistic setting through a diary-based method (such as in Schnitzspahn et al., 2016). Alternatively, external validity could be enhanced by constructing experimenter-given tasks with varied types of prospective memory tasks that emulate various social, work, health, organisational, and leisure-based PM tasks with differing regularity, temporal specificity, and lengths of delay.

Lastly, there are several implications from the robust findings for the effects of metacognitive awareness in older adults. Firstly, much of the metacognitive strategy research has shown improvement in PM performance through strategies such as imagery of prospective memory tasks (where participants visually imagine themselves seeing the specific PM cue and executing the paired action; Brewer et al., 2011); use of implementation intention (a strategy where a specific 'when and where' is given a PM task as opposed to vague intentions; Rummel et al., 2012); or performance predictions use (Meier et al., 2011) only in undergraduate university students. As such, it may be beneficial to investigate these metacognitive strategies further specifically in older adults; as the relationship between these strategies and PM performance may not only be substantially different but may also further explain the variance seen to be explained by metacognitive awareness in this study. Further, this finding around the benefit of metacognitive awareness for older adults strongly links with motivation and task importance. Motivation and task importance are usually examined in relation to PM performance (e.g., Alberle et al., 2010) but given the variance explained in older adults by metacognitive awareness, perhaps they could be better examined as to how they influence the use of metacognitive strategies in older adults.

## 7.5 Summary and Conclusions

Firstly, this study gives further evidence to support the theory that age-related declines in PM performance may be spared in a naturalistic setting (possibly enabled by a distributed cognitive system). Secondly, counter to the previous study examining differences in metacognitive awareness in a naturalistic setting (Schnitzspahn et al., 2011); this study suggests that metacognitive awareness is not better in older adults when compared to younger adults. However, a notable finding from this thesis was that metacognitive awareness in older adults' accounts for a substantial amount of the variance in PM performance, whereas in younger adults, metacognitive awareness is not an important contributor to PM performance. These results imply that older adults who 'actively manage' their remembering do much better in prospective remembering; while younger adults seem to attain their PM performance without much effort or attention being paid to how they remember. Thirdly, when using previous methods of analysis in determining how reminder use may impact PM performance between age groups such as comparing reminder use categories (e.g., Masumoto et al., 2011) or reminder frequency (e.g., Aranov et al., 2015) this study indicated these methods show no relationship between reminder use and PM performance. Yet, while there was only one significant result between reminder utility and PM performance with older adult's internal reminder utility having a significant negative correlation with PM; that one result is more than what was found through previously used methods. And reminder utility is still yet to be examined in detail, making it a promising future variable to investigate. Further, while interaction effects of reminder categories (external, internal, combined) were unable to be investigated through reminder use profiles due to sample size, the distribution of those reminder use profiles differed between younger and older adults and may affect PM performance. The results from the exploratory components of this thesis, while far from conclusive, support the need for more intricate and considered methods of investigating reminder use in prospective remembering.

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## Appendix A

### Reminder Use Survey



## Reminder-use Survey

Below is a list of different reminders you may have used to complete the prospective memory task. **External strategies** manipulate or rely on the environment to cue or jog your memory (e.g. notes, calendars, lists). **Internal strategies** are mental techniques you use in order to remember (e.g. repeating a word in your head to remember it). **Combination strategies** are a blurred area between external and internal strategies.

Please select the response options on the reminders that you used, if you did not use a specific reminder type then please select the 0 times option on the frequency question and ignore the utility question. Also, feel free to scroll back if you remember another reminder that you used.

Name (first and last)

**No reminders** - recognition of type and how many times the button has been pressed is just assumed to pop up when needed (no preparation just trusting you would monitor time and remember to remember approximately 3 times a day).

- This was my main/only method of remembering the task
- I used other methods to complete the task

### External Reminders

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**Asking someone else to remind you** - this will be relying on that person for completing the task and not collaboratively engaging in conversation about doing the task e.g. "Alex, you need to press the button now it has been 4 hours!" as opposed to you asking "has it been 4 hours yet? When did I last press the button?"

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
-

---

**Alarm** - using either a stand-alone timer with alarms set every 4 hours, a watch with set times for when to press the buttons, a phone with an alarm set for pressing the button the desired number of times in the day

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Taking Notes** - having a piece of paper or digital location for note writing e.g. having a paper with you for the task where you draw a circle or a square, write out a tally, write out the number etc.

Were the notes taken done so digitally?

- Yes  
 No, it was analogue

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Using notes to cue** - using notes in the workspace, home, or elsewhere as consistent reminders to press the button (e.g. attaching a post it note to your monitor at work saying 'press button every four hours + alternate buttons' or 'press button A at 9am, B at 1:15pm, then A at 5:30pm before leaving')

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Using a calendar or a weekly planner** - writing out planned times for the week or day with which you will press the button around the time period.

Was the calendar or planner used digital?

- Yes  
 No, it was analogue

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

**Whiteboard or noticeboard** - using a whiteboard or noticeboard to place or write relevant reminders or use something like a Kanban system (to do - doing - done).

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

**Other external reminder** - Please state here (and specify if the reminder is digital):

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

## Internal Reminders

**Mental rehearsing** - replaying the button type or number of button presses in your head over and over after pushing the button as an attempt to remember e.g. repeating to yourself "that was the 17th button press, 17th, 17th, 17th"

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

**Mental retracing** - recalling different activities you were doing, or button presses you made, step by step, to remember what button to press and when.

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

---

**Visual memory encoding** - using a visual memory technique (e.g. memory palace) to associate the number of button presses and type with different visual objects to strengthen remembering.

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Odd number strategy** - keep track of the number of times you have called and associating odd numbers with one button and even numbers with the opposite button.

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Rhyme** - Using rhymes about what you want button to press and/or how many presses have occurred (like using the rhymes "press number 8 avoid being late" "press number nine was fine").

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Other internal reminders** - Please describe here:

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

## Combined reminders

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**Collaborative memory strategy** - working with another person to complete the prospective memory task (outside of using them exclusively as an external)

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
-

---

**Reminder through association** - associating the button pressing intention with distinctive cues that will capture attention to provoke appropriate button pressing (e.g. placing a red ribbon on your desk so when you get to work, you are cued by the ribbon to remember to press a button).

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Typing to specific times** - planning each days/the weeks button press times (e.g. after 8am, 1pm, 7pm). When you are around these times (slightly after), you know you can press the button. DO NOT select this if you had an alarm set for these times.

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Typing to other life events** - syncing up the time of the button press with daily activity that is spaced greater than 4 hours apart e.g. breakfast, lunch, and dinner without specifically relying on time.

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Trial technique:** Trying to write out or imagine part of the information regarding number of button presses (and/or button type) to see if it sparks a memory.

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful
- 

**Other combined strategies** - please describe here:

I used this reminder

- 0 times  1-3 times  4-6 times  7-12 times  12-21+ times

I perceived this reminder was:

- Not Useful  Of Low Usefulness  Moderately Useful  Highly Useful

## Appendix B

### Reminder Capacity Survey



3) Please select the analogue methods you use regularly

- None
- Calendar
- Sticky notes
- Notepad
- asking someone else to remember for you or with you
- Paperback diary/journal
- Alarm clock
- Other (please specify)

---

4) Do you use any external reminder apps? (e.g. Google Calendar, Reminder app on iOS or Android, Wunderlist, Evernote, Google Keep, notion) If so, please list.

---

5) Do you have any individual such as a partner, parent, or secretary that regularly helps with remembering future tasks? Please briefly describe that person's role in aiding these memory tasks.

---

6) What digital devices have you used as an external memory aid?

- None
- Smart phone
- Tablet
- Digital calendar
- Alarm clock
- Memo reminders
- Pill dispensers
- Locator system (e.g. Tile)
- stove alarm
- Other (please specify)

7a) Please select the internal remembering methods you are aware of (use will be examined in the next question):

- Face-name association: Identifying a person's distinctive feature(s) and connecting the person's name with the feature(s).
  - Mental rehearsing: Mentally repeating to yourself what you want to remember.
  - Mental retracing: Thinking about something that happened before, or that may happen, step by step, in an attempt to remember something.
  - Memory palace: Using a well know location(s) you place tasks or cues mentally in rooms or areas that may or may not be associated with other images or item. Then, when you try to remember, you "mentally walk" around the locations, remembering each item you "put" in the location.
  - Alphabetic searching: Going through the alphabet one letter at a time to see if it sparks a memory.
  - Peg-wordsystem: Learning a series of number-word associations and then forming a vivid image of what you want to remember along with the number-word associations. For example, using the "one is a bun, two is a shoe, three is a tree.. ?' technique, you might imagine the first item you want to remember, say a book, as sandwiched inside a gigantic hamburger bun.
  - Rhymes: Using rhymes about what you want to remember (like using the rhyme, "Thirty days hath September..." to remember the number of days in the months).
  - Story method: Linking items or memories together by telling a story about them, or by making sentences about them.
  - Tie to other life events: Remembering by associating with another life event (such as "right after lunch" or "just before a history class").
- 

7b) Please select the internal remembering methods you have practiced and used previously:

- Face-name association: Identifying a person's distinctive feature(s) and connecting the person's name with the feature(s).
  - Mental rehearsing: Mentally repeating to yourself what you want to remember.
  - Mental retracing: Thinking about something that happened before, or that may happen, step by step, in an attempt to remember something.
  - Memory palace: Using a well know location(s) you place tasks or cues mentally in rooms or areas that may or may not be associated with other images or item. Then, when you try to remember, you "mentally walk" around the locations, remembering each item you "put" in the location.
  - Alphabetic searching: Going through the alphabet one letter at a time to see if it sparks a memory.
  - Peg-wordsystem: Learning a series of number-word associations and then forming a vivid image of what you want to remember along with the number-word associations. For example, using the "one is a bun, two is a shoe, three is a tree.. ?' technique, you might imagine the first item you want to remember, say a book, as sandwiched inside a gigantic hamburger bun.
  - Rhymes: Using rhymes about what you want to remember (like using the rhyme, "Thirty days hath September..." to remember the number of days in the months).
  - Story method: Linking items or memories together by telling a story about them, or by making sentences about them.
  - Tie to other life events: Remembering by associating with another life event (such as "right after lunch" or "just before a history class").
-

8) Do you plan your day with a planner? did you include the prospective memory task in this experiment, if so how?

9) How organized are the personal aspects of your spaces such as your house, workplace, and bedroom? (e.g. workplace may be well organized by others, but your work station may be messy and would be scored as a 1 or 2)

|           | 1 - Not organized at all | 2 - Not very organized | 3 - Slightly organized | 4 - Highly organized  |
|-----------|--------------------------|------------------------|------------------------|-----------------------|
| House     | <input type="radio"/>    | <input type="radio"/>  | <input type="radio"/>  | <input type="radio"/> |
| Workplace | <input type="radio"/>    | <input type="radio"/>  | <input type="radio"/>  | <input type="radio"/> |
| Bedroom   | <input type="radio"/>    | <input type="radio"/>  | <input type="radio"/>  | <input type="radio"/> |

10) how often do you remember tasks or events for others (e.g. children, family, or friends)?

| Never                 | 1-2 times per month   | 1-3 times per week    | 1-2 times per day     | 3+ times per day      |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### Appendix C

#### Reminder Use and PM

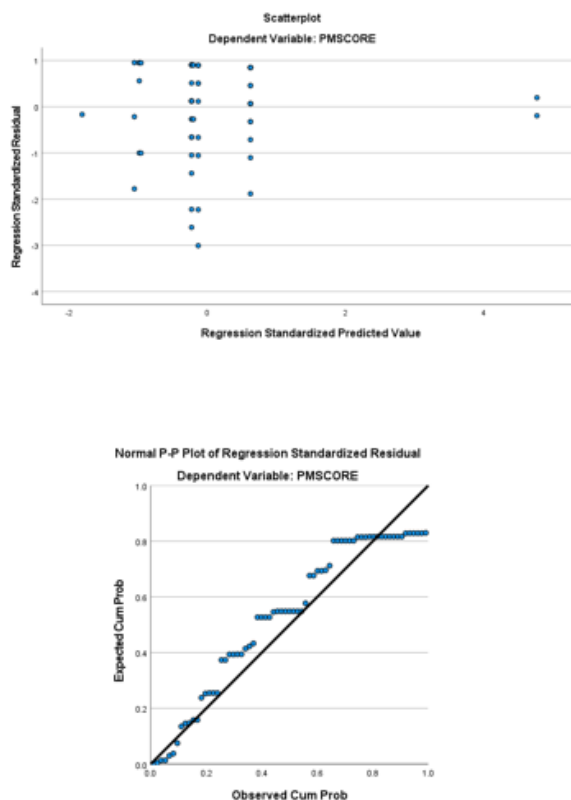
**Table C1**

*Model Summaries for Simultaneous Regression Analysis of Reminder Use Against PM Performance for the Whole Sample, Younger Adults, and Older Adults*

|                | Change Statistics |          |            |               |          |          |     |     |               |
|----------------|-------------------|----------|------------|---------------|----------|----------|-----|-----|---------------|
|                | R                 | R Square | Adjusted R | Std. Error of | R Square |          |     |     |               |
|                |                   |          | Square     | the Estimate  | Change   | F Change | df1 | df2 | Sig. F Change |
| Total          | .234              | .055     | -.020      | 2.516         | .055     | .728     | 5   | 63  | .605          |
| Younger Adults | .281              | .079     | -.075      | 2.52496       | .079     | .514     | 5   | 30  | .764          |
| Older Adults   | .320              | .102     | -.064      | 2.66788       | .102     | .615     | 5   | 27  | .689          |

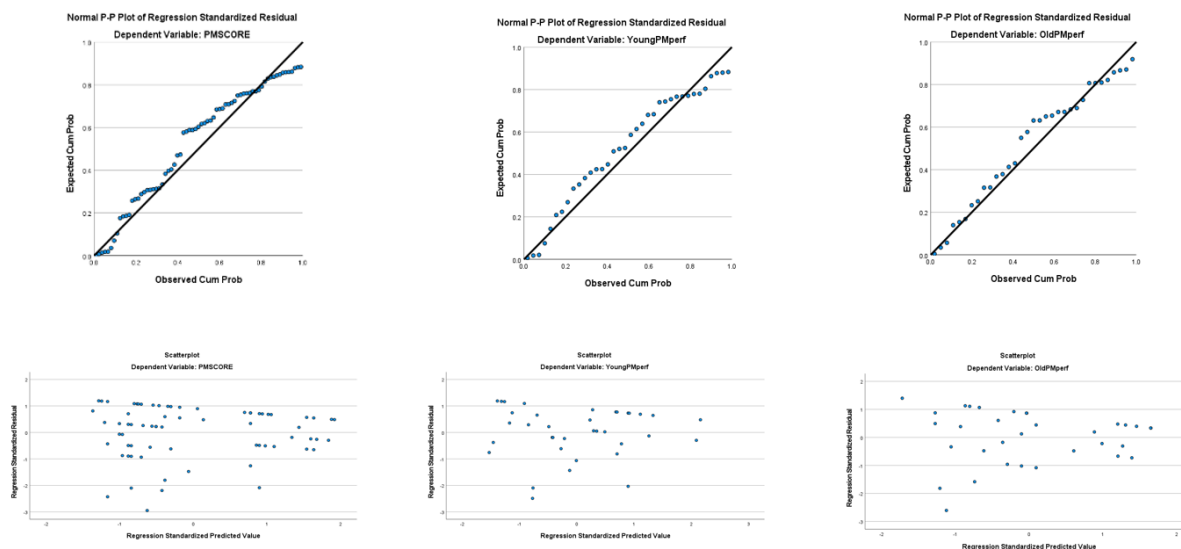
**Figure C1**

*P-P Plots and Scatterplots for Hierarchical Multiple Regression of Age, External, Internal, and Combined Reminder Use Against PM performance*



**Figure C2**

*P-P Plots and Scatterplots for Total Reminder Use, Younger Adult Reminder Use, and Older Adult Reminder Use Against PM Performance*



**Appendix D**

**Metacognition Results**

**Table D1***Correlations Between Metacognitive Awareness and Reminder Use*

|                        |                          | Metacognitive<br>Score | External<br>Reminder<br>Use | Internal<br>Reminder<br>Use | Combined<br>Reminder<br>Use | Total<br>Reminder<br>Use | Number<br>of<br>Reminders |
|------------------------|--------------------------|------------------------|-----------------------------|-----------------------------|-----------------------------|--------------------------|---------------------------|
| Pearson<br>Correlation | Metacognitive<br>Score   | 1.000                  |                             |                             |                             |                          |                           |
|                        | External Reminder<br>Use | .089                   | 1.000                       |                             |                             |                          |                           |
|                        | Internal Reminder<br>Use | .048                   | -.029                       | 1.000                       |                             |                          |                           |
|                        | Combined<br>Reminder Use | .164                   | -.106                       | .136                        | 1.000                       |                          |                           |
|                        | Total Reminder<br>Use    | .173                   | .520***                     | .639***                     | .573***                     | 1.000                    |                           |
|                        | Number of<br>Reminders   | .153                   | .383**                      | .613***                     | .588***                     | .912***                  | 1.000                     |

\* $p < .05$ \*\* $p < .01$ \*\*\* $p < .001$

**Table D2***Correlations Between Metacognitive Awareness and Reminder Use for Older Adults*

|                        |                                  | Oldpos<br>metcog | Olderext<br>use | Oldinternal<br>use | Oldcomb<br>use | Oldtotal<br>RU | Old<br>numrem |
|------------------------|----------------------------------|------------------|-----------------|--------------------|----------------|----------------|---------------|
| Pearson<br>Correlation | Old<br>metcognitive<br>awareness | 1.000            |                 |                    |                |                |               |
|                        | olderextuse                      | .173             | 1.000           |                    |                |                |               |
|                        | oldinternaluse                   | .117             | -.037           | 1.000              |                |                |               |
|                        | oldcombuse                       | .312*            | -.141           | .207               | 1.000          |                |               |
|                        | oldtotalRU                       | .339*            | .553            | .646               | .541           | 1.000          |               |
|                        | oldnumrem                        | .270             | .440            | .702               | .532           | .954           | 1.000         |
| Sig. (1-tailed)        | oldposmetcog                     | .                |                 |                    |                |                |               |
|                        | olderextuse                      | .168             | .               |                    |                |                |               |
|                        | oldinternaluse                   | .258             | .418            |                    |                |                |               |
|                        | oldcombuse                       | .039             | .217            | .124               | .              |                |               |
|                        | oldtotalRU                       | .027             | .000            | .000               | .001           |                |               |
|                        | oldnumrem                        | .064             | .005            | .000               | .001           | .000           | .             |

**Table D3***Metacognitive Awareness Predicting Total Reminder Use*

| Model | R                 | R Square | Adjusted R Square | Std. Error of the<br>Estimate |
|-------|-------------------|----------|-------------------|-------------------------------|
| 1     | .173 <sup>a</sup> | .030     | .015              | 6.36748                       |

*(Constant) = Independent Variable: metacognitive awareness***Table D4***Younger Adult Metacognitive Awareness as a Predictor of Total Old Reminder Use*

| Model | R                 | R Square | Adjusted R Square | Std. Error of the<br>Estimate |
|-------|-------------------|----------|-------------------|-------------------------------|
| 1     | .051 <sup>a</sup> | .003     | -.027             | 6.12537                       |

*(Constant) = Independent Variable: Younger adult metacognitive awareness*

**Table D5***Older Adult Metacognitive Awareness as a Predictor of Total Old Reminder Use**Model Summary*

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------------------|----------|-------------------|----------------------------|
| 1     | .339 <sup>a</sup> | .115     | .086              | 6.54021                    |

*(Constant) = Independent Variable: Older adult metacognitive awareness***Table D6***Older Adult Metacognitive Awareness as a Predictor of Total Older Adult PM Performance*

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------------------|----------|-------------------|----------------------------|
| 1     | .500 <sup>a</sup> | .250     | .225              | 2.27635                    |

*(Constant) = Independent Variable: Older adult metacognitive awareness***Table D7***Regression Analysis of Older Adult Metacognitive Awareness Against Older Adult PM Performance*

| Model |                             | Unstandardised Coefficients |            | Standardised Coefficients |        | Sig. |
|-------|-----------------------------|-----------------------------|------------|---------------------------|--------|------|
|       |                             | B                           | Std. Error | Beta                      | t      |      |
| 1     | (Constant)                  | 20.368                      | .639       |                           | 31.860 | .000 |
|       | Old metacognitive awareness | -.548                       | .171       | -.500                     | -3.211 | .003 |

*Dependent Variable: Old PM performance***Table D8***Younger Adult Metacognitive Awareness as a Predictor of Total Younger Adult PM Performance*

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------------------|----------|-------------------|----------------------------|
| 1     | .059 <sup>a</sup> | .003     | -.026             | 2.46693                    |

a. Predictors: (Constant), youngposmetcog

**Table D9**

*Regression Analysis of Younger Adult Metacognitive Awareness Against Younger Adult PM Performance*

| Model |                               | Unstandardised Coefficients |            | Standardised Coefficients |  | t      | Sig. |
|-------|-------------------------------|-----------------------------|------------|---------------------------|--|--------|------|
|       |                               | B                           | Std. Error | Beta                      |  |        |      |
| 1     | (Constant)                    | 18.817                      | .544       |                           |  | 34.589 | .000 |
|       | Young metacognitive awareness | -.055                       | .158       | -.059                     |  | -.345  | .732 |

*Dependent Variable: Young PM performance*

**Table D10**

*Simultaneous Regression Analysis Comparing Older Adults Metacognitive Awareness and Reminder Use*

| Model |                         | Unstandardised Coefficients |            | Standardised Coefficients | t     | Sig. | 95.0% Confidence Interval for B |             |
|-------|-------------------------|-----------------------------|------------|---------------------------|-------|------|---------------------------------|-------------|
|       |                         | B                           | Std. Error | Beta                      |       |      | Lower Bound                     | Upper Bound |
| 1     | (Constant)              | 1.084                       | 1.331      |                           | .814  | .423 | -1.643                          | 3.811       |
|       | Older external use      | .280                        | .199       | .525                      | 1.404 | .171 | -.129                           | .689        |
|       | Older internal use      | .253                        | .261       | .413                      | .968  | .342 | -.283                           | .788        |
|       | Old combined use        | .404                        | .232       | .604                      | 1.740 | .093 | -.072                           | .880        |
|       | Old number of reminders | -.906                       | .990       | -.572                     | -.915 | .368 | -2.935                          | 1.122       |

a. Dependent Variable: Older adult metacognitive awareness score

**Table D11***Regression Analysis Comparing Older Adults Metacognitive Awareness and Reminder Use*

*Coefficients<sup>a</sup>*

| Model                    | Unstandardised Coefficients |            | Standardised Coefficients | t     | Sig. | 95.0% Confidence Interval for B |             |
|--------------------------|-----------------------------|------------|---------------------------|-------|------|---------------------------------|-------------|
|                          | B                           | Std. Error | Beta                      |       |      | Lower Bound                     | Upper Bound |
| (Constant)               | .797                        | 1.139      |                           | .700  | .489 | -1.527                          | 3.120       |
| 1 Old total reminder use | .117                        | .058       | .339                      | 2.003 | .054 | -.002                           | .235        |

a. Dependent Variable: Older adult metacognitive awareness score

**Table D12***Correlations Between Young Metacognitive Score and Young Reminder Frequency*

|                        |                                 | Young<br>metacognitive<br>score | Young<br>external<br>use | Young<br>internal<br>use | Young<br>combined<br>use | Young<br>total RU | Young<br>number of<br>reminders |
|------------------------|---------------------------------|---------------------------------|--------------------------|--------------------------|--------------------------|-------------------|---------------------------------|
| Pearson<br>Correlation | Young<br>metacognitive          | 1.000                           |                          |                          |                          |                   |                                 |
|                        | Young<br>external use           | -.038                           | 1.000                    |                          |                          |                   |                                 |
|                        | Young<br>internal use           | .023                            | .017                     | 1.000                    |                          |                   |                                 |
|                        | Young<br>combined use           | .096                            | -.023                    | .032                     | 1.000                    |                   |                                 |
|                        | Young total<br>RU               | .051                            | .522                     | .624                     | .599                     | 1.000             |                                 |
|                        | Young<br>number rem             | .143                            | .446                     | .526                     | .606                     | .907              | 1.000                           |
| Sig. (1-tailed)        | Young<br>metacognitive<br>score | .                               |                          |                          |                          |                   |                                 |
|                        | Young<br>external use           | .414                            | .                        |                          |                          |                   |                                 |
|                        | Young<br>internal use           | .448                            | .460                     |                          |                          |                   |                                 |
|                        | Young<br>combined use           | .288                            | .447                     | .427                     |                          |                   |                                 |
|                        | Young total<br>RU               | .385                            | .001                     | .000                     | .000                     |                   |                                 |
|                        | Young<br>number rem             | .203                            | .003                     | .000                     | .000                     | .000              | .                               |

**Appendix E**  
**Reminder Use Profile**

**Table E1***Reminder Use Profile Descriptive Statistics*

|          | N  | Mean  | Std. Deviation | Std. Error | 95% Confidence Interval for Mean |             | Minimum | Maximum |
|----------|----|-------|----------------|------------|----------------------------------|-------------|---------|---------|
|          |    |       |                |            | Lower Bound                      | Upper Bound |         |         |
| Ext      | 14 | 19.00 | 2.828          | .756       | 17.37                            | 20.63       | 11      | 21      |
| Ext Int  | 15 | 18.07 | 2.685          | .693       | 16.58                            | 19.55       | 12      | 21      |
| All High | 8  | 20.13 | .991           | .350       | 19.30                            | 20.95       | 19      | 21      |
| Internal | 6  | 17.83 | 2.317          | .946       | 15.40                            | 20.26       | 14      | 21      |
| Int Com  | 4  | 20.00 | .816           | .408       | 18.70                            | 21.30       | 19      | 21      |
| Com      | 9  | 17.89 | 2.667          | .889       | 15.84                            | 19.94       | 13      | 21      |
| Ext Com  | 4  | 16.50 | 3.416          | 1.708      | 11.06                            | 21.94       | 13      | 21      |
| All Low  | 9  | 20.00 | 1.323          | .441       | 18.98                            | 21.02       | 18      | 21      |
| Total    | 69 | 18.72 | 2.490          | .300       | 18.13                            | 19.32       | 11      | 21      |

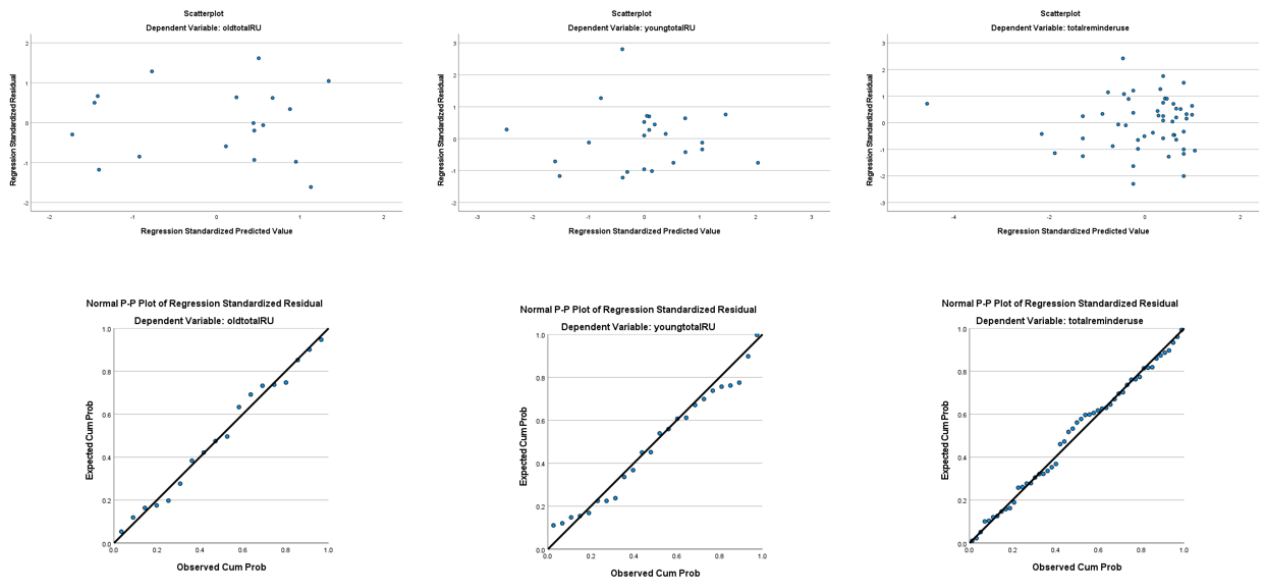
*Note.* The labels given to the reminder use profiles are stating what reminder was of above average use for the category based on reported frequency (the other reminder types will be below average if not listed). Additionally, ext means external, int means internal, and com means combined reminders.

## Appendix F

### Reminder Utility

Figure F1

*P-P Plots and Scatterplots for Internal, External, and Combined Reminder Utility Against Reminder Frequency, for Younger Adults, Older Adults, and the Whole Sample.*



**Table F1***Combined Regression Analyses of Reminder Utility Against Reminder Frequency*

|                       | Unstandardised Coefficients |            | Standardised Coefficients |       | Sig. |
|-----------------------|-----------------------------|------------|---------------------------|-------|------|
|                       | B                           | Std. Error | Beta                      | t     |      |
| <b>Total</b>          |                             |            |                           |       |      |
| Mean utility          | .745                        | 1.348      | .067                      | .553  | .582 |
| External utility      | 1.236                       | 1.131      | .166                      | 1.092 | .280 |
| Internal utility      | -.136                       | 1.319      | -.020                     | -.103 | .918 |
| Combined utility      | .640                        | 1.703      | .075                      | .376  | .709 |
| <b>Younger adults</b> |                             |            |                           |       |      |
| Mean utility          | 3.309                       | 1.900      | .286                      | 1.742 | .091 |
| External utility      | -1.038                      | 2.041      | -.116                     | -.509 | .617 |
| Internal utility      | 1.881                       | 1.317      | .303                      | 1.429 | .169 |
| Combined utility      | 2.236                       | 2.211      | .238                      | 1.012 | .324 |
| <b>Older Adults</b>   |                             |            |                           |       |      |
| Mean utility          | -.940                       | 1.911      | -.088                     | -.492 | .626 |
| External utility      | 3.449                       | 1.843      | .494                      | 1.871 | .082 |
| Internal utility      | .267                        | 1.325      | .048                      | .202  | .843 |
| Combined utility      | 1.968                       | 2.574      | .201                      | .764  | .457 |

\* $p < .05$

**Table F2***Independent Samples T Test Comparing Age Groups Perceived Utility of Reminder Types*

|                  | Levene's Test<br>for Equality of<br>Variances |      | t-test for Equality of Means |    |                     |                    |                          |   |       |
|------------------|---|------|------------------------------|----|---------------------|--------------------|--------------------------|---|-------|
|                  | F   | Sig. | t                            | df | Sig. (2-<br>tailed) | Mean<br>Difference | Std. Error<br>Difference | 95% Confidence<br>Interval of the<br>Difference |       |
|                  |   |      |                              |    |                     |                    |                          | Lower   | Upper |
| Mean utility     | .013  | .910 | -1.308                       | 67 | .195                | -.186              | .142                     | -.471   | .098  |
| External utility | 2.103   | .152 | .159                         | 65 | .875                | .024               | .150                     | -.276   | .324  |
| Internal utility | 1.433   | .237 | -1.202                       | 48 | .235                | -.302              | .252                     | -.808   | .203  |
| Combined utility | 1.664   | .202 | .055                         | 57 | .956                | .011               | .192                     | -.373   | .394  |

**Table F3***Correlations Between Reminder Utility and PM performance*

|         |                                      | PMSCORE | Ext utility | Int utility | Comb utility | Mean utility |
|---------|--------------------------------------|---------|-------------|-------------|--------------|--------------|
| PMSCORE | Pearson Correlation                  | 1       | -.001       | .175        | .172         | .045         |
|         | Sig. (2-tailed)                      |         | .995        | .218        | .193         | .718         |
|         | Sum of Squares and<br>Cross-products | 421.768 | -.085       | 19.944      | 18.828       | 3.837        |
|         | Covariance                           | 6.202   | -.001       | .399        | .325         | .058         |
|         | N                                    | 69      | 67          | 51          | 59           | 67           |

\* $p < .05$ \*\* $p < .01$

**Table F4***Correlations Between Reminder Utility and PM Performance for Younger Adults*

|                      |                                   | Young PM performance | Young external utility | Young internal utility | Young combined utility | Young mean utility |
|----------------------|-----------------------------------|----------------------|------------------------|------------------------|------------------------|--------------------|
| Young PM performance | Pearson Correlation               | 1                    | .055                   | -.070                  | .041                   | .045               |
|                      | Sig. (2-tailed)                   |                      | .755                   | .717                   | .823                   | .799               |
|                      | Sum of Squares and Cross-products | 207.639              | 2.595                  | -3.402                 | 1.817                  | 1.612              |
|                      | Covariance                        | 5.933                | .076                   | -.122                  | .059                   | .047               |
|                      | N                                 | 36                   | 35                     | 29                     | 32                     | 35                 |

\* $p < .05$ \*\* $p < .01$ **Appendix G****Reminder Utility Profiles****Table G1***Descriptives for Reminder Utility Profiles*

|                        | N  | Mean  | Std. Deviation | Std. Error | 95% Confidence Interval for Mean |             | Minimum | Maximum |
|------------------------|----|-------|----------------|------------|----------------------------------|-------------|---------|---------|
|                        |    |       |                |            | Lower Bound                      | Upper Bound |         |         |
| High utility, low use  | 9  | 19.56 | 1.509          | .503       | 18.40                            | 20.72       | 17      | 21      |
| High utility, high use | 28 | 18.82 | 2.001          | .378       | 18.05                            | 19.60       | 14      | 21      |
| Low utility, low use   | 23 | 19.09 | 2.575          | .537       | 17.97                            | 20.20       | 11      | 21      |
| Low utility, high use  | 9  | 16.67 | 3.571          | 1.190      | 13.92                            | 19.41       | 12      | 21      |
| Total                  | 69 | 18.72 | 2.490          | .300       | 18.13                            | 19.32       | 11      | 21      |