

Collaboration and Prospective Memory

Costs, Benefits, and Helpful Processes for Strangers
and Intimate Couples

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Thesis Abstract

In this thesis, I examined the effects of collaboration on prospective memory (PM) performance – remembering together to perform future intentions. Given the ubiquitous social nature of our daily lives, there has been a long tradition of examining the effects of collaboration on remembering the past. This field of research has shown that collaborating with others is not always beneficial; when collaborating, individuals typically do not perform to their potential, but instead demonstrate an effect known as collaborative inhibition. However, recent research has shown that certain groups –particularly intimate groups who use certain communication strategies – collaborate more effectively. This is consistent with transactive memory theory, which predicts that intimate groups, through communication, develop an efficient shared memory system over time.

To date, little research has investigated the effect of collaborating with others on PM. Therefore, across a series of four chapters and five studies, I systematically examined the effects of collaboration on PM in groups that varied in intimacy and PM ability. I examined collaborative PM in strangers, intimate couples, and couples where one partner had an acquired brain injury. I used a well-established laboratory PM measure – Virtual Week – in order to achieve experimental control with a task designed to simulate PM in daily life. Using Virtual Week, I was also able to test whether collaboration differentially affected tasks of varying difficulty. I also focused on individual differences within collaborating couples and examined communication processes during collaborative PM to determine what differentiates more successful, from less successful collaborators. Using findings from this qualitative analysis, I tested whether we can instruct groups to use strategies to improve collaborative PM performance, and whether these are better implemented on a group or an individual level. Overall, I aimed to bring together two fields of research and extend collaborative recall literature into the PM domain.

Statement of Originality

I certify that the work in this thesis entitled “Collaboration and Prospective Memory: Costs, Benefits and Helpful Processes for Strangers and Intimate Couples” has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree to any other university or institution other than Macquarie University. I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

The research presented in this thesis was approved by the Macquarie University Ethics Review Committee (Ethics Clearance numbers 5201400522 and 5201600313), and the Sydney Local Health District, RPAH zone Research Ethics Review Committee (Protocol No X15-0451 and HREC/15/RPAH/599).

A handwritten signature in black ink, appearing to read 'C. A. Browning'.

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Chapter 1

Introduction: Collaboration and Prospective Memory

Introduction

Prospective memory (PM) describes cognitive processes that support memory for intentions to be performed in the future, against a backdrop of ongoing tasks (Einstein & McDaniel, 1990; Ellis, 1996). Everyday PM tasks include common responsibilities of daily life, such as remembering to buy milk on the way home from work or remembering to pay the electricity bill. They also include tasks of greater importance where failure to remember has serious consequences, such as remembering to turn off the stove, remembering to take medication (Park & Kidder, 1996), and remembering to remove surgical instruments from patients after procedures (McDaniel & Einstein, 2007a). PM is important for an individual's social functioning – not only to remember pre-arranged social occasions, but to be regarded as a “reliable” person (Brandimonte & Ferrante, 2008). Therefore PM is vital for everyday living (Zeintl, Kliegel, Rast, & Zimprich, 2006) and functional independence (Rendell & Henry, 2009; Thöne-Otto & Walther, 2008). Despite the ubiquity of PM in our daily lives, we find PM tasks difficult. Both younger and older adults report PM as their most common type of memory failure (Crovitz & Daniel, 1984; Kliegel & Martin, 2003; Terry, 1988) and PM deficits are common in people with brain injury or neurodegenerative disease (Kliegel, Eschen, & Thöne-Otto, 2004; Rendell & Henry, 2009; Thöne-Otto & Walther, 2008).

In addition, we live – and remember – within social settings and we often need to perform PM tasks in collaboration with other people. For instance, families preparing to leave for an overseas vacation together must remember to pack their bags, arrange someone to look after the family pet, organise overseas currency, book a taxi to the airport, lock the house, and of course remember their passports. In educational settings, students frequently work together on group projects, which involve multiple occasions where they need to remember to do parts of the project in the future, the most important being to

submit it. In the workplace, people frequently work in teams where PM is part of their job. For instance, aircrews need to remember a sequence of steps to keep the airplane airborne (Dismukes, 2012; McDaniel & Einstein, 2007a), surgeons need to remember to remove surgical instruments from patients before finalising medical procedures (McDaniel & Einstein, 2007a), and sales assistants working in teams need to remember to secure the day's takings and lock the store safely at night.

While we often use external devices such as lists and smartphones to help us remember PM tasks, people from both healthy and clinical populations report collaborating with others as a beneficial strategy they use to support their PM performance in daily life (Evans, Wilson, Needham, & Brentnall, 2003; Intons-Peterson & Fournier, 1986; Parikh, Troyer, Maione, & Murphy, 2015; Thöne-Otto & Walther, 2008). Although much research has investigated PM performance in individuals (McDaniel & Einstein, 2007b), we know little about how PM performance might be influenced by collaboration (Brandimonte & Ferrante, 2008). Importantly, the intuitive view that collaboration is helpful for successful PM may not be accurate. In the vast body of literature investigating the effects of collaboration on *retrospective memory*, researchers have found that “collaborative inhibition” is the typical outcome in which collaboration impairs and disrupts recall performance (Marion & Thorley, 2016). Certainly, PM is different to retrospective memory in a range of ways, however it still involves a retrospective memory component. Individuals must recall the content of the PM task – what it is that they need to do, and when to do it (Ellis, 1996; Kliegel et al., 2004). Given this retrospective memory component in PM, we might expect to find collaborative inhibition in PM tasks too. However PM also involves a prospective component: remembering to retrieve the intention at the appropriate moment in the future (Einstein & McDaniel, 1996). It is less clear how collaboration might affect the prospective component of PM, and – as I will detail in this

Introduction – multiple predictions are possible. Therefore, I aimed to examine the effect of collaboration on PM performance, to determine whether collaboration is helpful or not. I also aimed to identify collaborative processes which might underlie successful collaboration, to inform the development of compensatory strategies for those experiencing PM difficulties.

In this Introduction, I begin by reviewing the literature on the effects of collaboration on recall, the mechanisms underlying these effects, and the factors that influence them. I then turn to review the literature on individual prospective memory and the processes involved in successfully completing PM tasks. Finally, I identify factors that might be expected to influence collaborative PM. In my program of research, I brought literatures on collaborative recall and prospective memory together to test the effects of collaboration on PM, as well as the mechanisms underlying these effects, and the factors that influence them.

Collaboration and Retrospective Memory: Collaborative Recall

Collaborative Inhibition

A large literature investigating collaborative (retrospective) recall – in which groups work together on episodic memory tasks like recalling word lists – typically shows costs of collaboration (for review see Harris, Paterson, & Kemp, 2008; Weldon & Bellinger, 1997). In order to quantify the potential that group members might achieve had they worked alone, these studies employ the “collaborative recall paradigm” (Weldon & Bellinger, 1997). The hallmark feature of the collaborative recall paradigm is the use of “nominal groups” as the control against which collaborative group performance is indexed. Nominal group scores are calculated as the pooled performance of an equal number of individuals as those in the collaborative group. The scores are not merely summed; rather, they are pooled and common items recalled by nominal group members are only counted

once. It is possible then to compare the actual performance of collaborative groups and the performance that these individuals should achieve had each group member recalled as they would alone (Harris, Paterson, & Kemp, 2008; Weldon & Bellinger, 1997). A very robust, and somewhat counter-intuitive finding from the collaborative recall paradigm is that although collaborating groups typically recall more than a single individual working alone (Weldon & Bellinger, 1997), they typically recall less than nominal groups. In other words, collaborative groups do not perform to their potential, and this effect is known as *collaborative inhibition* (B. H. Basden, Basden, Bryner, & Thomas, 1997; B. H. Basden, Basden, & Henry, 2000; Marion & Thorley, 2016; Rajaram & Pereira-Pasarin, 2010; Weldon & Bellinger, 1997).

Various possible reasons for collaborative inhibition in recall have been proposed and tested. Social loafing, a social phenomenon observed where people working together in groups exert less effort than when working as individuals and instead rely on others' contributions (Latané, Williams, & Harkins, 1979), was offered as a possible explanation. However, Weldon, Blair, and Huebsch (2000) manipulated participants' motivation to ensure they tried their hardest. In a series of experiments, they offered monetary incentives, reduced evaluation apprehension, increased personal accountability, increased group cohesiveness, and created all-female groups (to counter potential female reticence in mixed-gender groups). Despite these various attempts to increase motivation, collaborative inhibition prevailed. Therefore it is unlikely that the robust inhibitory effect is due to simple motivational effects.

Instead, the most commonly accepted and empirically supported explanation of collaborative inhibition is not social, but cognitive, and is known as the *retrieval disruption hypothesis* (B. H. Basden et al., 1997; Marion & Thorley, 2016). According to this explanation, individuals typically store, organise, and retrieve their memories in personally

relevant and idiosyncratic ways. When remembering within a group, individuals attempt to remember in an order that follows their own storage organisation, but are interrupted when they hear other group members' contributions. This causes them to abandon their own optimal retrieval strategies and instead either adopt the poorly matched retrieval strategy of other group members or adopt an entirely novel and less successful retrieval strategy. This results in them recalling less as a group than if they had recalled by themselves, as each individual within the group is disrupted. In a similar way, a retrieval disruption effect is observed in part-set cueing (for a review see Nickerson, 1984), by which individuals' recall is compromised when they are presented with a sub-set of a recall list during retrieval. D. R. Basden and Basden (1995) proposed that when some words from a list are provided during recall, these words are unlikely to coincide with the participants' own retrieval strategy already employed, and this interference encourages the participant to relinquish their own strategy – again causing disruption. In the case of collaborative recall, other group members (instead of an experimenter) are providing a sub-set of the recall list and causing retrieval disruption (Andersson, Hitch, & Meudell, 2006).

The retrieval disruption hypothesis has been supported by studies that show collaborative inhibition is reduced by a number of factors that enhance the ability of group members to strengthen and align their retrieval strategies. Examples where group members' individual storage or retrieval organisation were aligned, thus reducing disruption at retrieval, include: (1) studies where group members were instructed to organize their recall by category (B. H. Basden et al., 1997; Marion & Thorley, 2016); (2) studies that used materials to be remembered that contained more inherent structure such as stories, rather than uncategorized lists (Andersson & Rönnerberg, 1995; Marion & Thorley, 2016); (3) studies that used smaller groups (compared to larger groups) where the number of competing individual strategies is reduced (B. H. Basden et al., 1997; Marion &

Thorley, 2016), (4) studies that used cued recall rather than free recall, which imposes similar recall organisation on all participants (Finlay, Hitch, & Meudell, 2000); and (5) studies where group members collaboratively encoded materials to be remembered, which again encourages similar organisation of study materials (Barber, Rajaram, & Fox, 2012; Harris, Barnier, & Sutton, 2013), (but see Barber, Rajaram, & Aron, 2010; Marion & Thorley, 2016). Also consistent with the retrieval disruption hypothesis is evidence that collaborative inhibition was reduced when individuals kept separate and strengthened their own individual retrieval strategies, such as when group members were assigned different parts of a list (B. H. Basden et al., 1997).

Despite the support for the retrieval disruption hypothesis, there are several other cognitive processes that have been proposed to contribute to collaborative inhibition. These include retrieval inhibition, retrieval blocking, and production blocking (Barber, Harris, & Rajaram, 2015; Hyman, Cardwell, & Roy, 2013; Marion & Thorley, 2016). Retrieval inhibition occurs when words cued (or supplied) by another person lead to long-term suppression of the memory representation of non-cued words, making them unavailable. By this account, the non-cued items would therefore be unavailable for retrieval on subsequent individual tests of both free recall and recognition. Retrieval blocking occurs when words supplied or cued by another person are strengthened, which blocks access to non-cued words. However, this does not make them unavailable. By this account, the non-cued items would therefore be inaccessible in subsequent free recall tests but available in recognition tests. This was tested by Barber et al. (2010) who found that memory deficits persisted in subsequent individual tests of both free recall and recognition, providing evidence for a role of retrieval inhibition (Barber et al., 2015). Production blocking occurs when group members are unable to produce their response as it comes to mind because other group members are speaking. Wright and Klumpp (2004) showed that

production blocking alone did not explain collaborative inhibition. However, production blocking also predicts limited search, which occurs when group members sample from fewer categories when they recall. Consistent with this, Hyman et al. (2013) found that collaborative groups produce words from fewer categories than nominal groups. Therefore, although the retrieval disruption hypothesis is the most supported explanation of collaborative inhibition, there may be multiple cognitive mechanisms underlying the collaborative inhibition effect (Marion & Thorley, 2016).

Post-collaborative Recall

Despite the robust findings of collaborative inhibition during collaboration, evidence also shows that after collaboration, former group members recall more on individual tests (B. H. Basden et al., 2000; Henkel & Rajaram, 2011; Marion & Thorley, 2016; Rajaram, 2011; Weldon & Bellinger, 1997). This benefit exceeds that experienced by nominal group members simply from repeated testing. Post-collaborative benefits occur due to a release from the retrieval strategy disruption that occurred during collaboration, combined with re-exposure to items studied during collaboration (contributed by other group members), which leads to a net positive effect (Marion & Thorley, 2016).

Collaborative Recall and Errors

Another advantage of collaboration is that collaborative groups generally produce fewer memory errors than nominal groups – via the process of error pruning (B. H. Basden et al., 1997; Harris, Barnier, & Sutton, 2012; Hyman et al., 2013; Meade & Roediger, 2009; Ross, Spencer, Linardatos, Lam, & Perunovic, 2004). Such error pruning only occurs when collaborative groups engage in free flowing retrieval or reach a consensus (Harris et al., 2012), such that group members have the opportunity to correct each other's errors (Ross et al., 2004), but not when group members simply take turns without interacting (Harris et al., 2012; Thorley & Dewhurst, 2007).

Transactive Memory Systems

Looking beyond cognitive explanations of collaborative inhibition, research has suggested that the relationship between collaborators is an important factor for the outcomes of collaboration (for a review see Harris et al., 2008). Most collaborative recall studies have been conducted with undergraduate strangers, who meet for the first time in the experiment, recall relatively meaningless material, and have no joint outcome or goals (B. H. Basden et al., 1997; D. R. Basden & Basden, 1995; Weldon & Bellinger, 1997). Despite the robust inhibitory effect found in the collaborative recall literature, some groups may collaborate more effectively than others. Theoretical accounts of social remembering predict possible benefits of collaboration, but only in certain kinds of groups. Specifically, Wegner's theory of "transactive memory systems" posited that – over time and with experience remembering and communicating together – intimate dyads or groups develop efficient shared systems for encoding, storing and retrieving information (Wegner, 1987; Wegner, Giuliano, & Hertel, 1985). Furthermore, according to this theory, communication allows group members knowledge of, and access to, information in the other members' domains of expertise. The products of a group's transactive memory system are not merely the sum of its individual members' parts (Barnier, Klein, & Harris, 2017). Rather, each individual group member's contribution is integrated and transformed through the group interactive processes such that there are new and emergent properties; new information is produced and the transactive memory system becomes greater than the sum of its individual members (Wegner, 1987; Wegner et al., 1985). That is, through *processes* of communication, transactive memory systems enhance the *products* of group memory.

Information within transactive memory systems is either integrated, where information is held in common by group members, or differentiated, where information is held by only one group member (Wegner et al., 1985). Differentiation then allows the

efficient distribution of detailed knowledge throughout the system according to each group member's particular expertise (Wegner, 1987). In some groups, extreme cases of differentiation may emerge. In this case, Wegner et al. (1985) proposed that where one group member is the expert for particular memories or tasks, the memory of the group essentially is the memory for that individual. This may be particularly relevant when one partner within a couple experiences memory difficulty, for instance, or in work teams where roles are highly defined and distinct.

In support of the predictions of transactive memory theory, Wegner, Erber, and Raymond (1991) found that couples collaboratively recalled more categorized words than stranger pairs. However, this benefit only came about when couples were free to use their own intuitive (presumably, transactive) system for sharing recall responsibility.

Conversely, when couples had a system for sharing responsibility imposed upon them by the experimenter, they recalled less than stranger pairs. Wegner et al. (1991) suggested the experimenter-imposed system disrupted the implicit transactive memory systems that had already developed between couples for effectively sharing memories.

Critically, and of relevance to the current program of research, transactive memory systems are predicted to develop over a period of time – that is, in groups with long term relationships (Wegner, 1987; Wegner et al., 1985). There is evidence from the collaborative recall literature that the collaborative inhibition effect may be reduced or abolished in particular kinds of groups. Andersson and Rönnerberg (1995, 1996) found that friends showed less collaborative inhibition than strangers, an advantage they attributed to transactive memory systems (but see Gould, Osborn, Krein, & Mortenson, 2002). Johansson, Andersson, and Rönnerberg (2005) found that older couples who reported dividing their labour eliminated collaborative inhibition, which suggests there are individual differences amongst collaborative dyads in how effectively they collaborate.

Highlighting again the potential for individual differences in outcomes of collaboration, Harris, Keil, Sutton, Barnier, and McIlwain (2011) found that some older couples recalling both personal and non-personal information were able to abolish collaborative inhibition and in some cases to even reverse it. These couples were found to use particular beneficial cuing and communication strategies. Indeed, effective communication strategies have been found to underlie collaborative success in other types of groups. Meade, Nokes, and Morrow (2009) found that pairs of expert pilots who did not know each other, but were taught to use effective communication techniques as part of their pilot training recalled more than nominal groups – a rare instance of collaborative facilitation.

Taken together, these studies suggest factors such as the level of intimacy, group expertise, strategies, and communication processes, can moderate the effects of collaboration on retrospective memory tasks, as predicted by transactive memory theory. Based on these findings, we expect that these same factors could moderate the effects of collaboration on PM. I now turn to review the literature on individual PM performance before considering how collaboration may influence PM.

Prospective Memory

Prospective memory describes the processes required to remember to carry out intended plans in the future whilst engaging in ongoing activities (Einstein & McDaniel, 1990; Ellis, 1996). There is a retrospective memory component in PM: individuals must recall what it is that they need to do, and when to do it (Einstein & McDaniel, 1996; Ellis, 1996; Kliegel et al., 2004). Given this retrospective memory component, we might expect to find collaborative inhibition in PM tasks too. We might also expect similar moderating effects of intimacy, expertise, group strategies, or group-enhancing communication processes as identified for collaborative recall.

However PM also involves a prospective component – remembering to perform the

task at the required moment (Einstein & McDaniel, 1996). Individuals must recruit executive processes to monitor the environment for the appropriate target occasion, reinstate the intention, switch away from the ongoing activity, and then initiate and execute the intention (Ellis, 1996; Kliegel et al., 2004). The challenging feature of PM is that the individual is typically not explicitly prompted to complete the task, but instead must self-initiate retrieval of the intention despite distractions and other activities, and with varying levels of support from the environment. Some PM tasks are strongly supported by environmental cues that trigger the appropriate moment to reinstate the intention and perform the task; these have lower self-initiated retrieval demand. Other PM tasks are minimally supported by the environment; these have higher self-initiated retrieval demand. That is, the extent to which the individual must engage in self-initiated retrieval processes is inverse to the amount of environmental support (Craig, 1994).

PM tasks are distinguished according to the type of environmental cue inherent in the task, which in turn determines the degree to which self-initiated retrieval is required. Event-based PM tasks are performed when a certain external event occurs. An example would be remembering to post a parcel at the post office when at the local shops. The act of passing the post office while shopping acts as an external cue that prompts remembering at the appropriate event. Time-based PM tasks must be performed at a certain time, or after a certain amount of time has passed, for example, remembering to attend a dentist appointment at 10.00 am or remembering to take the cake out of the oven after 45 minutes has passed. In this case, there is no external cue to prompt remembering, so the individual relies more on careful and strategic monitoring in order to initiate the action at the appropriate time (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). Another way that PM tasks are distinguished is according to the focality of cue processing (McDaniel & Einstein, 2000). With focal tasks the PM cue is central and is processed as part of ongoing

task performance. An example is remembering to give theatre tickets to your friend the next time you see them. You might actually forget this intention, but the next time you meet your friend for coffee (the ongoing task), your attention is directed towards your friend, which allows spontaneous retrieval of the intention. With nonfocal tasks, the PM cue is peripheral to the ongoing task, for example trying to remember to stop for milk as you drive home from work when you do not pass a grocery store, and your attention is directed towards driving through peak hour traffic. Accordingly, focal tasks demand less strategic monitoring and attentional resources than nonfocal tasks.

Theoretical Perspectives on PM

The multiprocess theory of PM suggests that two pathways support PM retrieval, and the pathway that is recruited depends on the environmental support inherent in the PM task (McDaniel & Einstein, 2000; McDaniel, Umanath, Einstein, & Waldum, 2015). The first pathway depends on top-down, strategic attentional control processes that maintain activation of the intention in working memory, and monitor or search the environment for the cue that will trigger the appropriate moment to retrieve the intention. This pathway is more likely for tasks lower in environmental support. In contrast, the second pathway is thought to depend on bottom-up, spontaneous retrieval processes. This pathway is more likely for tasks higher in environmental support. Therefore, the multiprocess theory suggests that we perform PM tasks in two ways: we employ constant strategic monitoring and we also rely on spontaneous retrieval triggered by environmental cues. As well as each task's inherent environmental support, McDaniel and Einstein (2000) proposed a number of other factors that influence the extent to which we use strategic versus spontaneous retrieval processes. These factors include the distinctiveness of the target, the degree to which the target is associated with the intended action, the level of absorption in the ongoing task, individual personality differences, and the level of importance placed on the

task (McDaniel & Einstein, 2000).

The multiprocess theory is supported by evidence that shows more age related decrements in PM tasks that require strategic monitoring and self-initiated retrieval. Craik (1986) predicted the greatest effects of aging would be seen in memory tasks that relied heavily upon the self to initiate retrieval, as opposed to tasks where environmental support provided retrieval context. And indeed studies have shown that in PM, older adults show a particular deficit in time-based tasks compared to event-based tasks (Einstein et al., 1995; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; Rendell et al., 2011), and nonfocal tasks compared to focal tasks (Kliegel, Jager, & Phillips, 2008; Kliegel, Rendell, & Altgassen, 2008; Rendell, McDaniel, Forbes, & Einstein, 2007), and event-based PM tasks with high strategic demands compared to low strategic demands (Henry, MacLeod, Phillips, & Crawford, 2004) .

The preparatory attentional memory theory (Smith & Bayen, 2004) instead proposes that PM tasks always require demanding preparatory attentional processes for self-initiated retrieval and successful PM performance, regardless of the extent to which environmental cues are present. That is, PM task retrieval is never initiated spontaneously, and is always “capacity consuming” (although not necessarily the *focus* of attention), regardless of PM task parameters (e.g., target distinctiveness). Smith (2003) argued that because PM task paradigms were set up such that PM tasks were embedded within a backdrop of ongoing activity, the presence or absence of capacity-consuming monitoring could be measured by costs to ongoing task performance. Support for the preparatory attentional memory theory was shown when performance in an ongoing task (a lexical decision task) was better in a group that did not have an embedded PM task, than in a group that did have an embedded PM task. Costs were observed in the embedded PM task group even for non-PM target trials (Smith, 2003). Decreased performance in the ongoing task, even when no

PM target was presented, was interpreted as evidence that PM tasks are capacity consuming and thus deplete available cognitive resources.

While acknowledging that there are two lines of ongoing theoretical debate regarding how PM works in individuals, the aim of my research is not to adjudicate between the two. I will however consider the influence of collaboration on PM from the multiprocess theory perspective because this theory predicts differences in the effects of collaboration for different PM tasks depending on whether they involve effortful or spontaneous retrieval of intentions. Furthermore, in my research I measured PM performance using the “Virtual Week” methodology (Rendell & Craik, 2000), which indexes different kinds of PM tasks and produces evidence that supports the multiprocess theory (for example Rose, Rendell, McDaniel, Aberle, & Kliegel, 2010).

Prospective Memory Difficulties

Both younger and older adults report difficulties with PM (Crovitz & Daniel, 1984; Kliegel & Martin, 2003; Terry, 1988). However, PM is particularly impaired in older adults (Kliegel et al., 2004; Rendell & Craik, 2000) and individuals with brain injury and neurodegenerative disease (Kliegel et al., 2004; Rendell & Henry, 2009; Thöne-Otto & Walther, 2008). This is because the various cognitive processes involved in PM rely on different areas of the brain. The frontal region has been strongly associated with PM performance because PM requires executive functions to support the prospective component (Burgess, 1997; Kliegel et al., 2004). In addition, temporal regions have been associated with PM, as these ‘memory’ areas are important for the retrospective component (Ellis, 1996; Kliegel, Jager, Altgassen, & Shum, 2008; Reynolds, West, & Braver, 2008). Patients with an acquired brain injury experience varying degrees of PM difficulties (Cockburn, 1996; Fish, Wilson, & Manly, 2010; Groot, Wilson, Evans, & Watson, 2002), depending on the location of the brain lesion, as well as the type of PM

task (Adda, Castro, Além-Mar e Silva, de Manreza, & Kashiara, 2008; Henry, Phillips, et al., 2007; Kim, Craik, Luo, & Ween, 2009; Kinch & McDonald, 2012; Knight, Harnett, & Titov, 2005; Mioni, Rendell, Henry, Cantagallo, & Stablum, 2013). In addition, many studies have confirmed that individuals from clinical populations with other various neurological brain pathology including dementia, mild cognitive impairment, multiple sclerosis, Parkinson's disease, chronic heart failure, schizophrenia, and substance use, all have particularly impaired PM (Foster, Rose, McDaniel, & Rendell, 2013; Habota et al., 2015; Henry, Rendell, Kliegel, & Altgassen, 2007; Rendell, Gray, Henry, & Tolan, 2007; Rendell, Jensen, & Henry, 2007; Terrett et al., 2014; Thompson, Henry, Rendell, Withall, & Brodaty, 2010).

Because the pre-frontal cortex is associated with age-related functional and structural changes (see West, 1996, for a review), there are age-related declines in PM (Kliegel et al., 2004). Furthermore, as predicted by Craik (1986), older adults are particularly impaired on PM tasks that rely more on executive function, that is, on the PM tasks that are not spontaneously retrieved due to inherently low environmental support. Studies have shown that older adults show a particular deficit in time-based tasks compared to event-based tasks (Einstein et al., 1995; Rendell et al., 2011), and nonfocal tasks compared to focal tasks (Kliegel, Jager, & Phillips, 2008; Kliegel, Rendell, et al., 2008; Rendell, McDaniel, et al., 2007). Einstein, Holland, McDaniel, and Guynn (1992) also found age-related differences in performance related to the difficulty of the retrospective component: although older adults performed as well as younger adults on PM tasks with one target item to remember, older adults performed worse than younger adults on PM tasks with four target items to remember. Similarly, an age effect was observed for PM tasks which contained more complex task content and only one encoding opportunity, (i.e., higher retrospective memory demand), compared to PM tasks which contained less

complex task content, and multiple encoding opportunities (i.e., lower retrospective memory demand) (Kliegel, Rendell, et al., 2008; Rendell & Craik, 2000).

Intriguingly, an “age-paradox” has emerged in PM research where older adults actually perform better in *naturalistic* PM tasks (both event- and time-based) compared to younger adults, who in turn exhibit superior performance in *laboratory* tasks (Henry et al., 2004; Ihle, Schnitzspahn, Rendell, Luong, & Kliegel, 2012; Rendell & Craik, 2000).

Naturalistic tasks differ from laboratory tasks in that they are conducted outside the laboratory and are instead situated within participants’ daily lives. They are usually conducted over a number of days, whereas laboratory tasks are more often completed within a number of hours. They include tasks such as asking participants to log in to an electronic organiser at certain times during the day (Rendell & Thomson, 1999), or more complex tasks designed to mirror laboratory tasks, but are instead conducted within participants’ homes rather than in the laboratory (e.g., Experiment 2, in Rendell & Craik, 2000). Factors such as greater motivation, the likelihood of older adults to use external devices in everyday life, older adults’ lack of familiarity with technology, and greater routine assumed to be present in older adults’ lives have been put forward as explanations for the age-paradox. Studies have attempted to manipulate or control for some of these factors, however some have still found the age-paradox persists (Rendell & Craik, 2000; Rendell & Thomson, 1999).

To date the age paradox has not been resolved, however possible explanatory mechanisms that were found to moderate the age-related benefit observed in naturalistic tasks included: (1) parameters of the time-based tasks – naturalistic time-based tasks were generally “time-of-day” tasks which enjoyed contextual environmental support compared to laboratory time-based tasks which were generally nonfocal arbitrary passage-of-time tasks (Kliegel, Rendell, et al., 2008); (2) the nature of the ongoing task – in naturalistic PM

studies, ongoing tasks were often normal everyday activities, whereas in laboratory studies, ongoing tasks were experimenter devised (Bailey, Henry, Rendell, Phillips, & Kliegel, 2010); and (3) the level of importance that individuals placed on various tasks, and older adult's ability to adaptively reprioritise intentions compared to younger adults, gave older adults an advantage in naturalistic tasks (Ihle et al., 2012). Although the use of external devices – including other people – to act as reminders was associated with better PM performance overall (Ihle et al., 2012), it did not moderate the age effect. The authors noted however that different types of reminders were not differentiated, which leaves open the possibility that certain types of external devices are more effective for older adults.

Collaboration as a Compensatory Strategy to Improve PM

Similar to the age-paradox observed in PM research, Dixon, Gagnon, and Crow (1998) noted that despite widespread evidence supporting the decline of cognitive abilities with aging, many older adults are still very capable when carrying out activities of daily life. They proposed that memory compensation might be one mechanism by which the age-paradox occurred (Dixon et al., 1998). That is, older adults may use strategies in their day-to-day lives that boost their performance and that don't reflect the deficits seen on more formal testing. Similarly, in clinical populations, compensatory approaches to memory deficits are commonly recommended to patients, over and above therapies aimed to reconstitute function (Evans et al., 2003; Thöne-Otto & Walther, 2008).

Collaborating with a partner, friend or caregiver is a readily available external memory aid that could enhance memory in those experiencing difficulties (Dixon et al., 1998; Henkel & Rajaram, 2011), and people typically believe that collaborating with others is more helpful than working alone (Dixon et al., 1998; Henkel & Rajaram, 2011). Furthermore, in contrast to other external memory aids such as smartphones or calendars, Dixon et al. (1998) pointed out that collaborating with another person for memory support

encourages contributions that are active, strategic, productive, dynamic, and of course fallible. There is much evidence supporting the idea that people work with others to help with memory difficulties. Margrett, Reese-Melancon, and Rendell (2011) analysed collaborative dialogue between spouses supporting each other on PM and noted that the couples used each other as external memory aids. They also suggested that such collaboration could in part contribute to the age-paradox outlined above. Parikh et al. (2015) reported that older adult couples who were experiencing age-related memory decline helped each other in “partnership” to compensate for memory changes. In couples where one partner had mild cognitive impairment however, they found there was a shift towards the impaired partner relying more on the healthy partner for memory support (Parikh et al., 2015). Despite this evidence, Dixon, de Frias, and Bäckman (2001) reported that relying on others (spouse or friend) was the least reported memory compensation strategy of those they investigated, less endorsed than using external tools like calendars or internal strategies like mnemonics. However, reported reliance on others did increase with age and with cognitive decline (Dixon, Hopp, Cohen, de Frias, & Bäckman, 2003). In clinical populations, enlisting the help of others as an external memory aid is associated with functional independence of individuals with acquired brain injury (Evans et al., 2003). Even healthy younger adults enlist the help of others to carry out PM tasks (Intons-Peterson & Fournier, 1986), perhaps because young adults report PM as their most common memory failure (Croviitz & Daniel, 1984).

There is also evidence from the developmental literature that the social aspect of collaboration might be particularly beneficial for older adults, or indeed other populations where life circumstances dictate that social and emotional goals become salient. Social selectivity theory describes how older adults increasingly prioritize more emotionally meaningful goals and social interactions as they age (Carstensen, 1992; Lang &

Carstensen, 2002). Support for this idea is also found in PM literature. For instance, Altgassen, Kliegel, Brandimonte, and Filippello (2010) found that older adults performed better when PM tasks became more socially important, whereas there was no change in younger adults' performance. In addition, Niedźwieńska, Rendell, Barzykowski, and Leszczyńska (2014) showed that the age-related PM deficit was reduced when older adults received social feedback regarding their PM performance from an experimenter, but not when it was only delivered on-screen. The authors suggested that in older adults, social feedback produced positive emotions, which may in some way offset the increased frustration and lower levels of confidence that negative feedback can induce. Given the evidence outlined above, collaboration, which is innately a social activity, combined with effective feedback during task performance, may be particularly beneficial in populations experiencing PM difficulties.

In summary, given there is widespread evidence that people work together to help compensate for memory difficulties, and given that PM tasks are particularly difficult for older adults and certain clinical populations, it is important that we evaluate the effectiveness of collaboration on PM performance. This is particularly important considering the robust costs observed in the collaborative recall literature, which suggest that collaboration may not always be successful.

The Effects of Collaboration on PM

While the collaborative recall literature leads to a clear prediction of collaborative inhibition for the retrospective component of PM, it is unclear how collaboration will impact the prospective component of PM. Indeed, evidence from previous studies supports alternative hypotheses. On one hand, working with others offers a potential source of external support. Consistent with this possibility, research has shown that generally, the provision of reminders improves PM performance (Henry, Rendell, Phillips, Dunlop, &

Kliegel, 2012; Ihle et al., 2012), particularly if they specifically state “what” and “when” something needs to be done (Guynn, McDaniel, & Einstein, 1998). However, when participants were misled to believe they would receive a reminder they would never actually receive, the expectation of a reminder alone actually impaired performance (Kobayashi & Maruno, 1994; Schaefer & Laing, 2000). Schaefer and Laing (2000) suggested that transferring responsibility of a reminder and relying on someone else for external memory support decreases the activation of the intention. But a more interactive form of collaboration where group members are invested in joint outcomes might not result in a complete transfer of responsibility to someone else. This study also suggests that in some cases the reliability of external support is crucial. External support may be particularly important for difficult tasks that require a high degree of strategic monitoring and are otherwise low in environmental support. Given the differences in task demands related to the presence or absence of external environmental cues (as outlined above), we might expect collaboration to improve performance to a greater extent in relatively less supported time-based tasks and nonfocal tasks compared to the relatively more supported event-based and focal tasks.

On the other hand, the social interactions that occur during collaboration may interfere with individuals’ processes that support the prospective component of PM. Dividing attention, by increasing demands of the ongoing task at either encoding or retrieval have been shown to disrupt PM performance (Einstein, Smith, McDaniel, & Shaw, 1997). McDaniel and Einstein (2000) suggested that the more absorbing, engaging, or demanding the ongoing activity is, the less there would be available resources for strategic monitoring. Consistent with this possibility, Kvavilashvili (1987) found that increased ongoing task engagement decreased thoughts about PM tasks, and Henry et al. (2014) found that increased ongoing task engagement decreased PM performance itself.

Thus, to the extent that collaboration is engaging and salient, it may impair PM performance.

Of particular interest to this research is whether ongoing conversation alone might disrupt PM. In experimental PM paradigms, the ongoing task is designed to represent the daily activities against which prospective memory tasks must be remembered. Marsh and Hicks (1998) divided attention using different types of ongoing tasks to test whether some are more disruptive to PM than others. Specifically, they varied the ongoing tasks in such a way that they would each represent a different type of processing that takes place in working memory. Accordingly, they compared tasks that differentially engaged the various components of working memory; the central executive (counting forwards and backwards by 3s), the visuospatial sketchpad (watching a changing display of coloured pixels), and the phonological loop (repeating words aloud). In addition, they varied the cognitive load (high or low load) on each mode of ongoing task. They showed that PM performance suffered most for participants engaged in ongoing tasks that loaded more strongly on the central executive (executive control), but not the other ongoing task types. These findings suggest that collaboration might be disruptive to PM depending on how difficult the participants find the ongoing task and depending on the extent to which they require executive control to coordinate the requirements of the ongoing task with someone else. However, these findings also suggest that conversation alone during collaboration (which is similar to speaking words aloud) may not be disruptive to PM. In contrast to this finding however, Stone, Dismukes, and Remington (2001) found that while concurrently repeating words aloud was not detrimental to routine PM tasks, it was detrimental to non-routine PM tasks. Accordingly, they speculated that casual conversation in itself could disrupt the sort of PM tasks that are outside our normal routines. For any potential disruption caused by collaboration as outlined above, tasks that are low in environmental support would be more

detrimentally affected by collaboration due to their increased reliance on strategic processes required to retrieve intentions.

There have only been a handful of other studies investigating the role that social interaction plays in PM. In one study Margrett et al. (2011) analysed dialogue exchanged between married couples as they collaborated on the Virtual Week PM task (Rendell & Craik, 2000). Although they observed that couples actively supported each other, the effectiveness of this strategy for PM performance was not evaluated; measures of individual performance were not taken for comparison. Although no quantitative measure was taken, verbal evidence indicated accurate retrieval cues given by partners seemed to assist PM. Margrett et al. (2011) found that the most frequent verbal behaviours were tutoring, monitoring, encoding, and sociability, although only tutoring (a measure of general support) was significantly related to PM performance.

D'Angelo, Bosco, Bianco, and Brandimonte (2012) examined collaboration in PM by pooling the responses of individuals who were tested in the same room simultaneously, but seated at separate computers. Importantly, they were told their computers were connected, and their responses would be combined with their partners. They did not work together throughout the task and they could not see each other's responses. Results showed that individuals outperformed the collaborative groups, and the effect was attributed to social loafing – that is, the individuals in the collaborative condition did not exert as much individual effort and relied instead on their partner's contributions (Latané et al., 1979). However the experimental paradigm used in this study encouraged social loafing; collaborators were able to “hide” their individual contributions. This is not necessarily representative of collaborative efforts in daily life, where more often, individual contributions are known and have genuine consequences for group outcomes. Therefore in order to minimise social loafing opportunities and to maintain ecological validity, I

adopted a more interactive form of collaboration in my research. This is consistent with Barnier, Sutton, Harris, and Wilson (2008) who recommended that studies investigating collaborative cognition should encourage a “deeper” form of collaboration. This type of collaboration can be seen when individuals are jointly involved in a collective memory task and where they are both genuinely invested in successful performance.

To date, just one study has adopted the collaborative recall paradigm to examine PM, comparing PM performance of collaborative pairs to pooled nominal groups. After asking pairs of older adults aged above 65 to complete a novel tour around a university campus, Johansson, Andersson, and Rönnerberg (2000) found evidence of collaborative inhibition in PM for both married couples and strangers. Highlighting the potential for individual differences, some couples – specifically those who scored high on self-reported transactive memory systems – showed no inhibition. The authors cautioned that their naturalistic tour task set amidst an unfamiliar environment might not be analogous to common everyday PM activities. They suggested this might have led to an unexpected pattern of performance for PM tasks of varying difficulty. In addition, it is not yet known whether the effects on PM were driven by inhibition in the retrospective component of PM, the prospective component, or both. However, this study is a promising first step, and suggests potential costs – on average – for collaborative PM, as well as individual differences in outcomes.

The Current Research

The overarching aim of my research was to investigate the influence of collaboration on PM. Consistent with past research investigating the influence of collaboration on retrospective memory, I employed the collaborative recall paradigm (Weldon & Bellinger, 1997) and compared collaborative groups to nominal groups. In order to produce truly interactive collaboration, where both individuals in collaborative

dyads worked together as they would in daily life, I assessed PM performance using Virtual Week (Rendell & Craik, 2000; Rendell & Henry, 2009). Virtual Week is a computerised board game designed to simulate the PM activities of a typical week (Figure 1). It also allows systematic comparison of performance on different types of PM. Each virtual “day”, participants must remember to perform four event-based PM tasks (e.g., “Drop in dry-cleaning when out shopping”), four time-based PM tasks (e.g., “Take asthma inhaler daily at 11.00 am”), and two nonfocal PM tasks in which they monitor the real time on a stop-clock (e.g., “Check lung capacity at 2:00 minutes and 4:00 minutes on the stop-clock”), (Figure 2). Tasks vary in difficulty: some offer environmental reminders, whereas others require participants to self-initiate reminder cues (Rendell & Craik, 2000; Rendell & Henry, 2009). Virtual Week is a reliable and valid indicator of PM function in healthy individuals and clinical populations (Rendell & Henry, 2009), and it allows interactive, conversational collaboration (Margrett et al., 2011; Rendell & Craik, 2000).

Across the various experiments conducted, I aimed to examine how collaboration influenced PM performance in different kinds of groups – particularly in stranger dyads and intimate couples. I also aimed to tease out whether any collaborative inhibition effect observed was driven by the retrospective component, the prospective component, or both. Although I did not aim to directly test transactive memory theory, I used this theory as a framework to understand when and why some collaborating groups are more successful than others (Harris et al., 2011). Similarly, I did not set out to directly test the multiprocess theory of PM, but used this theory as a framework to interpret the influence of collaboration on the spontaneous retrieval of intentions, as well as the strategic retrieval of intentions.

In addition, it is only through the *processes* underlying effective communication and interactions among group members that transactive memory systems enhance the

product of group memory. Therefore, I aimed to not only evaluate the average products of collaborative PM, but to also qualitatively investigate the processes underlying the individual differences in collaborative outcomes. After identifying effective collaborative processes, I also aimed to test whether people collaborating on PM tasks can be instructed to use strategies to improve their collaborative outcomes. Finally, because enlisting the help of an intimate partner is often used as a compensatory strategy for those experiencing particular PM difficulties, I aimed to evaluate the effectiveness of people with acquired brain injury working together with their spouses on PM tasks.

Overview of the Thesis

This thesis takes the format of a “thesis by publication”, where each chapter is an independent manuscript relating to the overarching research questions. For this reason, the literature reviews in each chapter sometimes include overlapping information. A version of Chapter 2 has been submitted, and subsequently accepted for publication in the journal *Memory*. The remaining chapters have been prepared for submission to other journals that were considered to be appropriate for each paper’s research question. Therefore, each chapter has been prepared for a different target audience, with a different emphasis, and with different word limits. A brief introduction to each chapter indicates how it fits into my overall research program, and I have included details about each target journal.

In Chapter 2, I report two experiments where I adopted the collaborative recall paradigm to test whether stranger dyads (Experiment 1) would perform better on the Virtual Week task (Rendell & Craik, 2000; Rendell & Henry, 2009) when working together or each working alone – that is, whether I would replicate the robust collaborative inhibition effect in PM. Because PM involves both a prospective and retrospective component, I also attempted to measure and control for the retrospective component of PM. I did this in order to tease out whether any collaborative inhibition effect observed

was driven by the retrospective component, the prospective component, or both. In Experiment 2, I recruited intimate couples to work on the same task as Experiment 1, and tested whether the effects of collaboration in couples were similar or different to those observed in strangers.

In Chapter 3, I report the results of a qualitative analysis conducted to identify cognitive, social and communication processes that led to more successful collaborative PM in the first two experiments reported in Chapter 2. I analysed and compared the dialogue of 5 high performing and 5 low performing collaborating dyads each from Experiment 1 (strangers) and Experiment 2 (couples) – 20 dyads in total. I coded the transcripts for cognitive processes, social processes, and generalised conversational skills. A Principal Components Analysis yielded a four-factor solution, which I used to calculate factor scores for each dyad. In doing so, I was able to determine the processes that were associated with better and worse performance in couples and strangers.

In Chapter 4, I report an experiment where I manipulated strategies that collaborative dyads used as they played Virtual Week to explore whether we can instruct people how to collaborate more successfully on PM tasks. I developed these instructions based on the helpful collaborative processes I identified in Chapter 3. I also examined whether collaborative strategies are better implemented at a group, or an individual level.

In Chapter 5, I report the final experiment where I extended my research into a clinical population of patients with acquired brain injury and their spouses, to evaluate benefits (and costs) of working together on PM tasks for the patient, their spouse, and for the couple overall. Participants also completed neuropsychological assessments, intimacy scales, and caregiver burden scales. I also examined whether collaborative style influenced collaborative outcomes.

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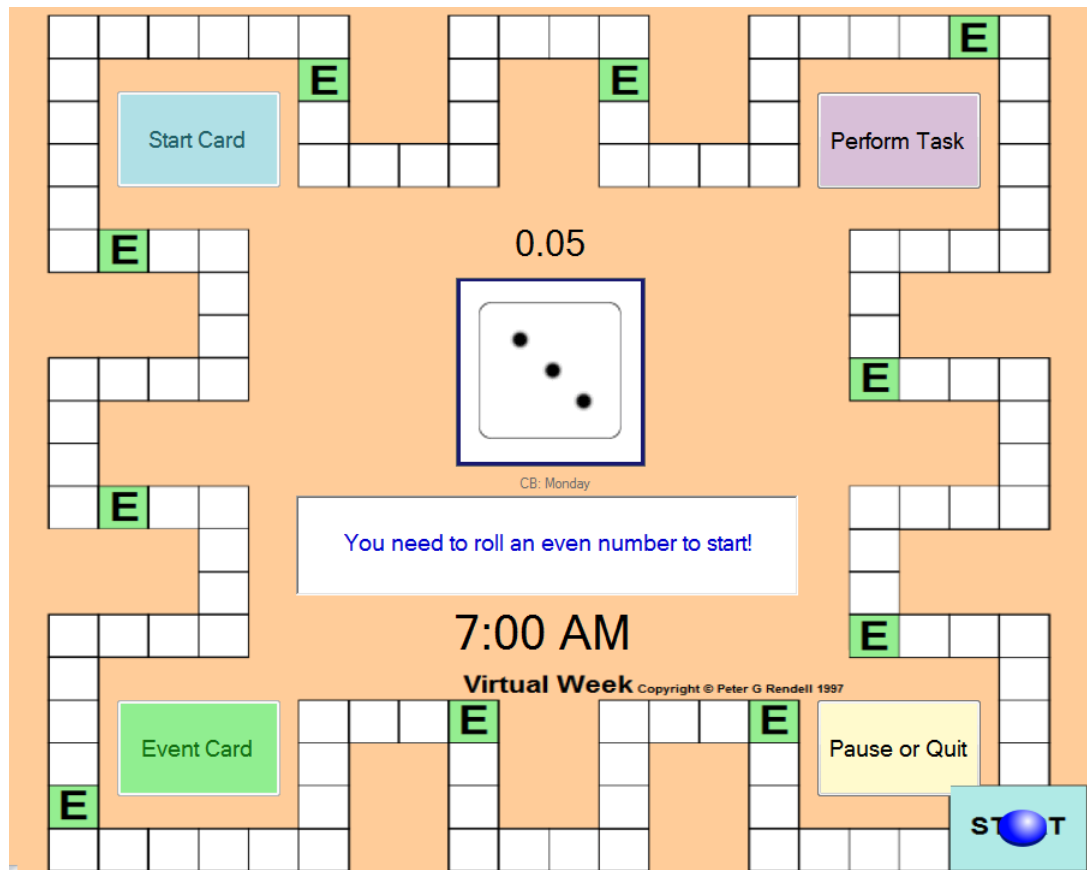
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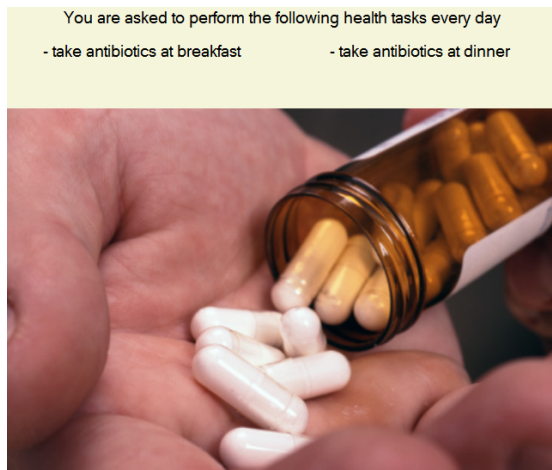
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Figure 1. Screenshot of the Virtual Week game board.

Regular Tasks

Irregular Tasks

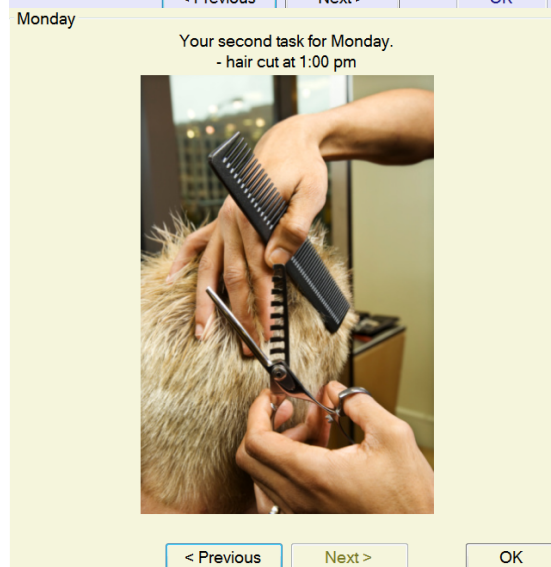
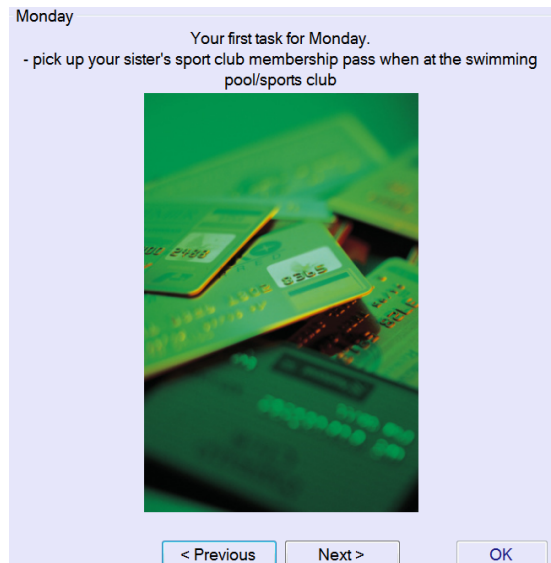
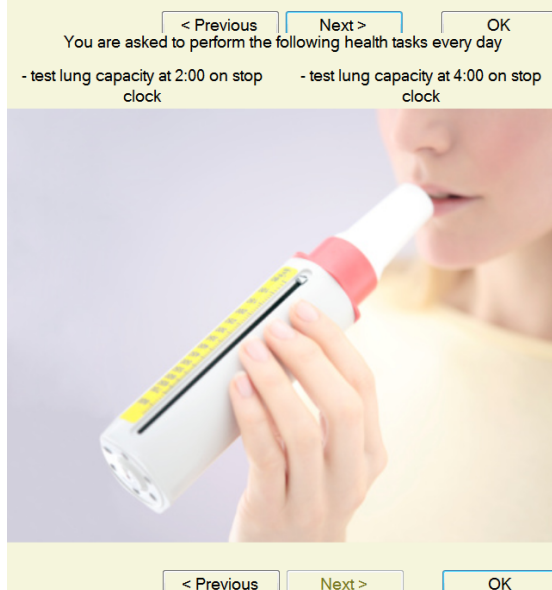
Event-based Tasks



Time-based Tasks



Time-check Task



Virtual Week Copyright © Peter G Rendell 1997

Figure 2. Screenshots of examples of the Virtual Week prospective memory task types.

Chapter 2

Collaborative Prospective Memory in Strangers and Couples

This chapter was prepared as:

Browning, C. A., Harris, C. B., Van Bergen, P., Barnier, A. J., & Rendell, P. G. (2017).

Costs and benefits of performing prospective memory tasks in collaboration with another person. Manuscript submitted for publication.

In this chapter, I present two experiments in which I extend the findings from the collaborative recall literature into the PM domain. I adapted the collaborative recall paradigm to use with a well-validated laboratory procedure that models PM in everyday life, “Virtual Week”, and I compared collaborative and nominal pairs. To establish a baseline for the effects of collaboration on PM, in the first experiment, I recruited strangers to work together on PM, consistent with most prior collaborative recall studies.

In the second experiment, I recruited intimate couples to work together, in order to test whether intimacy between collaborating partners would modulate the effects of collaboration on PM performance, as predicted by transactive memory theory and previous studies in the collaborative recall literature.

This chapter was prepared for the journal *Memory*, and a version of it was subsequently published as: Browning, C. A., Harris, C. B., Bergen, P. V., Barnier, A. J., & Rendell, P. G. (2018). Collaboration and prospective memory: comparing nominal and collaborative group performance in strangers and couples. *Memory, Published online February 1, 2018*, 1-14. doi:10.1080/09658211.2018.1433215. The description of this journal is appended to this chapter (p. 93). While this is a co-authored manuscript, I was the major contributor to all aspects of the experimental design, the participant recruitment, the data collection and analysis, and preparation of the manuscript. Each of these stages was conducted with input and advice from Celia Harris, and Amanda Barnier. Penny Van Bergen gave input and advice in interpretation of data, and preparation of the manuscript. Peter Rendell gave advice on implementing his Virtual Week prospective memory task (Rendell & Craik, 2000), and was consulted in regard to analysis of data. He also reviewed an earlier draft of the manuscript.

The research described in this chapter was presented at an international conference:

Browning, C. A., Harris, C. B., Barnier, A. J., & Rendell, P. G. (2015, June). *Collaborative inhibition in prospective memory*. Paper presented at the 11th Biennial Meeting for the Society for Applied Research in Memory and Cognition (SARMAC XI), Victoria, Canada.

Costs and Benefits of Performing Prospective Memory Tasks in Collaboration with
Another Person

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Abstract

To perform prospective memory (PM) tasks in day-to-day life, we often enlist the help of others. Yet the effects of collaboration on PM are largely unknown. Adopting the methodology of the “collaborative recall paradigm”, we tested whether stranger dyads (Experiment 1) and intimate couples (Experiment 2) would perform better on a “Virtual Week” task when working together or each working separately. In Experiment 1, we found evidence of collaborative inhibition: collaborating strangers did not perform to their pooled individual potential, although the effect was modulated by PM task difficulty. We also found that the overall collaborative inhibition effect was attributable to both the retrospective and prospective components of PM. In Experiment 2, however, there was no collaborative inhibition: there was no significant difference in performance between couples working together or separately. Our findings suggest potential costs of collaboration to PM. Intimate relationships may reduce the usual costs of collaboration, with implications for intervention training programs and for populations who most need PM support.

Costs and Benefits of Performing Prospective Memory Tasks in Collaboration with Another Person

Throughout the day, and within our social environment, we complete multiple prospective memory (PM) tasks: remembering that we must take medication, attend an appointment, complete a project, or carry out other planned intentions at specific points in the future (Einstein & McDaniel, 1990; Ellis, 1996). Both younger and older adults report finding PM tasks particularly difficult (Croviitz & Daniel, 1984; Terry, 1988). Perhaps because of their difficulty, people often enlist the help of others on PM tasks (Intons-Peterson & Fournier, 1986; Parikh, Troyer, Maione, & Murphy, 2015). Although there is a great deal of research on PM performance in individuals (McDaniel & Einstein, 2007), we know little about how PM performance might be influenced by collaboration (Brandimonte & Ferrante, 2008). Across two experiments, therefore, we tested the effects of collaboration on PM performance.

The Effects of Collaboration on Retrospective Memory

While there is little existing research on the effects of collaboration on PM performance, there is a large literature demonstrating that collaboration generally has costs for retrospective memory performance (for review see Harris, Paterson, & Kemp, 2008; Weldon & Bellinger, 1997). In the collaborative recall paradigm, the recall of collaborative groups is compared to the recall of “nominal groups”. Nominal group scores are formed by pooling the contributions of those who recall as individuals. Thus, it is possible to compare the actual performance of groups and the potential performance of the same number of individuals (Harris et al., 2008; Weldon & Bellinger, 1997). Collaborative groups typically recall more than a single individual working alone (Weldon & Bellinger, 1997), but critically, they recall less than nominal groups. That is, collaborative groups typically do not recall to their potential. This robust effect is known as collaborative inhibition (Basden,

Basden, Bryner, & Thomas, 1997; Basden, Basden, & Henry, 2000; Marion & Thorley, 2016; Rajaram & Pereira-Pasarin, 2010; Weldon & Bellinger, 1997).

The best supported explanation for collaborative inhibition is that collaborators experience retrieval strategy disruption (Basden et al., 1997; Marion & Thorley, 2016), although other cognitive mechanisms may also be involved such as retrieval inhibition or limited search (Barber, Harris, & Rajaram, 2015; Hyman, Cardwell, & Roy, 2013; Marion & Thorley, 2016), or social mechanisms such as social loafing (but see Weldon, Blair, & Huebsch, 2000). By the retrieval-strategy-disruption hypothesis, individuals typically store, organise, and retrieve their memories in idiosyncratic ways (Basden et al., 1997). When remembering with a group however, individuals may be forced to abandon their own retrieval strategies and instead adopt another sub-optimal strategy. They therefore recall less in the group than if they had recalled by themselves (Barber et al., 2015; Basden et al., 1997; Finlay, Hitch, & Meudell, 2000; Marion & Thorley, 2016).

Interestingly, despite the robust inhibitory effect found in the collaborative recall literature, other theoretical accounts of social remembering predict collaborative benefits. Transactive memory theory proposes that groups who are well known to each other develop shared systems for encoding, storing, and retrieving information (Wegner, Giuliano, & Hertel, 1985). Rather than disrupting one another's memory, group members instead demonstrate cognitive interdependence: gaining access to others' expertise and benefiting from new and emergent group information created when this expertise is integrated with one's own (Wegner, 1987). These transactive memory systems develop between intimate couples over a period of time, and depend on successful communication between individuals within the system (Wegner, 1987). Supporting this theory, the collaborative inhibition phenomenon appears less robust in several kinds of groups: friends (Andersson & Rönnberg, 1995, 1996); older couples who divide their labour (Johansson,

Andersson, & Rönnerberg, 2005); and older couples who prompt and cue each other with aligned communication strategies (Harris, Keil, Sutton, Barnier, & McIlwain, 2011). Indeed, in groups who are strangers to each other, but nonetheless have developed a facilitatory communication style – for example expert pilots who have been trained to use specific group-level communication strategies – collaborative inhibition was eliminated and facilitation was observed (Meade, Nokes, & Morrow, 2009). These studies suggest that group enhancing factors such as intimacy, group expertise, group-level recall strategies, and specific group-focused communication processes between collaborators may moderate the collaborative inhibition effect.

PM in Individuals: How Might Collaboration Affect Performance?

Given these robust findings for the effects of collaboration on (retrospective) recall, in the current studies we aimed to examine the effects of collaboration on PM. Prospective memory involves many cognitive processes (Einstein & McDaniel, 1990; Ellis, 1996). There is certainly a retrospective memory component in PM: individuals must remember what it is that they need to do, and when to do it (Ellis, 1996; Kliegel, Eschen, & Thöne-Otto, 2004). Given this retrospective memory component, we might expect to find collaborative inhibition in PM tasks too. We might also expect similar moderating effects of intimacy, expertise, group strategies, or group-enhancing communication processes as identified for collaborative recall.

However, PM also involves a prospective component. Individuals must monitor the environment, reinstate the intention, switch from the ongoing activity, and initiate the intention (Ellis, 1996; Kliegel et al., 2004). According to the multiprocess theory of PM, this happens in two ways (McDaniel & Einstein, 2000; McDaniel, Umanath, Einstein, & Waldum, 2015). First, top-down processes are used. Attentional control is used to maintain activation of the intention in working memory and monitor the environment for PM cues.

Second, bottom-up processes are used. Retrieval of PM cues occurs spontaneously in response to environmental reminders. The pathway that is recruited at any given time depends on the environmental support inherent within the PM task (Craig, 1986; McDaniel & Einstein, 2000).

It is unclear how collaboration will impact the prospective component of PM. On the one hand, working with others offers a potential source of external support. Consistent with this possibility, research has shown that generally, the provision of reminders improves PM performance (Guynn, McDaniel, & Einstein, 1998; Henry, Rendell, Phillips, Dunlop, & Kliegel, 2012; Ihle, Schnitzspahn, Rendell, Luong, & Kliegel, 2012), while *not* receiving an expected reminder impairs performance (Kobayashi & Maruno, 1994; E. G. Schaefer & Laing, 2000).

External support may be particularly important for tasks that require high degrees of strategic monitoring and are otherwise low in environmental support. Researchers have distinguished different kinds of PM tasks, and these vary in the degree to which they require strategic monitoring versus spontaneous retrieval, i.e., they are cued or triggered by the environment. Time-based tasks, which must be performed at a specific future point in time, are less supported by environmental cues than event-based tasks, which must be performed when another external event occurs. This lesser environmental support means that time-based tasks are typically more difficult to perform than event-based tasks, and require more strategic monitoring (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Henry et al., 2012; Rendell et al., 2011). A second distinction is between focal tasks in which the cue is processed as part of the ongoing task (e.g. encountering the petrol station on our typical route home), and nonfocal tasks in which the cue is peripheral, and not necessarily processed as part of the ongoing task (e.g. needing to turn off from our typical route home to go to the petrol station). Nonfocal tasks are lower in environmental

support and rely heavily on strategic monitoring, which makes these tasks difficult as well (Kliegel, Rendell, & Altgassen, 2008; Rendell & Craik, 2000; Rendell & Henry, 2009; Rendell, McDaniel, Forbes, & Einstein, 2007). Given these differences in task demands, and in the presence or absence of external environmental cues, we might expect collaboration to improve performance particularly in the time-based and nonfocal tasks since they lack environmental support.

On the other hand, the social interactions that occur during collaboration may interfere with individuals' processes that support the prospective component of PM. By increasing engagement in the ongoing task, for example, social interactions may direct attentional resources away from the PM task. McDaniel and Einstein (2000) suggest that the more absorbing, engaging, or demanding the ongoing activity is, less resources would be available for strategic monitoring (McDaniel & Einstein, 2000). Consistent with this possibility, Henry et al. (2014) found a decrease in PM performance with increased ongoing task engagement. Collaboration may also interfere with PM performance by dividing attention during either encoding or retrieval of the intention (Einstein, Smith, McDaniel, & Shaw, 1997; Stone, Dismukes, & Remington, 2001). In both cases, we would expect collaboration to impair performance particularly in the time-based and nonfocal tasks since they require more strategic monitoring.

To date, just one study has adopted the collaborative recall paradigm to examine PM. After asking pairs of older adults aged above 65 to complete a novel tour around a university campus, Johansson, Andersson, and Rönnerberg (2000) found evidence of collaborative inhibition in PM for both married couples and strangers. Highlighting the potential for individual differences, however, some couples – those who scored high on self-reported transactive memory systems – showed no inhibition. The authors caution that their naturalistic tour task may not be analogous to common day-to-day PM activities, and

the unfamiliar environment may have produced an unexpected pattern of performance for different types of PM tasks. In addition, it is not yet known whether the effects on PM were driven by inhibition in the retrospective component of PM, the prospective component, or both. However, this study suggests potential costs – on average – for collaborative PM, as well as individual differences in outcomes.

The Current Research

The aim of the current research was to examine the influence of collaboration on PM. Like Johansson et al. (2000), we adopted the collaborative recall paradigm. In Experiment 1 we compared the PM performance of adult strangers when collaborating or working alone (in nominal pairs). In Experiment 2 we compared the PM performance of intimate couples when collaborating or working alone (in nominal pairs). We extended Johansson et al.'s (2000) naturalistic work with older adults in three ways.

First, we implemented a measure of retrospective recall for content of the PM task, allowing us to begin teasing apart the retrospective and prospective components of PM. While Johansson et al. (2000) found significant collaborative inhibition in PM, it is possible that this effect was driven by inhibition in the retrospective component only. Measuring and controlling for retrospective recall of the task allowed us to investigate the influences on the prospective component.

Second, we used a computerised board game called “Virtual Week” to systematically compare performance on different types of PM (Rendell & Craik, 2000; Rendell & Henry, 2009). Virtual Week is designed to simulate the PM activities of a typical week and includes different types of PM tasks that participants must remember to perform each virtual “day”. Event-based PM tasks are triggered when a certain event occurs, which is indicated on an “Event-Card” that participants are required to pick up (e.g., “Drop in dry-cleaning when you go shopping”). Time-based PM tasks are triggered

when the appropriate virtual time within the “day” is shown on a central clock on the game-board (e.g., “Phone bank at 12.00 noon to arrange an appointment”). Time-check tasks are triggered when the appropriate real time is shown on a stop-clock that is independent of, and different to, the virtual time within the day (e.g., “Test lung capacity at 2:00 minutes on the stop-clock”). Time-check tasks differ to time-based and event-based tasks; the target time on the stop-clock is not processed during ongoing game-playing activity. As such they are considered nonfocal (see also Kliegel et al., 2008 for discussion). Virtual Week also manipulates task regularity; some tasks are required to be repeated each virtual day (regular event- and time-based tasks), while some tasks are unique, and are required to be performed only once (irregular event- and time-based tasks). Because these different tasks types are embedded within the game, tasks vary in difficulty: some offer environmental cues, and others require participants to instead rely more heavily on themselves to self-initiate retrieval of the intention (Rendell & Craik, 2000; Rendell & Henry, 2009). Virtual Week is a reliable and valid indicator of PM function (Rendell & Henry, 2009), and it permits interactive, conversational collaboration (Rendell & Craik, 2000).

Third, while Johansson et al. (2000) specifically recruited older adults, and their study investigated PM and aging, we focused on stranger dyads and intimate couples in general with no age restriction, and recruited from a university sample of younger to middle aged individuals as noted in Participants below.

Our hypotheses were driven by transactive memory theory. Because strangers do not share transactive systems, and because strangers typically show collaborative inhibition on recall, we hypothesised that collaborating stranger dyads would demonstrate collaborative inhibition on the Virtual Week task, although as noted above, mixed predictions were possible about the prospective component. This builds on Johansson et

al.'s (2000) findings for older adults, extending robust findings of collaborative inhibition in younger adults from retrospective memory to PM.

Because couples *do* sometimes share transactive systems, however, we hypothesised a reduction in collaborative inhibition in PM for couples in Experiment 2. This hypothesis is also consistent with transactive memory theory (Wegner, 1987) and with some previous research examining the influence of collaboration on retrospective memory performance. While collaborative recall amongst young-adult friends (Andersson & Rönnerberg, 1995, 1996) and older adult couples (e.g., Harris et al., 2011; Johansson et al., 2005) shows mixed results, very often collaborative inhibition is reduced or reversed in intimate groups.

Finally, and related to our second hypothesis, we hypothesised individual differences amongst collaborators. Specifically, we hypothesised that dyads showing higher levels of closeness (rapport, intimacy) and higher self-reported collaboration quality would also perform better on the PM task. This hypothesis is consistent with findings of individual differences amongst older-adult couples performing retrospective memory tasks together, with some showing collaborative inhibition and others showing no inhibition (Harris et al., 2011).

Experiment 1

In Experiment 1, we recruited strangers to complete Virtual Week alone or in pairs. Observing the effects on PM when stranger dyads collaborate is important because it allows direct comparison with previous collaborative recall studies, the majority of which have also used stranger participants. In addition, because we are sometimes required to collaborate with strangers on PM tasks in everyday life – for example, when newly created teams must work together to remember to do things in the workplace – there is real world applicability.

Method

Participants. We recruited 116 participants: 86 undergraduate students who participated for course credit, and 30 participants recruited on campus who received A\$22.50 (A\$15.00 per hour). Two dyads were excluded because one or both did not understand instructions for the PM task, and six dyads were excluded because they failed to complete the PM task within the allotted time of 90 minutes. The remaining sample included 100 participants ($M = 20.40$ years, $SD = 4.23$ years, 72% female). This sample size is consistent with that of previous collaborative recall research, providing sufficient power to detect collaborative inhibition. All participants were fluent English speakers.

Design. We used a 2×5 mixed factorial design. The between-dyads variable was *condition* (collaborative, nominal), the within-dyads variable was *PM task* (regular event-based, irregular event-based, regular time-based, irregular time-based, time-check), and the dependent variable was PM performance in Virtual Week. There were 25 dyads in the nominal condition, and 25 dyads in the collaborative condition. In all ANOVAs, Huynh–Feldt corrected F-values were reported ($\epsilon > 0.75$) if the assumption of sphericity was violated.

Measures.

PM performance. We used an adapted version of the computerised Virtual Week task to measure PM (Rendell & Craik, 2000). In Virtual Week, each circuit of the game-board displayed on the computer screen represents one virtual “day”. Participants move their tokens forward according to the roll of the die, on squares that are calibrated to the virtual time of day. Virtual time is displayed on a large clock positioned in the middle of the board, and the passage of real-time is displayed on a smaller stop-clock positioned above-centre. As participants move around the board, they pick up “Event Cards” when directed, that reveal everyday activities appropriate for the time of day. Participants are

required to make a choice of three options relating to each event – for example “It is breakfast. Do you have (a) fruit, (b) porridge or (c) cereal?”. The roll of the die that is required to proceed in the game (e.g., “roll a four to continue”) is determined by which of the three options was chosen. This game-playing activity acts as the ongoing task against which participants are required to remember to perform the PM tasks.

Various PM task instructions are presented to participants on the computer screen at certain times during the Virtual Week to provide them with the tasks they are required to perform. The regular PM task instructions are presented to participants after a Trial Day, and before the actual testing session begins. Participants are encouraged to repeat these tasks aloud three times correctly before progressing. The irregular task instructions are given either at the start of, or during each virtual day. As described above, Virtual Week manipulates PM task difficulty and regularity by providing a variety of PM task types: event-based, time-based, regular, irregular, and time-check tasks (see Table 1). Each type of the five PM tasks described in Table 1 is required to be performed twice per day, resulting in a maximum daily score of 10. Two different regular event-based and two different regular time-based tasks are required to be repeated each “day”. Likewise, two different irregular event-based and two different irregular time-based tasks are required to be performed each day, however, they are not repeated the next day, but are instead only performed once. For each task, when the appropriate time or event occurs, participants must click on the “perform task” button and choose the task from a list of options. Event-based PM tasks are triggered when a certain Event-Card occurs, time-based PM tasks are triggered when the appropriate virtual time within the day is shown on the central clock, and time-check tasks are triggered when the appropriate real time is shown on the stop-clock. Responses were scored correct if the participant performed the correct action at the correct time or event. For time and event tasks, this meant responding before the next die

roll. For the time-check tasks, this meant responding within ten seconds of the specified time (see Rendell & Craik, 2000). All other responses (e.g., wrong time, wrong action, or missed completely) were scored incorrect. Each type of the five PM tasks shown in Table 1 were required to be performed twice per “day”, resulting in a maximum daily score of 10.

Retrospective memory performance. To assess participants’ free recall of the PM task content, they were asked to write down all of the PM tasks they had been required to perform during the course of the PM day (see Foster, Rose, McDaniel, & Rendell, 2013). Note that it is not possible to directly measure the retrospective component of PM during the PM task itself, for two reasons. First, this would interrupt the PM task. Second, when performing a PM task in Virtual Week, participants choose the PM task required at that time from a list of possible tasks presented to them when they click the “perform task” button. As such, this is actually a recognition memory test rather than free recall, since the correct option is presented among a list of incorrect distractor items. A better test of the retrospective component and one that is more sensitive to collaborative processes is free recall (Barber, Rajaram, & Aron, 2010; Finlay et al., 2000; Marion & Thorley, 2016). Therefore, we followed other researchers in assessing retrospective memory for the content of each “days’ PM tasks by conducting a free recall test as soon as the day had concluded, which provides an exceptionally close approximation of recall ability and performance (Foster et al., 2013; Habota et al., 2015; Thompson, Henry, Rendell, Withall, & Brodaty, 2010). We would expect minimal loss of performance within this timespan, irrespective of the condition or task. Each task recalled was scored 0.5 for correctly identifying “what” needed to be done, and 0.5 for correctly identifying “when” the task was required to be performed. As there were 10 PM tasks required to be performed each day, there were 10 different tasks to recall, resulting in a maximum daily score of 10.

Collaboration quality. To measure individual differences in self-reported collaboration quality, participants in the collaborative condition individually completed the 15-item Transactive Memory Systems (TMS) Scale (Lewis, 2003). Note that genuine transactive memory systems are thought to develop over time: thus, we do not suggest that strangers will develop such systems during the laboratory session. The scale nonetheless asks participants to reflect on the quality of their group's performance, with three subscales comprised of five items each, measuring each group's Specialization, Credibility, and Coordination (Cronbach's $\alpha = .78, .67, \text{ and } .64$ respectively). For each item, participants record their responses on a 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*), resulting in a maximum score of 25 for each subscale. As the scale was originally developed for organisations, we changed six items to refer explicitly to Virtual Week. For example, "I had knowledge *about an aspect of the project...*" was changed to "I had knowledge *relevant to the Virtual Week game...*"

Self-report Rapport Scale. To measure individual differences in self-reported rapport, participants in the collaborative condition also individually completed a 6-item adapted version of Lakens and Stel (2011). This provides an indication of relationship quality for non-intimate strangers. The scale measures mutual attentiveness, mutual positivity, and coordination, and Cronbach's α was .73. For each of the six items, participants were presented a statement about them and their partner and asked to indicate their agreement on a 7-point Likert scale from 1 (*I did not feel this way at all*) to 7 (*I felt very strongly this way*), resulting in a maximum score of 42. As the original measure asked participants to rate the rapport of other couples, all items were changed to make them appropriate for self-report. For example, we changed "To what extent do you think the individuals liked each other" to "I liked the other participant".

Procedure. Following institutional ethics approval, we randomly allocated participants to either the collaborative or the nominal condition. Participants in the collaborative condition presented to the lab in pairs determined by the time-slots they signed up to, and sat side-by-side at a desk in front of a shared computer. We asked the pair to introduce themselves to each other and to make themselves comfortable so they could both see the computer screen. Participants assigned to the nominal condition came into the lab individually.

Participants played Virtual Week either alone or in pairs, depending on their condition. Participants in both conditions received the same verbal instructions explaining how to play Virtual Week; however, those in the collaborative condition were also asked to “work together to play this game” with no specific instructions about how to manage this. An audio recording was also made of the collaborative sessions. After participants completed a trial day, they played four “days” of the Virtual Week, and sessions lasted approximately 1.5 hours. Each participant was asked to perform 40 PM tasks in total, consisting of eight tasks for each of the five types of PM tasks: regular event, regular time, irregular event, irregular time and time-check (10 PM tasks per day, 2 of each type; see Table 1).

At the end of each virtual day, participants also completed the retrospective recall task. Participants in the collaborative condition were instructed to work together to recall the content of the PM tasks, whilst those in the individual condition continued to work alone. Finally, participants in the collaborative condition individually completed the Rapport Scale and TMS Scale.

Scoring. Scores for participants in the nominal condition were calculated by pooling the non-redundant performance of two individuals to make *nominal dyads*, consistent with the collaborative recall paradigm (Basden et al., 2000; Weldon &

Bellinger, 1997). Individuals were arbitrarily allocated to nominal dyads in the order they fell in the data file, which corresponded to the order they presented to the lab. To be counted as correct, at least one individual in the nominal dyad needed to have performed/remembered the task correctly. If both individuals were correct, this was only counted once. Thus, the resulting score is analogous to the score that individuals in a collaborative dyad could potentially achieve if they both performed in the collaborative context exactly the same as they would perform individually (where, if at least one member of the dyad performs/remembers the task, the dyad is correct). This scoring allowed us to compare the performance of two individuals working individually vs. collaboratively: a strong test of potential processing costs when collaborating with others.

Results

PM performance. To test for collaborative inhibition in PM, we conducted a 2 (Condition: collaborative, nominal) \times 5 (PM task) mixed-model ANOVA. Refer to Table 2 for means. There was a significant main effect of condition, $F(1, 48) = 11.90$, $MSE = 0.01$, $p = .001$, $\eta_p^2 = .20$, indicating that collaborative performance was lower than that of nominal pairs, i.e., collaborative inhibition. There was also a main effect of task, $F(4, 166) = 17.69$, $MSE = 0.02$, $p < .001$, $\eta_p^2 = .27$, suggesting PM tasks differed in difficulty. However these main effects were moderated by a significant condition \times task interaction, $F(4, 166) = 3.83$, $MSE = 0.02$, $p = .008$, $\eta_p^2 = .07$. Follow-up pairwise comparisons with Bonferroni adjustment showed that nominal dyads outperformed collaborating dyads on the regular event-based tasks, $p = .010$, $d = 0.78$, and the time-check tasks, $p = .001$, $d = 1.11$, with no significant differences for the other three task types, all $ps > .076$, all $ds < .53$. That is, collaborative inhibition was greater for some tasks than for others.

Retrospective memory performance. To determine whether there was collaborative inhibition in retrospective memory (recall of the PM task content at the end

of each day), we conducted a 2 (Condition: collaborative, nominal) \times 5 (PM task) mixed-model ANOVA. Refer to Table 3 for means. There was an overall significant main effect of condition, $F(1, 48) = 13.09$, $MSE = 0.02$, $p = .001$, $\eta_p^2 = .21$, indicating that collaborative performance was lower than that of nominal pairs, i.e., collaborative inhibition. There was also a main effect of task, $F(2, 103) = 94.57$, $MSE = 0.01$, $p < .001$, $\eta_p^2 = .66$, indicating recall of tasks differed in difficulty. These main effects were moderated by a significant condition \times task interaction, $F(2, 103) = 11.28$, $MSE = 0.01$, $p < .001$, $\eta_p^2 = .19$. Follow-up pairwise comparisons with Bonferroni adjustment showed that nominal dyads recalled irregular event-based tasks significantly better than collaborating dyads, $p < .001$, $d = 1.29$. There were no other significant differences, all $ps > .077$, all $ds < .36$.

Teasing apart retrospective and prospective components of PM. Given we found collaborative inhibition on both PM performance and retrospective memory performance, we aimed to examine whether the collaborative inhibition observed in PM performance was due solely to the failure of the retrospective components of PM or to both retrospective and prospective components. We conducted an analysis of covariance (ANCOVA). Condition was entered as an IV, PM performance was entered as a DV (averaged across all five tasks), and retrospective memory performance was entered as a covariate (averaged across all five tasks). Not surprisingly, the covariate of retrospective memory performance was significantly related to prospective memory performance, $F(1, 47) = 6.68$, $p = .013$, $\eta_p^2 = .12$, which confirms that our retrospective memory task was successful in accounting for some of the PM performance. Importantly, however, condition remained significant once the covariate was accounted for, $p = .047$, $\eta_p^2 = .08$. This suggests a unique collaborative inhibition effect for the prospective component of PM (see Thompson et al., 2010 for similar analysis).

Collaboration quality, rapport, and PM performance. To determine how individual differences between dyads might relate to overall collaborative PM, we conducted correlations between PM performance in the collaborative condition and dyad responses on the Rapport Scale and the TMS subscales. Because PM performance was at the dyad level and questionnaire scores at the individual level, however, we first calculated dyad scores on the questionnaires by taking the average of the two individual scores (see Lewis, 2003, for a similar approach)¹.

Dyad scores on the Rapport Scale were high ($M = 36.62$ out of 42, $SD = 3.09$), reflecting strong rapport. Perhaps for this reason, there was no significant relationship with PM performance, $r = .13$, $p = .52$. Dyad scores for TMS subscales showed more variability: Specialization ($M = 16.66$, $SD = 2.53$), Credibility ($M = 20.32$, $SD = 1.93$), and Coordination ($M = 21.06$, $SD = 2.00$). There was a significant correlation between PM performance and Credibility, $r = .52$, $p = .008$, but not Specialisation or Coordination, all r s $< .31$, all p s $> .126$. These findings suggest that dyads who reported trusting and having confidence in one another also performed better together.

Discussion

The aim of Experiment 1 was to investigate the effect of collaboration between strangers on PM performance. Consistent with our first hypothesis, we found evidence of collaborative inhibition in PM. Collaborating dyads performed worse than nominal dyads. As in past studies (Basden et al., 1997; Basden et al., 2000; Weldon & Bellinger, 1997), a similar pattern was found for the retrospective memory task too. To estimate the impact of collaboration on the prospective component of PM alone, we repeated our analysis of collaboration on PM while controlling for retrospective recall (a proxy for the retrospective component of PM). The significant difference in performance between collaborating and

nominal groups remained, suggesting that collaboration impairs both the retrospective and prospective components of PM.

Interestingly, findings for PM (including prospective components) and retrospective recall varied by task. For PM, collaborative inhibition was specific to the regular time-check and regular event-based tasks. This finding is discussed in further detail in the general discussion. For retrospective recall, performance was close to ceiling for regular event, regular time and time-check tasks. On the irregular event-based task, which has higher retrospective memory demand (Foster et al., 2013), collaborative inhibition was observed.

Moreover, we identified individual differences in group outcomes. Those dyads who reported higher trust and confidence in their partner's contributions collaborated more successfully. To further examine the role of relationship variables in influencing collaborative outcomes, in Experiment 2 we turned to study intimate couples.

Experiment 2

Transactive memory theory suggests that intimate groups develop a shared system for encoding, storing, and retrieving information, such that the group is able to recall more than the sum of the individuals alone. In everyday life, individuals may sometimes collaborate with strangers, but perhaps more often collaborate with spouses, family members, close friends and colleagues. As we discuss in our introduction, previous studies on collaboration and retrospective memory have suggested that the nature of the group may influence their collaborative success, with the magnitude of collaborative inhibition modulated by factors such as levels of intimacy, group expertise, strategies used, and communication processes employed (Andersson & Rönnerberg, 1995, 1996; Harris et al., 2011; Johansson et al., 2005; Meade et al., 2009).

In Experiment 2, we recruited intimate couples to collaborate on Virtual Week. As in Experiment 1, the performance of the collaborating couples was compared to a nominal control group (pooled performance of couples working alone) to measure whether collaborating couples were performing to their potential. We also measured individual differences in intimacy and TMS scores to examine whether these might be related to PM performance for collaborating couples.

Method

Participants. We recruited 50 heterosexual couples ($n = 100$, $M = 23.50$ years, $SD = 9.57$ years) who had been in a romantic relationship for longer than 12 months ($M = 45.96$ months, $SD = 54.89$ months). Couples were made up of one undergraduate psychology student participating for course credit and their non-student partner who instead received A\$22.50 reimbursement. All participants were fluent English speakers.

Design. As in Experiment 1, we used a 2×5 mixed factorial design. The between-couples variable was *condition* (collaborative, nominal), the within-couples variable was *PM task* (regular event-based, irregular event-based, regular time-based, irregular time-based, time-check), and the dependent variable was PM performance in Virtual Week. There were 25 couples in the nominal condition, and 25 couples in the collaborative condition.

Measures.

PM performance and retrospective recall. As in Experiment 1, we used Virtual Week to measure PM and a retrospective memory task as a proxy for the retrospective component of PM.

Collaboration quality. To determine individual differences in collaboration quality we again administered the TMS Scale, as in Experiment 1. Cronbach's alphas were as follows: Specialization (.77), Credibility (.55), and Coordination (.79). One item loaded

poorly on the Credibility subscale. Removing this item did not change the relationship between Credibility and PM performance (reported below), so the item was retained.

Intimacy. To measure individual differences in relationship quality, participants in each condition individually completed an adapted 24-item Personal Assessment of Intimacy in Relationships (PAIR) Scale (M. T. Schaefer & Olson, 1981). The original scale is comprised of five sub-scales (Emotional, Social, Intellectual, Recreational, Sexual), but for the privacy of the participants we excluded the Sexual sub-scale. Each subscale consisted of six items. For each item, participants were asked to record their responses on a 5-point Likert scale, which ranged from 1 (*Strongly disagree*) to 5 (*Strongly Agree*), resulting in a maximum score of 30 for each subscale. Cronbach's alphas for each subscale were as follows: Emotional (.71), Social (.59), Intellectual (.66), Recreational (.28). Reverse-scored items drove the low alphas in the Social and Recreational subscales. Removing these items did not change associations with collaborative PM (reported later), so these items were retained, but results should be interpreted with caution.

Procedure. Following institutional ethics approval, we randomly allocated couples to either the collaborative or the nominal condition. All couples arrived at the lab together. Those assigned to the collaborative condition were seated side-by-side at a shared computer, while those assigned to the nominal condition were seated at separate desks, with separate computers, divided by a partition. Participants then played the Virtual Week game, as in Experiment 1. All participants then completed the PAIR inventory, while only participants in the collaborative condition completed the TMS Scale. Scoring was identical to that in Experiment 1. All participants completed the questionnaires individually on separate computers.

Scoring. Scoring procedures for the Virtual Week PM task and the Retrospective Memory Task were identical to Experiment 1.

Results

PM Performance. To test whether collaborating couples would show collaborative inhibition relative to nominal couples, we conducted a 2 (Condition: collaborative, nominal) \times 5 (PM task) mixed-model ANOVA. Refer to Table 4 for means. There was no main effect of condition, $F(1,48) = 1.64$, $MSE = 0.02$, $p = .207$, $\eta_p^2 = .03$. That is, in contrast to Experiment 1, we did not find significant collaborative inhibition in Experiment 2. There was however a main effect of PM task, $F(3,160) = 8.98$, $MSE = 0.03$, $p < .001$, $\eta_p^2 = .16$. Follow-up comparisons with Bonferroni adjustment showed poorer performance on the time-check task than the regular event and irregular event tasks, $ps < .05$, $ds > .40$. In turn, irregular time tasks were performed more poorly than regular event and irregular event tasks, $p < .043$, $ds > .43$. There were no other differences between tasks, all $ps > .076$, all $ds < .38$, and no condition \times task interaction, $F(3,160) = 0.51$, $MSE = 0.03$, $p = .696$, $\eta_p^2 = .01$.

Retrospective memory performance. To determine whether there was collaborative inhibition in retrospective memory (recall of the PM task content at the end of each day), we conducted a 2 (Condition: collaborative, nominal) \times 5 (PM task) mixed-model ANOVA. Refer to Table 5 for means. There was no effect of condition, $F(1,48) = 1.60$, $MSE = 0.01$, $p = .213$, $\eta_p^2 = .03$. As for PM performance, we did not find significant collaborative inhibition in Experiment 2. There was however a significant main effect of task, $F(4,171) = 13.54$, $MSE = 0.01$, $p < .001$, $\eta_p^2 = .22$. Follow-up comparisons with Bonferroni adjustment showed poorer recall for both irregular event and irregular time tasks than for regular event, regular time, and time-check tasks, all $ps < .045$, all $ds > .42$. There were no other differences between tasks, all $ps = 1.00$, all $ds < .24$, and no condition \times task interaction, $F(4,171) = 1.18$, $MSE = 0.01$, $p = .320$, $\eta_p^2 = .02$.

Teasing apart retrospective and prospective components of PM. Although we found no overall effect of collaborative inhibition for PM amongst couples, we nonetheless performed an ANCOVA to determine whether collaborative inhibition in the prospective component of PM would emerge once retrospective memory performance was controlled. As in Experiment 1, condition was entered as an IV, PM performance was entered as a DV (averaged across all five tasks), and retrospective memory performance was entered as a covariate (averaged across all five tasks). The covariate was significant, $F(1,47) = 87.88$, $p < .001$, $\eta_p^2 = .65$, suggesting a clear role for retrospective memory in PM performance in general. However, the effect of condition was not significant, $p = .668$, $\eta_p^2 = .01$.

Collaboration quality, intimacy, and PM performance. To determine how individual differences between couples might relate to overall collaborative PM, we conducted correlations between PM performance and dyad responses on the PAIR Inventory and the TMS subscales. As in Experiment 1 we calculated dyad scores on each of the TMS and PAIR subscales by taking the average of the two individual scores within each couple². Overall discrepancy scores for the PAIR were also calculated: subtracting the lowest from the highest total PAIR score within each couple. This provided a measure of differences in perceived intimacy.

Scores on each PAIR subscale were relatively high – Emotional Intimacy ($M = 25.86$, $SD = 2.66$), Social Intimacy ($M = 21.68$, $SD = 3.56$), Intellectual Intimacy ($M = 24.25$, $SD = 2.80$) and Recreational Intimacy ($M = 24.70$, $SD = 1.87$) – and did not correlate with PM performance, all r s $< .22$, all p s $> .287$. There was however a significant negative correlation between PM performance and the PAIR discrepancy score ($M = 7.52$, $SD = 6.98$), $r = -.43$, $p = .031$. That is, couples who showed the highest overall discrepancy in perceived intimacy collaborated more poorly.

Scores on the TMS showed more variability: Specialization ($M = 17.6$, $SD = 2.73$), Credibility ($M = 20.84$, $SD = 1.95$), and Coordination ($M = 21.50$, $SD = 2.12$). However, there was no relationship between PM performance and scores on any of the three subscales, all $r_s < .10$, all $p_s > .647$.

Discussion

The aim of Experiment 2 was to investigate the effect of collaboration between intimate couples on PM performance. In contrast to our findings in Experiment 1, we did not find significant collaborative inhibition on any PM task. Across tasks, collaborating and nominal couples performed similarly. This was the case even for the most difficult task on which the collaborating strangers in Experiment 1 had been most impaired.

We found a similar pattern of results in the retrospective memory task. Collaborating couples recall of task content at the end of each day was similar to that recalled by the nominal couples. This again is indicative that when intimate couples worked together they did not exhibit the same costs, on average, that are typically found when strangers collaborate on retrospective memory tasks. After controlling for retrospective memory performance, we found no collaborative inhibition in either the prospective component or the retrospective component, strengthening the interpretation that couples did not experience collaborative inhibition in PM tasks.

General Discussion

Our aim across Experiments 1 and 2 was to examine the effect of collaboration on PM. We used the collaborative recall paradigm as a stringent test of the effects of collaboration: comparing collaborative performance (collaborative condition) to group potential (nominal condition) to identify any costs incurred when collaborating.

Collaborative PM in Strangers and Couples

As hypothesised, we found a robust collaborative inhibition effect on PM performance amongst stranger dyads in Experiment 1: collaborating dyads performed worse than two pooled individuals. This effect extended to both the retrospective and prospective components of PM. Findings for the retrospective component of PM mirror those of numerous previous collaborative recall studies, with the retrieval disruption hypothesis offering one possible explanation for these findings (Basden et al., 1997). Findings for the prospective component of PM are unique, however, and demonstrate a disruptive influence of collaboration on other aspects of processing that are needed to bring to mind and initiate an intention in the future.

Intimate couples in Experiment 2 were more successful collaborators than the strangers in Experiment 1, and showed no significant collaborative inhibition for either the prospective or retrospective components of PM. Our finding that there was no collaborative inhibition for intimate couples was consistent with a number of previous collaborative recall studies focused on retrospective recall. In these studies, a reduction in collaborative costs is found amongst groups of friends, expert pilots, and older couples who share closeness or expertise (Andersson & Rönnerberg, 1995, 1996; Harris et al., 2011; Johansson et al., 2005; Meade et al., 2009). We extend these findings to intimate couples performing PM tasks and highlight their applicability to both retrospective and prospective PM components.

Although intimate couples were able to reduce the costs associated with collaboration, they did not show net benefits as proposed by Wegner's (1987) transactive memory theory, in which intimate groups are proposed to develop efficient shared systems of encoding, storage, and retrieval to benefit group performance. Because transactive memory systems are predicted to develop in intimate couples over time (Wegner, 1987), it is possible that the younger undergraduate couples in our study simply had insufficient

time to fully develop shared knowledge and communication strategies. The mean relationship duration was 3.83 years and we did not ask participants whether or not they were cohabitating. On this argument, transactive memory systems may emerge only after significant periods of time.

Alternatively, collaborative benefits amongst some couples may have been balanced by inhibition amongst others. While past research examining within-group variation in collaboration is relatively limited, evidence for individual differences amongst older adults emerges for both retrospective memory and PM tasks (Harris et al., 2011; Johansson et al., 2000, 2005). The variation in scores between couples in Experiment 2 was larger than the variation in scores between strangers in Experiment 1, suggesting that some couples may have been engaging in transactive processes that are more effective or better aligned than others. We explore this possibility in more detail below.

Individual Differences Amongst Collaborators

Above we suggest that individual differences amongst couples may predict collaborative inhibition or facilitation in PM, leading to heterogeneity in the outcomes and overall null effects (see also Harris et al., 2011). This suggestion receives preliminary support from our supplementary questionnaire measures. In Experiment 1, trust and confidence between strangers predicted collaborative success. In Experiment 2, discrepancies in perceptions of intimacy between couples predicted collaborative difficulty. While other associations did not emerge, we highlight the potential for other individual differences in both couples and strangers to also account for variance in PM. As in emerging retrospective memory studies, for example, group expertise, strategies used, and communication processes amongst familiar couples may contribute (Harris et al., 2011; Meade et al., 2009). And as suggested by our findings in Experiment 1, some strangers may also be more effective collaborators than others.

The Nature of the PM Task

Over and above our overall findings of collaborative inhibition for PM amongst strangers (Experiment 1) but not couples (Experiment 2), the significant task differences in each experiment provide insights into the kinds of tasks most likely to be affected by collaboration. In Experiment 1, the tasks most disrupted by collaboration were the regular event-based and time-check tasks. Interestingly, both of these tasks are considered to have relatively low retrospective memory loads due to their regular nature (Foster et al., 2013), and retrospective memory performance amongst collaborating participants was near ceiling for both tasks. In other words, participants were able to remember what they needed to do. This suggests that although we found that collaboration impaired both retrospective and prospective components of PM in Experiment 1, the prospective component of these tasks was particularly affected. Therefore, the findings provide clear evidence that the prospective and retrospective components of collaborative PM are differentially taxed by various PM tasks.

Collaborative inhibition was the largest for the time-check task: a nonfocal task with low environmental support and the hardest PM task overall (see Table 2). Clock monitoring is considered essential for successful performance of the time-check task (Einstein et al., 1995; Waldum, Dufault, & McDaniel, 2016). It is possible that collaboration disrupted the attentional processes needed to engage in such monitoring while instead diverting attention to the social interaction (Einstein et al., 1997; McDaniel & Einstein, 2000). The couples in Experiment 2 may have been less likely to divert attentional resources to the social interaction for two reasons. First, as romantic partners, they are likely to have already developed automatized communication patterns with one another. They might also be more sensitive to the appropriate time to provide reminders, ensuring that they do not interfere with their partner's processing. Second, shared intimacy

may protect them from the expectations of negative judgement if their attention is diverted elsewhere.

Collaborative inhibition on the time-check task may also be driven by a non-attentional prospective planning disruption akin to retrieval disruption in retrospective memory (Basden et al., 1997). Although we accounted for retrieval disruption of the *PM task content* by testing recall of task content at the end of each day, successful PM also involves self-initiating remembering regarding the retrieval of the PM intention (McDaniel & Einstein, 2000) – an additional retrieval that is not controlled for by the “end-of-the-day” proxy test. According to the retrieval disruption hypothesis, each individual within a group has their own idiosyncratic way to organize and retrieve memories. These unique retrieval strategies are disrupted when exposed to another’s response, thereby reducing each individual’s output within a group. In tasks with more environmental support, however, collaborative inhibition is reduced as an organized structure is already imposed on the group (Basden et al., 1997; Finlay et al., 2000; Meade & Roediger, 2009). In a similar way, it is possible that strangers’ idiosyncratic strategies to self-initiate reminders to retrieve PM intentions during the time-check task was disrupted by their partner’s own idiosyncratic strategies. To test whether attention, self-initiated retrieval of intentions, or other cognitive processes are more strongly disrupted by collaboration amongst strangers, we suggest a series of follow-up collaborative PM experiments manipulating cognitive load and the presence of intentional reminders.

While we expected collaborative inhibition in Experiment 1 to be strongest on the time-check task, which is lacking in environmental support, it is less clear why inhibition was also found for regular event-based tasks. Regular event-based tasks are the least cognitively demanding of the PM tasks tested and should therefore experience the least disruption. Indeed, individuals performed particularly well on these PM tasks. One

possible explanation is social loafing. If strangers found the regular event-based tasks particularly easy, for example, they may have implicitly diverted their attention to other tasks while assuming that their partner would be fine on their own. While social loafing does not adequately explain collaborative inhibition in recall tasks (Weldon et al., 2000), it may still reduce collaborative performance on the prospective component of PM. Intimate couples, with more expertise in coordinating PM tasks between themselves, may be less susceptible to these oversights or more committed to joint outcomes. To examine this possibility further, we suggest that future PM research employ motivational manipulations similar to that used by Weldon et al. (2000) to determine the role of social loafing in retrospective tasks.

Limitations and Future Directions

Above we highlight the potential for future research to isolate and test competing explanations for collaborative inhibition in PM. In addition, we suggest intervention research aimed at enhancing PM success in everyday life. While we considered healthy young to middle aged adults in our experiments, for example, collaboration may be particularly valuable for populations who experience PM difficulties (Thöne-Otto & Walther, 2008). There may be a particular need for interventions designed to enhance collaborative success in normal aging, and clinical populations with brain injury or neurodegenerative disease (e.g., see Kliegel et al., 2004; Rendell & Henry, 2009).

Similarly, we advocate for research moving beyond a focus on average performance to consider what particularly successful and non-successful collaborators do differently. Research that targets the communication processes and strategies used amongst the successful collaborators could inform the development of collaborative interventions for individuals experiencing PM difficulties due to normal aging or neurological pathology.

Finally, we suggest a replication of Johansson et al. (2000) with older adults using a more tightly controlled PM task. If older adult couples showed collaborative facilitation in PM using Virtual Week, it would validate the reported reliance older couples place on each other to perform everyday memory tasks (Parikh et al., 2015). Within this replication, we recommend measuring other benefits of collaboration. In research focused on memory tasks in everyday life, for example, Henkel and Rajaram (2011) find that participants typically hold positive beliefs about the value of collaboration. We recommend that future research adopt a broad perspective of success when measuring the impact of collaboration.

Conclusion

We aimed to examine the influence of collaboration on PM in strangers and intimate couples. We found a robust collaboration inhibition effect in strangers, but not in intimate couples. Interestingly, and notwithstanding our finding of collaborative inhibition, in everyday life there remain subjective benefits to collaborating on a PM task (relative to competing the same task on one's own). By using the collaborative recall paradigm we can nonetheless begin to understand some of the processing costs incurred when collaborating. Strangers incurred these costs more heavily, which suggests the strength of the relationship influences collaborative success. By understanding the processes used by better collaborators, and by determining strategies based on these processes, we advocate for interventions that can enhance PM performance amongst populations experiencing PM difficulties.

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Footnotes

¹ Individual scores within each collaborative dyad were significantly associated on the Rapport scale, $r = .68$, $p < .001$, and on the Credibility and Coordination subscales of the TMS, $r_s > .41$, $p_s < .042$, but not the Specialization subscale of the TMS, $r = .31$, $p = .134$.

² Couples' individual scores on each TMS subscale were significantly associated, all $r_s > .53$, all $p_s < .007$; likewise, couples' individual scores on each PAIR subscale were also significantly associated, all $r_s > .64$, all $p_s < .001$.

Table 1

Summary of Five Types of PM Tasks Required to be Performed Twice Each Virtual Day of Virtual Week.

	Regular		Irregular	
	Description	Example	Description	Example
Event-based	Cued by an external event and repeated each virtual “day”.	<i>Take antibiotics at breakfast each “day”</i>	Cued by an external event and performed only once.	<i>Drop in dry-cleaning when out shopping.</i>
Time-based	Cued by the time of day and repeated each virtual “day”.	<i>Take asthma inhaler each day at 11.00 am each “day”.</i>	Cued by the time of day and performed only once.	<i>Put casserole in oven at 5.00 pm</i>
Time-check	Performed after a certain passing of time, each virtual “day”.	<i>Check lung capacity at 2.00 minutes on the stop clock each “day”.</i>		

Table 2

Experiment 1: Proportion of PM Tasks Correctly Performed in Virtual Week

	Event-based		Time-based		Time-check (regular)	Averaged across all task
	Regular	Irregular	Regular	Irregular		
Condition	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Nominal dyads	.96 (.06)	.99 (.04)	.86 (.18)	.85 (.15)	.88 (.12)	.91 (.07)
Collaborative dyads	.90 (.11)	.96 (.06)	.84 (.15)	.74 (.25)	.67 (.26)	.82 (.10)
	.93 (.09)	.97 (.05)	.85 (.17)	.79 (.21)	.77 (.23)	

Table 3

Experiment 1: Proportion of PM Task Content Correctly Recalled

	Event-based		Time-based		Time-check (regular)	Averaged across all tasks
	Regular	Irregular	Regular	Irregular		
Condition	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Nominal dyads	1.00 (.00)	.85 (.12)	1.00 (.00)	.93 (.10)	.99 (.12)	.96 (.04)
Collaborative dyads	.99 (.04)	.69 (.13)	.99 (.03)	.90 (.11)	.99 (.03)	.91 (.05)
	.99 (.03)	.77 (.15)	.99 (.02)	.91 (.11)	.99 (.02)	

Table 4

Experiment 2: Proportion of PM Tasks Correctly Performed in Virtual Week

	Event-based		Time-based		Time-check (regular)	Averaged across all tasks
	Regular	Irregular	Regular	Irregular		
Condition	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Nominal couples	.90 (.17)	.99 (.03)	.89 (.23)	.83 (.12)	.83 (.24)	.89 (.12)
Collaborative couples	.88 (.22)	.91 (.20)	.86 (.22)	.80 (.23)	.74 (.21)	.83 (.17)
	.89 (.19)	.95 (.15)	.87 (.22)	.81 (.19)	.78 (.23)	

Table 5

Experiment 2: Proportion of PM Task Content Correctly Recalled

	Event-based		Time-based		Time-check (regular)	Averaged across all tasks
	Regular	Irregular	Regular	Irregular		
Condition	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Nominal couples	.99 (.03)	.92 (.08)	.96 (.12)	.93 (.07)	.99 (.03)	.96 (.04)
Collaborative couples	.98 (.10)	.88 (.14)	.97 (.11)	.88 (.14)	.98 (.10)	.94 (.09)
	.99 (.07)	.90 (.12)	.96 (.12)	.91 (.11)	.99 (.07)	

Journal Description (2016 impact factor = 2.118)

Memory publishes high quality papers in all areas of memory research, including experimental studies of memory (including laboratory-based research, everyday memory studies, and applied memory research), developmental, educational, neuropsychological, clinical and social research on memory. By representing all significant areas of memory research, the journal cuts across the traditional distinctions of psychological research.

Memory therefore provides a unique venue for memory researchers to communicate their findings and ideas both to peers within their own research tradition in the study of memory, and also to the wider range of research communities with direct interest in human memory (from

<http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=pmem20>).

Chapter 3

Successful and Unsuccessful Collaborative Processes in Strangers and Couples Performing Prospective Memory Tasks

This chapter was prepared as:

Browning, C. A., Harris, C. B., & Van Bergen, P. (2017). *Successful and unsuccessful collaborative processes in strangers and couples performing prospective memory tasks*. Manuscript in preparation.

In this chapter, I explored the individual differences that I found within collaborating strangers and collaborating couples described in Chapter 2. In order to identify cognitive, social, and communication processes that led to more successful collaborative PM, I transcribed, divided into separate clauses, coded, analysed and compared the dialogue of 5 high performing and 5 low performing collaborating dyads each from Experiment 1 (strangers) and Experiment 2 (couples) – 20 dyads in total. A trained second-coder coded 30% of the transcripts to ensure reliability. I limited my analysis to 20 transcripts due to the time-consuming nature of this process. Each Virtual Week “day” yielded long transcripts and a total of 9,691 clauses were individually coded. Due to the intensive nature of qualitative analysis, previous studies that analysed collaborative dialogue to identify individual and group differences also used similarly small samples (e.g., Harris, Keil, Sutton, Barnier, & McIwain, 2011; Margrett, Reese-Melancon, & Rendell, 2011; Meade, Nokes, & Morrow, 2009). I used parametric statistics despite the small sample size, consistent with these other studies upon which my research was based. Preliminary analyses using non-parametric statistics yielded a similar pattern of results.

I coded the transcripts using an adapted version of Margrett et al.’s, (2011) coding protocol to capture the processes that might be important for PM outcomes: cognitive processes, social processes, and generalised conversational skills used by the collaborating dyads. A Principal Components Analysis indicated that these collaborative processes clustered into four factors, and I calculated factor scores for each dyad. In addition, I analysed the relative contribution of collaborating partners within each dyad (measured as a proportion of words spoken).

This chapter was prepared specifically for the journal *Discourse Processes*. This journal was the most appropriate because it publishes both quantitative and qualitative

interdisciplinary research and has published related papers on remembering in conversation. The description of the journal is appended to this chapter (p. 147). While this is a co-authored manuscript, I was the major contributor to all aspects of experimental design, the participant recruitment, the data collection and analysis, the coding and qualitative data analysis, and preparation of the manuscript. Each of these stages was conducted with input and advice from Celia Harris. My previous associate supervisor Amanda Barnier assisted with input and advice during the experimental design and coding stage. My new associate supervisor Penny Van Bergen assisted with input and advice during the data analysis and writing stage.

The data described in this chapter were presented at two international conferences:

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Successful and Unsuccessful Collaborative Processes in Strangers and Couples Performing
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Abstract

In recent research, we have found that individuals generally perform worse on prospective memory (PM) tasks when they collaborate, consistent with similar findings of “collaborative inhibition” for episodic recall tasks. However, research has suggested strong individual differences in the outcomes of collaboration, such that some collaborative groups are more effective than others. To identify the most helpful collaborative processes, we examined the dialogue of 10 stranger dyads and 10 couples working together on an interactive PM task, “Virtual Week”. These dyads were selected because they were identified as being either the most or least successful collaborating stranger dyads or couples in a larger study (Browning, Harris, Van Bergen, Barnier, & Rendell, 2017). We coded the transcripts for cognitive processes, social processes, and generalised conversational skills. A Principal Components Analysis indicated that processes clustered into four factors, and we calculated factor scores for each dyad. Findings were threefold. First, greater quantities of communication overall led to better PM outcomes. Second, some processes were more beneficial than others. The cognitive processes encoding, monitoring, tutoring, and task division, together with social processes sociability and encouragement, were helpful to all dyads, regardless of their relationship. In addition to these processes, rehearsal was particularly helpful to strangers. Third, some processes were more harmful than others. Specifically, demanding and critical behaviour were particularly harmful to couples. We therefore suggest that recommendations for strategies to improve collaborative PM performance might depend on who is collaborating.

Successful and Unsuccessful Collaborative Processes in Strangers and Couples Performing Prospective Memory Tasks

The most common memory failures reported by people of all ages involve *prospective memory* (PM): that is, remembering to perform tasks, keep appointments etc. at some future point in time (Crovit & Daniel, 1984; Terry, 1988). This is not surprising, since PM involves many demanding cognitive processes (McDaniel & Einstein, 2000). To compensate for such difficulties in everyday life, we often enlist the help of others to assist us in carrying out PM tasks (Ahn, Haines, & Mason, 2017; Intons-Peterson & Fournier, 1986; Parikh, Troyer, Maione, & Murphy, 2015). To test whether collaboration with others is an effective strategy, we recently (Browning, Harris, Van Bergen, Barnier, & Rendell, 2017) examined PM performance within stranger dyads and intimate couples collaborating on the “Virtual Week” task (Rendell & Craik, 2000; Rendell & Henry, 2009). We found that stranger dyads in fact showed “collaborative inhibition” seen in episodic recall, such that on average they performed poorly compared to two separate individuals (B. H. Basden, Basden, Bryner, & Thomas, 1997; D. R. Basden & Basden, 1995; Weldon & Bellinger, 1997). However, intimate couples did not show significant collaborative inhibition. Moreover, in both strangers and couples, there were strong individual differences in collaborative performance, such that some dyads were more effective collaborators than others. In the current analysis, we aimed to identify why some pairs were better collaborators than others: what characterises “good collaboration”? Previous research on collaborative recall has identified that heterogeneity in outcomes can be explained by the use of collaborative processes (Harris, Keil, Sutton, Barnier, & McIlwain, 2011). In order to reveal the underlying processes that contributed to better or worse collaborative PM, we examined the collaborative dialogue of strangers and couples as they worked together to perform the PM tasks reported in Browning et al. (2017).

Collaborative Retrospective Memory

A large body of literature has focused on “collaborative recall”: that is, how does remembering with other people influence recall performance? Typically, groups collaborating to recall the past together remember less than nominal groups comprised of an equivalent number of individuals recalling independently – an effect known as collaborative inhibition (Andersson & Rönnerberg, 1995; B. H. Basden et al., 1997; B. H. Basden, Basden, & Henry, 2000; Harris, Barnier, & Sutton, 2012; Harris, Barnier, Sutton, Keil, & Dixon, 2017; Rajaram & Pereira-Pasarin, 2010; Ross, Spencer, Linardatos, Lam, & Perunovic, 2004; Weldon & Bellinger, 1997).

Despite these robust collaborative costs, some kinds of groups may collaborate more effectively than others. Most collaborative recall studies are conducted with undergraduate strangers, who meet for the first time in the experiment, recall relatively meaningless material, and have no joint outcome or goals (B. H. Basden et al., 1997; D. R. Basden & Basden, 1995; Weldon & Bellinger, 1997). Yet transactive memory theory proposes that – over time and with experience remembering together – groups develop efficient shared systems for the acquisition (encoding), holding (storage) and use (retrieval) of information (Wegner, 1987; Wegner, Giuliano, & Hertel, 1985). Through communication, a transactive memory system allows group members knowledge of, and access to information in the other member’s domain of expertise. Furthermore, such an interdependent system produces new and emergent information, such that the transactive memory system of the group is greater than the sum of its individual members (Wegner, 1987; Wegner et al., 1985). Such transactive memory systems are proposed to exist within intimate couples and others in close relationships, developing over a period of time and depending on successful communication between individuals within the system (Wegner,

1987; Wegner et al., 1985). Thus, we might expect that intimate groups, and groups that use effective communication strategies, would collaborate more effectively.

The predictions of greater collaborative success amongst more intimate groups have been supported by several studies on collaborative recall, involving particular kinds of collaborating groups such as friends (Andersson & Rönnerberg, 1995, 1996), married couples (Barnier et al., 2014; Harris et al., 2017; Harris et al., 2011; Johansson, Andersson, & Rönnerberg, 2005), and expert pilots (Meade, Nokes, & Morrow, 2009). Consistent with transactive memory theory, these studies found that the nature of the group influences their collaborative success with the magnitude of collaborative inhibition modulated by factors such as levels of intimacy, strategies used, shared knowledge, and communication processes employed (e.g., repetitions and elaborations) (Andersson & Rönnerberg, 1995, 1996; Barnier et al., 2014; Harris et al., 2011; Johansson et al., 2005; Meade et al., 2009). Importantly, it also seems that a relationship alone is not sufficient – even in long-standing groups there are individual differences in outcomes of collaboration, and success depends on communication (Harris et al., 2011).

Collaborative PM

While there is a robust literature on collaborative recall, there is so far little research on collaboration and prospective memory. In recent research aimed at addressing this gap, we (Browning et al., 2017) asked 50 stranger dyads (Experiment 1) and 50 intimate couple dyads (Experiment 2) to perform a “Virtual Week” PM task (Rendell & Craik, 2000; Rendell & Henry, 2009). Half the dyads in each experiment performed the task individually, with their individual performance later pooled to make nominal scores, while half completed the task collaboratively. We found collaborative inhibition for PM – collaborating pairs performed poorly compared to nominal pairs - but only for strangers and not for intimate couples. Furthermore, both couples and strangers (and particularly

couples) showed individual differences in collaborative success, just as in collaborative recall (Harris et al., 2011) and as predicted by transactive memory theory (Wegner et al., 1985). Even amongst the intimate couples, who had experience in performing tasks together, some dyads may have developed effective communication techniques and some may have not (see Harris et al., 2011), and some couples may have developed greater expertise regarding knowledge of each other's cognitive strengths and weaknesses than others (Dixon & Gould, 1998). That is, not all couples develop equally effective transactive memory systems.

Although we found evidence of individual differences in collaborative success for prospective memory tasks, it is not yet clear what communication patterns and processes during collaboration contributed to stronger or weaker performance. Taking a subsample of high and low performing strangers and couples from Browning et al. (2017), we examined differences in: (1) the quantity of communication during collaboration, and (2) the cognitive processes, social processes, and generalised conversational skills present during collaboration. As a secondary aim, we also examined the extent to which the quantity of communication was balanced between partners. We aimed to examine the features of successful and unsuccessful collaboration, and to determine whether these features were the same for couples and strangers.

Does the Quantity of Communication Matter?

Some evidence suggests that simply a greater quantity of communication between collaborating partners results in better collaborative outcomes (Margrett, Reese-Melancon, & Rendell, 2011; Meade et al., 2009). On the other hand, research on PM suggests a greater quantity of communication could disrupt attentional processes requisite for effective PM, and thereby be detrimental to performance (Einstein, Smith, McDaniel, & Shaw, 1997; McDaniel & Einstein, 2000; Stone, Dismukes, & Remington, 2001). This

disruption could either be specific to the PM task (e.g., providing a reminder about an upcoming PM task at an insensitive time), or occur as part of the background activity (e.g., social interaction and other off-task chatter).

What Cognitive Processes, Social Processes, and Generalised Conversational Skills are Helpful in Collaborative PM?

Although it is important to understand how the quantity of communication affects collaborative PM outcomes, perhaps it is more important to know *what* successful collaborating partners are saying, and *how* they say it. Previous research suggests three kinds of processes that might be important for PM outcomes: cognitive processes, social processes, and generalised conversational skills. The first two kinds of processes – cognitive and social – were examined by Margrett et al. (2011) when analysing the assistance provided by older adults to their partners on the Virtual Week PM task (Rendell & Craik, 2000; Rendell & Henry, 2009). The third kind of process – generalized conversational skills – was examined in collaborative recall literature as a contributor to performance (Gould, Trevithick, & Dixon, 1991; Harris et al., 2011; Meade et al., 2009).

Cognitive processes. Cognitive processes are a subset of known PM processes used by individuals and groups when performing PM tasks. Margrett et al. (2011) developed codes based on specific PM processes outlined by Kliegel, Mackinlay, and Jager (2008). These included encoding (the process where individuals acquire or learn the content of a PM task), monitoring (where an individual directs attention to environmental events to notice the appropriate moment to perform a PM task), task execution (when the intended PM task is executed), and output monitoring (awareness that a PM task was completed, or not). Tutoring (defined as the provision of global strategies from a partner and represents attempts to engage each other) and task division (where individuals attempted to reduce cognitive load by determining an appropriate division of labour) were

cognitive processes included in the Margrett et al. (2011) coding protocol because evidence suggests collaborative teams can benefit from these processes too (Margrett et al., 2011).

Another cognitive process commonly used by individuals undertaking PM tasks that was not considered in the Margrett et al. (2011) coding protocol was task rehearsal. In some ways task rehearsal is similar to the Margrett et al. (2011) definition of monitoring because the participants are thinking about upcoming tasks. However, we wanted to distinguish between processes that reflected recollections about outstanding tasks at random periods throughout the day (rehearsals) and processes that reflected attention and thoughts directed towards specific upcoming tasks as the target was approaching (monitoring). Whereas monitoring refers to observing the environment for the appropriate time or event, in our definition of rehearsals, there is no ongoing observation of the environment because the target times/events are not temporally close. Rehearsals instead capture processes where intentions are periodically recalled from long-term memory (Ellis, 1996; Kvavilashvili & Fisher, 2007), often at random times that are not necessarily close to the target time or event. The content of the intention is rehearsed. Ellis (1996) referred to similar processes in the individual as “recollections” which were defined as remembrances of a delayed intention prior to its performance, which could occur either spontaneously, deliberately, or come as reminders from other people (Ellis, 1996). Therefore, it is a form of self-reminder. In a collaborative environment, there is potential for rehearsals to be spoken aloud, and shared. Table 1 describes the complete list of cognitive processes.

When examining the range of cognitive processes described above, Margrett et al. (2011) found only tutoring to be positively associated with collaborative PM performance. Notwithstanding this, findings from other research suggest that other cognitive processes could improve collaborative outcomes too. For example, Harris, Barnier, and Sutton

(2013) found that joint encoding improved collaborative recall (but see Barber, Rajaram, & Aron, 2010). Similarly, task division could be helpful because it could reduce the cognitive demand associated with PM, such that partners can act as external memory aids and enhance PM performance (D'Angelo, Bosco, Bianco, & Brandimonte, 2012; Henry, Rendell, Phillips, Dunlop, & Kliegel, 2012; Schaefer & Laing, 2000). The efficacy of task division may depend on the relationship of the collaborators however because effective delegation requires knowledge of your partner's expertise, such as the knowledge described in effective transactive memory systems, like couples (Wegner, 1987). Indeed Harris et al. (2011) found that explicitly stated strategies were beneficial to couples' recall. Previous findings however have suggested that task delegation can be detrimental to collaborative couples' outcomes. Hollingshead (1998) found that when couples explicitly developed strategies and delegated responsibility, they did so in a way that was inconsistent with their implicit systems already developed.

In summary, although Margrett et al. (2011) only found tutoring to be predictive of collaborative PM performance, there is much evidence to suggest that employing these cognitive processes should improve collaborative PM outcomes. We suggest there are a number of possible explanations for the Margrett et al. (2011) findings that warrant further research. First, the authors did not distinguish between helpful and unhelpful instances of certain cognitive processes. For example, participants in our study sometimes encoded the content of the intention inaccurately and it is improbable that incorrect encoding could predict better PM performance. Second, as Margrett et al. (2011) noted in their discussion, they did not adequately capture retrieval cues provided by partners (where one partner prompts or provides the content of the intention). Instead retrieval cues were combined with monitoring, and the authors advocated that future research should distinguish between the two. Accordingly, we adapted the original coding protocol to account for these two

factors, which is described in the Method section below. Finally, the nature of the collaboration in Margrett et al. (2011) could be described as one that would encourage tutoring behaviour in verbal communication over and above the other coded processes. Specifically, the collaboration was of the kind where one partner was responsible for playing the Virtual Week game and the other partner was instructed to “offer assistance”. In daily life however, it is more common that both partners work together to achieve common goals – that is that the collaboration is more interactive. The less interactive collaboration in Margrett et al. (2011) may have affected the collaborative processes adopted and their effect on performance.

Social processes. Social processes are processes that are not PM task specific but are instead related to managing the social interaction. They include sociability (personal discussions not relevant to the task), encouragement, demanding behaviour, and critical dialogue. These social processes scored by Margrett et al. (2011) were mostly derived from previous collaborative cognition literature (Gould, Kurzman, & Dixon, 1994; Kimbler & Margrett, 2009). They are thought to differentially affect collaborative performance, especially on PM tasks. For instance, greater amounts of sociability are potentially detrimental to collaborative PM outcomes – increased non-task relevant discussion could divert attention away from strategic monitoring required for PM performance (McDaniel & Einstein, 2000; Stone et al., 2001). On the other hand, increased sociability could potentially benefit PM performance – particularly for strangers. Strangers lack expert knowledge about their partner’s cognitive resources in the absence of a developed transactive memory system, and additional sociability enables them to “get to know” their partner (Gould et al., 1994; Kimbler & Margrett, 2009). Turning to negative social processes, such as demands (when one partner attempts to control their partner) and critical dialogue (which is intended to negatively affect how one’s partner feels about their self),

there is evidence to suggest such processes are detrimental to group performance. For example, controlling behaviour (evidenced by dominance) was informally observed to be detrimental to collaborative performance in Johansson, Andersson, and Rönnerberg (2000). In addition, strategy disagreements and corrections (i.e., indicators of controlling behaviour) were found to load on a group diminishing factor that predicted poorer outcomes when older married couples collaborated to recall personal lists (Harris et al., 2011). Equally one would expect encouraging statements would create more cooperation within dyads (Margrett et al., 2011) and be beneficial to performance.

Generalised conversational skills. Evidence from collaborative recall literature shows that generalised conversational skills that are non-task specific, are associated with enhanced collaborative recall performance (Harris et al., 2011; Meade et al., 2009). For example, the use of repetitions and restatements, which involve repeating back or paraphrasing what your partner just said, have both been shown to be associated with better collaborative recall performance, while simple acknowledgements (e.g., “OK”, “yes”) are associated with poorer performance (Harris et al., 2011; Meade et al., 2009). The use of elaborations, which involve building on ideas generated by your partner and providing additional information, were also found to be associated with enhanced collaborative recall in expert pilots recalling aviation scenarios (Meade et al., 2009) and in younger and older adults recalling prose (Gould et al., 1991). In a possible explanation for the finding that couples are less susceptible to collaborative inhibition than strangers, Gagnon and Dixon (2008) found that couples used elaborations more than stranger dyads when retelling stories. Elaborations need to be task relevant however to improve performance: Harris et al. (2011) found that elaborations that were not relevant were associated with poorer collaborative recall when older adult couples recalled

autobiographical lists. Taken together, this evidence suggests that the conversational skills used between collaborators are important for collaborative outcomes.

Relative Contribution

A secondary aim of this study was to consider how individuals within the dyads vary in their relative contribution to group outcomes. Previous studies investigating group performance show that an imbalance of relative contribution can be detrimental to group performance (Collaros & Anderson, 1969; Johansson et al., 2000; Karau & Williams, 1993). Imbalances of relative contribution can arise due to reasons such as partner dominance (Johansson et al., 2000), social loafing (where motivational factors reduce individual effort (Karau & Williams, 1993) or evaluation apprehension (where group members fear negative evaluation of other group members (Collaros & Anderson, 1969; Diehl & Stroebe, 1987).

Social loafing and other motivational factors were discounted as explanations for collaborative inhibition in collaborative recall when Weldon, Blair, and Huebsch (2000) still found collaborative inhibition after increasing various individual motivational factors. Motivational factors have not been discounted as an explanation for collaborative inhibition in PM however. There is some evidence where reduced individual effort was observed in certain social PM contexts (see D'Angelo et al., 2012; Schaefer & Laing, 2000). However, the nature of the task and stimuli in these experiments resulted in collaboration that was very different to the collaboration in Virtual Week. The game-playing context of Virtual Week produces interactive collaboration, where it is difficult to “hide” poor individual contributions, in contrast to the tasks used in Schaefer and Laing (2000) and D'Angelo et al. (2012). An analysis of collaborative dialogue will allow the opportunity to measure the relative contribution (in terms of proportion of words spoken)

of individuals within the collaborating dyads, to determine whether this affected PM outcomes in Virtual Week, and to examine whether it differed for couples and strangers.

Aims of the Current Study

The overarching aim of the current study was to determine what collaborative processes were helpful for collaborative PM and whether they were similar or different for strangers and couples. First, we aimed to determine whether better collaborators communicated more, and whether this was modulated by the relationship between the collaborators. We predicted that better collaborators would communicate more than poorer collaborators. Second, we aimed to examine cognitive processes, social processes, and generalised conversational skills that led to better, or worse collaborative PM, and whether these processes would be similar or different for strangers and couples. This analysis was mostly exploratory, however we predicted that better collaborators would adopt more of the positive cognitive processes than poorer collaborators. We also predicted that better collaborators would adopt less sociability, demands, and critical processes, but offer more encouragement than poorer collaborators. Next, we predicted that better performers would adopt more generalised conversational skills evidenced by detailed, rather than minimal, utterances. Finally, we aimed to measure the relative contribution of individuals within dyads to the collaborative dialogue, and compare this to PM performance, and the relationship between collaborators.

Method

Participants

The participants were a subset of 20 collaborating dyads (40 participants) recruited for Browning et al. (2017). Ten dyads from Experiment 1 were strangers to each other ($M = 19.05$ years, $SD = 1.39$ years, 11 females and 9 males), and ten dyads from Experiment 2 were intimate heterosexual couples ($M = 23.65$ years, $SD = 12.81$ years, 10 females and 10

males) who had been in a romantic relationship for longer than 12 months ($M = 52.20$ months, $SD = 89.50$ months). The ten dyads from each of the previous experiments were the top five and bottom five performing collaborating dyads. They were selected for this analysis based on their overall collaborative PM performance, which was measured as the proportion of PM tasks correctly performed in the Virtual Week game (see description below), averaged across all tasks. This approach of selecting a subset of the top 5 and bottom 5 performers has been used previously with good success in identifying individual and group differences (Meade et al., 2009). The five highest performing couples and the five lowest performing couples had been in a relationship for a similar period of time, $t(8) = 0.97$, $p = .359$. Participants received either psychology course credit or A\$22.50 (A\$15.00 per hour) for their participation.

Design

We used a 2×2 between-dyads design. The between-dyads variables were *relationship* (strangers, couples) and *PM performance group* (high performers, low performers), and the dependent variable was PM performance in Virtual Week in (Browning et al., 2017). There were 5 dyads in each cell, i.e., five high-performing strangers, five low-performing strangers, five high-performing couples and five low performing-couples.

Measures

Prospective memory task. PM accuracy was assessed using an adapted version of the computerised Virtual Week task (Rendell & Craik, 2000; Rendell & Henry, 2009). Virtual Week is a computerised board game that simulates everyday activities over a one-week period. Each lap of the game-board displayed on the computer screen represents one virtual “day”. Participants use the mouse to roll the die and move their tokens forward on squares that are calibrated to the virtual time of day, and work through the day.

Participants were given 10 PM tasks to perform each virtual day. Participants needed to monitor both the virtual time-of-day on a clock positioned centrally in the middle of the board, and real-time on a smaller stop-clock positioned above the die in a less-focal position. When the appropriate time (on the relevant clock), or event (cued by an “Event Card”) occurred, participants “performed” the PM task by clicking on the “perform task” button and chose the appropriate task from a list of options, including distractor items. Participants also picked up Event Cards when required. At some of these events participants were required to remember to perform a PM task – for example “take antibiotics at breakfast”. In addition, each event required participants to make a choice of three options (e.g., “It is breakfast. Do you have (a) fruit, (b) porridge or (c) cereal?”). These options determined the roll of the die required to proceed in the game but were irrelevant to successful PM performance. Instead, rolling the correct die number, moving the token and making choices about the “Event” activities provided the backdrop of ongoing activities against which the participant needed to remember the PM tasks – an important aspect of PM performance.

Procedure

Participants in Browning et al. (2017) were randomly allocated to either the collaborative or the nominal condition. Stranger participants in the collaborative condition in Experiment 1 presented to the lab in pairs determined by the time-slots they signed up to. They sat side by side at a desk in front of a shared computer. In Experiment 2, the couples arrived at the lab together and those assigned to the collaborative condition were seated side-by-side at a shared computer, while those assigned to the nominal condition were seated at separate desks, with separate computers, divided by a partition. We asked the stranger dyads to introduce themselves to each other, and we instructed all dyads to make themselves comfortable so they could both see the computer screen. Participants

were asked to play the computerised Virtual Week game (Rendell & Craik, 2000, described above). The dyads were instructed that they needed to “work together to play this game”. We gave them no specific instructions regarding how to interpret this, leaving the collaborators free to devise their own collaborative strategies. Dyads gave permission to make an audio recording of the session. After the participants completed a practice day, they played four days of the Virtual Week, and sessions lasted approximately 1.5 hours. Each dyad was asked to perform 40 PM tasks in total, consisting of eight tasks for each of the five types of PM tasks: regular event, regular time, irregular event, irregular time and time-check (10 PM tasks per day, 2 of each type).

Scoring

PM performance. Scoring in Browning et al. (2017) was consistent with Rendell and Craik (2000). Each of the 10 PM tasks performed each day were scored as correct or incorrect. Responses were scored correct if the participant performed the correct action at the correct time or event. For time and event tasks, this meant responding before the next die roll. For the time-check tasks, this meant responding within ten seconds of the specified time. Responses were scored as incorrect if they included the wrong time, wrong action, or were missed completely.

Relative contribution. The relative contribution of each individual within the collaborating dyads was calculated as the proportion of the dyads’ words that each individual spoke during collaboration. These relative contribution scores were dependant on each other within the dyad, such that for each dyad, the relative contribution of the both partners necessarily summed to 1.

Coding of Collaborative Dyads’ Dialogue While Playing Virtual Week

The dialogue of the five highest performing collaborative dyads (high performers), (measured by PM accuracy) and the five lowest performing collaborative dyads (low

performers) in both the strangers and the couples in Browning et al. (2017) was transcribed and analysed; that is, we focused our detailed coding and analysis on 20 transcripts. In addition, we chose to transcribe and analyse the dialogue of the “Monday” and “Tuesday” of the Virtual Week only. We chose these two days firstly because the regular health tasks (required to be performed each day of the Virtual Week) were introduced at the start of Monday. They were in addition to irregular PM tasks that were given each day and differed each day. In this way, we captured the busy start of the week when the participants were loaded with many tasks. It was during this initial encoding phase that they needed to coordinate and communicate the most before settling into a routine. Secondly, we observed the pattern of PM performance over the course of the Virtual Week and found that although performance generally increased each day, it levelled off on “Wednesday” and “Thursday”. Thus, we decided to transcribe and analyse the collaborative dialogues from only the first two days of the Virtual Week, reflecting the period that demonstrated the greatest coordination between the collaborators, and the greatest variance in PM performance.

We coded the transcripts using an adapted version of Margrett et al.’s, (2011) coding protocol to capture the processes that might be important for PM outcomes: cognitive processes, social processes, and generalised conversational skills used by the collaborating dyads. See Table 1 for a full list of processes and definitions. All transcripts were checked and corrected for accuracy. The total number of words spoken across the two “days” of all 20 transcripts was 40,586. Prior to coding, we divided utterances within the transcripts into clauses that reflected complete thoughts by each speaker. The total number of clauses across all 20 transcripts was 9,691. Each clause received a unique behavioural code. A primary coder (the first author) coded all transcripts and a trained second coder coded 30% of the transcripts. Interrater reliability was very strong ($ICC = .948$). The codes

of the primary coder were retained for data analysis. We refined Margrett et al.'s (2011) coding scheme in several ways after noticing that some relevant aspects of the collaborative dialogue were not adequately captured using the existing scheme.

Specifically, these changes were:

Cognitive processes. First, we distinguished between helpful and unhelpful instances of certain cognitive processes – encoding and retrieval cues – that were sometimes performed inaccurately or unsuccessfully. Second, we introduced an additional code “Rehearsals” which aimed to capture the behaviour when dyads periodically took time out to rehearse the contents of upcoming tasks they were still required to perform that day. Here the participants paused at random times throughout the day to rehearse their intentions. That is, they recited to each other a “to do” list of all the tasks they still needed to do that day. It was similar to monitoring only in that they were thinking about upcoming tasks, however they weren't actively monitoring the environment for the next task. They were rehearsing or reinstating the content all the PM tasks, and in this way reminding themselves and each other about their upcoming tasks (Ellis, 1996). Third, in accordance with recommendations by Margrett et al. (2011) we also attempted to refine the original “monitoring” classification to reflect the difference between monitoring and retrieval of the intention. The former is when an individual is aware that a task is upcoming and accordingly directs attention to the environment for cues, whereas the latter is when an individual retrieves the content of the PM task from memory at the appropriate time (Ellis, 1996; Kliegel et al., 2008; McDaniel & Einstein, 2000). Previously these processes were captured by the same code, so instead we created separate codes for monitoring and retrieval cues.

Social processes. No changes were made to the coding of social processes: we adopted the coding system of Margrett et al. (2011; see Table 1).

Generalized conversational skills. In order to capture differences in the conversational skills between collaborating dyads, particularly while they were engaged in cognitive processes, while still retaining the cognitive process categories developed by Margrett et al. (2011), we introduced separate codes for the detailed or minimal instances of tutoring, encoding, monitoring, and retrieval cues. For instance, we wanted to distinguish between minimal instances of encoding (e.g., simply responding “yes” after listening to a partner read out a new task instruction), and more detailed instances of encoding that might include repetitions or elaborations (e.g., “So we need to take antibiotics at breakfast. Antibiotics breakfast, antibiotics breakfast”). See Table 1 for other examples.

Results

Comparison of PM Performance Between Groups

To show that high performing dyads differed significantly in their overall PM ability compared to low performing dyads, separate independent samples t-tests were performed for strangers and couples. For strangers, the high performing group scored significantly higher on overall PM performance ($M = 0.94$, $SD = .03$), than the low performing group ($M = 0.66$, $SD = .07$), $t(8) = 8.30$, $p < .001$, $d = 5.6$. Similarly, for couples, the high performing group scored significantly higher on overall PM performance ($M = 0.98$, $SD = .02$), than the low performing group ($M = 0.59$, $SD = .23$), $t(4) = 8.30$, $p = .019$, $d = 3.12$ (note corrected df is reported here because equal variances were not assumed). Therefore, selecting the top 5 and bottom 5 performers each from the strangers and couples formed high and low performing groups who differed significantly in their performance.

Productivity of Collaborating Dyads

To test whether better collaborators communicated more, and whether this varied between strangers and couples, we conducted a 2 (Relationship: strangers, couples) \times 2 (PM performance group: high, low) between-dyads analysis of variance (ANOVA). The dependent variable was the total number of words spoken per dyad. This analysis yielded a main effect of relationship $F(1, 16) = 7.42$, $MSE = 293,564.53$, $p = .015$, $\eta_p^2 = .32$, and PM performance group $F(1, 16) = 14.17$, $MSE = 293,564.53$, $p = .002$, $\eta_p^2 = .47$, but no significant interaction between relationship and PM performance group, $F(1,16) = 0.11$, $MSE = 293,564.53$, $p = .918$, $\eta_p^2 = .00$. Consistent with our prediction, high performing dyads spoke significantly more words ($M = 2485.30$, $SD = 644.60$) than low performing dyads ($M = 1573.30$, $SD = 590.55$). In addition, couples spoke significantly more words ($M = 2359.30$, $SD = 765.06$) than strangers ($M = 1699.30$, $SD = 631.68$). Taking into consideration the finding that couples did not show the typical collaborative inhibition (Browning et al., 2017), this finding is also consistent with our prediction that better PM collaborators communicate more.

Processes That Contribute to Better or Worse PM Performance

Our process coding scheme allowed us to code each dyad's dialogue on 20 behavioural codes. For data reduction, and to determine the relationships among our coded processes, we conducted a Principal Component Analysis using a varimax rotation and an eigenvalue criterion of 1¹. There was a low subject to variable ratio, and as such this analysis should be considered exploratory. The analysis yielded a four-factor solution, which accounted for 80.82% of the variance. The factor loadings are presented in Table 2, with factor loadings $< .40$ suppressed. Factor 1 included task division, tutoring (detailed), encoding (detailed), monitoring (detailed and minimal), sociability, and encouragement. Factor 2 included tutoring (minimal), encoding (detailed), encoding (minimal), rehearsals (detailed and minimal), and monitoring (detailed and minimal). Factor 3 included incorrect

encoding, inaccurate/unsuccessful retrieval cues, and output monitoring. Factor 4 included task division, retrieval cues (successful/accurate), demands, and critical dialogue. Most items loaded strongly on their respective factors (see Table 2). Task division loaded strongly on Factor 1 and moderately on Factor 4.

We also obtained standardized component score coefficients from the principal component analysis by converting each item into a *z* score and using these to calculate the score on each factor for each dyad. This allowed us to examine scores of the high and low performing groups of the strangers and couples on the four factors (see Table 3), to see whether factor scores were associated with collaborative success. We conducted four separate 2 (Relationship: strangers, couples) \times 2 (PM performance group: high, low) between dyads analysis of variances (ANOVAs) with the dependent variables consisting of the factor scores for each dyad. The results from these ANOVAs are summarised in Table 4 and we describe them next.

For Factor 1, there was a main effect of relationship: couples ($M = .40$, $SD = 1.14$) adopted these processes more than strangers ($M = -.40$, $SD = .67$). There was also a main effect of PM performance group: high performers ($M = .55$, $SD = 1.05$) adopted these processes more than low performers ($M = -.55$, $SD = .57$). There was no interaction between relationship and PM performance group however. Therefore we conceptualized Factor 1 – task division, tutoring (detailed), encoding (detailed), monitoring (detailed and minimal), sociability, and encouragement – as a “general group-enhancing” factor for PM performance (see Harris et al., 2011). The presence of these features indicates that higher performing dyads interacted dynamically to perform the PM task. They took advantage of the collaborative environment and divided task responsibility between them. Together they adopted detailed tutoring, detailed encoding of the task, and together monitored the appropriate time to perform it. They encouraged each other and adopted sociable

conversation. All of these processes were associated with better PM performance. Overall, couples adopted these processes more than strangers, which is perhaps why they were able to reduce collaborative inhibition (compared to strangers) in PM in Browning et al. (2017).

For Factor 2, there was a main effect of relationship and a main effect of PM performance group, but importantly there was an interaction between relationship and PM performance group. Contrasts showed that for strangers, high performers ($M = 1.24$, $SD = 1.07$) adopted these processes more than low performers ($M = -0.45$, $SD = 0.43$), $p = .022$. For couples, high performers ($M = -0.39$, $SD = 0.72$) and low performers ($M = -0.40$, $SD = 0.58$) did not differ. Therefore, we conceptualized Factor 2 – encoding (detailed and minimal), minimal tutoring, rehearsals (detailed and minimal), and monitoring (detailed and minimal) – as a “strangers-enhancing” factor: beneficial only for strangers.

For Factor 3, there were no main effects of relationship or PM performance group, nor any interaction. We conceptualized the third factor – incorrect encoding, inaccurate retrieval cues and output monitoring – as a “memory errors” factor. Both couples and strangers adopted this behaviour, and it did not significantly adversely affect performance. When information was initially encoded erroneously, dyads could only offer inaccurate retrieval cues at a later stage, as well as much subsequent discussion devoted to trying to remember whether a task was completed or not (output monitoring).

For Factor 4, there was a main effect of relationship: couples ($M = 0.57$, $SD = 1.13$) adopted these processes more than strangers ($M = -0.57$, $SD = 0.34$). There was no main effect of PM performance group. However, there was an interaction between relationship and PM performance group. Planned contrasts showed that for strangers, high performers ($M = -0.72$, $SD = 0.21$) did not differ in these processes compared to low performers ($M = -0.42$, $SD = 0.40$), $p = .533$. For couples, low performers ($M = 1.16$, $SD = 1.36$) adopted these processes more than high performers, ($M = -0.02$, $SD = 0.40$), $p = .024$. Therefore,

we conceptualized Factor 4 – task division, retrieval cues, demands, and critical, – as a “couples-diminishing” factor: detrimental only for couples.

Relative Contribution to Group Productivity

Finally, in order to investigate whether the relative contribution of individuals within collaborating dyads was equal, and whether this varied between high and low performers, or strangers and couples, we conducted a $2 \times 2 \times 2$ mixed-model analysis of variance (ANOVA) with the between-dyads factors of relationship (strangers, couples) and PM performance group (high performers, low performers) and the within-dyads variable of relative contribution of words spoken (more dominant narrator, less dominant narrator). The dependent variable was the proportion of words spoken by individuals within each dyad (described above). We were interested in whether there was a main effect of contribution (indicating that there was a significant discrepancy in words spoken) and whether this depended on the performance level or relationship within the group. Any main effects of relationship and PM performance group are redundant because we compared the proportions of words spoken within each dyad, which adds to one, so the other main effects compared equal means of 0.5 each. This analysis yielded a main effect of relative contribution $F(1, 16) = 46.04$, $MSE = .016$, $p < .001$, $\eta_p^2 = .74$, and no significant interactions, all $ps > .144$, all $\eta_p^2s < .13$. This suggests that on average, within each dyad, regardless of whether they were in the high or low performing group, there was a more dominant narrator who spoke on average twice as much ($M = .64$, $SD = .09$) as a less dominant narrator ($M = .36$, $SD = .09$).

Discussion

The aim of this study was to examine the collaborative processes underpinning successful PM performance. Drawing on a subsample of collaborating stranger dyads and couples from Browning et al. (2017) we identified collaborative PM processes that were

beneficial for both strangers and couples. We also found differences in processes that were beneficial or detrimental for couples and strangers, such that some were helpful only for strangers and others detrimental only for couples. Thus, the effect of the various processes on performance depended on the relationship between collaborators. These findings are discussed below.

Productivity

As predicted we found better PM outcomes were associated with greater quantities of communication among group members. This finding is interesting because it is inconsistent with predictions arising from previous research: although one might expect more communication to be characteristic of better collaborators generally, there is potential for talking to disrupt attentional processes necessary for the strategic monitoring required to complete certain PM tasks (McDaniel & Einstein, 2000; Stone et al., 2001). Therefore, when better PM collaborators talked, we suggest they did so in a non-disruptive manner that was sensitive to attentional requirements. Furthermore, couples talked to each other more than stranger dyads overall when collaborating on PM tasks, which suggests that intimate couples may be expert communicators (Harris et al., 2011).

General Group-Enhancing Factor

We analysed the content of communication exchanged between collaborative dyads in order to determine what the features of successful collaborative PM were. We found a general group-enhancing factor – Factor 1. This factor was comprised of helpful cognitive processes (task division, detailed tutoring, detailed encoding, and monitoring (detailed and minimal)) and positive social processes (sociability and encouragement). Both high performing couples and strangers displayed these processes; however overall, couples adopted these processes more than strangers. We found that task division loaded on to this group-enhancing factor. Task division is a process that takes advantage of the collaborative

environment where task responsibility is delegated to reduce individual cognitive load. This finding suggests that allocating and undertaking individual responsibility for task performance is important. It converges with evidence from a reminder study (Schaefer & Laing, 2000) where participants were either told to expect a reminder from another person (thereby reducing personal responsibility), or they were asked to provide a reminder to another person (thereby increasing personal responsibility). Reducing personal responsibility diminished PM performance, whereas increased responsibility marginally enhanced performance. We suggest that in successful collaborative PM teams, talking about delegating task responsibility increases the amount of personal responsibility for one person, but at the same time it may not completely take away responsibility from the other group member. The finding that task division was beneficial to strangers as well as couples is interesting because strangers have no previous knowledge about each other's areas of expertise to enable effective task delegation. They needed to trust each other's ability, consistent with the finding from Browning et al. (2017) that for strangers in particular, PM performance was positively related to their level of confidence and trust in their partner's ability.

Consistent with Margrett et al. (2011) and Kimbler and Margrett (2009), we found that tutoring loaded on to this group-enhancing factor, clustering with other cognitive and social processes that were beneficial for collaborative outcomes. Margrett et al. (2011) interpreted this finding in terms of the relative skill level of the older adults participating in their study. In their study, one partner was asked to assist the other partner playing Virtual Week. They argued more skilled partners provided frequent tutoring to less skilled partners, who in turn encouraged their partners to help them. This interpretation was consistent with Kimbler and Margrett (2009) where the best interactive style in collaborative problem solving was also found to be one where one partner displayed high

levels of tutoring and the other displayed high levels of encouragement. Our finding suggests that tutoring and encouragement are also important in an interactive collaborative PM environment, where both participants are actively engaged in the task.

We also found that cognitive processes required for successful individual PM outcomes – encoding and monitoring – loaded on to this group-enhancing factor. Collaborative encoding has previously been found to improve collaborative recall. Harris et al. (2013) suggested that collaborative encoding allowed similar organisation of stored memories, producing more similar retrieval strategies among group members and improving collaborative recall. Discussion during the encoding process also allows an opportunity to test partners' memories for the content of the PM task and make error corrections when appropriate. Previous studies have found a reduction in memory errors is a benefit of collaborative recall, even where collaborative inhibition was found (Harris et al., 2012, 2013; Ross et al., 2004). The effects of collaborative monitoring has not been tested before, however this finding suggests that joint monitoring can enhance PM performance rather than disrupt it.

Surprisingly, and contrary to our predictions, sociability (which was non-PM task relevant) loaded on this group-enhancing factor. Therefore, it was not disruptive as predicted. Furthermore, it was more common for couples to use sociability statements than strangers. These findings are in contrast with findings from previous studies investigating collaborative recall and collaborative problem-solving, which showed that sociability statements were more common to older-adult strangers than couples (Gagnon & Dixon, 2008; Gould et al., 1994; Kimbler & Margrett, 2009). Furthermore, sociability statements were negatively related to recall (Gould et al., 1994). One possibility for this difference is the age difference in the participants. Older adults find it more difficult to block out distractions compared to younger adults and their performance is more susceptible to

distractions (Hasher & Zacks, 1988). Couples displayed greater amounts of sociability overall compared to strangers, without compromising PM performance. This points to the emergence of couples as collaborators with “relationship expertise”; sociability is somewhat automatic and non-disruptive for couples. This may be a consequence of couples having experience and practice with performing cognitive tasks together (Dixon & Gould, 1998).

Finally, the general group-enhancing factor included instances when tutoring, encoding and monitoring were delivered in a detailed fashion. This included repetitions, re-statements and elaborations, which are associated with enhanced collaborative recall (Gould et al., 1991; Harris et al., 2011; Meade et al., 2009). Meade et al. (2009) suggested that repetitions and restatements, compared to simple acknowledgements, allow explicit agreement on what content is common ground, and thereby facilitate joint attention to relevant information. This idea was evident in the dialogue between successful collaborators in this study. For example, detailed encoding included instances of joint learning of new tasks, testing each other about task content, and clarifications made at the time of learning. Repeating the information to each other offers additional encoding opportunities. Detailed monitoring included instances where the task was repeated back to the other partner, or elaborated upon. It reflected a truly interactive form of collaborative tutoring, encoding, and monitoring, which demonstrated evidence of transactive memory systems, where shared knowledge in closed groups can enhance memory. Our finding that the more detailed instances of these processes loaded separately from more minimal forms suggests that nuanced distinctions are necessary for understanding beneficial collaborative processes.

Future research should be directed towards testing whether groups can improve their collaborative PM outcomes by implementing strategies that adopt some of these

processes. Such strategies might encourage interactive encoding and monitoring, using repetitions, elaborations, and simple acknowledgements, and delegation of task responsibilities. Strategies that support sociable and encouraging dialogue could be tested too.

Stranger Dyads-Enhancing Factor

We identified some collaborative processes that were helpful for stranger dyads but not for couples. High performing strangers adopted these processes significantly more than low performing strangers, whereas couples adopted these processes to a lesser degree, and it made no difference to their PM outcomes. The stranger dyads-enhancing factor included cognitive processes that are known to be necessary for PM (tutoring, encoding, and monitoring), but they differed to the processes found in the general group-enhancing factor in that they included additional minimal versions of these processes too (i.e., “yes”, “no”, “hmm”). Minimal utterances like simple acknowledgements have previously been shown to be associated with poorer recall (Harris et al., 2011; Meade et al., 2009). It should be noted that in this study these processes are helpful for strangers *in addition* to the detailed instances of encoding and monitoring. It may be that in the case of strangers, minimal utterances also establish common ground between partners even though they do not allow explicit agreement on content in the same way that repetitions do (Meade et al., 2009). This might provide additional assistance to collaborating partners who do not know each other, in the absence of an established transactive memory system. Furthermore, minimal utterances may represent a minimal level of engagement that all couples already have, which may be why such minimal utterances occur less and are less helpful or necessary for couples. Pasupathi, Carstensen, Levenson, and Gottman (1999) found that happy older married couples used backchannels such as these less than happy middle-aged couples, which supports the idea that they become less necessary as relationships develop time.

Rehearsals – when collaborating dyads periodically paused throughout the virtual day to rehearse their “to-do” list from memory to each other – also loaded on to this stranger-dyads enhancing factor. They refreshed or reinstated the contents of the intention. In some ways interactive rehearsals spoken aloud and exchanged between two people are similar to the provision of reminders (Ellis, 1996), which have been shown to boost PM performance (Guynn, McDaniel, & Einstein, 1998; Henry et al., 2012; Ihle, Schnitzspahn, Rendell, Luong, & Kliegel, 2012). Rehearsals differed however in that collaborators interactively cooperated to remind each other about all the outstanding tasks that needed to be performed. It is interesting that strangers rehearsed to a greater extent, with more successful outcomes than couples. Perhaps rehearsal of upcoming PM tasks serves to compensate for the lack of implicit knowledge that might exist between couples. It could be that after joint encoding, couples are confident in each other’s ability to remember and feel less need to stop and rehearse the content aloud (Hollingshead, 1998).

Given our findings that some processes are more beneficial for strangers than for couples, any future research directed towards testing strategies to improve collaborative PM outcomes should be tailored according to the relationship between the collaborators. In addition to the processes identified in the group-enhancing factor, stranger dyads in particular should be given strategies that encourage the use of rehearsals.

Memory Errors Factor

Both couples and strangers scored similarly on this factor, which was associated with memory errors (incorrect encoding, inaccurate retrieval cues, and output monitoring) (see Table 2). Mean scores showed memory errors were more common in low performers than high, however the difference was not significant. This finding shows that incorrect encoding occurs in collaborative PM, perhaps due to disruption. Furthermore, not surprisingly, incorrect encoding was associated with inaccurate retrieval cues supplied at

time of retrieval. When output monitoring was observed, similar to observations in Margrett et al. (2011), it appeared to be an attempt to remember whether a task had been done that day or whether they were confusing it with another day. Therefore, although the effect of memory errors was not significantly detrimental to performance (probably due to their low incidence), memory errors occurred in collaborative PM in both couples and strangers.

Couples-Diminishing Factor

We also found collaborative processes that were detrimental for couples but not for strangers. Low performing couples adopted these processes significantly more than high performing couples, whereas strangers adopted these processes to a lesser degree, and it made no difference to their PM outcomes. Demanding and critical processes loaded on this couples-diminishing factor, clustering with other cognitive processes that overall contributed to low performance in couples. This finding converges with evidence from a collaborative problem solving study where older adult couples used demands more than strangers (Kimble & Margrett, 2009). Here it was suggested that older adult couples strategically used demands more than strangers due to couples having more knowledge regarding each other's expertise, which could lead to one person taking charge, but the effect of such demands on couples' performance was not tested.

Our findings suggest that demanding and critical processes are detrimental to couples' performance – at least in this sample of younger adult couples. This converges with evidence from Johansson et al. (2000) where it was informally observed that partner dominance in older married couples (which can include demanding behaviour) working together on PM tasks was deleterious to PM performance. Harris et al. (2011) also found that corrections and strategy disagreements were detrimental to collaborative recall in older couples. Furthermore, these negative social processes may flag a broader problem with the

quality of the relationship for the couples. For instance Carstensen, Gottman, and Levenson (1995) found that middle aged and older long married couples' conversations regarding marital problem areas involved greater exchanges of negative affect (e.g., anger, contempt, domineering) in unhappy couples compared to happy couples. Likewise, Pasupathi et al. (1999) found that emotionally negative and less responsive speaking, as well as listener's negative emotional expression was greater in unhappy couples compared to happy couples, although older long married couples seem to be more resilient to less responsive generic listening (eye contact and back channels). The quality of the relationship in couples could in turn affect group outcomes. Indeed Browning et al. (2017) showed couples' PM performance was negatively related to discrepancies in their intimacy ratings.

Task division moderately loaded on the couples-diminishing factor in addition to loading on the general group-enhancing factor (see Table 2). Its loading on the couples-diminishing factor suggests that delegating tasks is not always successful for couples. We observed that task delegation was sometimes assigned according to perceived expertise of a particular group member, suggesting that strategic task division may be at odds with implicit knowledge about expertise and systems that exist within couples. Indeed, there is previous evidence to suggest that explicit delegation of tasks can disrupt implicit systems present in couples with developed transactive memory systems (Hollingshead, 1998).

Finally, cues that were used to either solicit or provide the content of the intention loaded on to this couple-diminishing factor. Although the use of retrieval cues has been shown to boost collaborative recall in long-term couples (Harris et al., 2011), they have also been associated with the disruption of idiosyncratic retrieval strategies of group members (B. H. Basden et al., 1997). In the present study, task content was encoded collaboratively, which suggests a degree of shared knowledge, that it is argued would lead

to more successful retrieval cues in collaborative recall (Harris et al., 2011; Johansson et al., 2005). It was noticed however that when collaborative dyads played Virtual Week together, a greater incidence of retrieval cues usually coincided with a greater number of disagreements and uncertainty about task content. We suggest it might be the uncertainty about the task content (a retrospective memory failure or encoding failure) that was reflected in poorer performance, rather than the cues themselves. Couples might have shown a greater incidence of this behaviour because strangers may not have felt confident enough to disagree aloud with their partners. Instead strangers may have been following social norms, as proposed by Kimbler and Margrett (2009) when they observed strangers did not make as many demands as couples, when performing a collaborative problem solving task.

Again, future research directed towards testing strategies to improve collaborative PM outcomes should be tailored according to the relationship between the collaborators. That is, strategies recommended to improve collaborative PM outcomes for couples should be specifically tailored for couples. As well as encouraging processes identified as group enhancing, strategies should discourage demanding behaviour or critical processes, and discourage explicit task division that is not consistent with systems already in place.

Relative Contribution

When exploring the relative contribution made by individuals within dyads, we found that within both stranger dyads and couples, whether they were better collaborators or not, one person typically took the lead in conversation, and spoke significantly more than the other person. The fact that the average discrepancy was similar in high performers as well as low, suggests unequal contributions (of conversation) may not always detrimentally affect performance. For example, not all collaborations in which one person takes the lead necessarily represent social loafing on the part of the non-dominant partner:

particularly in groups that excelled. They might instead be indicative of effective coordination and task division that arises in transactive memory systems where partners have knowledge about their partner's ability and expertise (Kimble & Margrett, 2009; Wegner, 1987). Furthermore, Cuc, Ozuru, Manier, and Hirst (2006) found that the presence of a dominant narrator facilitated the formation of group memory. Although they did not evaluate the costs of group remembering compared to individual memory, they showed that a dominant narrator in conversation is important to have in social remembering. We should also consider that this pattern of interaction may have arisen due to the game-board nature of the task where one person might take the lead in directing the flow of the game (or take control of the computer mouse), and therefore the effect may have been driven by the nature of the task.

Interestingly, we noted a gender effect of relative contribution in couples. A post-hoc comparison of means showed overall, females talked more than males, and that on the lower performing couples, female partners did most of the speaking (i.e., females $M = .63$, $SD = .08$, compared to males $M = .37$, $SD = .08$, $t(4) = 3.36$, $p = .028$). However, in the higher performing couples, contributions were more equitable between males and females (i.e., females: $M = .53$, $SD = .11$, compared to males: $M = .47$, $SD = .011$, $t(4) = 0.57$, $p = .598$). These observations are interesting given the findings of a recent study where Ahn et al. (2017) examined gender differences in the provision of PM reminders within heterosexual couples. They found that females reported providing the majority of PM reminders for couples in their everyday life. Although our observation was that this imbalance was not present in all couples, these analyses suggest that when PM load falls on one partner more than the other, the couple's performance suffers. It was not possible to observe gender contribution in the stranger group because not all dyads were mixed-

gender. We did observe however that 60% (3/5) of high performing strangers were all-female dyads, and 80% (4/5) of low performing strangers were mixed gender dyads.

These observations may be confounded by the fact that each female member of the couples was also a student recruited from a predominantly female psychology participant pool. As such the female was more familiar with university research participation than her male non-student partner. Accordingly, she may have assumed the “expert” role within the team. Therefore, the observed effect may be attributed to expertise rather than gender.

When the designated expert spoke the most within each couple, PM performance was low, whereas when the novice matched the expert’s contribution, PM performance was high.

This is consistent with findings from Harris et al. (2011) which showed that the nomination of an expert within couples was detrimental to collaborative recall. The imbalances of relative contribution observed and outlined above should be investigated further in future research that manipulates individual motivation and gender in collaborative PM, similar to the way in which individual motivation and gender was previously manipulated in collaborative recall (Weldon et al., 2000).

Conclusions

In collaborative PM, some dyads are more successful collaborators than others (Browning et al., 2017). We found evidence that collaborative processes explain some of this heterogeneity, just as in episodic collaborative recall (Harris et al., 2011). We identified beneficial collaborative PM processes across strangers and couples. However, we also found some differences in beneficial vs. detrimental processes depending on relationship. Therefore, our recommendations for strategies aimed to improve collaborative PM outcomes might depend on the relationship between the collaborators. We would recommend that all groups collaborating on PM, regardless of their relationship, should talk to each other more and interact in a dynamic and engaged way. They should talk to

each other when encoding and monitoring, and use repetitions, elaborations and non-minimal responses. They should take advantage of the collaborative environment and talk about how they might delegate task responsibility and provide general strategies that might help each other. At the same time, they should adopt more social discussion and encourage each other. We would recommend that strangers should try to regularly stop and help each other rehearse their “to-do” list of outstanding tasks. Couples should not be demanding or critical of their partner. Furthermore, we would recommend that couples should be careful when attempting to delegate task responsibility that they do not override implicit systems they have already established. Whether such recommendations can be implemented to influence collaborative outcomes in PM needs to be tested in future research.

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Footnotes

¹We excluded metacognitive positive and negative processes from the analyses because they did not load strongly on a single factor in the factor analysis. They accounted for less than .3% and .9% of the total clauses each. Removing these variables gave the cleanest set of factors with strong items loading on each. Task execution was also excluded as this behavior represents PM performance and is redundant.

Table 1

Process Codes Applied to Dyads' Collaborative Interaction

	Definition (Example)
<i>Cognitive processes</i>	
Task division	Attempts to reduce the cognitive load of a partner or establish division of labor; (“So, if you can keep a track on the times, I’ll keep a track on the events”.’’)
Tutoring (detailed)	Provision of global strategies to assist partner. Must be detailed, rather than minimal utterance. Includes elaborations – additional information to that already supplied by partner, as well as repetitions; (“You have to roll again to move”; “Ok, we’ve finished the first day.”)
Tutoring (minimal)	Provision of minimal utterances to support task and game-playing performance. Could be a response to partner’s detailed tutoring, but also stand-alone minimal utterances not related to other processes; (“OK”, “yes”, “no”, “Hmm”).
Encoding (detailed)	Attempts to encode information (e.g., repeating information so an intention is formed). Must be detailed, rather than minimal utterance. Includes elaborations – additional information to that already supplied by partner – as well as repetitions; (P1: “Lung capacity, two and four minutes.” P2: “Yeah, lung capacity at two minutes and four minutes on the stopwatch, OK”.
Encoding (minimal)	Minimal attempts to encode information; (“Yes”, “OK”, “Hmm”)
Incorrect encoding	Instances of inaccurate encoding of PM task content; (“Ok, so you’ve got antibiotics breakfast, asthma inhaler at 11 and 9” – Antibiotics at dinner was omitted)
Rehearsals (detailed)	Dialogue reflecting participants periodically pausing to rehearse or reinstate the content of upcoming tasks previously encoded. These often occur in the form of a “to-do” list of tasks that are outstanding. They show certainty (rather than confusion) about what the task is and when it is required. Although thinking about upcoming task, not to be confused with monitoring, because this is not monitoring the environment for the appropriate moment to carry out the task. Must be detailed, rather than minimal utterance. Includes elaborations and repetitions; (P1: “So we’ve got 5pm...” P2: “We’ve got 5pm, we’ve got, umm...” P1: “9pm”. P2: “9pm”. P1: “We’ve got

	Definition (Example)
	to return the..." P2: "And we've got about 40 seconds before we need to check lung capacity again". P1: "40 seconds". P2: "And then just bits and pieces throughout the day, like with the library, and dropping off the dry-cleaning and going shopping.").
Rehearsals (minimal)	Minimal responses made during the rehearsal process; ("Yes", "Yep", "Hmm")
Monitoring (detailed)	Indication of thinking about upcoming PM tasks. Monitoring for appropriate time and upcoming events as the target time/event approaches. Can include statements that are specific about what and when. Must be detailed, rather than minimal utterance. Includes elaborations and repetitions; ("OK, it's nearly 4 o'clock". "We have to get a haircut at one, which is coming up")
Monitoring (minimal)	Minimal responses regarding upcoming task monitoring; ("Yes", "Yep", "Hmm")
Retrieval cues (detailed)	Dialogue meant to prompt or provide content of intentions to or from the other person. Cues solicited and provided with detail and/or elaborations, and/or repetitions; (P1: "What do we have to do?" P2 "we need to phone...")
Retrieval cues (minimal)	Minimal attempts to provide or solicit the content of intentions; "Uh huh", "Hmm".
Inaccurate/unsuccessful retrieval cues	Inaccurate or unsuccessful prompts for content of intention. (P1: "Then what do I do, drop in dry cleaning?" P2: "Dunno".)
Task execution	Completion of a PM task; ("Perform task now", "We're dropping off the dry cleaning")
Output monitoring	Conveying awareness that tasks have been completed, or should have been completed; ("Did we take our antibiotics?")
Metacognitive – positive	Positive thoughts regarding one's thinking or memory (e.g., statements of self-efficacy; "I could probably remember them")
Metacognitive – negative	Negative thoughts regarding one's thinking or memory. Definitive statements about one's own inability to remember something; ("I feel like I'm forgetting something")
<i>Social processes</i>	
Sociability	Discussion not explicitly relevant to task completion (i.e., personal discussions or jokes). Include here discussion surrounding "Event" card choices. ("If I'm at home at night, I would probably assume it's my Mum, so I would ignore the signal". "Oh no, I'm just in the mood for pancakes at the moment")

	Definition (Example)
Demands	Dialogue intended to control one's partner or the pace / outcome of the testing session; Statements are practical or factual in nature, rather than strategic; ("Quickly, tell me!")
Encouragement	Positive dialogue to prompt or reinforce partner's participation in the collaborative task; ("You did it! I'm so proud")
Critical	Dialogue discouraging partner participation or criticising performance. Includes any dialogue that is intended to negatively affect how their partner feels about their self, their performance, or their situation; ("You've just shot past!" and "Oh it's so hard, so hard" in a sarcastic tone)

Note. When coding we included other non-substantive codes to allow coding of all clauses as directed by Margrett et al.'s (2011) coding manual. These included "Reads question", "No code" (incomplete thoughts and utterances e.g., "Um") and "Other" (parts of dialogue that cannot be classified under any category e.g., counting the spaces aloud while moving the token). There were no significant differences between groups and the use of these codes. The original codes used by Margrett et al. (2011) were Task division, Tutoring, Encoding, Monitoring, Task execution, Output monitoring, Metacognitive, Sociability, Demands, Encouragement and Critical.

Table 2

Collaborative PM performance on Virtual Week: Component Matrix for Factor Analysis

<i>Rotated Component Matrix</i>				
<i>Process</i>	<i>Factor 1 General group- enhancing factor</i>	<i>Factor 2 Stranger dyads- enhancing factor</i>	<i>Factor 3 Memory errors factor</i>	<i>Factor 4 Couples- diminishing factor</i>
Task division	.783			.427
Tutoring (det.)	.917			
Tutoring (min.)		.854		
Encoding (det.)	.670	.635		
Encoding (min.)		.743		
Incorrect encoding			.830	
Rehearsals (det. and min.)		.813		
Monitoring (det. and min.)	.718	.570		
Retrieval cues (det. and min.)				.644
Inaccurate/unsuccessful retrieval cues			.734	
Output monitoring			.922	
Sociability	.884			
Demands				.849
Encouragement	.837			
Critical				.953
% of variance	28.30	19.50	16.56	16.46

Note. Values indicate loadings of each variable on each factor in the rotated component matrix. Factor loadings less than 0.4 have been suppressed. Det. = detailed. Min. = minimal.

Table 3

Scores for Strangers and Couples on each Factor

<i>Group</i>	<i>Factor 1 General group- enhancing factor</i>		<i>Factor 2 Stranger dyads- enhancing factor</i>		<i>Factor 3 Memory errors factor</i>		<i>Factor 4 Couples- diminishing factor</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Strangers								
Low PM performers	-0.77	0.26	-0.45	0.43	-0.07	0.38	-0.72	0.21
High PM performers	-0.03	0.78	1.24	1.07	-0.29	0.18	-0.42	0.40
Total	-0.40	0.67	0.39	1.18	-0.18	0.31	-0.57	0.34
Couples								
Low PM performers	-0.34	0.74	-0.40	0.58	0.59	1.96	1.16	1.36
High PM performers	1.14	1.02	-0.39	0.72	-0.23	0.34	-0.02	0.40
Total	0.40	1.14	-0.39	0.62	0.18	1.39	0.57	1.13

Table 4

Two-Way (Relationship and PM performance group) Analyses of Variance for the Standardized Component Scores for the Four Factors

Variable and source	<i>df</i>	<i>MSE</i>	<i>F</i>	<i>p</i>	η_p^2
General group-enhancing factor – Factor 1					
Relationship	1		5.65	.030	.26
PM Performance Group	1		10.98	.004	.41
Relationship \times PM Performance Group	1		1.23	.284	.07
Error	16	0.56			
Stranger dyads-enhancing factor – Factor 2					
Relationship	1		5.64	.030	.26
PM Performance Group	1		6.54	.021	.29
Relationship \times PM Performance Group	1		6.48	.022	.29
Error	16	0.55			
Memory errors factor – Factor 3					
Relationship	1		0.63	.440	.04
PM Performance Group	1		1.32	.268	.08
Relationship \times PM Performance Group	1		0.44	.515	.03
Error	16	1.03			
Couples-diminishing factor – Factor 4					
Relationship	1		11.66	.004	.42
PM Performance Group	1		1.72	.208	.10
Relationship \times PM Performance Group	1		4.90	.042	.23
Error	16	0.55			

Journal Description (2016 impact factor 2.074)

Discourse Processes is a multidisciplinary journal providing a forum for cross fertilization of ideas from diverse disciplines sharing a common interest in discourse – prose comprehension and recall, dialogue analysis, text grammar construction, computer simulation of natural language, cross-cultural comparisons of communicative competence, or related topics. The problems posed by multisentence contexts and the methods required to investigate them, although not always unique to discourse, are sufficiently distinct so as to require an organized mode of scientific interaction made possible through the journal.

The journal accepts original experimental or theoretical papers that substantially advance understanding of the structure and function of discourse. Scholars working in the discourse area from the perspective of sociolinguistics, psycholinguistics, discourse psychology, text linguistics, ethnomethodology and sociology of language, education, philosophy of language, computer science, and related subareas are invited to contribute (from

<http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=hdsp20>).

Chapter 4

Group-level Strategies Help Collaborative Groups Perform Better on Prospective Memory Tasks

This chapter was prepared as:

Browning, C. A., Harris, C. B., & Van Bergen, P. (2017). *Group-level strategies help collaborative groups perform better on prospective memory tasks. Manuscript in preparation.*

In this chapter, I tested whether I could instruct collaborating dyads to implement some of the successful strategies identified in Chapter 3 in order to improve their PM performance. I also tested whether collaborative strategies were more effective when implemented at a group-level or an individual level. I adopted the methodology used in the “collaborative recall paradigm”. I recruited 160 participants (80 dyads) and allocated them to one of four conditions: one nominal condition, and three collaborative conditions (“no strategy”, “individual-level strategy”, and “group-level strategy”). I used the PM task Virtual Week because it allowed interactive collaboration, and I tested performance across a range of PM tasks of varying difficulty. This research is a step towards evaluating the application of collaborative PM in workplaces, schools, and family life – and particularly in those people experiencing PM difficulties. Previous research has proposed the potential applied value of collaborative remembering for supporting memory in older adults (Blumen, Rajaram, & Henkel, 2013).

This chapter was prepared specifically for submission to the *Journal of Applied Research in Memory and Cognition (JARMAC)*, since the applied nature of the findings are relevant to researchers in psychological science, as well as other professionals and practitioners who are interested in how prospective memory works in collaboration with others, for instance in workplaces and educational institutions. Because the journal is aimed at a wide audience, the introduction and discussion sections are limited to 2000 words. A general audience summary is also required. These requirements are designed to ensure the prose has broader appeal. The description of this journal is appended to this chapter (p. 177). While this is a co-authored manuscript, I was the major contributor to all aspects of the experimental design, the participant recruitment, the data collection and analysis, and preparation of the manuscript. Each of these stages was conducted with input and advice from Celia Harris and Penny Van Bergen.

Group-level Strategies Help Collaborative Groups Perform Better on Prospective Memory
Tasks

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Abstract

We often enlist others to help perform prospective memory (PM) tasks, yet collaboration during PM is not always successful. In this study, we manipulated strategies that collaborative dyads used as they played “Virtual Week” to test whether we can improve groups’ performance when collaborating on PM tasks. We also examined whether these collaborative strategies were more effective when implemented at a group- vs. an individual-level. Adopting the methodology used in the “collaborative recall paradigm”, we recruited 160 participants (80 dyads) and allocated them to one of four conditions: one nominal and three collaborative conditions (“no strategy”, “individual-level strategy”, and “group-level strategy”). We found that collaborating dyads who were instructed to use a group-level strategy performed the best numerically, and out of the three collaborative groups, instructing dyads to focus on group-level strategies enabled this group to eliminate collaborative inhibition. In contrast, collaborating dyads instructed to use individual-level strategies incurred the usual costs of collaboration. Practical implications are discussed.

Group-level Strategies Help Collaborative Groups Perform Better on Prospective Memory Tasks

Prospective memory (PM), or remembering to perform an action in the future (Einstein & McDaniel, 1990; Ellis, 1996), is reported as the most common memory failure by people of all ages (Crovitiz & Daniel, 1984; Terry, 1988). Prospective memory tasks include those that need to be done at a certain time (e.g., keeping appointments) and those that need to be done when another event occurs (e.g., dropping off clothes when passing the dry cleaners). We frequently remember within social interactions: turning to our workmates, friends and family to help us carry out difficult, and often important, PM tasks (Intons-Peterson & Fournier, 1986; Parikh, Troyer, Maione, & Murphy, 2015). Yet collaboration has been shown to inhibit prospective memory (Browning, Harris, Van Bergen, Barnier, & Rendell, 2017). In this study, we aimed to explore whether we can help collaborative pairs perform better on PM tasks by instructing them to use specific strategies. We used the “Virtual Week” task, which includes a range of different kinds of PM tasks, parallels daily life in terms of their content, and has a board-game style which lends itself to collaboration (Rendell & Craik, 2000; Rendell & Henry, 2009).

Costs Incurred for Collaborative Memory

Evidence suggests that people typically collaborate poorly when remembering together. In the collaborative recall literature, a robust finding is that collaborating groups do not perform to their potential (Basden, Basden, Bryner, & Thomas, 1997; Basden, Basden, & Henry, 2000; Ross, Spencer, Linardatos, Lam, & Perunovic, 2004; Weldon & Bellinger, 1997). Specifically, groups collaborating to recall the past typically remember less than nominal groups comprised of the same number of individuals recalling independently – “collaborative inhibition” (Weldon & Bellinger, 1997). We recently investigated collaborative PM in both stranger-dyads and intimate couples (Browning,

Harris, Van Bergen, et al., 2017) who collaborated to complete the Virtual Week PM task (see Rendell & Craik, 2000; Rendell & Henry, 2009). We found collaborative inhibition in strangers, but not in couples, and particularly for the more difficult PM tasks which have little environmental support to remind participants to complete them (Browning, Harris, Van Bergen, et al., 2017). We also found marked individual differences in collaborative outcomes – some collaborative dyads were better than others (Browning, Harris, Van Bergen, et al., 2017), similar to findings for collaborative episodic memory tasks (Andersson & Rönnerberg, 1995; Harris, Keil, Sutton, Barnier, & McIlwain, 2011; Meade, Nokes, & Morrow, 2009; Weldon & Bellinger, 1997).

We identified collaborative processes that were associated with better performance (Browning, Harris, & Van Bergen, 2017). Some of these processes (encoding, monitoring and rehearsal) were known to be associated with successful PM in individuals. For example, encoding task content (where individuals encode and store the content of the PM task) is necessary for allowing one to remember what to do (Ellis, 1996). Monitoring (where an individual directs attention to the environment to notice the appropriate moment to perform the PM task) is necessary for self-initiating the PM task (McDaniel & Einstein, 2000). Finally, rehearsing or reminding oneself of task content between the time when the task is encoded and the time when the task is performed, is associated with better PM performance (Kvavilashvili & Fisher, 2007; Szarras & Niedźwieńska, 2011). Because the analysis in Browning, Harris, and Van Bergen (2017) measured instances of these processes in collaborative dialogue, it was not possible to identify whether these strategies were being employed at an individual- or a group-level, and whether these processes were producing benefits specific to collaboration or simply enhancing individuals' PM performance within the groups. In the current study, we aimed to determine whether we could promote more successful collaboration by instructing collaborating dyads to use

specific encoding, monitoring and rehearsal strategies as they played Virtual Week, and whether these strategies were more effective at an individual-level or a group-level.

Individual-Level Strategies to Improve Collaborative PM

We conceptualise individual-level strategies as unshared, and not involving interaction with other group members (e.g., individually creating personally relevant associations for each word on a list). On the other hand, we conceptualise group-level strategies as coordinated and discussed interactively by group members (e.g., when a husband and wife coordinate categories they will remember words by). There are two lines of evidence to suggest that encouraging participants to maintain their individual strategies during collaboration might be beneficial. The first is related to the best-supported explanation of collaborative inhibition – the retrieval disruption hypothesis (Basden et al., 1997; Marion & Thorley, 2016). Individuals store, organise, and retrieve their memories in idiosyncratic ways. When remembering within groups, individuals abandon their own optimal retrieval strategies upon hearing recall of others, and instead adopt other poorly matched strategies. This results in individuals recalling less in a group than if they had recalled by themselves. Thus, group outcomes are enhanced when group members keep separate their own individual retrieval strategies, and strengthen their idiosyncratic organisation, such as being assigned responsibility for different parts of a list (Basden et al., 1997), or when group members are unable to see or hear other other's responses (Wright & Klumpp, 2004), or performing repeated individual retrieval prior to collaboration (Blumen & Rajaram, 2008; Congleton & Rajaram, 2011; Marion & Thorley, 2016; Rajaram & Pereira-Pasarin, 2010).

Second, individual-level strategies are, by definition, less interactive. PM already places considerable demand on working memory and attentional resources (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh & Hicks, 1998; McDaniel & Einstein, 2000). PM

performance suffers when PM tasks are required to be performed in conjunction with demanding ongoing tasks (Marsh & Hicks, 1998). Stone, Dismukes, and Remington (2001) proposed that conversation alone might constitute an ongoing task that is detrimental to PM outcomes.

Group-Level Strategies to Improve Collaborative PM

There is also evidence to support the effectiveness of group-level strategies in collaborative PM. Group encoding might encourage similar organisation of information across group members, which encourages similar, rather than idiosyncratic and disruptive retrieval strategies. This idea is supported by Harris, Barnier, and Sutton (2013) who found that group encoding reduced collaborative inhibition. Likewise, group rehearsal facilitates group re-exposure to task content, which might strengthen group organisation, in the same way repeated exposure strengthens individual organisation (Blumen & Rajaram, 2008; Rajaram & Pereira-Pasarin, 2010). Similarly, as group members rehearse task content together, they may test each other, and strengthen group organisation of information in the same way repeated testing prior to collaboration reduces collaborative inhibition (Congleton & Rajaram, 2011). Group-level strategies have been found to enhance collaborative recall in older-adult couples by coordinating and optimising individual group members' knowledge and expertise (Harris et al., 2011). This is particularly so when groups use effective communication devices such as repetitions (Harris et al., 2011). In addition, group-level strategies, since they are by definition communicated, result in participants encoding the material aloud, which has been found to improve memory performance compared to encoding silently (Conway & Gathercole, 1987). Thus, we expected that encouraging participants to engage in group-level strategies during collaboration might also improve their performance on collaborative PM.

The Current Study

We tested whether we could promote successful collaboration on PM tasks by encouraging strategy use – either individual-level or group-level strategies. First, we aimed to determine whether strategies that encouraged encoding, monitoring and rehearsals could improve PM performance, thereby reducing collaborative inhibition, and whether the type of PM task moderated this effect. Second, we aimed to determine whether it was better for members of collaborative groups to use these strategies on an individual-level, or whether it was better for groups to share and use these strategies interactively on a group-level. We predicted that strategy instruction would enhance PM performance and thereby decrease the effect of collaborative inhibition in PM, compared to using no strategy at all. However, given that prior research predicts benefits for both individual-level, and group-level strategies, we did not have a prediction about which would be more beneficial.

Method

Participants

We recruited 163 participants, of which 132 were undergraduate students from Macquarie University who took part in the experiment in exchange for psychology course credit. An additional 31 were non-student participants from the Macquarie University campus who received A\$15.00 for one hour of participation. Two individuals (one dyad) were excluded because they were close friends rather than strangers which may have influenced their collaboration (see Browning, Harris, Van Bergen, et al., 2017). One individual was excluded because he could not follow task instructions. Thus, the remaining sample for analysis was 160 participants ($M = 21.40$ years, $SD = 5.90$ years, 119 females and 41 males). All participants self-reported being fluent English speakers.

Design

Participants were allocated to 20 dyads (40 individuals) in each of the four conditions. Therefore, there were 20 dyads in the nominal condition, 20 dyads in the

collaborative “no strategy” condition, 20 dyads in the collaborative “individual-level strategy” condition, and 20 dyads in the collaborative “group-level strategy” condition. All analyses were conducted at the dyad level. We used a 4×5 mixed factorial design to examine the effects of various collaborative strategies on PM task. The between-dyads variable was a 4-level manipulation of *condition* (nominal, collaborative “no strategy”, collaborative “individual-level strategy”, and collaborative “group-level strategy”). The within-dyads variable was a 5-level manipulation of *PM task* (regular event-based, irregular event-based, regular time-based, irregular time-based, time-check), embedded into the Virtual Week task. The dependent variable was PM performance on the Virtual Week task, as described below.

Measure

We used an adapted version of the computerised Virtual Week (Rendell & Craik, 2000; Rendell & Henry, 2009) to test PM. Virtual Week is a computerised board game that tests PM using a number of tasks that vary in demand. Each circuit of the game-board displayed on the computer screen represents one virtual “day”. Participants use the mouse to roll the electronic die and move their tokens around the board on squares that are calibrated to the virtual time of day. The virtual time of day is shown on a clock positioned centrally in the middle of the board, and real-time is shown on a smaller stop-clock positioned above the die in a less-focal position. As they travel around the board, participants pick up “Event Cards” when required. Event Cards represent activities that occur throughout the day (e.g., It is breakfast).

Each virtual day participants are given 10 different PM tasks to perform. Four tasks are required at a specific time within the virtual day (time-based tasks – e.g., haircut at 1.00 pm), four tasks are required when particular events occur as described on the Event Cards (event-based tasks – e.g., take antibiotics at breakfast), and two tasks are required to

be performed at 2.00 and 4.00 minutes on the stop-clock (time-check tasks). These latter two tasks are in real-time, rather than Virtual Week time, and are separate to the game-playing activities. As such they are considered to be nonfocal tasks (Kliegel, Rendell, & Altgassen, 2008).

To ensure that some tasks load less on retrospective memory, six of these tasks are given at the start of the Virtual Week. The task instructions encourage repetition so that they are well learned before the testing session commences. In addition, they are required to be repeated each virtual day, and thus are regular tasks. The repetition each day offers re-learning opportunities. The other four tasks are given at the start of, or during each day. These differ each day, and thus are irregular tasks. Because they are only encoded once, rather than being studied to criterion, and have more complex task content, they load more heavily on retrospective memory. When the time or event trigger occurs, participants “perform” the PM task by clicking on the “perform task” button and choose the appropriate task from a list of options, including the correct item and a number of distractor items.

In addition to remembering to perform the PM tasks, participants are required to participate in other game-playing activities. For example, at each event, participants are required to make a choice from three options (e.g., “Do you have (a) fruit, (b) porridge or (c) cereal?”). These options determine the roll of the die required to proceed in the game, but are irrelevant to successful PM performance. Instead, rolling the correct die number, moving the token and making choices about the “event” activities provide the backdrop of ongoing other activities (i.e., the ongoing task) against which the participant needs to remember the PM tasks – an important aspect of PM performance.

Procedures

Following approval from the Macquarie University Human Research Ethics Committee, we allocated participants to either a nominal condition or one of the three collaborative conditions. Participants assigned to the nominal condition came into the lab individually and worked alone. They were arbitrarily allocated to nominal dyads in the order they fell in the data file, which corresponded to the order they presented to the lab. Participants in the collaborative conditions presented to the lab in dyads determined by the time-slots they signed up to. Each dyad was assigned to a specific collaborative condition in the order they presented to the lab, rotating through the conditions in a sequential order. In this way, allocation to collaborative conditions was random. Participants in the collaborative conditions sat side by side at a desk in front of a shared computer. We asked these participants to introduce themselves to each other and to make themselves comfortable so they could both see the computer screen. Participants in the collaborative conditions also gave permission to make an audio recording of the session.

In both nominal and collaborative conditions, participants were then instructed to play the computerised Virtual Week game (Rendell & Craik, 2000, described above in Measures). Participants in the collaborative condition and participants in the nominal condition both received the same detailed verbal instructions on how to play Virtual Week. However, we gave participants in the collaborative conditions additional instructions in order to manipulate the collaborative strategies they employed. These are detailed below:

Collaborative “no strategy” condition. Collaborators in the “no strategy” condition were instructed to “work together to play this game”, consistent with instructions given in the collaborative condition in previous collaborative PM research (Browning, Harris, Van Bergen, et al., 2017). We gave them no specific instructions regarding how to interpret this, leaving the collaborators free to devise their own collaborative strategies.

Collaborative “individual-level strategy” condition. Collaborators in the “individual-level strategy” condition were given the following instructions, to focus on individual-level encoding and monitoring strategies: “There are two things you can do to help you score well in this game. First, it is helpful if you practice and repeat each task that you are required to remember, when you receive it. When you receive a new task instruction, I want you to practice and *repeat it to yourselves, in your head*, to help yourself learn it. Second, it is helpful to keep an eye on times and events that are coming up. Every so often, I want you to *think to yourselves, in your head*, about what is coming up, and about what the upcoming tasks you need to complete are.”

Collaborative “group-level strategy” condition. Collaborators in the “group-level strategy” condition were given the following instructions, to focus on group-level encoding and monitoring strategies: “There are two things you can do to help you score well in this game. First, it is helpful if you practice and repeat each task that you are required to remember, when you receive it. When you receive a new task instruction, I want you to practice and *repeat it to each other aloud*, and help each other to learn it. Second, it is helpful to keep an eye on times and events that are coming up. Every so often, I want you to *talk to each other, and remind each other*, about what is coming up, and what the upcoming tasks you need to complete are.”

All on-screen Virtual Week instructions that were relevant to the strategy manipulations described above were changed where appropriate. For example, a general instruction for the Event Cards in the “no-strategy” condition gave the default Virtual Week instruction “Once you have read each task, please look away from the screen and repeat the task aloud.” In the “individual-level strategy” condition it was changed to “Once you have read each task, please look away from the screen and repeat the task *to yourselves, in your head*.” And finally, in the “group-level strategy” condition it was

changed to “Once you have read each task, please look away from the screen and repeat the task *aloud to each other*.” The participants in the nominal condition who worked individually received the same on-screen instructions as the collaborative “no strategy” condition – that is, the default Virtual Week instructions (see example given above).

The participants were then instructed to commence the trial day of the Virtual Week. After a trial day was completed, instructions relevant to the participants’ particular condition as described above were repeated prior to commencing the testing phase. Participants then played two “days” of the Virtual Week, as detailed in Measures. Sessions lasted approximately one hour. While playing Virtual Week, participants were given 20 PM tasks in total, consisting of four tasks for each of the five types of PM tasks: regular event, regular time, irregular event, irregular time and time-check. Finally, all participants completed questionnaires that requested age and gender information.

Scoring

Scoring of Virtual Week. Consistent with Rendell and Craik (2000), each of the 10 PM tasks performed each virtual day were scored as correct or incorrect. Responses were scored as correct if the participant performed the correct action at the correct time or event. Responses were scored as incorrect if they included the wrong time, wrong action, or were missed completely. Time-based or event-based PM tasks were scored as correct if participants responded after the die roll for the move that took the token on or past the target time or event and before the next die roll following the target time or event. Time-check tasks were scored as correct if they responded at the target time or within ten seconds.

Pooling individual data to create “nominal dyad” scores. We compared collaborative dyads with nominal dyads, calculated by pooling the non-redundant performance of two individuals working alone. By creating nominal dyads, we set up a

strict canonical comparison to collaborative performance that was established in collaborative recall research, and known as the collaborative recall paradigm (Basden et al., 2000; Weldon & Bellinger, 1997). It allows a comparison between collaborative performance and the potential the dyad might otherwise achieve had they each worked individually. That is, to count as “performed” in the nominal dyad, and count towards the nominal dyad’s score, at least one individual in the dyad performed the task – in the same way that to count as “performed” in a collaborative group, if one person in the group performs the task, then it counts towards the group’s collaborative score. If both individuals performed a particular PM task, rather than overinflating the score by counting it twice, this was only counted once. If neither individual in the nominal dyad performed the task, the task was scored as “incorrect”. Pooling the scores of two individuals in this manner creates a score that is analogous to the score that individuals in a collaborative dyad could potentially achieve if they both performed in the collaborative context exactly the same as they would perform individually – in which, if at least one member of the dyad performs the task, the group gets it right.

Results

The proportion of correct responses on Virtual Week for each condition and PM task are presented in Table 1. These proportions were calculated as the number of correct responses divided by the four total tasks of each type. In order to test whether collaborative inhibition depended on collaborative strategy and PM task, we conducted a 4 (Strategy Condition: nominal, collaborative “no strategy”, collaborative “individual-level strategy”, collaborative “group-level strategy”) \times 5 (PM Task: regular event, regular time, irregular event, irregular time, time check) mixed-model ANOVA. This analysis yielded significant main effects of condition, $F(3, 76) = 3.44$, $MSE = 0.01$, $p = .021$, $\eta_p^2 = .12$, and PM task,

$F(4, 273) = 11.86$, $MSE = 0.03$, $p < .001$, $\eta_p^2 = .14$, but no significant interaction was found between condition and PM task, $F(11, 273) = 0.71$, $MSE = 0.03$, $p = .729$, $\eta_p^2 = .03$.

We interpreted the main effect of condition in two ways, to answer two different research questions. First, in order to identify whether collaborative inhibition was present, and whether this depended on the collaborative strategy employed, three planned pairwise comparisons, with Bonferroni adjustments compared each of the three collaborative conditions to the nominal condition (see Figure 1). The usual effect of collaborative inhibition was observed for collaborative dyads using the “individual-level strategy” ($M = .82$, $SD = .15$) who were outperformed by the nominal condition ($M = .92$, $SD = .07$), $p = .015$, $d = .91$. Similarly, collaborating dyads that used “no strategy” ($M = .85$, $SD = .12$), were numerically outperformed by the nominal condition, $p = .219$, $d = .67$, however this difference was not statistically significant. Importantly however, collaborating dyads using the “group-level strategy” ($M = .90$, $SD = .08$) performed as well as the nominal condition, $p = 1.00$, $d = .24$. That is, dyads using the “group-level strategy” performed similarly to nominal groups and were able to eliminate collaborative inhibition.

Second, in order to determine which collaborative strategy instruction was most effective, further planned pairwise comparisons compared the PM performance of the three collaborative conditions to each other. These showed that although collaborating dyads using a “group-level strategy” performed numerically better than collaborating dyads using an “individual-level strategy”, this difference was not significant, $p = .098$, $d = .73$, with a Bonferroni adjustment applied. Furthermore, the “no strategy” condition was not significantly different from either, all $ps > .713$, $ds < .46$ with Bonferroni adjustments applied. Overall, although there were no significant differences between the three collaborative conditions, those in the group-level strategy condition performed numerically the best, those in the individual-level strategy condition performed numerically the worst,

and those in the no strategy condition were somewhere in between (see Figure 1).

Furthermore, these effects did not depend upon PM task difficulty since the interaction was non-significant.

Follow-up comparisons for the main effect of PM task, with Bonferroni adjustments, indicated performance of some tasks differed in difficulty as expected. Participants performed most poorly on irregular time-based tasks ($M = .76$, $SD = .25$); significantly worse than regular event-based tasks ($M = .91$, $SD = .17$), irregular event-based tasks ($M = .93$, $SD = .13$), regular time-based tasks ($M = .88$, $SD = .21$) and time-check tasks ($M = .88$, $SD = .18$) all $ps < .005$, all $ds > .41$. There was no significant difference between performance on regular event-based tasks, irregular event-based tasks, regular time-based tasks, and time-check tasks, which were all performed as well as each other, all $ps > .166$, all $ds < .27$. Based on the means, order of tasks from most difficult to easiest were: irregular time-based, time-check, regular time, regular event, and irregular event.

In summary, the results suggested that when collaborative dyads were instructed to use an “individual-level strategy”, they showed the typical collaborative inhibition effect, and performed the worst of all the collaborative groups. However, when collaborative dyads used a “group-level strategy”, they were able to eliminate the typical costs of collaboration and perform to their potential, with similar scores to nominal groups.

Discussion

We tested whether we could promote successful collaboration on PM tasks by encouraging strategy use and instructed collaborating pairs to use specific strategies either on an individual-level or group-level. Our prediction that using a strategy would be better than none was only partly supported. We found that pairs who had been instructed to collaboratively encode, monitor, and rehearse as an interactive group, performed the best

of the collaborative conditions – and to a similar level as the nominal control group. That is, they eliminated collaborative inhibition. However, the group instructed to use the same strategies individually performed the worst, demonstrating collaboration inhibition.

Overall, these findings suggest that interactive group-level encoding, monitoring, and rehearsals were effective in enhancing group PM performance. This is consistent with research from collaborative recall literature which shows that group-level strategies (Harris et al., 2011) and shared encoding (Harris et al., 2013) enhance collaborative outcomes. We also found no evidence that greater amounts of conversation amongst group members was disruptive to attention and working memory (Marsh & Hicks, 1998; Stone et al., 2001). Instead, group-level strategies facilitated group performance.

On the other hand, individual-level strategy use was not successful. Consistent with the retrieval disruption hypothesis (Basden et al., 1997), we propose that in the absence of group-level coordination, the more individuals focus on and strengthen their own unique strategies, the more disruptive their partner's idiosyncratic strategies become. In support of this idea, Harris et al. (2011) showed that similarity of individual retrieval strategies was not critical for better collaborative outcomes. Rather, the presence of coordinated group-level strategies was more important.

The advantage that “group-level strategy” users enjoyed over “individual-level strategy” users, whereby the former were able to eliminate collaborative inhibition, and the latter were not, could be partly attributed to the production effect, where the distinctiveness of items encoded aloud leads to better memory performance (Conway & Gathercole, 1987). However, “group-level strategy” users also outperformed those in the “no strategy” condition at least numerically, where on-screen instructions also instructed participants to read instructions aloud. This suggests group-level strategies boosted collaborative performance over and above the production effect, although future research is needed to

directly test this. The benefits of the production effect during collaboration should not be discounted though – collaboration encourages encoding aloud through its inherently interactive nature.

Limitations

Ceiling effects were observed in some tasks, and future studies should present more difficult PM tasks to address this. The relatively high scores across conditions may have made it harder to detect differences between them. The lack of interaction between the collaborative strategy employed and PM task type suggests however that the effectiveness of each strategy was consistent across PM tasks, regardless of difficulty. Additionally, we were unable to measure the success of the strategy implementation in the “individual-level strategy” condition. That is, we don’t know whether these participants were following instructions to repeat during encoding, and remind themselves, since they did this silently. In future research we could consider other strategy manipulations e.g., rehearsing by writing.

Applications

Despite these limitations, we were still able to observe differences between conditions. Those in the individual strategy condition performed the worst out of the collaborative conditions and showed significant collaborative inhibition. In contrast, those in the group strategy condition performed the best out of the collaborative conditions, at a similar level to those in the nominal condition, thus eliminating collaborative inhibition. These findings have significant applied value in that they suggest the collaborative success of groups could be enhanced via a relatively simple instruction to use a group-level strategy. We found this strategy worked in a convenience sample of strangers collaborating to perform tasks that have no real-world importance or consequence. Therefore, we expect these effects are likely to be stronger with a deeper manipulation of group-level strategy

use, and in groups that have genuine joint goals and outcomes to achieve. This research is promising for collaborative teamwork in universities and workplaces where people who do not know each other well are asked to work together and are required to remember to do things together. Even amongst groups of people who do know each other, such as intimate couples, families, and friends, individual differences in collaborative success abound, and strategies may boost success. We have previously reported that there is some overlap and some difference in the communication processes that lead to costs and benefits for couples vs. strangers collaborating to perform PM tasks (Browning, Harris, & Van Bergen, 2017). Further research could investigate the effectiveness of specifically tailored group-level strategies for intimate groups, which may have applications to teaching families how to effectively support PM performance in populations that need such support, such as those with brain injuries or cognitive decline (Barnier, Harris, & Congleton, 2013; Blumen, Rajaram, & Henkel, 2013).

General Audience Summary

Remembering to do things in the future, such as remembering to drop off a suit at the dry cleaners, or remembering a doctor's appointment at 4.00 pm, is known as prospective memory. Most people find this type of remembering difficult, so we often enlist the help of family, friends, and work mates to help them with these difficult tasks. To evaluate the costs and benefits of remembering together, researchers use the collaborative recall paradigm. Here, instead of comparing a collaborative group's performance to that of a single individual working alone, we compare collaborative performance to the pooled performance that all individuals in the group might have achieved had they each worked alone. This allows us to quantify the benefits (or costs) of collaboration compared to the potential that group members might each achieve alone. Contrary to what might be intuitively expected, this comparison reveals *negative* effects when people collaborate to

perform prospective memory tasks. That is, people remember to do things better alone than when remembering together. So, although it is true that two heads are better than one, they are not better than two heads working individually.

This research also shows however that there are strong individual differences in collaborative outcomes – some collaborators are better than others. By studying the dialogue of successful collaborators (compared to those who do not work as well together), we have identified strategies that help collaborative prospective memory. In this study we tested the effectiveness of these strategies. We also tested whether it was better for group members to use these strategies as a dynamic, interactive group, or whether it was better for group members to use these strategies on an individual basis.

We found that collaborating pairs who were instructed to use a group-level strategy performed the best, and eliminated the typical costs of collaboration. On the other hand, those who were instructed to use an individual-level strategy incurred the typical costs of collaboration.

These findings have significant applied value in that they suggest the collaborative success of groups can be enhanced via a relatively simple instruction to use a group-level strategy, even for groups of strangers collaborating to perform tasks that have no real-world importance or consequence. There are therefore strong implications for collaborative teamwork in universities and workplaces where people who do not know each other well are asked to work together and are required to remember to do things together.

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Table 1

Prospective Memory Performance: Proportion of Correct Responses in Virtual Week

Condition	Event-based		Time-based		Time-check
	Regular	Irregular	Regular	Irregular	
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Nominal dyads	.96 (.09)	.95 (.10)	.93 (.14)	.79 (.26)	.95 (.13)
Collaborative dyads: No strategy	.90 (.17)	.95 (.10)	.88 (.25)	.75 (.26)	.79 (.25)
Collaborative dyads: Individual-level strategy	.82 (.26)	.86 (.19)	.80 (.25)	.73 (.23)	.86 (.18)
Collaborative dyads: Group-level strategy	.95 (.10)	.96 (.09)	.90 (.17)	.76 (.26)	.91 (.12)

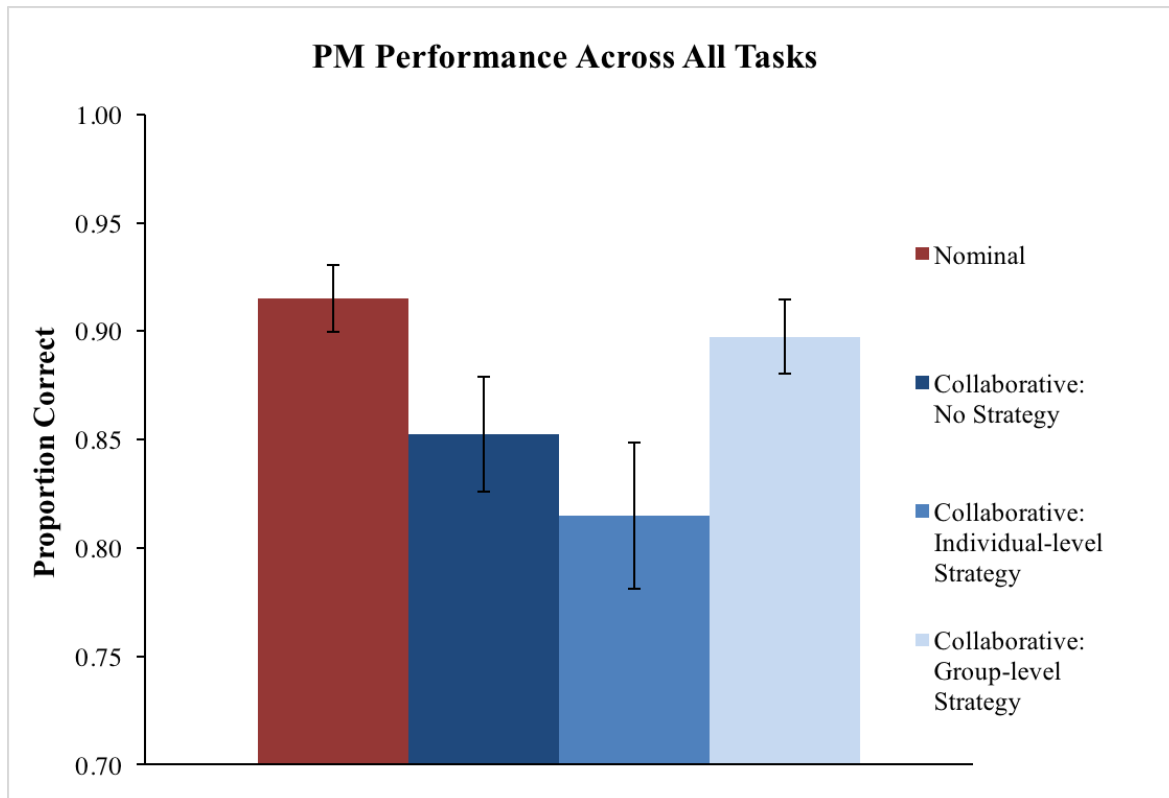


Figure 1. Mean proportion of PM tasks performed, averaged across all tasks. Error bars represent standard error of the mean.

Journal Description (2016 impact factor 2.850)

The *Journal of Applied Research in Memory and Cognition (JARMAC)* publishes a mix of empirical reports, review articles, and target papers with invited peer commentary. The goal of this unique journal is to reach both psychological scientists working in this field and related areas but also professionals and practitioners who seek to understand and apply research on memory and cognition. In pursuit of these aims, we encourage brevity and crisp, lively prose that appeals to a wide audience. Each paper also includes a General Audience Summary, clearly describing the paper and its practical implications in language accessible to non-specialists. *JARMAC* is an official journal of Society for Applied Research in Memory & Cognition (from <https://www.journals.elsevier.com/journal-of-applied-research-in-memory-and-cognition/>).

Chapter 5

Costs and Benefits of Collaboration with an Intimate Partner for Prospective Memory in Acquired Brain Injury

This chapter was prepared as:

Browning, C. A., Harris, C. B., Van Bergen, P., Morris, T., & Miller, L.A. (2017). *Costs and Benefits of Collaboration with an Intimate Partner for Prospective Memory in Acquired Brain Injury*. Manuscript in preparation.

In this chapter I extended my research into a clinical population of patients with an acquired brain injury (ABI) and their spouses, to evaluate potential benefits or costs of working together on PM tasks for the patient, their spouse, and for the couple overall. Enlisting the help of others is often reported as a compensatory strategy for those experiencing PM difficulties, but the effectiveness of this strategy is unknown. I adapted the methodology of the “collaborative recall paradigm” in order to quantify collaborative costs and benefits; eight couples’ collaborative PM performance on “Virtual Week” (Rendell & Craik, 2000) was compared to their pooled individual “nominal pair” performance, as well as their individual performance. Participants also completed neuropsychological assessments, intimacy scales, and caregiver burden scales. I also examined whether collaborative processes – operationalized as the amount of words spoken by the couple, and the proportion spoken by each individual within the couple – influenced collaborative outcomes. I used nonparametric statistics that tested the difference in the mean ranks rather than means due to the small sample size, consistent with other neuropsychological studies. Mean scores are reported however, consistent with neuropsychological journals.

This chapter was prepared specifically for the *Journal of Clinical and Experimental Neuropsychology (JCEN)*. This journal was the most appropriate because it publishes experimental studies regarding neuropsychological consequences of brain injury, and it had also previously published clinical Virtual Week studies. The description of the journal is appended to the chapter (p. 236). The abstract is set out in accordance with this journal’s requirements. While this is a co-authored manuscript, I was the major contributor of all aspects of experimental design, participant recruitment, data collection and analysis, and preparation of the manuscript. Laurie Miller, a clinical neuropsychologist, identified suitable patient participants from her neuropsychology outpatient practice at a major

Sydney hospital for me to contact. Tom Morris, also a clinical neuropsychologist, assisted with data collection and clinical support. Tom and I tested the patient and their spouse simultaneously as they individually completed Virtual Week and neuropsychological testing. We conducted this part of the testing session simultaneously in order to reduce the time taken to complete the entire testing session for the comfort of the patients and their spouse. I then conducted the part of the testing session where the patient and their spouse completed Virtual Week collaboratively as a couple. Tom also assisted by double-scoring the neuropsychological assessments. Each of the other stages was conducted with input and advice from Celia Harris, Penny Van Bergen and Laurie Miller.

The research described in this chapter was presented at the following workshop:
Browning, C. A., Harris, C. B., & Miller, L. A. (2016, November). *Costs and benefits of collaborative prospective memory in acquired brain injury*. Paper presented at the CCD Memory Workshop: 'What is new in memory research?'. The University of Sydney, Sydney.

Costs and Benefits of Collaboration with an Intimate Partner for Prospective Memory in
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Abstract

Introduction: Enlisting the help of an intimate partner is often reported as a compensatory strategy for those experiencing prospective memory difficulties, yet we know little about the effectiveness of this strategy. We recently found that – similar to results for episodic memory – collaboration impaired prospective memory (PM) in pairs of strangers, but not in intimate couples (Browning, Harris, Van Bergen, Barnier, & Rendell, 2017). In the present study, we extended this work into a clinical population of outpatients with Acquired Brain Injury (ABI) and their spouses to evaluate costs and benefits of working together on PM tasks.

Method: Eight couples' collaborative PM performance on an adapted version of "Virtual Week" (Rendell & Craik, 2000) was compared to their pooled "nominal" performance, as well as their individual performance. We quantified collaborative processes by counting the total number of words produced and the proportion spoken by each individual within the couple. Participants also completed neuropsychological assessments, intimacy scales and caregiver burden scales.

Results: As a group, ABI patients differed from spouses in individual PM and anxiety. During collaboration, we found collaborative inhibition – collaborative performance was lower than pooled nominal group performance. In addition, couples' collaborative performance was higher than individual patients, but lower than spouses' individual performance. Patients' individual PM performance was related to their Verbal Memory (Total Learning and Delay). The proportion of healthy spouses' contribution during collaboration was related to their individual PM ability, perceived level of care from patients, patient mood, and caregiver burden. Furthermore, there was a tendency for spousal contribution to be negatively related to patients' inhibition scores, but otherwise their contribution was not related to any other cognitive scores of the patients, or

themselves. Patients who felt greater levels of care from their spouse contributed less during collaboration. Collaborative processes were not associated with collaborative PM outcomes, however spousal levels of stress and patient needs were.

Conclusions: Collaboration within couples where one person has an ABI can benefit the patient's prospective memory, but this comes at a cost to the performance of the healthy partner. Despite these costs, spouses provide greater support during collaboration when they believe the patient needs assistance, and when they feel their partner cares for them.

Costs and Benefits of Collaboration with an Intimate Partner for Prospective Memory in Acquired Brain Injury

Prospective memory (PM) involves processes that support memory for intentions to be performed in the future (Einstein & McDaniel, 1990; Ellis, 1996). It is considered vital for everyday living (Zeintl, Kliegel, Rast, & Zimprich, 2006) and functional independence (Rendell & Henry, 2009; Thöne-Otto & Walther, 2008). Recent research has shown that working with other people has both costs and benefits for PM performance, depending on the relationship between the collaborators (Browning, Harris, & Van Bergen, 2017b; Browning, Harris, Van Bergen, Barnier, & Rendell, 2017). Patients with Acquired Brain Injury (ABI) frequently experience PM difficulties (Groot, Wilson, Evans, & Watson, 2002) and report using other people as external memory aids (Evans, Wilson, Needham, & Brentnall, 2003). However, we know little about the effectiveness of this strategy. This study aimed to investigate how effective it is for ABI patients to collaborate with their intimate partners to perform everyday PM tasks.

Prospective Memory in Acquired Brain Injury

Remembering to carry out intended plans in the future involves many cognitive processes (Ellis, 1996; Kliegel, Eschen, & Thöne-Otto, 2004), which rely on different areas of the brain. PM involves retrospective (episodic) memory processes, in order to encode, store and retrieve the content of the intention – individuals need to remember what they need to do and when to do it (Einstein & McDaniel, 1996; Ellis, 1996). PM also involves a prospective component – remembering to retrieve and perform the intention at the appropriate moment (Einstein & McDaniel, 1996; Ellis, 1996), which is supported by executive functions required to plan the intention, monitor the environment for the appropriate cue to carry out the task, inhibit ongoing activity, switch to the intended action, and execute the task (Kliegel et al., 2004). Accordingly, the frontal lobes, and medial temporal lobes have shown to be involved in various PM processes (Kliegel, Jäger,

Altgassen, & Shum, 2008; Reynolds, West, & Braver, 2008; West & Krompinger, 2005; Zöllig et al., 2007). Patients with ABI experience varying degrees of PM difficulties (Cockburn, 1996; Fish, Wilson, & Manly, 2010; Groot et al., 2002) depending on the severity and location of the brain lesion, as well as the type of PM task (Adda, Castro, Além-Mar e Silva, de Manreza, & Kashiara, 2008; Kim, Craik, Luo, & Ween, 2009; Kinch & McDonald, 2012; Knight, Harnett, & Titov, 2005).

Different types of PM vary in difficulty (McDaniel & Einstein, 2000). PM tasks can be categorised based on cue-type: (1) Event-based tasks require an action to be carried out when a particular event-cue occurs (e.g., you need to pass on a message when you next see your friend); (2) Time-based tasks require that an action be performed at a particular time, or after a certain period of time has passed (e.g., you need to remember an appointment at the doctors at 4.00 pm). Because the environment does not cue time-based tasks to the same extent as event-based tasks, time-based tasks require more strategic monitoring and rely more on self-initiated retrieval (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; McDaniel & Einstein, 2000). Accordingly, they are thought to rely more on executive function for task performance (Kinch & McDonald, 2012; Mioni, Rendell, Henry, Cantagallo, & Stablum, 2013). PM tasks can also be categorised based on routine; (1) Regular tasks need to be performed repeatedly (e.g., you must take your medication after eating breakfast each day); (2) Irregular tasks need to be performed only once.

The “Virtual Week” (Rendell & Craik, 2000; Rendell & Henry, 2009) is a computer-based test, set up like a game board where participants are asked to carry out event- and time-based, regular and irregular PM tasks as they go about the activities of everyday life. Regular tasks in Virtual Week are believed to load less heavily on retrospective memory because the task contents are simple, they are learned to criterion,

and each time they are performed offers a new learning opportunity (Foster, Rose, McDaniel, & Rendell, 2013; Mioni et al., 2013). In contrast, irregular tasks are believed to load more heavily on retrospective memory, because the task content is more complicated, they are learnt incidentally, and are only encoded once (Foster et al., 2013; Mioni et al., 2013).

Related to the idea that different PM tasks place different demands on retrospective memory and/or executive function, some studies that investigated PM using Virtual Week found that certain populations were selectively impaired on specific PM tasks according to the nature of their cognitive impairment (e.g., Foster et al., 2013; Kim et al., 2009; Mioni et al., 2013; Rendell & Craik, 2000). However other studies that used Virtual Week in clinical populations (e.g., individuals with traumatic brain injury (TBI), mild cognitive impairment (MCI), chronic heart failure, multiple sclerosis, schizophrenia, and long-term opiate dependence) have tended to find general patterns of impairment across PM tasks, which suggests PM difficulties are relatively ubiquitous (Habota et al., 2015; Henry, Rendell, Kliegel, & Altgassen, 2007; Rendell et al., 2012; Rendell, Jensen, & Henry, 2007; Terrett et al., 2014; Thompson, Henry, Rendell, Withall, & Brodaty, 2010). Researchers have suggested that these clinical populations have a general PM impairment that seems to be over and above what might be expected from their separate retrospective memory or executive function difficulties (Habota et al., 2015; Henry et al., 2007; Rendell et al., 2012; Rendell et al., 2007; Terrett et al., 2014; Thompson et al., 2010). In the present study, we compared patients and their healthy spouses on their individual PM performance across the different types of tasks using Virtual Week, to examine whether the patients showed general or specific PM impairments when alone.

Collaborative Remembering

In daily life, PM tasks are sometimes performed collaboratively (e.g., you ask your

spouse to remind you to call the doctor's office when you get home from an outing). There are two ways that researchers can measure the effects of collaboration on memory performance. The first way employs the collaborative recall paradigm (Weldon & Bellinger, 1997). Here, total performance of collaborating groups is compared to the pooled performance of nominal groups comprised of individuals recalling individually. This stringent nominal group comparison allows researchers to quantify whether collaboration disrupts recall – where group interactions cause processing costs that prevent group members performing to their potential. It can also measure when collaboration facilitates recall – where group interactions produce new, emergent information that is more than the sum of its individual parts. Contrary to what might be intuitively expected, most research using this paradigm has revealed robust *negative* effects when people collaborate to recall the past: collaborative groups recall less than nominal groups – that is two heads together are not as successful as two heads apart. This effect is known as collaborative inhibition (Basden, Basden, Bryner, & Thomas, 1997; Basden, Basden, & Henry, 2000; Harris, Paterson, & Kemp, 2008; Marion & Thorley, 2016; Weldon & Bellinger, 1997).

Recently, we used the collaborative recall paradigm to measure the effects of collaboration in PM (Browning, Harris, Van Bergen, et al., 2017). We too found collaborative inhibition in strangers; however, we also found that intimate couples did not show collaborative inhibition. Similar effects have been observed in collaborative retrospective memory in some older married couples (Harris, Keil, Sutton, Barnier, & McIlwain, 2011). That is, collaborating with an intimate partner can be relatively beneficial both when remembering the past and when performing a PM task, but the degree to which it is successful depends on factors such as the nature of the relationship between the couple and the communication processes employed (Browning, Harris, et al., 2017b).

The second way to measure the effects of collaboration on memory performance is to simply compare collaborative group performance to performance of single individuals alone (rather than to a nominal group). Using this method, collaborative recall studies reliably show collaborating groups outperform single individuals working alone – that is two heads working together are indeed better than one head working alone (e.g., Clark, Stephenson, & Kniveton, 1990; Weldon & Bellinger, 1997). Looking at the data in our own studies (Browning, Harris, & Van Bergen, 2017a; Browning, Harris, Van Bergen, et al., 2017), we too have observed this effect, suggesting it extends to collaborative PM. This method has been argued to be a more ecologically valid comparison (Ross, Spencer, Blatz, & Restorick, 2008). In everyday life, couples don't work in nominal groups where they each individually try to remember the same tasks alone and combine their performance. Rather, couples' personal experience is that they remember more together than either of them would when they remember alone (Henkel & Rajaram, 2011; Ross et al., 2008). Whereas the nominal group comparison allows researchers to measure the processing costs of collaborative interactions, it does not allow a comparison of whether it is helpful for patients with memory impairment to work with their spouses on PM tasks in their daily life. In that case, a comparison between the patients' individual performance compared to when they work collaboratively is more informative.

Furthermore, the premise of the nominal control group assumes that all group members have similar ability, and therefore, any processing costs or benefits identified using this comparison group are assumed to be approximately equal for each group member. Pooling nominal performance masks important differences. For example, a couple where both score five, with four overlapping would score a pooled total of six. A couple where one scores six, and the other scores only one (overlapping with the other) would similarly score a pooled total of six. But collaboration in these two cases might be

different in a number of interesting ways. Therefore, in this study we will examine costs and benefits of collaboration in intimate patient/healthy spouse couples using both methods because both are informative.

Finally, some studies have shown that – at least for retrospective recall tasks – there are flow-on benefits of collaboration that occur beyond the period of collaboration, with increased subsequent, post-collaborative individual recall amount and accuracy (Blumen & Rajaram, 2008; Harris, Barnier, & Sutton, 2012, 2013). The repeated learning opportunities and error pruning that occur during collaborative processes are believed to be responsible for this effect (Blumen & Rajaram, 2008; Harris et al., 2011). We do not know yet how such processes may influence collaborative PM, and nor do we know if such benefits extend to clinical populations.

Collaborative Processes

One way of understanding how groups might collaborate successfully is to examine the way they communicate together – that is, their collaborative processes. Previous studies found that good collaboration requires effective communication (Harris et al., 2011; Meade, Nokes, & Morrow, 2009). In a collaborative PM study, we found that couples (as well as strangers) who talked more while collaborating on a PM task had better outcomes (Browning, Harris, et al., 2017b). Another way of understanding collaborative processes is to examine the relative contribution of individuals within the group during collaboration. Previous studies investigating group performance typically reveal that an imbalance of contributions between partners, due to factors such as partner dominance, social loafing, or evaluation apprehension, can be detrimental to group performance (Collaros & Anderson, 1969; Harris et al., 2011; Johansson, Andersson, & Rönnerberg, 2000; Karau & Williams, 1993).

However, we previously found that in both high and low performing collaborative

groups, there was usually a dominant narrator – one person who took the lead in the collaboration and who spoke on average twice as much as the other partner (Browning, Harris, et al., 2017b). This finding suggested that unequal contributions were not necessarily deleterious to collaborative outcomes. Instead, a dominant narrator might indicate the presence of effective coordination within the group based on knowledge about each other’s ability and expertise. This idea is consistent with transactive memory theory (Wegner, Giuliano, & Hertel, 1985), which proposes that – over time and with experience remembering together – groups develop efficient shared systems for the acquisition, storage and retrieval of information (Wegner, 1987; Wegner et al., 1985). Therefore a dominant narrator may reflect collaborative processes adopted to take advantage of relative strengths and weaknesses within the group. In the present study, we examined the collaborative processes of couples in which one member had an ABI. We also explored whether the amount of words spoken by the couple, and/or the relative contributions of patients and their spouses during collaboration was related to the collaborative PM outcome.

Relationship Qualities

We also examined the role of relationship variables in influencing the outcomes of collaboration. The quality or strength of a couple’s intimate relationship has been found to affect how well they work together on memory tasks (Barnier et al., 2014; Browning, Harris, Van Bergen, et al., 2017; Harris et al., 2011). Two dimensions of the quality of an intimate relationship that are particularly relevant to couples when one partner has an ABI are “care” and “control”; the greater the extent to which individuals believe their partners show care, consideration, support, and understanding towards them, and the lower the extent to which individuals feel their partner controls, orders, dominates, or is critical of them, is believed to reflect optimal intimacy (Wilhelm & Parker, 1988). Another important

aspect of intimacy in couples where one partner has ABI is caregiver burden. Smith, Del Sala, Logie, and Maylor (2000) found that PM failures in Alzheimer's Disease patients frustrated their caregivers more than retrospective memory failures. We examined the relationship between these relationship measures and collaborative PM performance and collaborative processes respectively.

Aims of the Study

The main aim of this study was to examine whether collaboration has costs or benefits for PM performance in individuals with an ABI and in their healthy spouses. We also sought to determine whether the effectiveness of collaboration depended upon the type of PM task. In addition, we investigated how neuropsychological deficits, collaborative processes, aspects of the relationships, and mood were related to each other and to collaborative PM performance.

Method

Participants

Potential participants were selected from adult neurological outpatients seen at the Royal Prince Alfred Hospital Neuropsychology Unit on the basis of their assessment results. Patients who had nondegenerative, fairly isolated cognitive deficits that were expected to affect their PM (i.e., low scores on tests of anterograde memory or executive function) and who lived with an intimate partner were identified. Inclusion criteria for both the patients and their partners included: (1) no psychiatric disorders, (2) an estimated IQ >80 and (3) English as a first language. Originally, we recruited nine individuals with ABI and their healthy spouses (18 individuals), but one couple was excluded because the spouse was unable to understand the instructions for the Virtual Week. The final sample was comprised of eight ABI patients and their healthy spouses, who in turn formed eight patients in the individual patient condition, eight spouses in the individual spouse

condition, and eight collaborative couples in the collaborative condition. Although two (of the eight) couples were unable to complete the second round of virtual “days” due to patient fatigue, their data was still included for analysis. Their performance was scored based on the tasks given on the days completed. These two couples were excluded however from the analysis of post-collaborative performance (see below). ABI patients consisted of 4 men and 4 women aged between 33 and 67 years (see Table 1 for mean ages of patients and their spouses). The etiologies for the patients included 4 cases with epilepsy (2 post-stroke and 1 post-temporal lobectomy), 1 viral meningitis, 1 colloid cyst, 1 autoimmune encephalitis and 1 brain tumour. All couples were heterosexual and were in long-term relationships with each other ($M = 257.50$ months, $SD = 133.61$ months). Participants were each paid AUD\$15 per hour of participation.

Measures

Prospective memory – Virtual Week. An adapted version of Virtual Week (Rendell & Craik, 2000; Rendell & Henry, 2009), a computerised board game that incorporates activities that people encounter during everyday life, was used to measure PM. Each circuit of the game-board represented one virtual “day” (Figure 1). As they moved through the day, participants were required to remember a number of PM tasks. Participants used the mouse to roll the electronic die and move their token around the board. The virtual time of day was shown on a clock positioned centrally in the middle of the board. As they travelled around the board, participants were sometimes directed to pick up “Event Cards”, which described activities that occurred throughout the day (e.g., It is breakfast).

In this study, in order to avoid potential floor effects and fatigue in ABI patients playing Virtual Week, we reduced cognitive demand by excluding the two time-check tasks that appeared in the original version of Virtual Week (Rendell & Craik, 2000).

Therefore, in each virtual day, the participants were given 8 (instead of 10) different PM tasks to perform (Figure 2). These were comprised of two each of the four different PM task types. Four tasks were required to be performed when particular events occurred as described on the Event Cards and four tasks were required to be performed at a specific time within the virtual day. Four of the tasks (2 event- and 2 time-based) were “regular” – that is they were repeatedly performed every day of the week. Furthermore, they were learned to criterion before beginning the test phase – participants were required to look away from the screen and repeat all the regular tasks correctly three times before progressing. Finally, four of the tasks were “irregular” and differed each day. For these irregular tasks the instructions were given only once – either at the start of, or during each virtual day. When the event- or time-trigger occurred, participants were to “perform” the PM task by clicking on the “perform task” button and choose the appropriate task from a list of options, which included the correct item and a number of distractor items.

In addition to remembering to perform the PM tasks, participants were required to participate in other decision-making and game-playing activities. For example, at each event, participants were required to make a choice from three options (e.g., At breakfast: “Do you have (a) fruit, (b) porridge or (c) cereal?”). These options determined the roll of the die required to proceed in the game but were irrelevant to successful PM performance. Instead, rolling the correct die number, moving the token and making choices about the “event” activities provided the backdrop of on-going distracting daily activities against which the participant needed to remember the PM tasks (the ongoing task).

Estimated Intelligence Quotient (TOPF). The Test of Premorbid Functioning (TOPF, Wechsler, 2009) was used to estimate the Full Scale Intelligence Quotient (FSIQ). The TOPF assesses the participant’s ability to pronounce words that have irregular grapheme-to phoneme translation. Raw scores were converted to Wechsler Adult

Intelligence Scale - IV FSIQ estimates according to the test manual (Wechsler, 2009).

Global Cognition – Mini-Mental Status Examination (MMSE). The MMSE (Folstein, Folstein, & McHugh, 1975) was used to measure global cognition. The MMSE is a 30-item measure which assesses orientation with regard to time and place, recall, attention, calculation and language skills. It is used as a screen for dementia, but for our participants, none scored below the cut-off of 27, indicating overall intact cognitive function for patients and their partners.

Mood – Depression Anxiety Stress Scales, 21 Items (DASS21). The DASS21 (Lovibond & Lovibond, 1995) was used to measure symptoms of depression, anxiety and stress experienced over the last week. Participants report the frequency of occurrence for each item on a four-point scale ranging from 0 (did not apply to me at all) to 3 (applied to me very much or most of the time). Raw scores were used in our analyses.

Executive function – inhibition (Hayling Error Score). The Hayling Sentence Completion Test (Burgess & Shallice, 1996) was used to assess cognitive inhibition. The key component of the test – Part B – requires the participant to finish a sentence, but to inhibit the congruent response, and instead provide an incongruent response. We calculated the error score (standardized) based on errors that participants made during Part B, according to the test manual (Burgess & Shallice, 1997).

Executive function – initiation (Word fluency). A test of verbal (letter) fluency (Tombaugh, Kozak, & Rees, 1999) was used to measure cognitive initiation. We asked participants to generate as many words as possible beginning with the letters F, A, and S, given one minute each. We calculated age- and education-adjusted z-scores using norms from Tombaugh et al. (1999).

Working memory – Total Digit Span. The digit span subtest from the Wechsler Adult Intelligence Scale-IV (WAIS-IV) (Wechsler, 2008) was used to measure working

memory. Participants were presented with random numerical sequences of increasing length and were asked to repeat these in forward order, backwards order or numerical order until two sequences of the same length are failed. A total score was calculated from these three measures, and the corresponding age-adjusted standard score was calculated from WAIS-IV norms.

Verbal memory – Rey Auditory Verbal Learning Test (RAVLT). The Rey Auditory Verbal Learning Test (Rey, 1941) was used to measure participants' verbal learning and memory. A 15-item word list (List A) is read to participants over five learning trials. In each trial, after the list was read aloud, participants are asked to recall as many words as possible, in any order. Next, a distractor list of 15 items is read aloud (List B), and participants are asked to recall this list (once). Participants then perform recalls of List A again immediately and after a 20 min filled delay interval. We calculated z-scores for total learning (Trials 1–5) and delayed recall, using norms supplied by Geffen, Butterworth, Forrester, and Geffen (1994).

Intimate Bond Measure (IBM). The Intimate Bond Measure (Wilhelm & Parker, 1988) consists of 2 subscales that participants completed to measure the dimensions of “care” (e.g., is gentle and kind to me) and “control” (e.g., tends to order me about) they perceived from their partner towards them. This 24-item questionnaire asks participants to rate their partner's various attitudes and behaviours towards them on a 4-point Likert-type scale that ranges from 3 (*very true*) to 0 (*not true at all*). Higher scores represented the presence of the behaviour.

Caregiver Burden Scale (CBS). The Caregiver Burden Scale (Macera, Eaker, Jannarone, Davis, & Stoskopf, 1993) was used to measure caregiver burden. The CBS is a 15-item scale that asks caregivers (the spouses) about particular tasks and asks them to respond first whether the patient needed assistance (yes/no; Patient Needs subscale),

second whether they provided assistance for the tasks (yes/no; Caregiver Tasks subscale) and third, whether it added to their stress level (yes/no; Stress level). A Caregiver Burden score was indicated by the number of items where all three answers were yes.

Procedures

Following approval from the Sydney Local Health District (RPAH zone) Research Review Committee, and the Macquarie University Human Research Ethics Committee, we invited suitable patients and their spouses to attend the RPAH Neurology Unit together for a testing session that would last up to three hours. We sent a package of information and questionnaires, in separate envelopes for each participant, to their homes, to be completed privately and separately in advance of the testing session. These questionnaires included demographic information and the Intimate Bond Measure. In addition, the spouse completed the Caregiver Burden Scale.

After the participants arrived at RPAH and signed consent forms they were instructed together about how to play the computerised Virtual Week game. The couple sat together in front of a laptop computer and were assisted as necessary in carrying out a trial day together, to become familiar with Virtual Week. They were told that it was important that both participants practiced and they were encouraged to ask questions.

After completing the trial day, the members of the couple were separated into two rooms where they played the first day (“Monday”) of the Virtual Week individually on separate computers with an examiner present. Just prior to starting the Monday, participants were reminded again verbally and on-screen that they needed to perform the same four regular tasks each day of the Virtual Week. After they were satisfied they knew them, we asked the participants to repeat the regular health task aloud three times, looking away from the computer. They were also advised that there would be four irregular (unrepeated) tasks to be performed each day.

Next, the participants were brought together to play the second day (“Tuesday”) collaboratively. Before they were reunited, in order to minimise demand characteristics of the hospital setting, the spouse of the patient was told: *“Even though you’ve been encouraged to hold back and allow time for your partner to remember and respond by themselves, here we want you to work together as you might normally help each other at home”*. When the partners were seated together, ready to commence Tuesday, they were instructed: *“We want you to work together and help each other to remember as much as you can to play Tuesday”*. We also advised that we were about to start an audio recording for which we had previously obtained the participants’ consent. After the participants played Tuesday, they were separated again to play “Wednesday” individually. Finally, after the participants completed Wednesday, they were brought together to play “Thursday” collaboratively.

Recognition Test of PM task content. After completing each virtual day, we tested participants’ recognition memory for the content of the PM tasks they had been required to complete during that virtual day. This recognition test provides an approximation of the retrospective component of the PM task, since it assesses whether participants recognise the content of what they had to do. A list of PM tasks was presented to the participants on the computer screen (e.g., take antibiotics), which needed to be matched with the corresponding PM cue (e.g., at breakfast) from another list. Distractor items were included. Following collaborative “days” Tuesday and Thursday, the recognition task was completed collaboratively.

Neuropsychological assessments. After the Virtual Week testing session, the participants took a break. Then we conducted the neuropsychological assessments individually, in separate rooms, completing the measures detailed above. After completing these tasks, we brought the couple back together for a debriefing session.

Scoring

Prospective memory –Virtual Week. We scored responses for Virtual Week as being either (1) Correct, or Incorrect, with Incorrect responses further categorised as either (2) Early/Late, or (3) Missed. Correct responses were those in which the correct action was performed in association with the correct time or event. Execution time was counted as correct if participants responded after the die roll for the move that took the token on or past the target time or event, and before the next die roll. Incorrect responses categorised as Early/Late were those where the correct action was performed outside the parameters described for correct execution time. Incorrect responses categorised as Missed responses were those where the participant did not remember the task at any time. Note that on only 2 occasions a patient selected the wrong task at the wrong time. Because of its low occurrence, this type of error was not analysed separately, but was included in Early/Late responses.

The main score employed in this study as a measure of PM performance was the proportion of Correct responses (Correct/Total Possible Items), though in one set of analyses we also considered group differences in number of Early/Late and Missed items. Note that we needed to terminate the Virtual Week testing session for two couples after they played the first individual and collaborative days (Monday and Tuesday) due to patient fatigue. Their scores were based on the days completed. Scores for the remaining couples were averaged across the two individual and two collaborative days.

Two types of scores from the individual days were used to evaluate the effects of collaboration. First, the nominal score for a couple was calculated by pooling the non-redundant Correct scores of each individual during their performance on the individual days. Therefore, to count as Correct for a nominal dyad, at least one member of the couple had to perform the PM task correctly. If both individuals performed a particular PM task

correctly, rather than overinflating the score by counting it twice, this was only counted as correct once. If neither individual in the nominal dyad performed the task correctly, the task was treated as incorrect. Then in turn, nominal scores were calculated for Early/Late and Missed. For example, to count as Missed, both members of the nominal couple missed the task completely. Second, the proportion of Correct responses for both the ABI patient and the spouse were separately calculated for their individual days and these were compared to the proportion Correct on the collaborative days.

Recognition Test of PM task content. Responses were scored as correct if the participant matched the correct PM task with the correct cue.

Collaborative Processes. The dialogue of all collaborating couples was transcribed from audio recordings made while the couples played Virtual Week together to measure certain aspects of collaborative processes. The number of words spoken was calculated as the average words spoken during each collaborative virtual day. The relative contribution of each individual within the couple was calculated as the proportion of the couples' words that each individual spoke during collaboration. These relative contribution scores were dependant on each other within the couple, such that for each couple, the relative contribution of the patient and the spouse necessarily summed to 1.

Statistical Analyses

A standard alpha of $\leq .05$ was employed for the within group comparisons and correlations. Given the small sample size (i.e., $n = 8$ patients, healthy spouses and couples), nonparametric statistics were used. Because analysis was performed on the dyad level, and the patients and spouses formed the couples, the groups were related. Therefore Wilcoxon signed-ranks tests were used to examine within-dyad comparisons. Spearman's rank-order correlations were used to examine associations between variables. We used the normed/scaled scores on the neuropsychological tests to compare patients' performance to

their healthy spouses'. However, we used the raw scores on these tests when performing correlational analysis with PM performance, because there are no age norms for Virtual Week scores. Related to this, there was no association between participant's age and their PM performance as they worked either individually or collaboratively, all $ps > .523$

Results

Participant Characteristics

Patients and their spouses did not differ in age, years of education, estimated IQ, or global cognition, $Zs < 0.63$, $ps > .528$, (see Table 1). These analyses were performed on normative scores (displayed in Table 1) to avoid any confounding effects of age, since our participants ranged substantially in age, and to show relative abilities. Although patients obtained numerically lower scores than their spouses on all the standardized measures of cognition and mood, somewhat surprisingly, we also found few significant differences between the two groups, although our sample size was small. Patients did, however, report significantly higher levels of anxiety and they also showed a trend toward difficulties with inhibition (Hayling Error scores; see Table 1). It may be important to note that the mean Caregiver Burden score for this sample was low ($M = 2.13$, $SD = 2.59$), with scores ranging from 0 to 7 out of a possible score of 15, which suggests spouses in this sample were not overburdened by the care required by their patient partner. Using normative scores, we found that five patients demonstrated at least one score on the measures of cognition that fell greater than 1.64 standard deviations (i.e., in the bottom 5th percentile), below the normal mean. Overall though, our patient sample appeared to be relatively high functioning.

Performance on Virtual Week

Individual PM performance. The proportions of Correct responses on Virtual Week are presented in Table 2. When they worked individually, the patients were

significantly impaired compared to their spouses on all four types of PM tasks, all Z s > 2.12 , $ps < .034$. When we considered the types of errors made, we found that patients working individually had a higher proportion of Missed responses ($M = .37$, $SD = .26$) than their spouses working individually ($M = .05$, $SD = .06$), $Z = 2.52$, $p = .012$, as well as when couples worked collaboratively ($M = .05$, $SD = .04$), $Z = 2.54$, $p = .011$. There was no difference in Missed responses between spouses working individually or collaboratively, $Z = 0.32$, $p = .750$. In contrast, patients, spouses, and couples performed a similar proportion of tasks either too early or too late ($M = .23$, $SD = .20$, $M = .11$, $SD = .16$, $M = .18$, $SD = .22$, respectively), Z s < 1.61 , $ps > .107$. Overall, patients' lower PM scores came from missing responses entirely.

Effects of collaboration. On average, scores were higher in the nominal condition ($M = .89$, $SD = .19$) than when couples collaborated ($M = .77$, $SD = .24$), indicating the typical negative effect of collaboration on PM, $Z = 2.06$, $p = .039$. That is, we found collaborative inhibition, such that the couple did not perform to the potential of the two individuals. When individual scores of patients and spouses were compared to the couples' collaborative scores, patients' individual scores were significantly lower than couples' scores on time-based, regular and irregular tasks, Z s > 1.94 , $ps \leq .05$, and trending towards lower than couples' collaborative scores on event-based tasks, $Z = 1.69$, $p = .090$. In contrast, spouses achieved slightly higher scores when working individually than when working collaboratively, for irregular tasks in particular, though the level of significance was marginal, $Z = 1.89$, $p = .059$. The difference in the other three task types failed to reach significance, but was in the same direction, Z s < 1.00 , $ps > .317$. Overall, these analyses suggest that collaboration boosted the PM performance of the patient but had costs for the PM performance of the spouse.

Recognition of PM Task Content

Individual recognition performance. When working individually, patients recognised significantly less PM task content ($M = .82$, $SD = .17$) than their spouses ($M = .98$, $SD = .05$), $Z = 2.20$, $p = .028$, indicating memory impairment in the patient group.

Effects of collaboration. On average, scores were higher in the nominal condition ($M = .98$, $SD = .03$) than when couples collaborated ($M = .93$, $SD = .07$), indicating the typical negative effect of collaborative recall, although the significance level was marginal, $Z = 1.76$, $p = .078$. Compared to couples' collaborative performance, spouses had higher scores as individuals, $Z = 1.86$, $p = .063$, while patients had lower scores, $Z = 1.89$, $p = .058$, though the significance levels were marginal. As for PM, recognition showed benefits of collaboration for patients, but costs for spouses. Correlational analysis showed that neither patients' nor their spouses' individual recognition of task content was associated with their individual PM performances respectively, or couples' collaborative PM performance, all $r_{ss} < .539$, all $ps > .130$. However, couples' collaborative recognition performance was strongly and positively associated with couples' collaborative PM performance, $r_s = .725$, $p = .042$.

Post-collaborative Performance

To examine whether individual performance for the patients and/or the spouses improved after collaboration, we compared individual PM performance on “Wednesday” and “Monday”. (Note, only 6 couples contributed to these analyses because two couples were unable to complete all four days). For patients, we found no significant difference between their post-collaborative performance on “Wednesday”, ($M = .46$, $SD = .31$), compared to their “Monday” pre-collaborative performance ($M = .46$, $SD = .32$), $Z = 0.137$, $p = .891$. For spouses, mean performance improved by 17% on “Wednesday”, ($M = .90$, $SD = .15$) compared to “Monday” ($M = .73$, $SD = .29$), although this failed to reach significance, $Z = 1.63$, $p = .102$. Next, to test whether couples' collaborative performance

improved over time, we compared couples' "Thursday" collaborative performance ($M = .81$, $SD = .13$) to their "Tuesday" collaborative performance ($M = .77$, $SD = .29$) and found no significant difference, $Z = 1.08$, $p = .914$.

Associations between PM Performance and Cognition

We examined the relationship between individual cognitive scores and PM performance for the two groups (patients and spouses) separately (Table 3). We found that for patients, overall individual PM performance was not related to executive function, however it was positively related to Verbal Memory (Total Learning) and Verbal Memory (Delay), indicating that memory impairments can disrupt PM performance. For their spouses however, individual PM performance was not related to any measures of cognition. Table 3 also shows the relationships between individual scores on cognitive measures and the couples' collaborative PM; analyses indicated no significant relationships.

Collaborative Processes

To test whether talking more (total words spoken by both members of the couple during collaboration) affected PM performance, we conducted a correlational analysis between number of words spoken and couples' collaborative PM performance. If anything, more conversation was actually associated with poorer performance, though this failed to reach significance, $r_s = -.55$, $p = .154$.

We also found no significant difference in the number of words spoken by patients ($M = 680.8$, $SD = 405.6$) and spouses ($M = 660.8$, $SD = 239.3$), during the collaborative sessions, $Z = 0.28$, $p = .779$, indicating equal contributions between partners. Furthermore, we found no association between couples' collaborative PM performance and the patients' relative contribution to the conversation, $r_s = -.22$, $p = .606$. We tested whether the relative contribution of each individual during collaboration was associated with their individual

PM performance, separately for patients and spouses. For patients, the relationship between individual PM performance and relative contribution was not significant, $r_s = -.21$, $p = .627$. For spouses, there was a trend towards a positive association, such that higher performing individuals contributed more during collaboration, $r_s = .63$, $p = .096$. Thus, it appears that spouses with better individual abilities on the task were more likely to take the lead.

Associations between Collaborative Processes and Cognition

Correlations between collaborative processes (i.e., each partner's relative contribution) and participants' cognition scores are shown in Table 3. Note that only the associations with patients' relative contributions are displayed; the spouses' associations are complementary, that is, the same size and level of significance, but in the opposite direction. There was a trend towards a strong positive association between patients' inhibition scores and their relative contribution – that is, there was a tendency for patients with lower inhibitory control to contribute less during collaboration. There were no other significant associations.

Mood and PM

We examined the relationship between individual mood scores and individual PM performance, as well as couples' collaborative PM performance, separately for patients and spouses (see Table 4). We found that for patients, there was a trend towards greater levels of stress relating to poorer individual PM performance. In contrast however, for their spouses we found that greater levels of both stress and anxiety were positively and strongly related to their individual PM performance. Greater levels of spouses' stress were also significantly related to couples' collaborative PM performance. However, there were no other associations between patients' or spouses' mood scores and overall collaborative PM performance. This implies that more anxious spouses had higher performance.

Correlations between mood scores and collaborative processes (i.e., each partner's relative contribution) are also shown in Table 4. For patients, we found a significant positive association between their levels of depression and their relative contribution during collaboration. For spouses, we found no association between their mood and relative contribution.

Relationship Quality and PM

Correlations between relationship quality, collaborative PM performance and collaborative processes (i.e., each partner's relative contribution), are shown in Table 5. We found no associations with patients' or spouses' relationship intimacy scores and couples' collaborative PM performance. However, for patients we found a significant strong, and negative association between the extent to which they believed their spouse cared for them, and their relative contributions. That is, higher care was associated with less contribution. For spouses we found a significant strong and positive association between the extent to which spouses believed the patient cared for them and their (spouse) relative contribution (note that the complementary negative association between spouse's perceptions of patient's care and the patient's relative contribution is the relationship actually shown in Table 5). In contrast, perceptions of control were not correlated with relative contributions during collaboration. The results indicated that although measures of relationship quality – care and control – were not related to couples' collaborative PM outcomes, higher levels of perceived care in the partner were associated with increased contributions by the spouse and reduced contributions by the patient during collaboration.

Table 5 also shows how caregiver burden was related to couples' collaborative PM performance and collaborative processes. There was a trend towards an association between patient needs and couples' collaborative PM performance, otherwise there were no associations between these other aspects of relationship quality and couples'

collaborative PM performance. In terms of collaborative processes, scores from the CBS were strongly correlated with contribution during collaboration (with 2 of the 3 reaching significance). Higher scores from the CBS were associated with greater contribution during collaboration by the healthy spouse (and a complementary lesser contribution during collaboration by the patient).

Discussion

This study aimed to test the extent to which collaboration helps or hinders PM functioning in a person with an ABI and their healthy spouse. On average, when individually performing the Virtual Week, patients scored significantly lower than their spouses on all types of PM tasks (i.e., event-based, time-based, regular and irregular). Thus ABI patients were impaired on these tasks. We found that collaboration resulted in higher PM scores than when patients worked alone, but this came at a cost to their healthy spouses' individual performance. This was true both for PM performance during a Virtual Week day and for the recognition memory test afterwards. Several factors were associated with collaborative processes, but these processes themselves were not directly related to collaborative PM performance. However, other individual differences, such as levels of spouses' stress and patient needs, were related to couples' collaborative PM.

Collaboration and its Effect on PM Outcomes

We used two methods to compare couples' collaborative PM performance to individual performance. Using scores from a nominal "control" group (comprised of the pooled individual scores of patients and their spouses), we found a collaborative inhibition effect; couples as a nominal group outperformed their collaborative scores by 12%. The magnitude of this effect is consistent with the size of the collaborative inhibition effect in other studies of both PM and of episodic memory (Basden et al., 1997; Basden et al., 2000;

Browning, Harris, Van Bergen, et al., 2017; Harris et al., 2011; Weldon & Bellinger, 1997).

Using a second method, we separately compared couples' collaborative performance to patients' and spouses' individual performance. Using this method, we found that couples' collaborative PM performance was significantly better than when patients worked alone on three of the four PM tasks (time-based, regular and irregular), with a similar trend for non-significant event-based tasks. The effect of collaboration on the spouses' PM, however, was negative. Spouses worked better individually than when the couple worked together. Although the difference in PM performance between spouses' individual and couples' collaborative performance failed to reach significance in three of the four tasks, there was a trend towards a significant difference for irregular task performance. In contrast, evidence from previous collaborative memory studies (both retrospective and PM) involving healthy participants reliably shows the opposite. When comparing collaborative performance to that of a single individual (rather than the nominal group), collaborating groups consistently outperform individuals working alone (Browning, Harris, Van Bergen, et al., 2017; Weldon & Bellinger, 1997). For example, inspection of the data from Browning, Harris, Van Bergen, et al. (2017), showed that healthy adult couples working together on Virtual Week scored 12% greater than single individuals working alone. Therefore, when considered against evidence from previous studies, these findings suggest that healthy spouses did not experience the usual advantages of collaboration and if anything, collaboration came at a cost. We found a similar pattern of results in recognition of task content. Taken together, these two methods of evaluating the effects of collaboration first show that in couples where one partner has impaired PM we find the typical effect of collaborative inhibition. This suggests that on average, two heads together do not perform as well as two heads apart. Taking into consideration that

one of the partners has significantly lower individual PM ability however, we can see using the second method that patients actually experienced benefits during collaboration, while their spouses experienced costs to PM performance.

We also investigated whether collaboration produced any post-collaborative benefits. In healthy participants, subsequent individual recall is typically improved after collaboration (Blumen & Rajaram, 2008; Harris et al., 2012, 2013). We found some nonsignificant post-collaborative gains for spouses, but no post-collaborative gains for patients, nor any advantages for couples when they collaborated a second time. Together, these findings suggest that while spouses demonstrated a trend towards improvement over time and with practice, the patients did not. Furthermore, when spouses collaborated with the patients, the natural tendency to improve with practice was diminished such that collaboration did not improve across sessions.

Identifying the Nature and Influence of the PM Impairment

PM difficulties in the ABI patients were evident across all types of tasks, which is consistent with previous studies using Virtual Week in some clinical populations (Habota et al., 2015; Rendell et al., 2012; Rendell et al., 2007; Terrett et al., 2014; Thompson et al., 2010). Collaboration with a healthy spouse assisted the patient's performance consistently and, for most types of tasks, had no significant effect on the spouse's success level. However, for Irregular tasks, collaboration caused a trend towards a drop in the spouse's score compared to their individual performance. This finding, if confirmed in future studies, could be used to inform rehabilitative strategies, where seeking support from a partner is a recommended strategy for ABI patients to manage PM tasks. This recommendation might depend on the type of task, such that irregular tasks might be best outsourced in everyday life to the healthy spouse alone, rather than enlisting a collaborative strategy.

There was no relationship found for this small sample between working memory or executive function and Virtual Week PM performance, but anterograde verbal memory ability was positively correlated with patients' overall PM score. The patients' poorer performance on the recognition memory test compared to their spouses' supports the idea that deficits in memory processes of encoding and storage were contributing to PM deficits. However there was no association between patients' subsequent recognition of task content and their PM scores. This, combined with the lack of variability in impairment across task regularity suggests patients' PM deficits cannot be attributed to retrospective memory deficits alone. If retrospective memory deficits (forgetting task content) were solely responsible for patients' poor PM performance, they would have shown a disproportionate impairment on Irregular tasks. In addition, although patients were able to recognise 82% of task content after each virtual day, their PM task performance was only 41%, indicating they could only remember to implement half of the delayed intentions they could later recognise.

The pattern of missed responses further suggests that patients forgot the PM task completely. The ABI patients completely missed 37% of tasks, which was significantly greater than the 5% of tasks missed by spouses. In contrast, most errors by spouses were early or late rather than missing. The ABI patients in this sample did not differ from their spouses in incidences of momentary lapses of attention or the faulty retrieval that might result in performing tasks at the wrong time. Together, these findings suggest that patients were not only impaired on remembering task content, but they also were also impaired on remembering to retrieve the delayed intention. These findings are consistent with findings from studies investigating PM in other patient groups with retrospective memory difficulties, including MCI and early dementia (Thompson et al., 2010).

Other patient groups with ABI that have greater difficulties with executive functioning (e.g., those with traumatic brain injuries; TBI) showed a different pattern of errors on Virtual Week (Mioni et al., 2013), such that time-based tasks were particularly impaired compared to event-based tasks. In turn, these underlying differences could have an impact on collaborative processes and/or PM outcome during collaboration. This awaits further investigation.

Collaborative Processes

There were large individual differences in collaborative processes among the couples. We found no significant relationship between total words spoken by the couple and their collaborative PM performance, though if anything, the relationship was negative. This contrasts with findings from a previous collaborative PM study with healthy couples, where those who spoke more showed better PM performance (Browning, Harris, et al., 2017b). This suggests that when patients and spouses work together, at least for some, dialogue might act as a distraction. If spouses assume responsibility for PM tasks and also try to assist patients to remember by using verbal cues, their limited-capacity working memory might be overburdened. This idea is supported by findings from R. L. Marsh and Hicks (1998) that showed PM performance suffered when ongoing tasks are more difficult. Indeed Stone, Dismukes, and Remington (2001) suggested that casual conversation with another person in itself could be distracting and disrupt PM processes, particularly when the task is non-routine.

We also found no significant difference in the number of words spoken by the spouses compared to patients. This suggests that spouses in this study did not consistently “take-over” and perform all the tasks on behalf of patients. However, the way the couples collaborated was associated with the spouses’ individual PM abilities. That is, the better the spouses’ PM ability, the more the spouse contributed during collaboration. In contrast,

we found no relationship between the patients' individual PM ability and the extent to which they contributed during collaboration. These findings are suggestive of an established transactive memory system where individuals within collaborating groups have knowledge about each individual's level of expertise (Wegner et al., 1985) and act accordingly, sensitively to the spouse's ability and allowing the spouses to lead when they were more able at the task. Our findings also suggest that the patient's ability was not the main determinant of relative contribution.

When we examined whether measures of cognition for either patients or their spouses were associated with their relative contribution, we generally found no associations. There was however a tendency towards those patients with lower inhibitory control contributing less, perhaps indicating they found the task more difficult, although inhibitory control was not associated with their PM performance.

Importantly, when examining the relative contributions of patients and their spouses during collaboration, we found no relationship between collaborative processes and collaborative PM performance. That is, there was no single pattern associated with PM success – both couples where the spouse contributed more and in couples where contributions were more equal performed similarly. Overall, there were large individual differences in collaborative processes, and one particular style (more or less egalitarian) was not reliably associated with success.

Relationship Quality and Other Individual Differences

We found that certain individual differences were related to collaborative processes. Relationship qualities of care and control were associated with collaborative processes, but they were not associated with collaborative PM performance. Interestingly, the direction of the association between perceived levels of care displayed by the partner and who took the lead during collaboration depended upon whether the perception of care

was obtained from the patient or the spouse. Patients were inclined to contribute *less* during collaboration when they believed their spouses cared more for them. In contrast, we also found that spouses were inclined to contribute *more* during collaboration when they believed their partner (patients) cared more for them. These two findings suggest that patients more readily accepted support from their spouses when they believed their spouses cared for them, and equally, spouses more readily provided support when they felt reciprocal levels of care from their partners. Of course, because this is a correlational analysis, the direction of the relationship is not known, but it converges with evidence that shows caregiver burden is decreased in the presence of reciprocity (Reid, Moss, & Hyman, 2005). We did not find any associations between relative contributions and perceived “control”, which suggests the degree to which individuals contributed during collaboration was not representative of a form of dominance in the relationship, and is consistent with our interpretation of greater partner contributions not necessarily being detrimental to PM performance.

Examples of Collaborative Dialogue

As mentioned above, we observed large individual differences in collaborative processes. Extracts from transcripts are presented to illustrate some of these differences. Couple 1 was comprised of long-married older adults and Couple 2 was comprised of married younger adults. In both couples the patient was female. The patients scored in the severely impaired and moderately impaired range respectively on delayed verbal memory. The percentage differences in their individual PM abilities (overall) were such that the male spouse in Couple 1 scored 50% higher than the female patient, and the male spouse in Couple 2 scored 88% higher. When the couples collaborated, however, their scores reflected a “cost” of 50% for the male spouse in Couple 1, but a “cost” of only 6% for the male spouse in Couple 2. The following exchange between Couple 1 illustrates how the

male spouse encouraged an interactive approach to the collaboration to the cost of his own contribution. Here the couple was required to remember to put a casserole in the oven at 5.00 pm, which was approaching:

M1: Okay, what's the time? What did we have to do at five o'clock?
 F1: Put the casserole on.
 M1: Right. (And he performs the task).

Then a little later...

F1: We didn't put the casserole on.
 M1: Yes we did.
 F1: You're sure?
 M1: I'm positive. Five o'clock we did it.
 F1: Oh.
 M1: [Laughs].

Note that the male spouse cued the patient successfully, resulting in her contribution. Also note that a little later in the game, the patient completely forgot that she had done this. The spouse maintained his good humour though and kept assuring the patient that it was done. They were both able to laugh about it.

Here is another example where the spouse in Couple 1 supported the patient's memory and encouraged her to remember. They were running through a "to-do" list of tasks. He again successfully cued her about taking antibiotics with dinner. Interestingly, they promptly forgot to take the antibiotics at breakfast, indicating that the additional conversation might have caused disruption of retrieval of the intention.

M1: Antibiotics at - when - breakfast and...?
 F1: Breakfast and dinner.
 M1: Yeah. What about your inhaler? The inhaler - when?
 F1: I don't know... The inhaler?
 M1: Eleven o'clock.

The following exchange between Couple 2 represents a more one-sided and less interactive style by the male spouse. They were approaching 3.00 pm when they were required to remember to submit a report.

M2: Okay, so three tasks we have to do. X-ray was at four.
 F2: Submit a report?

- M2: No. Take antibiotics. Tradesman coming to check security alarm. Tradesman coming to check security alarm. I think that's more – sounds, yeah...
- F2: That was it?
- M2: Yeah. Submit your football tips. Now I have to pick up a card. When you meet Jill for coffee we need to ask for the book back. Ask Jill for the book she borrowed. Do you have a muffin, donut, coffee? I have a donut. Six (rolled die). Okay, 4:00 pm we had to do something. Do you remember? I think it was have an x-ray. Sounds familiar? I think so.

As the spouse proceeded to lead the game, he attempted to cue the patient, but immediately provided the answers himself. He missed her contribution regarding the approaching report. He also made the choice regarding what they would eat without consulting the patient. Later when the patient and her spouse were completing the recognition test of task content, again he dismissed her correct suggestion that they were required to submit a report at 3.00 pm.

These two examples illustrate that while most spouses encouraged the patients during collaboration, some had more patience than others! Moreover, they illustrate how social goals of encouraging and cuing the patient's contribution may have come at a cost to performance. In these two cases, Couple 1's collaborative scores were low and the spouse experienced costs compared to their individual performance, whereas for Couple 2, when the spouse was more inclined to forge ahead and focus on their own individual strategies, their collaborative scores were higher and similar to that of the spouse alone. The additional load on working memory that is required to carefully and sensitively pay attention to the patient may explain this effect. In the examples given above, the couple who engaged in more banter produced poorer collaborative outcomes in terms of PM performance, which contrasts to our earlier findings for healthy couples (Browning, Harris, et al., 2017b).

These differences in approach to the task of collaborative PM may reflect different motivations or goals that couples have regarding their collaboration. The function of collaborative PM is complex with patients and their spouses, and their individual

motivations may even compete. Similar to collaborative retrospective remembering, accuracy is not necessarily the goal of collaborative PM (Harris, Barnier, Sutton, & Keil, 2014; E. J. Marsh, 2007; Pasupathi, 2001). For some partners, their goal seemed to be to help their impaired partners remember, to increase their self-efficacy, and reduce the patient's stress. Other spouses seemed to feel it was more important to get tasks done at the correct time and sacrificed greater levels of interaction with the patient for the sake of accuracy. Indeed, in everyday life, accuracy is very important for some PM tasks such as taking medication or removing a pot from the stove before it burns. Patients too may have competing motivations – they may feel that relying on their spouses will make them less independent (Thöne-Otto & Walther, 2008). They may be concerned with maintaining agency and sense of self. Further research should investigate the various motivations underlying behavior when memory impaired patients collaborate with their spouses, and the tradeoff between task completion and relational aspects.

Limitations

The sample recruited for this study was very small, and accordingly all the findings should be interpreted with caution. Also, the couples who participated in this study represent a particular subset of the population who were willing to donate three hours of their time (sometimes taking time off work), as well as travel to a city hospital to participate in a memory study. These couples may not be representative of couples where one partner has an ABI within the wider community. Furthermore, the ABI patients (although impaired on Virtual Week) were fairly high functioning (and reported caregiver burden was relatively low). Findings are likely to differ for patients with more severe deficits or different patterns of deficits. It should be noted, however, that Virtual Week is probably too difficult for many ABI patients, as even amongst our sample two patients became too fatigued to complete a second round of “days”. Additionally, there were some

interesting relationships with mood, PM performance, and collaborative processes, and some were not always in expected directions. Because the mood questionnaire was given after completion of the Virtual Week task, it is difficult to know whether mood influenced performance or vice versa. It might have been better to administer the DASS first to gain an independent assessment. Future research could focus on the ways in which stress is produced and/or influences PM performance in collaborating couples when one partner has an ABI.

Conclusions

In this study we examined the effects of collaboration on PM when patients with an ABI worked together with their spouses. We found that while patients experienced benefits during collaboration, their spouses incurred costs and overall, nominal group performance was better than collaborative. The way couples collaborated (in terms of who contributed more during collaboration) was influenced by the spouses' PM ability, patients' inhibition scores, aspects of patients' mood, perceptions of care and perceptions of patients' needs. However, we did not find that these collaborative processes (number of words spoken or equality of contributions) was associated with PM performance. We found some preliminary evidence that the costs to the spouse depended on the function of collaboration. Further analyses of the transcripts will be carried out to explore the possibility that PM performance is actually more compromised when the spouse provides more opportunities for the ABI patient to contribute in collaborative memory situations. This would reflect a tradeoff between correct performance on the task and relational aspects of collaboration. Taken together, the findings raise some interesting issues concerning the usefulness of remembering collaboratively when one member has a significant memory impairment. If remembering to carry out a task correctly is paramount, then for difficult PM tasks (e.g., irregular PM tasks), it seems to make more sense for the

healthy spouse to assume responsibility. The impact of relative contribution during collaboration on patient's self-esteem and self-efficacy are important areas for future investigations.

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Table 1

Demographic Characteristics and Neuropsychological Assessment Results

	ABI Patients		Spouses		Comparison	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>Z</i>	<i>p</i>
Age (years)	49.38	13.15	50.13	12.03	0.35	.725
Education (years)	14.88	3.19	15.88	3.72	0.63	.528
Estimated IQ (TOPF)	101.25	14.37	100.57	13.60	0.53	.596
Global Cognition (MMSE)	29.00	1.07	29.13	0.84	0.33	.739
Mood (DASS21)						
Depression	2.75	3.65	1.63	2.56	0.53	.596
Anxiety	3.25	1.39	0.63	0.74	2.39	.017
Stress	4.75	5.18	3.25	2.25	0.31	.753
Executive function						
Hayling Errors (SS)	5.13	2.53	7.13	0.83	1.89	.058
Word fluency (z-score)	-0.52	1.00	-.043	1.37	0.56	.575
Working memory (Total DS) (SS)	8.50	1.69	9.88	3.40	0.93	.352
Verbal memory (RAVLT)						
Total Learning (z-score)	0.04	1.77	1.12	0.99	1.26	.208
Delayed recall (z-score)	-0.40	1.85	0.72	0.69	1.54	.123
Intimate Bond measure						
Care	2.58	0.58	2.45	0.63	0.32	.752
Control	0.67	0.45	0.93	0.73	0.77	.441
Caregiver Burden	N/A				N/A	
Patient Need			5.38	2.72		
Task Assistance			5.25	2.71		
Caregiver Burden			2.13	2.59		

Note. TOPF = Test of Premorbid functioning; MMSE = The Mini-Mental State Examination; DASS21 = Depression Anxiety Stress Scales 21; DS = Digit Span; RAVLT = Rey Auditory Verbal Learning Test; SS = Scaled Score.

Table 2

*Prospective Memory Performance: Proportion of Correct Responses in Virtual Week;
Mean (SD)*

Type of Task	Individual Patient	Individual Spouse	Collaborative Couples
Event-based	.47 (.33) ^a	.91 (.19)	.81 (.27)
Time-based	.35 (.31) ^{a,b}	.79 (.30)	.73 (.25)
Regular	.47 (.39) ^{a,b}	.92 (.13)	.86 (.28)
Irregular	.34 (.22) ^{a,b}	.77 (.24) ^c	.69 (.24)
Overall	.41 (.28) ^{a,b}	.84 (.19)	.77 (.24)

Note: ^aSignificantly different from Individual Spouse; ^bSignificantly different from Collaborative Couples;

^cTrend towards difference from Collaborative Couples, $p = .059$

Table 3

Associations between Cognition and (a) PM Performance (Individual and Collaborative), and (b) Relative Contribution

Neuropsychological Assessment	PM Performance: Individual (<i>r_s</i>)	PM Performance: Collaborative Couples (<i>r_s</i>)	Relative Contribution: Patients (<i>r_s</i>)
Patient			
Initiation (Fluency)	– .21	.48	–.31
Inhibition (Hayling Errors)	.51	– .37	.63*
Working memory	.08	.41	–.36
Verbal memory (Total Learning)	.71**	.37	.21
Verbal memory (Delay)	.84***	.32	–.11
Spouse			
Initiation (Fluency)	.25	.30	–.41
Inhibition (Hayling Errors)	.31	.03	–.20
Working memory	.29	.27	–.60
Verbal memory (Total Learning)	.11	–.01	–.52
Verbal memory (Delay)	.17	.11	–.46

Note. Spearman Rank Correlations with neuropsychological assessments results (raw scores) for patient and spouse and their Individual PM performance (proportion of Correct responses), Collaborative Couples' PM performance (proportion of Correct responses), and Patients' Relative Contribution (proportion of words spoken), respectively. Note correlations with Spouses' Relative Contribution (proportion of words spoken) are exactly the same as the patients', except in the opposite direction.

* $p < 0.10$, ** $p < .05$, *** $p < .01$

Table 4

Associations between Mood and (a) PM Performance (Individual and Collaborative), and (b) Relative Contribution

Mood Scores	PM Performance: Individual (<i>r_s</i>)	PM Performance: Collaborative Couples (<i>r_s</i>)	Relative Contribution: Patients (<i>r_s</i>)
Patient			
Depression	– .54	.03	.75**
Anxiety	– .44	.29	.55
Stress	– .66*	.38	.22
Spouse			
Depression	.09	.02	–.39
Anxiety	.65*	.48	–.05
Stress	.73**	.88***	–.17

Note. Spearman Rank Correlations between DASS21 (Depression Anxiety Stress Scales 21) mood scores for patient and spouse and their Individual PM performance (proportion of Correct responses), Collaborative Couples' PM performance (proportion of Correct responses), and Patients' Relative Contribution (proportion of words spoken), respectively. Note correlations with Spouses' Relative Contribution (proportion of words spoken) are exactly the same as the patients', except in the opposite direction.

* $p < 0.10$, ** $p < .05$, *** $p < .01$

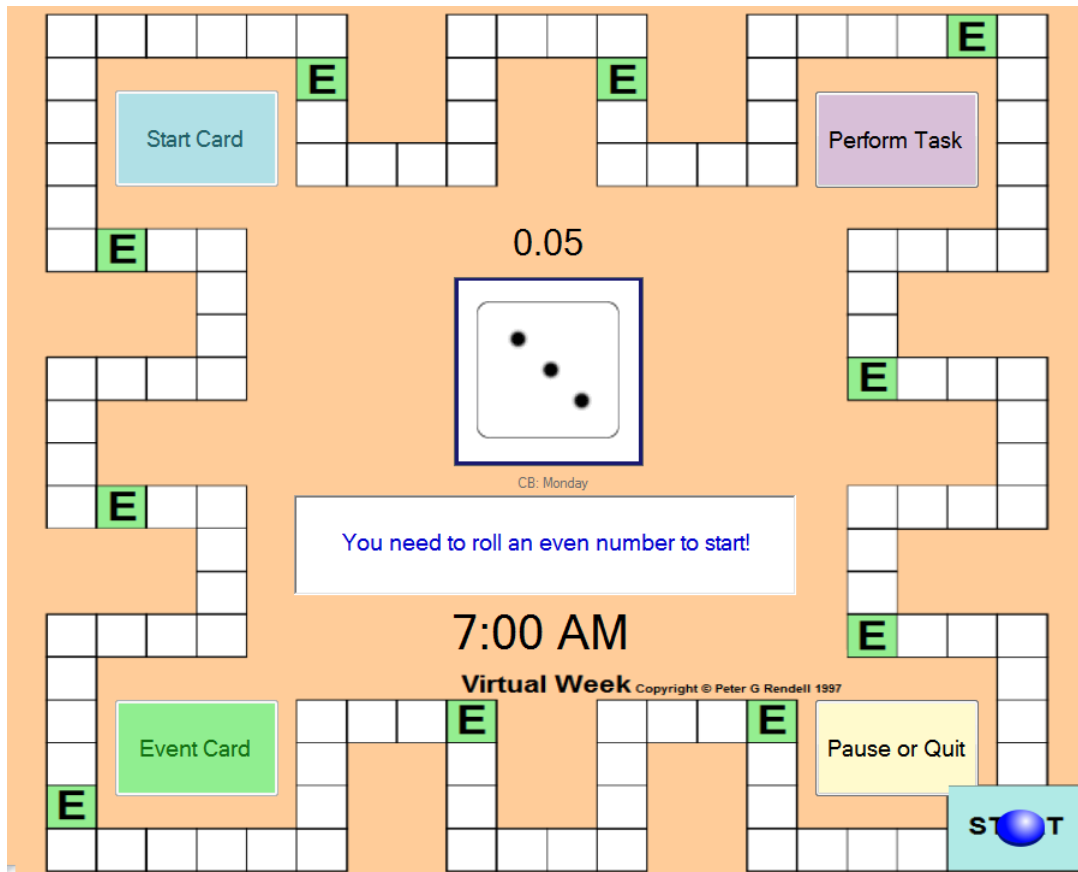
Table 5

Associations between Relationship Quality and (a) PM Performance (Collaborative), and (b) Relative Contribution

Relationship Quality	PM Performance: Collaborative Couples (<i>r_s</i>)	Relative Contribution: Patients (<i>r_s</i>)
Patient		
<i>Intimate Bond Measure (IBM)</i>		
Perception of Spousal Care	.15	-.81 **
Perception of Spousal Control	.31	.00
Spouse		
<i>Intimate Bond Measure (IBM)</i>		
Perception of Patient's Care	.04	-.64*
Perception of Patient's Control	-.15	.04
<i>Caregiver Burden Scale (CBS)</i>		
Patient Needs	.63*	-.84**
Caregiver Tasks	.49	-.83**
Caregiver Burden	.55	-.68 *

Note. Spearman Rank Correlations with aspects of relationship quality and Collaborative Couples' PM performance (proportion of Correct responses), and Patients' Relative Contribution (proportion of words spoken), respectively. Note correlations with Spouses' Relative Contribution (proportion of words spoken) are exactly the same as the patients', except in the opposite direction.

* $p < .10$, ** $p < .05$.



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Figure 1. Screenshot of the Virtual Week game board

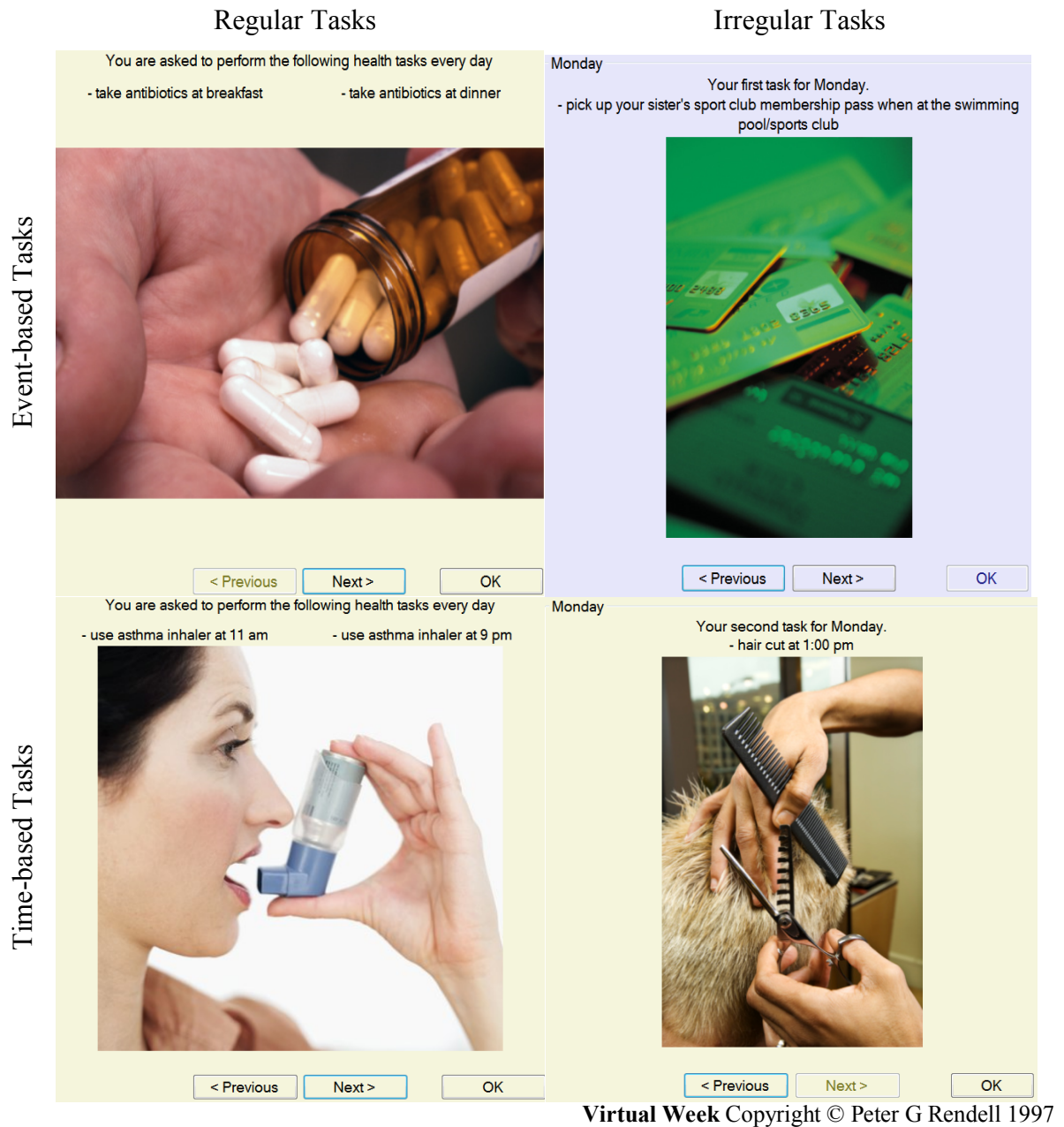


Figure 2. Screenshots of examples of the Virtual Week prospective memory task types.

Journal Description (2016 impact factor 1.839)

Journal of Clinical and Experimental Neuropsychology (JCEM) publishes research on the neuropsychological consequences of brain disease, disorders, and dysfunction, and aims to promote the integration of theories, methods, and research findings in clinical and experimental neuropsychology. The primary emphasis of *JCEM* is to publish original empirical research pertaining to brain-behaviour relationships and neuropsychological manifestations of brain disease. Theoretical and methodological papers, critical reviews of content areas, and theoretically-relevant case studies are also welcome.

Emphases of interest include: the impact of injury or disease on neuropsychological functioning; validity studies of psychometric and other procedures used in neuropsychological assessment of persons with known or suspected brain damage; empirical evaluation of behavioural, cognitive and pharmacological approaches to treatment/intervention; psychosocial correlates of neuropsychological dysfunction; and theoretical formulation and model development. Throughout the world, neuropsychologists, neuropsychiatrists, clinical psychologists, neurologists, cognitive scientists and neuroscientists use this journal to access cutting edge research and theory on the neuropsychological consequences of brain disease and disorders (from <http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=necen20>).

Chapter 6

Discussion and Synthesis

In my program of research, I aimed to examine the influence of collaboration on prospective memory (PM). Recognising that PM involves many cognitive processes, both retrospective and prospective, I extended the findings from the collaborative recall literature into the PM domain. I did this by applying the collaborative recall paradigm to “Virtual Week”: a well-validated laboratory procedure that models PM in everyday life. Consistent with most prior collaborative recall studies, I began my program of research by recruiting strangers to work together on PM (Chapter 2, Experiment 1). This enabled me to establish a baseline for the effects of collaboration on PM. Next, I moved forward to a more common real-world collaborative PM context by recruiting intimate couples to work together (Chapter 2, Experiment 2). This enabled me to test the predictions of transactive memory theory (Wegner, 1987; Wegner, Giuliano, & Hertel, 1985) that couples might collaborate more effectively than strangers. I found that couples – in contrast to strangers – did not show significant collaborative inhibition for PM, but still did not experience benefits. I also observed wide variation in collaborative effects – some dyads appeared to collaborate more successfully than others. Therefore, I used qualitative analysis to examine these individual differences by identifying processes that were more and less helpful for strangers and couples (Chapter 3). In my next experiment (Chapter 4), I examined whether I could improve collaborative PM by instructing groups to use the helpful processes I had identified, and found that this simple intervention did boost group performance. Finally, to focus on the real-world applications and whether collaboration might support PM performance, I recruited intimate couples in a clinical setting in which one partner had an acquired brain injury (ABI) (Chapter 5). I found that collaboration had benefits for patients but costs to their spouse. In this final discussion chapter, I: (1) synthesise the findings across the experiments in terms of the robust collaborative inhibition effect; (2) consider how collaborative inhibition applies to the prospective, as well as the retrospective

component of prospective memory, as distinguished by the multiprocess theory of PM (McDaniel & Einstein, 2000); (3) discuss the importance of individual differences found amongst collaborative groups, and the value of conducting research that looks beyond group means; (4) discuss the implications for transactive memory theory; (5) discuss the implications for PM research; (6) outline methodological issues with the collaborative recall paradigm; (7) discuss limitations of the current research, and directions for future research aimed to further elucidate the influence of collaboration on PM.

Collaborative Inhibition in PM

In this program of research, I extended collaborative recall research – which has previously demonstrated robust collaborative inhibition for retrospective memory tasks – to PM. I found collaborative inhibition in certain types of collaborating dyads, but not others. For instance, in Chapter 2, Experiment 1, collaborating stranger dyads performed more poorly on the Virtual Week task (Rendell & Craik, 2000; Rendell & Henry, 2009) than two strangers working alone. That is, I replicated the collaborative inhibition effect in strangers collaborating on PM tasks, demonstrating that the standard finding from the retrospective memory literature extends to PM tasks. In Experiment 2, however, intimate couples working together on the same task did not show collaborative inhibition.

In Chapter 4, I demonstrated that stranger dyads who were instructed to use specific PM strategies at an individual level also showed collaborative inhibition. Similarly, stranger dyads who received no strategy instructions – with the same procedure as the collaborating strangers in Chapter 2 – showed numerical collaborative inhibition (although this difference was not statistically significant). In contrast, collaborating strangers who were instructed to use PM strategies at an interactive group level showed no collaborative inhibition, performing similarly to nominal groups.

Finally, in Chapter 5, I found that collaborating intimate couples with unequal memory ability – where one partner had an ABI – also showed collaborative inhibition, such that these couples performed better as two separate individuals than when they collaborated. Essentially the healthy partner seemed to be driving collaborative performance in some cases.

In summary, I found collaborative inhibition for PM in strangers who worked without specific strategies, in strangers working together using individual-level strategies, and in intimate couples where one partner had impaired PM ability. I found no collaborative inhibition in healthy couples, and in strangers who worked together using interactive group level-strategies.

The Source of the Collaborative Inhibition Effect

Because PM involves executive processes that support the prospective component, as well as episodic memory processes that support the retrospective component, I aimed to examine the source of the collaborative inhibition effect in PM. In my first two experiments (Chapter 2), I also measured *recall* of PM task content on a separate retrospective memory test and found the same pattern of results as for PM task performance – on recall, I found collaborative inhibition in strangers, but not in couples. Overall my analyses converged to suggest that the overall collaborative inhibition effect in PM performance was attributable to *both* the retrospective and prospective components of PM, however the larger effects of collaborative inhibition in the regular event-based tasks and time-check tasks were only attributable to the prospective component (because recall for these tasks was 100%). Note that although the retrospective component could not be measured directly at time of task execution, it was measured as the ability to recall of task content at the end of each virtual day. This is considered a very close approximation, and has been used similarly by other PM researchers (Foster, Rose, McDaniel, & Rendell,

2013; Habota et al., 2015; Thompson, Henry, Rendell, Withall, & Brodaty, 2010). In the following sections I will separately discuss possible mechanisms that underlie collaborative inhibition in the retrospective component and the prospective component.

Collaborative Inhibition in the Retrospective Component

On the recall test – a proxy to measure the retrospective component – the greatest amount of collaborative inhibition in strangers was observed for irregular event-based tasks. Interestingly, these are the kind of tasks argued to carry the greatest retrospective memory load (Foster et al., 2013). Therefore, rather than assisting with more difficult tasks – as I might have predicted – collaboration instead seemed to disrupt them the most.

Despite this finding being counter to what might be expected, it is consistent with the collaborative recall literature. In the collaborative recall literature, retrieval disruption is the best supported mechanism underlying collaborative inhibition (Marion & Thorley, 2016). By this explanation, the unique and personal retrieval strategies of each group member are disrupted by poorly matched competing retrieval strategies of other group members. Inhibition is reduced when organisation of studied material is more aligned among group members (Marion & Thorley, 2016). This account potentially offers a useful explanation for differences between disruption of PM task content too. In Virtual Week, the tasks with the lowest retrospective load were the regular tasks. These tasks showed the least disruption during the separate recall test, with recall at ceiling. These tasks were repeated every virtual “day”, and the content relating to the “what” and “when” of the PM task was short and easily summarised. These characteristics may have made them easier for collaborating dyads to recall. For example, remembering to “take antibiotics at breakfast” was often shortened to “antibiotics, breakfast” as pairs worked together. Thus, group members were likely to encode and organise simple task information in similar ways. In contrast, irregular event-based tasks such as “pick up your sister’s sports club

membership pass when at the swimming pool” were more semantically complex. This makes it more likely that irregular event-based task content was encoded and organised in different ways for different group members, depending on their own life experience and idiosyncratic associations. This idiosyncratic encoding and organisation for irregular event-based tasks may in turn increase the chance of disruption at retrieval.

This idea that idiosyncratic encoding and organisation of task content underlies the disruption of recall of task content is further supported by the qualitative analysis of collaborative PM dialogue described in Chapter 3. Incidences of collaborative encoding loaded onto a PM group-enhancing factor (clustering with other cognitive and social processes), indicating that collaborative encoding offered an opportunity for group members to organise their storage of task content in a similar way and reduce disruption (see Harris, Barnier, & Sutton, 2013, on shared encoding and collaborative inhibition). Furthermore, in Chapter 4, when group members were instructed to repeat new PM tasks aloud to each other, collaborative performance was enhanced and collaborative inhibition was eliminated. In contrast, although the non-interactive, individual encoding instructions encouraged group members to strengthen their own individual representations of task content, they did not allow an opportunity to align storage organisation amongst group members (Basden, Basden, Bryner, & Thomas, 1997; Blumen & Rajaram, 2008; Congleton & Rajaram, 2011; Marion & Thorley, 2016).

Finally, there is a theoretical argument that disruption of the retrospective component may not be solely due to disruption of retrieval of task *content* alone. Although I operationalised the retrospective component consistent with previous PM research as end-of-day recall of task content (Foster et al., 2013; Habota et al., 2015; Thompson et al., 2010), arguably there is more to the retrospective component than the ability to retain and retrieve task content, although it has been conceptualised in this way (e.g., Einstein &

McDaniel, 1990; Einstein & McDaniel, 1996). Ellis (1996) defined the retrospective component as the formation and encoding of the intention and action, which includes forming a representation of the future retrieval context that will prompt retrieval of the intention (Burgess & Shallice, 1997; Ellis, 1996). Representations of future retrieval contexts are drawn from autobiographical memory (Burgess & Shallice, 1997), similar to recent research on future thinking as involving recombination of episodic memory details (e.g., Schacter, Addis, & Buckner, 2007). Indeed, recent studies have found that episodic future thinking is related to PM performance in children, and both younger and older adults (Nigro, Brandimonte, Cicogna, & Cosenza, 2014; Terrett et al., 2016). Specifically, Brewer and Marsh (2010) showed that episodic future thinking is involved when encoding the future intention. Therefore, it is possible that a disruption of the retrospective component might occur due to a mismatch of group members' future retrieval context representations. Dissimilar representations among group members are more likely to occur for tasks that are novel and unfamiliar, or previously unshared, as in the case of strangers. In both cases, this mismatch could disrupt the mechanism by which the retrieval context was noticed at the appropriate time to retrieve the intention. Given the direction of recent literature that points to the involvement of episodic future thinking in encoding of PM intentions, future research should consider a broader understanding of the retrospective component of PM when investigating potential disruptive mechanisms.

In summary, similar to findings from the collaborative recall literature, the retrieval disruption hypothesis is a potential candidate to explain the collaborative inhibition of the retrospective component in PM. This could occur due to poor alignment between group members' encoding and organisation of task content, and/or due to a mismatch of group members' future retrieval context representations.

Collaborative Inhibition in the Prospective Component

One key benefit of my chosen methodology was that it enabled me to observe costs of collaboration in the prospective component of PM (remembering to retrieve the intention at the right moment), over and above the costs attributable to disruption of the retrospective component. In the first experiment with stranger dyads, for example, two types of task were most disrupted: regular event-based and time-checks tasks. Both of these tasks are considered to have relatively low retrospective memory loads due to their regular nature (Foster et al., 2013), and performance on the separate recall test was near ceiling for both tasks. This suggests that participants were able to remember what they needed to do, but did not remember to perform the task at the required moment: in other words, they failed the prospective component (Einstein & McDaniel, 1996). The time-check task, which has the least inherent environmental support, was the most difficult Virtual Week task due to its nonfocal and time-based nature. Therefore, the task that could potentially benefit the most from additional support available during collaboration was actually the most inhibited. I turn now to discuss possible mechanisms underlying collaborative inhibition of the prospective component of PM.

Disruption of attention. First, it is possible that, during collaboration, group members' attention was diverted away from strategic monitoring to social interaction. However, in Chapter 3, the qualitative analysis of collaborate dialogue indicated that sociability statements (i.e., personal discussions not relevant to the task) clustered together with other processes on a PM group-enhancing factor (in both collaborating couples and strangers). Furthermore, greater amounts of communication among group members overall were associated with better PM outcomes. Therefore, it seems unlikely that the inhibition on the time-check task resulted from divided attention due to additional social interaction.

Disruption of retrieval strategies for the intention. Alternatively, it is possible that the prospective component of PM is subject to retrieval disruption just like the

retrospective component. Individual strategies devised by group members to self-initiate remembering to retrieve *intentions* could be disrupted. In the collaborative recall literature, memory tasks with greater environmental support, such as cued recall, show reduced collaborative inhibition (Barber, Rajaram, & Aron, 2010; Finlay, Hitch, & Meudell, 2000). It was suggested that when the same organised recall structure was imposed upon both the collaborative group members and the nominal group members, both groups were equally disrupted (Barber et al., 2010; Finlay et al., 2000; Marion & Thorley, 2016). In the PM literature, PM tasks that are heavily environmentally cued, such as event-based tasks, have been likened to cued recall tasks (Einstein & McDaniel, 1996). For successful performance of these PM tasks, the cue and the target need to be associated at encoding, and when the cue is presented or noticed in the environment, the intention will be retrieved (Einstein & McDaniel, 1996). When both collaborative and nominal groups encounter event-based cues, the same retrieval organisation for recalling the intention is imposed upon both groups, equally disrupting any retrieval strategies that may have been in place, and reducing collaborative inhibition for this task.

On the other hand, for tasks with few environmental cues (e.g., time-based tasks), group members need to rely more on their own diverse and idiosyncratic strategies to help them remember to retrieve the intention, and these strategies might be interrupted by the other group members' mismatched strategies. For instance, strategies for retrieving the intention can vary in the extent to which individuals rely on strategic monitoring or spontaneous retrieval (McDaniel & Einstein, 2000). Individual differences believed to affect decisions regarding retrieval of intention strategies span the cognitive, metacognitive and personality domains (McDaniel & Einstein, 2000, 2007).

I found two pieces of evidence that suggest that aligning retrieval strategies for the intention could reduce collaborative inhibition. In Chapter 3, collaborating strangers who

regularly stopped and rehearsed upcoming PM tasks (as well as other cognitive behaviours that clustered together) scored higher in PM performance. Furthermore, collaborative monitoring (when individuals direct their attention to the environment for cues that signal the appropriate time to retrieve the intention) also loaded onto a group-enhancing factor (for both strangers and couples). Thus, it appears that retrieval disruption could influence the prospective component as well as the retrospective component to produce collaborative inhibition in PM.

Social loafing. Interestingly, in Chapter 2 strangers showed significant collaborative inhibition for regular event-based tasks. This was unexpected because these tasks are heavily cued and are therefore the least cognitively demanding of the PM tasks tested. Social loafing is a potential mechanism underlying this effect, even though it has previously been discounted as the cause of collaboration inhibition in collaborative recall (Weldon, Blair, & Huebsch, 2000). In PM, previous studies have observed reduced individual effort in certain social contexts (Brandimonte & Ferrante, 2008; Schaefer & Laing, 2000). The non-interactive nature of the tasks and stimuli in these previous studies allowed the participants to “hide” poor individual contributions, which would be more difficult in Virtual Week. However, participants may have identified the regular event-based tasks as easy and they simply assumed that their partner would perform them. Intimate couples, with more expertise in coordinating PM tasks between themselves, may be less susceptible to these oversights or more committed to joint outcomes. In my analysis of the strangers’ and couples’ collaborative dialogue (described in Chapter 3), I measured relative contributions of collaborating partners in terms of proportion of words spoken. I found that across all groups there was usually a dominant narrator who took the lead in conversation. However, this occurred in both high and low performing groups, suggesting that any social loafing was not necessarily driving collaborative inhibition.

In summary, collaborative inhibition of the prospective component of PM could be due to a number of mechanisms. In the case of the nonfocal time-check tasks, which were not supported by environmental cues, the most likely mechanism seems to be a disruption of individual retrieval strategies for the intention, rather than a disruption of attention. In the case of the heavily environmentally supported regular event-based tasks, the underlying mechanism may be a form of social loafing, although analysis of transcripts suggested this might not be the case. Future research is required to investigate this further.

Individual Differences in Collaborating Groups

A major theme that emerged across my experimental studies was that individual differences exist within collaborating groups: some groups collaborate more effectively than others. In both couples and strangers in Chapter 2 (Experiments 1 and 2), there was a substantial variability in collaborative performance, particularly for couples. The patient-couples in Chapter 5 also showed heterogeneity across their collaborative performance, and in their collaborative goals. To determine whether these individual differences in performance related to differences in the way that collaborating couples relate to one another, I used questionnaires to measure dyads' transactive memory systems and intimacy. In the case of the patient-couples in Chapter 5, I used measures of relationship quality, caregiver burden scales and mood scales.

In addition to using questionnaires and scales to investigate whether individual differences were related to performance, consistent with Wegner et al.'s (1985) suggestion that an analysis of transactive memory systems also requires an analysis of communication between group members, I conducted qualitative analysis of collaborative dialogue. Previous research examining dialogue during collaborative recall among certain kinds of collaborating groups, such as older collaborating couples and expert pilots, has revealed important insights regarding individual differences in communication that are associated

with collaborative success (Harris, Keil, Sutton, Barnier, & McIlwain, 2011; Meade, Nokes, & Morrow, 2009). Thus, relationship alone is not sufficient. Success depends also on strategies used, shared knowledge put to use, and communication processes employed. In the current research, I used detailed qualitative coding to yield rich data about differences in the processes of collaboration across dyads. The following sections describe how relationship factors such as transactive memory systems, relationship quality, and collaborative processes are related to collaborative performance.

Transactive Memory Systems

Previous research has shown that couples with self-reported transactive memory systems – where there was a high division of responsibility mutually agreed on by the couple, or there was self-reported development of a transactive memory system in their daily life (Johansson, Andersson, & Rönnerberg, 2000, 2005) – showed no collaborative inhibition. Consistent with these past findings, I found preliminary evidence in Chapter 2 that aspects of transactive memory were associated with collaborative success. In strangers, in Chapter 2 (Experiment 1), this finding was specific to credibility – a measure of the trust and confidence in their partner’s ability (Lewis, 2003). Specifically, those who scored higher on the credibility subscale scored higher in collaborative PM. While I did not expect to find evidence of transactive memory systems in strangers, credibility is considered necessary for transactive memory systems to develop. While the positive association of credibility with PM outcomes may not reflect the emergence of a developed transactive memory system therefore, it is nonetheless an indication of strangers’ positive reflections on their collaborative performance.

For the couples in Chapter 2 (Experiment 2), I found no association with any measures of transactive memory systems and performance. I examined the data to determine whether the absence of an association could be due to generally high mean

scores, with little variance. This might have occurred due to response bias, where the couples thought they should answer positively in accordance with social expectations. However, this was not the case – the mean scores and variance on this measure for couples was similar to that in strangers. It may be though, that couples' responses did not measure only their reflections of how well they worked together on Virtual Week. Instead, the couples may have reflected on how well they worked together generally on PM in their daily life, over the period of their relationship. In this case, an association with their performance on Virtual Week, a novel task, would be less likely.

Relationship Quality

Some evidence from the collaborative recall literature suggests that the level of intimacy between partners may modulate the magnitude of collaborative inhibition (Andersson & Rönnerberg, 1995, 1996; Harris et al., 2011). In Chapter 2 (Experiment 1), I found no association between strangers' self-reported levels of rapport – as measured by a rapport scale (Lakens & Stel, 2011) after playing Virtual Week – and their collaborative PM performance. This might be explained by the fact that the mean score was high, with little variance. It is possible that playing Virtual Week increased rapport among strangers. It is also possible that response bias was present, so they reported high rapport with their partners because of social norms. In either case, because there was a lack of variance, it was not possible to examine whether rapport might be associated with collaborative performance in strangers.

For couples in Chapter 2 (Experiment 2), although I found that couples' perceptions of intimacy scores per se were not related to collaborative performance, I found that discrepancies in their perceptions of intimacy within each couple were. Specifically, discrepancies in intimacy scores, which are an indication of a mismatch between partners' assessment of the quality of their relationship, were associated with

poorer collaborative performance. Of course, the direction of this association is unknown. Communication, or interactions within intimate partners, are the “transactions” of transactive memory (Wegner, 1987; Wegner et al., 1985), and in the absence of such communication, Wegner et al. (1985) predicted that relationships breakdown. Thus, according to Wegner et al. (1985), poor collaborative memory may predict poor relationships, or alternatively it may be that poor relationship quality may predict poor collaborative memory.

Certain communication behaviours were problematic for couples. PM performance was diminished in healthy couples who used demanding and critical statements (as well as other behaviours that clustered on a couples-diminishing factor) during collaboration (described in Chapter 3). This finding is consistent with evidence from collaborative recall research where corrections and strategy disagreements were found to be detrimental to collaborative recall in older-couples (Harris et al., 2011). In contrast, I found that PM performance was better in couples who used more sociability statements (as well as other behaviours that clustered on a group-enhancing factor), which included banter and other off-topic conversations. These findings converge with an observation made by Crystal (1998) who noted that playful language within couples or families is evidence of a good relationship, whereas the absence of playful language within couples or families is evidence of a breakdown in that relationship. Taken together, the findings from the intimacy scale, together with qualitative analysis of couples’ dialogue suggest that in this sample of younger healthy couples, those who have better relationship quality enjoyed better collaborative PM outcomes.

In the ABI patient-couples reported in Chapter 5, I found that the greater the patients’ needs (as perceived by the spouse), the better the collaborative PM performance, although caregiver burden itself was not associated with collaborative performance. Since

collaborative PM outcomes were similar to spouses' individual PM outcomes, and significantly different to patients' it seems that spouses were mostly responsible for collaborative success. Therefore, this association with patients' needs suggests that spouses worked harder in the collaborative condition when they perceived their patient partner required more assistance.

Collaborative Processes

Individual differences in collaborative processes were also associated with differences in collaborative performance. In most cases, couples who communicated more with one another (measured by words spoken) performed better on the Virtual Week task, although this was not the case in the ABI patient-couples. While healthy collaborating strangers and couples can avoid conversational distractions and find greater amounts of communication beneficial for collaborative PM outcomes, when ABI patients and their spouses worked together, dialogue may have acted as a distraction. An analysis of collaborative dialogue among collaborating strangers and couples reported in Chapter 3 showed that using more descriptive, elaborative statements and repeating what the other partner said, was associated with better PM performance, while minimal statements helped too. Again, this is consistent with findings from collaborative recall literature that show that better communication enhances collaborative recall (Harris et al., 2011; Meade et al., 2009).

In regards to contributions during collaboration, in both healthy stranger dyads and couples, whether they were better collaborators or not, one person typically spoke significantly more than the other person. This might suggest that some collaborators engaged in adaptive coordination of task division, based on knowledge about their partner's ability and expertise, as predicted in transactive memory systems (Kimbler & Margrett, 2009; Wegner, 1987), and equally, it might suggest the presence of some social

loafing. I did find a gender effect in healthy couples. Overall, females talked more than males, but this varied by group performance. In the low PM performing couples, males did not contribute as much as females. In the high performing couples, males matched female contributions. This effect is interesting. It could be evidence of female dominance in the PM domain. Equally, it could be evidence of male loafing. While no research to date has considered gender differences in social loafing in the PM domain, evidence from other fields suggests possible differences in mental workload. For example, Ahn, Haines, and Mason (2017) examined gender differences in the coordination of mental workload by surveying heterosexual couples about their PM practices in day-to-day life. Not only did they find that females provided the majority of PM reminders within couples, they also found that men were assumed to carry less of this load, and felt less societal pressure to do so (Ahn et al., 2017). The present finding that relying too heavily on the female partner was associated with poorer performance is consistent with Ahn et al. (2017), who described the excessive cognitive demand when female partners are required to remember their own PM tasks as well as remind their male partner. There is also evidence that gender stereotypes may be maintained in transactive memory systems (Hollingshead & Fraidin, 2003). My findings for gender must be interpreted with caution, as gender was confounded with role in my study: most females in the couples reported in Chapter 2 (Experiment 2) were also psychology students experienced with cognitive testing who brought along their non-student male partner. Thus, further research is required to isolate the effects of gender.

A different pattern of relative contributions was observed in the patient-couples in Chapter 5. On average, spouses and patients contributed equally during collaboration. That is, there was no evidence of a dominant narrator, indicating that healthy spouses did not automatically assume control over the patients. Perhaps because of the patient's impairment, or perhaps because their relationships were longer-standing, these couples

may have been more conscious about ensuring equal contributions than the healthy couples in Chapter 2. However, the degree to which contributions were equal for the patient-couples was associated with other individual differences including the healthy spouses' PM ability, perceived level of care from patients, patient mood, and caregiver burden.

Overall, collaborative processes and communication variables were an important individual difference, but which specific processes were helpful varied across relationship.

Implications for Transactive Memory Theory

Contrary to robust findings of collaborative inhibition effects in past literature, transactive memory theory predicts that small intimate groups can enjoy benefits of collaborative memory through successful communication (Wegner, 1987; Wegner et al., 1985). Consistent with the predictions of this theory, and as discussed above, I found that intimacy modulated the magnitude of collaborative costs – couples in Chapter 2 (Experiment 2) showed no collaborative inhibition compared to stranger dyads. However, intimacy alone did not ensure successful collaboration: some couples were more successful than others. And indeed, some strangers in Chapter 2 (Experiment 1), with no prior acquaintance were also successful collaborators. Individual differences that might determine some of this heterogeneity among collaborating groups, such as varying communicative and collaborative styles, and relationship quality are outlined above. My findings converge to suggest that intimacy helps, but is not sufficient, to ensure successful collaboration.

Across my studies, I also found other evidence of developing transactive memory systems as described by Wegner et al. (1985). In my qualitative analysis, I found that division of task responsibility – consistent with differentiation within groups based on relevant expertise (Wegner, 1987; Wegner et al., 1985) – was multifaceted. It loaded strongly on the general group-enhancing factor (Chapter 3). However, it also loaded on to

the couple-diminishing factor. This is consistent with previous findings that explicitly stated strategies can interfere with implicit strategies already developed in couples (Hollingshead, 1998), and suggests that simply dividing responsibility in the interests of efficiency is not necessarily the most beneficial approach for couples, who may work better more jointly and interactively (see also Barnier, Klein, & Harris, 2017).

The ABI patient study in Chapter 5 offered insights into transactive memory systems in intimate couples where memory ability was not equal. First, I found that the degree to which healthy spouses contributed during the collaborative sessions was not determined by the patients' individual ability, but instead the healthy spouses' individual ability. This meant that it wasn't the case that the worse the patients' ability, the more the spouses participated, which might be expected in an ideal supportive role. Instead it meant that the better the spouses' ability (relative to other healthy spouses), the more the spouses participated. And conversely, the worse the spouses' PM ability (relative to other healthy spouses), the more the patients contributed. The patients' actual ability was not considered here. Although *prima facie*, this is suggestive of an established, efficient, and differentiated transactive memory system – where individuals within groups have knowledge about and access to other group members' expertise (Wegner et al., 1985) – the system is skewed towards knowledge about only the spouses' expertise. There is also evidence of extreme differentiation in these couples where the spouse is regarded as the expert. In this case, Wegner et al. (1985) predicted that when extreme differentiation occurred, the memory for the group would not exceed the memory for that individual, which is what I found: collaborative couples – even among the best performing couples – only scored as well as the healthy spouse alone.

Finally, Wegner (1987) proposed that a function of a transactive memory in intimate couples is to develop a successful relationship, as much as a successful

relationship promotes transactive memory. The collaborative PM goals of ABI patient couples differed among couples. For some spouses, consistent with Wegner (1987), their goal was to perform the task in a way that promoted patient self-efficacy, increased intimacy and relationship quality. For others however, their goal seemed to be efficient and accurate task performance. There are also suggestions from the transcripts detailed in Chapter 5, that the former may have been costly for PM outcomes, however closer analysis of these transcripts is required to test this formally. However, these preliminary suggestions point to the need to consider goals beyond “remembering as much as possible, as accurately as possible”, when testing memory tasks in couples and in real-world scenarios, to place memory performance within its broader everyday context (see also Harris, Barnier, Sutton, & Keil, 2014).

Implications for Prospective Memory Research

Although I did not set out to test various theories of PM, I nonetheless used the perspective of the multiprocess theory (McDaniel & Einstein, 2000) to interpret the influence of collaboration on PM. This theory offered a means of addressing the influence of the PM task itself, and of capturing both effortful and spontaneous retrieval of intentions in PM. I found evidence in collaborative PM that is consistent with previous findings regarding PM task difficulty in individuals. Virtual Week includes up to five different PM tasks, with varying cognitive load. I found across all my experiments that time-based tasks were more difficult to perform than event-based tasks, indicating that Virtual Week captures this difference between the two kinds of tasks (see also Henry, Rendell, Phillips, Dunlop, & Kliegel, 2012; Rendell et al., 2012), and this distinction helps inform interpretations of effects of task in my results.

In Chapter 5, I found PM difficulties in ABI patients across all types of tasks regardless of their load on the retrospective versus prospective component. This is

consistent with previous studies using Virtual Week in clinical populations, even when their cognitive profiles predicted disproportionate difficulties with retrospective memory (Habota et al., 2015; Rendell & Henry, 2009; Rendell et al., 2012; Rendell, Jensen, & Henry, 2007; Terrett et al., 2014; Thompson et al., 2010). The ABI patients reported in Chapter 5 showed a positive correlation between their anterograde verbal memory ability and their PM scores, suggesting retrospective memory difficulties were responsible for their PM difficulties. However, I found consistent impairment across task regularity. This suggests ABI patients' PM deficits cannot be entirely attributable to their retrospective memory deficits of task content alone. Similar patterns have been found in other populations with retrospective memory difficulties – for example patients with mild cognitive impairment and early dementia (Thompson et al., 2010). Taken together, these findings suggest that in some populations, there may be a global PM impairment that extends beyond the retrospective task content of PM. Recent links between episodic future thinking and prospective memory (outlined above) may explain this impairment, but additional research is needed to understand this link.

Finally, much traditional PM research involves using indirect methods to assess processes involved in successful PM, since these processes occur in silence, internal to the individual completing the task. Some other studies have attempted to capture the extent to which individuals are engaged in spontaneously thinking about upcoming tasks, and rehearsals more directly, by using diary entries (e.g., Kvavilashvili & Fisher, 2007; Szarras & Niedźwieńska, 2011). Similar to the study conducted by Margrett, Reese-Melancon, and Rendell (2011), the qualitative analysis of collaborative PM dialogue detailed in Chapter 3 offers a unique window into observing these PM processes as they occur. Certainly not all cognitive processes that occur during collaborative PM tasks are vocalised, however, the qualitative analysis of dialogue suggested that participants regularly engaged in strategic

monitoring, spontaneous rehearsal of upcoming tasks, and spontaneous retrieval of intentions in response to certain PM cues. This methodology therefore provides preliminary converging evidence that successful PM requires many cognitive processes: both strategic and spontaneous.

Methodological Considerations

Throughout the research presented in this thesis I adopted the collaborative recall paradigm – and particularly the nominal group comparison – and used it to evaluate the effectiveness of collaboration in PM. I did this for two reasons. First, by adopting the collaborative recall paradigm, I was able to extend the findings from the collaborative recall literature focused on retrospective memory, and make comparisons between collaboration for retrospective memory and collaboration for PM. Second, by adopting the collaborative recall paradigm I was able to evaluate whether there was any evidence of emergence as predicted by transactive memory theory, such that the memory performance of an established group is greater than the sum of its parts. I was also able to evaluate an alternative hypothesis, that collaboration may cause processing costs such that members in a group do not perform to their potential.

Despite being the standard comparison in the collaborative recall literature, the use of the nominal control group raises two methodological considerations. The first concerns the method by which scores are pooled to comprise each nominal dyad amongst strangers. In experiments with couples, the individual scores from each partner within the couple are combined to form a nominal pair. As described by Wright (2007) however, the formation of nominal groups amongst strangers is typically more arbitrary. For instance, some researchers describe combining individuals according to their presentation in the data file, while others describe “random combinations” of individuals. These methods may introduce unnecessary error because assigning individuals to a nominal group in this way

only considers the scores of one pairing, where in fact there are many possible pairings (Wright, 2007).

To account for possible errors introduced by idiosyncratic nominal group combinations, Kelley and Wright (2010) offer a statistical method of nominal group formation by which 10,000 combinations of nominal groups can be sampled from individual participant's data. Sample characteristics such as mean and variance of these groups are calculated, and a set of nominal groups that is most representative of the larger set is produced. Using the program supplied by Kelley and Wright (2010), I ran supplementary analyses in which I calculated alternate sets of nominal scores for my two experiments with strangers in Chapter 2 and Chapter 4. However, I found a problem using this method to form nominal pair scores in within-subjects designs. Virtual Week allowed within-subject manipulation of up to five different PM tasks. Calculating a set of representative nominal pairs using the data from each different PM task produced five different sets of representative nominal pairs. That is, the same individuals were not paired together consistently across all task types. This meant that within-subject comparisons effectively became between-subject comparisons. To overcome this, I calculated sets of nominal scores using individuals' overall data across all tasks. From this new set of representative nominal pairs I worked backwards to create a set of nominal pair scores for each task-type. This meant the new nominal pair scores per task type were different from the representative nominal pair scores originally calculated per task type. Nonetheless, I conducted statistical analyses using these new nominal dyad scores and I found no difference to the patterns of results or significance for any of the comparisons I made using the traditional method of pooling (i.e., data file order). Because the Kelley and Wright (2010) method produced inconsistent combinations of individuals for each nominal groups

for each task type, compromising the integrity of the within-subject comparisons, I instead adopted the traditional method and reported these results throughout my research.

The second methodological consideration relating to the nominal group is whether the strict canonical nominal group comparison used in previous collaborative recall research is the best comparison group to use for collaborative PM research. My overarching research question – similar to the research question in collaborative recall literature – was to evaluate the process costs and benefits of collaborative PM due to collaborative interactions. That is, I wanted to test if the findings of collaborative inhibition in collaborative recall literature would also be replicated in collaborative PM. I also aimed to test whether there was evidence of emergence, as predicted by Wegner et al. (1985), where the product of an efficient transactive memory system is greater than the sum of its parts. These process costs or emergent benefits can only be quantified by comparing collaborative performance to the benchmark set by a nominal group comprised of pooled individual performance, where interactions are not present; that is, collaborative and nominal groups are matched in terms of the number of individuals within them, and the only difference between conditions is the presence or absence of collaborative interaction.

While the nominal group comparison is important when measuring processing costs, it is nonetheless a very high comparative benchmark to set. This same benchmark may not be particularly relevant when evaluating whether some groups will benefit from collaboration in their daily life. For instance, when one group member has impaired memory, such as the ABI patient couples reported in Chapter 5, a comparison to a hypothetical nominal group has little practical relevance. What is more relevant in this case is an evaluation of the real-world effect of collaboration measured in gains or losses for each individual. With nominal scores there is also an implicit assumption that all nominal group members have similar memory ability, and this is not true in the case of ABI patient

couples (or other groups who have PM difficulties due to aging, brain injury, or neurodegenerative conditions). Pooling across individuals can mask quite different patterns of performance within groups. Given this, in Chapter 5 I benchmarked collaborative group performance against both nominal scores and individual scores (for the patient and their healthy spouse separately), and using this methodology found that although there were benefits for the patients, there were costs for the spouse. These findings would not have emerged if only the nominal comparison was made. Another problem with the nominal group comparison is that it does not represent peoples' own subjective beliefs that they remember better in a group than by themselves (Henkel & Rajaram, 2011; Ross, Spencer, Blatz, & Restorick, 2008). Supporting this idea, inspection of my data from the other experiments with healthy participants showed that collaborative pairs outperformed single individuals, which is consistent with past research that makes this comparison (Weldon & Bellinger, 1997).

Given the conceptual difficulties with the nominal group outlined above, other methods to quantify the effectiveness of collaboration may need to be considered. Larson (2009) offered alternative ways to measure small group outcomes in terms of synergy. Weak synergy is group performance that exceeds individual performance of a typical group member (Larson, 2009). This is analogous to the comparison of collaborative performance to mean individual performance. Weak synergy is a useful concept because it captures the subjective gains that individuals experience when they collaborate (Ross et al., 2008). In contrast, strong synergy is group performance that exceeds the individual performance of the best group member (Larson, 2009). Taken literally, if the performance of the best group member's score is calculated per item, it is analogous to the nominal group comparison. However, an alternative reading is that the benchmark for strong synergy should be taken as the best group member's mean performance *across all items*. If

so, this is a different and lower benchmark than the nominal group. These concepts of strong and weak synergy – and the alternative comparisons they suggest – might be useful to index the effects of collaboration in future studies. It may be particularly relevant where collaboration is being considered as a compensatory strategy in individuals experiencing memory difficulties such as older adults and clinical populations.

Another consideration when choosing the appropriate comparison group to use in collaborative PM was to consider the effect of redundancy. In collaborative recall, when nominal scores are calculated by pooling the non-redundant individual items, the redundant items that are discarded are merely words on a list. In PM, redundant items mean that both individuals in a nominal dyad performed the same task. That is, the task was performed twice. In a real-world situation, such redundancy is a waste of time at best and dangerous at its worst: for example, if both parents administered the same medication to their child. The nominal group is just a hypothetical control group designed to allow the costs of collaborative processes to be determined, so these scenarios are hypothetical also. However, it may be informative in future collaborative PM research to measure the redundancy in nominal groups and somehow offset this against the gains.

Limitations and Directions for Future Research

Across the studies presented in this thesis I have identified limitations and directions for future research, which are reported in each chapter. As well as investigating the effects of collaboration on PM using the collaborative recall paradigm, my research also aimed to examine the source of the collaborative inhibition effect: that is, whether the retrospective or the prospective component was most disrupted. Although I employed a methodology utilised by other Virtual Week researchers to index the retrospective component (introducing a separate recall test), Virtual Week does not allow a direct test of recall of task content at the time of retrieval of the intention – participants select the task to

be performed from a list, rather than having to produce it themselves. Because we know that cued recall of this kind reduces collaborative inhibition effects, I added a free recall test of task content at the end of each virtual day. As I discuss in detail above (pp. 57-58), however, this is only an indirect test of memory for task content. It does not allow me to measure recall of task content at the time of task execution. Future research would be enhanced if recall of task content could be measured with a free recall task at the time of retrieval of intention instead of recognition.

My research also aimed to investigate the processes underlying individual differences in collaborative outcomes. For Chapter 3, I transcribed, divided into clauses, then carefully coded and analysed the collaborative dialogue of collaborating stranger dyads and couples who were a subset of larger samples in two experiments. The total number of clauses individually coded was 9,691. They were also double-coded by a trained assistant. Due to the time-consuming and costly nature of this task, it was only possible to transcribe a small sample of 10 stranger couples and 10 collaborating couples, which substantially reduced statistical power. This type of research provides rich data that is otherwise unavailable using quantitative methods alone, so it is worthwhile and informative to use such methods. In future studies however, it is worth considering transcribing, coding and analysing dialogue only from specific points in the Virtual Week game. This could include encoding regular tasks at the beginning of each week, encoding new task instructions at the beginning of only one day, and selecting specific portions of dialogue for one day as participants approach regular, irregular, time based, event-based, and time-check tasks when they need to monitor and perform upcoming tasks.

Another limitation in this research was that I was only able to recruit a small number of couples to participate in the study where one member of the couple had an ABI. Recruitment and testing collaborating dyads can be challenging even when the target

population is healthy young adults, as two timetables must be coordinated at once. It was especially difficult to recruit the ABI patient couples: not only due to the kind of patients required, but because the healthy spouse often had to take time off work to attend. Other factors that contributed to the difficulty in recruiting suitable couples were: (1) it was necessary to conduct the testing sessions at a hospital because ABI patients are a seizure risk, which limited available testing times to the neurology unit's outpatient clinic's working hours; (2) healthy spouses had often attended many hospital visits with their ABI patient spouse in a supporting role, and had therefore already typically given up significant work time to do so; and (3) the combination of multiple neuropsychological assessments as well as Virtual Week meant the testing sessions were long, which was also deterred potential participants who were approached. Despite the small sample recruited however, the research was novel and informative in that it focused on a real-world situation where collaboration is used as a compensatory strategy. Although it showed that collaborating with an intimate partner is helpful to patients, it can be detrimental to spouses' performance. Due to the difficulties experienced with recruiting for the ABI study described in Chapter 5 however, future research might be better directed at populations where both partners are retired, and where medical facilities are integrated with their living quarters, such as in an aged care facility.

A replication of the experiments described in Chapter 2, but with older adults in a long-term relationship, would be particularly informative. Johansson et al. (2000) showed collaborative inhibition when older adult couples worked together on a naturalistic PM task, however there were problems arising from the naturalistic context. Using a more tightly controlled PM task such as Virtual Week would address this. Similar to the study described in Chapter 5 where the effect of collaboration was evaluated in couples where one person had an ABI, it would also focus on a real-world situation where collaboration

has been reported to be a compensatory strategy (Parikh, Troyer, Maione, & Murphy, 2015). It could also resolve some of the recruitment difficulties identified above where work commitments are less likely in retired older adults.

Other future directions include examining whether couples can be instructed to use helpful group-level strategies, similar to the stranger-dyads in Chapter 4. The instructions could be tailored according to the processes described in Chapter 3 that either enhanced or diminished couples' PM performance in Chapter 2. Once this has been tested in young couples, I could extend this into populations who most need PM support: for instance, couples consisting of older adults or other clinical populations. This would enhance our knowledge of the applied value of these strategies and pave the way for future interventions or recommendations about effective PM support.

Finally, the role of social loafing in collaborative PM should be explored. This could be done by systematically increasing motivation and accountability within collaborating groups similar to Weldon et al. (2000), when they investigated whether social loafing was responsible for collaborative inhibition in recall. Questions arising from my research include an examination of whether the impact of social loafing on PM is particular to PM tasks that appear easier, whether it occurs within intimate couples, and whether it is consistent with stereotypical gender roles and responsibilities.

Conclusions

In my program of research, I aimed to examine how collaboration affected PM performance in different kinds of groups – particularly in stranger dyads and intimate couples. I also aimed to identify collaborative processes that lead to better outcomes, and to test whether people collaborating on PM tasks can be instructed to use these strategies to improve their collaborative outcomes. Finally, because enlisting the help of an intimate partner is often used as a compensatory strategy for those experiencing PM difficulties, I

aimed to evaluate the effectiveness of patients with an ABI working together with their spouses on PM tasks. I found collaborative inhibition in PM, but I also found that some collaborators were more successful than others depending on collaborative processes. I found preliminary evidence that groups can be instructed to use specific group-level PM strategies to improve collaborative outcomes and eliminate the usual costs of collaboration. These findings extend the empirical literature regarding collaborative inhibition into the PM domain, while also extending the empirical PM literature into the domain of social cognition.

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Appendix

Ethics Approvals



Catherine Browning <catherine.browning@mq.edu.au>

RE: HS Ethics Application - Approved (5201400522)(Con/Met)

1 message

Fhs Ethics <fhs.ethics@mq.edu.au>

Thu, May 8, 2014 at 10:47 AM

To: Dr Celia Harris <celia.harris@mq.edu.au>

Cc: Associate Professor Amanda Barnier <amanda.barnier@mq.edu.au>, Mrs Catherine Anne Browning <catherine.browning@students.mq.edu.au>

Dear Dr Harris,

Re: "The effect of collaboration on prospective memory performance"(5201400522)

Thank you for your recent correspondence. Your response has addressed the issues raised by the Faculty of Human Sciences Human Research Ethics Sub-Committee and approval has been granted, effective 8th May 2014. This email constitutes ethical approval only.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Associate Professor Amanda Barnier
Dr Celia Harris
Mrs Catherine Anne Browning

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).
2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 8th May 2015
Progress Report 2 Due: 8th May 2016
Progress Report 3 Due: 8th May 2017
Progress Report 4 Due: 8th May 2018
Final Report Due: 8th May 2019

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Sub-Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).
4. All amendments to the project must be reviewed and approved by the Sub-Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:
http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms
5. Please notify the Sub-Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.
6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

<http://www.mq.edu.au/policy>

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of approval to an external organisation as evidence that you have approval, please do not hesitate to contact the Ethics Secretariat at the address below.

Please retain a copy of this email as this is your official notification of ethics approval.

Yours sincerely,

Dr Simon Boag
Acting Chair
Faculty of Human Sciences
Human Research Ethics Sub-Committee

Faculty of Human Sciences - Ethics
Research Office
Level 3, Research HUB, Building C5C
Macquarie University
NSW 2109

Ph: +61 2 9850 4197
Fax: +61 2 9850 4465

Email: fhs.ethics@mq.edu.au

ADDRESS FOR ALL CORRESPONDENCE
RESEARCH ETHICS AND GOVERNANCE OFFICE
ROYAL PRINCE ALFRED HOSPITAL
CAMPERDOWN NSW 2050



Health
Sydney
Local Health District

TELEPHONE: (02) 9515 6766
FACSIMILE: (02) 9515 7176
EMAIL: sharon.falleiro@sswahs.nsw.gov.au
REFERENCE: X15-0451 & HREC/15/RPAH/599

31 March 2016

Dr L Miller
Neuropsychology Unit
Level 8, Building 89
Royal Prince Alfred Hospital

Dear Dr Miller,

Re: Protocol No X15-0451 & HREC/15/RPAH/599 - "The effects of collaboration on prospective memory functioning in people with and without an acquired brain injury."

The Executive of the Ethics Review Committee, at its meeting of 24 March 2016 considered your correspondence of 29 February 2016. In accordance with the decision made by the Ethics Review Committee, at its meeting of 9 December 2015, ethical approval is granted.

The proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research*.

This approval includes the following:

- NEAF (AU/1/F6D2212)
- Information for Participants (Master Version 2, 25 February 2016)
- Information for Partner Participants (Master Version 2, 25 February 2016)
- Participant Consent Form (Master Version 1, 25 November 2015)
- Consent to be Contacted About Research Projects (Master Version 1, 25 February 2016)
- PAIR Inventory (Master Version 2, 25 February 2016)
- Rey Auditory Verbal Learning Test (Version 1, 25 February 2016)
- Controlled Oral Word Association Test (Version 1, 25 February 2016)

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ABN 17 520 269 052
www.slhd.nsw.gov.au

- The Hayling Sentence Completion Test (Version 1, 25 February 2016)
- Mini Mental State Examination (M.M.S.E) (Version 1, 25 February 2016)
- DASS21 (Version 1, 25 February 2016)
- Caregiver Burden Scale (Version 1, 25 February 2016)
- Screenshot of Virtual Week (Rendell & Craik, 2000; Rendell & Henry, 2009)
- Intimate Bond Measure (IBM) Questionnaire (undated)
- Memory Compensation Questionnaire (MCCQ) (undated)
- Everyday Memory Strategy Checklist (undated)
- Comprehensive Assessment of Prospective Memory (CAPM) – Patient (undated)
- Comprehensive Assessment of Prospective Memory (CAPM) - Spouse/Partner's Version (undated)
- Debriefing Information Sheet (undated)

You are asked to note the following:

- **This letter constitutes ethical approval only.**
- **You must NOT commence this research project at ANY site until you have submitted a Site Specific Assessment Form to the Research Governance Officer and received separate authorisation from the Chief Executive or delegate of that site.**

On the basis of this ethics approval, authorisation may be sought to conduct this study within any NSW public health organisation and/or within any private organisation which has entered into an appropriate memorandum of understanding with the Sydney Local Health District, Sydney Local Health Network or the Sydney South West Area Health Service.

The Committee noted that authorisation will be sought to conduct the study at the following sites:

- Royal Prince Alfred Hospital
- This approval is valid for four years, and the Committee requires that you furnish it with annual reports on the study's progress beginning in **April 2017**. If recruitment is ongoing at the conclusion of the four year approval period, a full re-submission will be required. Ethics approval will continue during the re-approval process.
- This human research ethics committee (HREC) has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review and is constituted and operates in accordance with the National

Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research* and the CPMP/ICH Note for Guidance on Good Clinical Practice.

- You must immediately report anything which might warrant review of ethical approval of the project in the specified format, including unforeseen events that might affect continued ethical acceptability of the project.
- You must notify the HREC of proposed changes to the research protocol or conduct of the research in the specified format.
- You must notify the HREC and other participating sites, giving reasons, if the project is discontinued at a site before the expected date of completion.
- If you or any of your co-investigators are University of Sydney employees or have a conjoint appointment, you are responsible for informing the University's Risk Management Office of this approval, so that you can be appropriately indemnified.
- Where appropriate, the Committee recommends that you consult with your Medical Defence Union to ensure that you are adequately covered for the purposes of conducting this study.

Should you have any queries about the Committee's consideration of your project, please contact me. The Committee's Terms of Reference, Standard Operating Procedures, membership and standard forms are available from the Sydney Local Health District website.

A copy of this letter must be forwarded to all site investigators for submission to the relevant Research Governance Officer.

The Ethics Review Committee wishes you every success in your research.

Yours sincerely,



Sharon Falleiro
Executive Officer
Ethics Review Committee (RPAH Zone)

HERC\EXCOR\16-03

Office of the Deputy Vice-Chancellor
(Research)

Research Office
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NSW 2109 Australia
T: +61 (2) 9850 4459
<http://www.research.mq.edu.au/>
ABN 90 952 801 237



3 May 2016

Dear Professor Barnier

Reference No: 5201600313

Title: *The effects of collaboration on prospective memory functioning in people with and without an acquired brain injury*

Thank you for submitting the above application for ethical and scientific review. Your application was considered by the Macquarie University Human Research Ethics Committee (HREC (Medical Sciences)).

I am pleased to advise that ethical and scientific approval has been granted for this project to be conducted at:

- Macquarie University

This research meets the requirements set out in the *National Statement on Ethical Conduct in Human Research* (2007 – Updated May 2015) (the *National Statement*).

Standard Conditions of Approval:

1. Continuing compliance with the requirements of the *National Statement*, which is available at the following website:

<http://www.nhmrc.gov.au/book/national-statement-ethical-conduct-human-research>

2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol.

3. All adverse events, including events which might affect the continued ethical and scientific acceptability of the project, must be reported to the HREC within 72 hours.

4. Proposed changes to the protocol and associated documents must be submitted to the Committee for approval before implementation.

It is the responsibility of the Chief investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Ethics Secretariat on 9850 4194 or by email ethics.secretariat@mq.edu.au

The HREC (Medical Sciences) Terms of Reference and Standard Operating Procedures are available from the Research Office website at:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics

The HREC (Medical Sciences) wishes you every success in your research.

Yours sincerely

A handwritten signature in black ink, appearing to read 'Tony Eyers', with a stylized flourish at the end.

Professor Tony Eyers

Chair, Macquarie University Human Research Ethics Committee (Medical Sciences)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.

ADDRESS FOR ALL CORRESPONDENCE
 RESEARCH ETHICS AND GOVERNANCE OFFICE
 ROYAL PRINCE ALFRED HOSPITAL
 CAMPERDOWN NSW 2050
 TELEPHONE: (02) 9515 7899
 FACSIMILE: (02) 9515 7176
 EMAIL: maree.larkin@sswhs.nsw.gov.au
 REFERENCE: X15-0451



Health
 Sydney
 Local Health District

22 April 2016

Dr L Miller
 Neuropsychology Unit
 Level 8, Building 89
 Royal Prince Alfred Hospital

Dear Dr Miller,

Re: Protocol No X15-0451 - "The effects of collaboration on prospective memory functioning in people with and without an acquired brain injury."

HREC/15/RPAH/599

SSA/16/RPAH/192

Thank you for submitting a Site Specific Assessment Form (AU/2/5785211) for this study. I am pleased to inform you that authorisation has been granted for it to be undertaken at the **Royal Prince Alfred Hospital**.

The approved information and consent documents for use at this site are:

- **Information for Participants (RPAH Version 1, 13 April 2016) based on Master Version 2, 25 February 2016**
- **Information for Partner Participants (RPAH Version 1, 13 April 2016) based on Master Version 2, 25 February 2016**
- **Participant Consent Form (RPAH Version 1, 13 April 2016) based on Master Version 1, 25 November 2015**
- **Consent to be Contacted About Research Projects (RPAH Version 1, 13 April 2016) based on Master Version 1, 25 February 2016**

The following conditions apply to this research study. These are additional to those conditions imposed by the human research ethics committee (HREC) that granted ethical approval:

1. When required, the appropriate documentation must be submitted to me for authorisation before any new external researcher is authorised to be on-site for the project.
2. Proposed amendments to the research protocol or conduct of the research, which may affect the ethical acceptability of the study and which are submitted to the lead HREC for review, must be copied to me.
3. Proposed amendments to the research protocol or conduct of the research, which may affect the ongoing site acceptability of the study, must be submitted to me.

I wish you every success in your research.

Yours sincerely,

Maree Larkin
Research Governance Officer
SLHD (RPAH Zone)

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