

MASTER

Reminding systems aiding prospective memory receiving reminders of the right time?

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Reminding systems aiding prospective memory
Receiving reminders *at the right time?*

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Summary

Reminder systems are systems that prompt people about what they intended to do. These systems can thereby prevent people from forgetting intentions. Though evaluation studies show that reminder systems can be effective in preventing forgetting, it remains unclear what makes a reminder systems effective. Research on prospective memory (PM), which is memory for intentions, falls short in providing knowledge on what causes prospective forgetting. The current thesis aims to bring prospective memory and reminding systems research together in order to gain a better understanding of how reminders can support prospective memory. A demonstration study was conducted, in which reminders were introduced in a prospective memory experiment.

The experiment comprised a within-subject design with 4 conditions, varying the length of the delay between receiving a reminder and the possibility to execute a prospective memory task. Delays of 0-1 minutes, 1-2 minutes, 3-4 minutes and 5-6 minutes were used, counterbalanced between participants (58 participants) to control for order effects. The research question was 'what is the effect on performance of the length of a delay between receiving a reminder and executing a prospective memory task?'. Three aspects were considered in answering the research question: prospective memory performance, performance on the ongoing task and clock checking behavior. Results showed that prospective forgetting (operationalized as not being in time for a PM task) increased with longer delays, and that clock checking occurred more often in longer delays both in absolute terms (in a block of seven minutes) and in relative terms (clock checking frequency per minute). Participants also tried to start with the PM task too early when the delay was long. Monitoring the clock and moving to the PM task slowed down reaction time on the ongoing tasks. However, this did not result in longer RTs in blocks with a longer delay. Possibly the ongoing tasks used in this experiment are more or less robust to switches in attention. All in all it seems that, short delays are more beneficial for performance than long ones.

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1. General Introduction

Imagine the following: You are working in your office, writing an article and you realize that you need to look up an article of another researcher whose work you want to refer to. You start searching in your archive and as you are busily engaged in your search, you totally forget about the time. Only half an hour later, you suddenly realize that the meeting you had to attend started fifteen minutes ago.

Sound familiar? In our daily work, but also at home, we have plans about what we want to do that day or week, like attending a meeting. However, for various reasons, we sometimes forget to execute these plans. Memory for intentions or plans is called *prospective memory*. Failures of prospective memory are not always problematic. In the example of missing the meeting you planned to go to, maybe you even like it that you forgot about it because it would be boring anyway. However, failures of prospective memory can cause serious problems in many cases, for example, when it comes to having to take medicines at a specific time.

Because forgetting intentions can sometimes cause problems, it would be very nice if we had a system that would prevent us from forgetting. The system would remind us at the right moment that we should not forget to do such and such. And indeed, such systems exist: they are called *reminding systems*. Evaluation studies show that reminding systems can to some extent prevent problems of prospective memory, but little is known about how we interact with these systems and the conditions under which they work. What makes such a system effective? How does it support prospective memory? Are there key features which influence the effectiveness of a reminder?

To gain more insight into how reminder systems can effectively support prospective memory, studying both reminder systems and prospective memory may be beneficial. This thesis attempts to combine the experimental study of prospective memory with the more pragmatic field of reminding systems. The first part of the thesis gives a theoretical account of both research fields and how they can be combined. The second part of the thesis provides a demonstration of how this combined research can take place.

The research question addressed in this thesis concerns the influence of time between receiving a reminder and executing a prospective memory task. The question is: “what is the effect of the length of a delay between receiving a reminder and

executing a prospective memory task on prospective memory performance, ongoing task performance and clock checking behavior?" A long delay between receiving a reminder and executing the task may have a negative effect on prospective memory performance; the to-be-remembered task can be forgotten. A long time between the reminder and the task furthermore may lead to worse performance on the ongoing task (that is, the main task) since during this period the intended action has to be remembered by self-reminding. During the time between receiving a reminder and executing the intended action, one may need to check the clock frequently in order to be in time for the to-be-remembered task.

This research question will be addressed in an experiment. The experiment serves a general and a specific goal, respectively to shed some light on how prospective memory and reminding systems interact and in particular the role of timing of reminders, and to serve as an example of how research combining reminding systems and prospective memory could take form.

The thesis is structured as follows: In the first part, a literature review of prospective memory research will be given (Chapter 2), and then literature on reminding systems is reviewed (Chapter 3). In Chapter 4, I will argue that a combined research approach may prove more fruitful when the objective is to support prospective memory. I will also describe in this chapter how this combined research could take form. The second part starts with an introduction to the research question (Chapter 5). The chapters that follow report the experiment that was conducted to answer the research question, Chapter 6 therefore deals with the methodology, Chapter 7 reports the results, Chapter 8 discusses the results and Chapter 9 will serve as an overall conclusion to the thesis.

2. Literature review of prospective memory research

2.1 Introduction

When one wants to know how prospective memory can be supported best, one first needs to know what prospective memory is, including a general idea of how it may work and how it can be studied. Therefore, this chapter offers a literature review of prospective memory. It will start with a definition of prospective memory and what is special about prospective memory, and then a general review follows on the theories that play a central role in the area. After that, a discussion follows on the cognitive processes that are assumed to underlie prospective memory performance. The chapter ends by giving an account of how prospective memory is currently studied in laboratory settings and how the lab setting could gain more ecological validity.

2.2 Definition of prospective memory

Prospective memory is memory for intended plans or actions. By definition, prospective memory is a specific kind of *memory*. It is the memory that is concerned with events that are still to take place, so it concerns future events. This is in contrast to *retrospective memory*, which concerns past events. Both *prospective* and *retrospective memory* are part of *autobiographical memory*. Autobiographical memory is the memory for events in one's personal life (Roediger, Marsh & Lee, 2002).

Because prospective memory is part of autobiographic memory, it concerns everyday life events which we are all familiar with. Let's take an everyday situation as an example to show some general rules of (prospective) memory.

A woman stands up in the morning. She walks to the kitchen and makes some coffee. As she opens the fridge to fetch the milk, she notices that the milk carton is almost empty. At that moment she forms the intention to drop by the grocery store in the afternoon to buy some milk.

In the example, the woman forms the intention to buy milk and retains this intention in memory until the time is right to execute this intention. Memory in general can be

seen as taking in information at time X and taking the same piece of information out at time $X+n$.

Whatever one's ideas about how prospective memory works, we can all acknowledge that several things may go wrong before the woman buys the milk. First, her memory might be a little distorted; that is, she may remember her intention incorrectly, namely that she has to buy milk *tomorrow*. Second, the woman may have forgotten totally about her intention to buy milk in the afternoon: If her husband asked her whether she needs to buy something in the afternoon, she would reply that they do not need anything. Third, she may think of buying milk on the way home when she gets into her car in the afternoon, but then forget to stop when she passes the shop.

The interesting part of prospective memory is that not only "*the what*" has to be remembered, but also "*the when*." For prospective memory to be successful, the intention should come into our mind *at the right time*.

2.3 *Time-based versus event-based prospective memory tasks*

In the prospective memory literature, two types of tasks for the memory system are distinguished, namely event-based tasks and time-based tasks. An example of an event-based task is to remember to ask your colleague something as soon as you meet him again. 'Meeting the colleague' is in this case the event (or cue) that should elicit the execution of the planned action. An example of a time-based task is to remember to take your medicines at 18:00. In this case, the planned action is to be executed at a specific point in time. In general, time-based tasks are harder to fulfill than event-based tasks (Henry, MacLeod, Philips, & Crawford, 2004). Probably, event-based tasks are easier because there is a cue in the environment which brings back the memory of the intention. In time-based tasks, such a cue is absent. Both types of tasks are used in laboratory studies of prospective memory and typically the studies show that, as with all kinds of human memory, prospective memory is prone to errors (Einstein & McDaniel, 1990; Einstein et al. 1995; Maylor, 1996).

2.4 *Why would prospective forgetting occur?*

Errors of prospective memory are interesting to study because they shed more light on the general question of how prospective memory functions. First a few theories will be discussed that try to describe how prospective memory functions, followed by hypotheses on why forgetting of intended actions occurs.

Most prospective memory researchers use terms stemming from the information processing account of memory. According to this information processing account, memory in general works as follows. First, information is encoded, in other words, it is turned into a mental representation (Eysenck & Keane, 2000). This can be compared to the process that takes place in a digital camera when taking a picture: visual information is encoded in the memory store of the camera into zeros and ones. Second, information is kept in memory by a process called retention. Third, information is retrieved from memory by a process called retrieval. Encoding, retention and retrieval should work well to be able to retrieve the information correctly (Tulving & Thompson, 1973).

Besides general theories on memory, a host of theories have been created to describe how prospective memory functions. Although there seem to be many different theories in the field of prospective memory, most come down to the same idea; they focus almost solely on retrieval. Most likely, the focus on retrieval is central in PM theories, because retrieval is the most characteristic part of prospective memory: the intention has to come into mind *at the right time*. There are two types of theories on prospective memory, namely those that view the retrieval process as one, inseparable whole, and those that view the retrieval process as a process consisting of two parts. To start with the later, in many theories the retrieval process is thought to consist of two separate, consecutive stages. One of the better known examples of such a theory is the early theory of Einstein and McDaniel (1996), the Noticing+Search theory. According to this theory, a person first needs to notice the cue or event as something that signals a prospective action. The second stage is searching for the memory content of what needs to be done. Maylor (1993) offers a similar theory describing the retrieval process in two stages, in which she calls the first stage of retrieval *memory for intention* and the second stage *memory for content*.

Besides two-stage models, there are also models that regard the retrieval process as one inseparable whole, such as McDaniel, Robinson-Riegler and Einstein's (1998) *associative memory system model*. According to this model, the cue is encoded together with the intended action during the encoding phase. In the retrieval phase, when the cue arrives, the complete memory trace is recovered. This memory trace consists not only of the awareness that the cue signals that an action has to be undertaken, but also of the details of the intended action.

How could it be that prospective forgetting occurs? When assuming a two-stage model, prospective memory failure could stem from either stage. Some researchers have used laboratory tests that are able to distinguish between the two stages, and they have shown that a participant can fail in the second stage while succeed in the first (Maylor, 1993). In everyday life, failure in either the first or second stage would result in the intended action not being executed.

But acknowledging that failure of PM may result from a failure in one of the two stages of retrieval is still no answer on the question what causes prospective forgetting. Three answers on this question are worth mentioning. First, according to Craik and Kerr (1996, in West & Craik, 1999), prospective forgetting occurs due to Momentary Lapses of Intention (MLIs). MLIs are moments in which the intention falls below conscious awareness. Second, when taking the Noticing+Search model as a starting point, intended actions may not be executed because the cue is not noticed (Cohen, Dixon, Lindsay & Masson, 2003). Cohen et al. argued that when the cue is perceptually salient it may prove more effective in bringing the intention into conscious awareness. A third possible reason that prospective forgetting occurs is that the participant is simply too burdened by the ongoing task and thus no cognitive resources are left to either notice a cue/event or think about the fact that other things (namely the prospective memory task) should be done beside the concurrent task. This third answer prompted a debate in the field about the role of cognitive resources in prospective memory tasks. For this reason, we will focus for a moment on the issue of cognitive resources.

2.5 The role of cognitive resources in prospective memory performance

Several theories in the field make competing predictions on whether retrieval in prospective memory requires cognitive resources. The associative memory system model (McDaniel, Robinson-Riegler, & Einstein, 1998) predicts that retrieval of the memory trace is automatic and requires no cognitive resources. The earlier model of Einstein and McDaniel (1996), the Noticing+Search model, predicts that the noticing part of the retrieval process does not require resources, but the search part is under voluntary control and requires cognitive resources. Their latest Multiprocess Model (McDaniel & Einstein, 2000) incorporates both ideas: some prospective memory tasks require cognitive resources and others do not. Roediger, Weldon and Challis (1989) take a comparable stand with their Transfer Appropriate Processing (TAP)

hypothesis. The TAP hypothesis states that the more similar the processes required for the ongoing task and cue detection are (cue detection means noticing the event/cue which signals that a certain intention has to be executed), the higher the chances of successful prospective memory task performance. Thus the degree of similarity between the two types of tasks would be a predictor of whether the prospective memory task interferes with the ongoing task. For example, switching between different levels of processing¹ may be resource demanding and thus increase the likelihood of forgetting. Roediger, Weldon and Challis (1989) manipulated the levels of processing needed for performance on the ongoing task and on the prospective memory task. When the level of processing differed between the two types of tasks, performance on the PM task was lower than when the tasks required the same level of processing.

These competing theories find their origin in contrasting findings; in some experiments adding a PM task to the ongoing task seems to go without costs on the ongoing task performance (Einstein et al., 2000; Cohen & Gollwitzer, in press), whereas other experiments (e.g., Einstein et al., 1997; Marsh & Hicks, 1998) show decreased ongoing task performance when a prospective memory task is added. The reason for these seemingly contradictory results may be that different researchers use different ongoing tasks and different events in the event-based paradigm. Although walking and talking both require mental resources, we are perfectly able to combine the two. Apparently, those tasks require *different* cognitive resources and consequently performance on the one task does not interact with performance on the other task. In the same way as walking and talking can be easily combined, some ongoing tasks may be easily combined with prospective memory tasks. The explanation for the different findings thus may be that the researchers used tasks that require different or the same resources instead of using PM tasks that require resources or that require no resources.

If a prospective memory task requires cognitive resources, the question arises: what kind of cognitive resources are required for successful PM performance? One answer to this question is that retrieval in prospective memory functions through working memory (this idea is supported, amongst others, by Marsh & Hicks, 1998;

¹ Levels of processing in the sense of Craik and Lockhart (1972): stimuli can be processed on several levels, e.g., on a semantic or perceptual level. The “deeper” the level of processing, the better the information is retained in memory. Manipulating the level of processing is one of the many ways of achieving similarity in the TAP hypothesis.

Park et al., 1997; McDaniel & Einstein, 2000). Working memory is “a system for temporarily holding and manipulating information as part of essential cognitive tasks such as learning, reasoning and comprehending” (p. 49, Baddeley, 1997). According to the *multicomponent model of working memory* (Baddeley & Hitch, 1974, in Baddeley, 1997), working memory consists of three components: 1) the visuo-spatial sketchpad, 2) phonological loop, and 3) the central executive. The first two components are slave-systems that serve the central executive. The central executive is supposed to, among other things, combine information, direct attention, and coordinate cognitive processes in a dual-task situation. Information that is processed comes from different sources, namely internal or external sources. External sources are the sensory inputs, whereas internal sources are sources within the person, for instance, short term memory (STM) or long term memory (LTM).

What are the reasons to assume that working memory is one of the cognitive resources required for successful PM performance? First of all, the central executive is believed to be responsible for coordinating cognitive processes when several processes should run in parallel (Baddeley, 1997). Prospective memory tasks in real life are always embedded in other tasks (you don't wait all day until it is 18 o'clock when you have to take your medicines, doing nothing at all). Consequently, PM tasks always require multi-tasking and are thus believed to be coordinated by the central executive. Secondly, the central executive is thought to combine information from different sources (Baddeley, 1997), such as LTM. LTM is needed in many PM tasks as we may form an intention to do something tomorrow, next week or even next month. This intention presumably needs to be stored in long term memory to retain it over such a long time. Retrieval of the intention requires information from LTM to come into conscious attention, which is the task of the central executive. Thirdly, the central executive is hypothesized to direct attention (Baddeley, 1997), and attention is needed to become aware of the fact that a given intention requires action at a given moment. Fourth, working memory has limited capacity, which can result in lower performance on one task when a second task is added (Baddeley, 1997). This decrease in performance is sometimes found on the ongoing task in prospective memory experiments. For these reasons, this thesis uses the assumption that working memory is the main mechanism underlying prospective memory.

2.6 Similarities and differences with standard dual-task paradigms

As the reader may have noticed, prospective memory tasks bear resemblance with standard dual-task paradigms. For example, prospective memory tasks are always embedded in other tasks. Therefore, prospective memory performance at least implies dual-tasking. As a consequence, prospective memory tasks require cognitive resources to be distributed over the different tasks, just as in standard dual-task situations. Another consequence of multi-tasking is that it often shows our limited capacity; one task may interfere with performance on the other. Furthermore, both multi-tasking and prospective memory tasks require switches in attention between the tasks. Another similarity is that the tasks used in experimental settings in prospective memory studies and divided attention studies are short duration tasks: tasks typically take a few hundreds of milliseconds, although the tasks in the prospective memory studies do not need to be that short.

Given these similarities, prospective memory tasks can be seen as a special type of dual-tasking. There is, however also a large difference between standard dual-task experiments and prospective memory experiments. In standard dual-task experiments, both tasks require judgments or actions in response to information stemming from external sources. A task in a traditional attention experiment for instance is to search for a blue L among letters with different colors. In a prospective memory experiment, working memory has to divide attention between information stemming from external sources (e.g., the environment) and information stemming from internal (memory) processes. Performing the ongoing task requires attention to be directed at the environment and performing the prospective memory task at the right time requires attention to be directed at memory.

2.7 The standard PM paradigm and its ecological (in)validity

Let us now turn to how this special type of dual-task is studied in the experimental setting. In the 1990s, Einstein and McDaniel (1990; see also Einstein et al., 1995) developed a method for studying prospective memory in the lab. Their method is widely accepted and used by the research community.

Experimental studies investigating prospective memory ask participants to stay busy with a main task (called the *ongoing task*) and occasionally respond to either a specific cue (*event*, in the event-based paradigm) or at a specified *time* (in the time-based paradigm) by pressing a key. The ongoing task and the prospective memory

task (the intended action) are often tasks that can be executed in a few hundreds of milliseconds. An example of an ongoing task is a lexical decision task (e.g., 'press Y for a word, press N for a non-word'), which per stimulus takes only a few hundreds of milliseconds to respond. The prospective memory task in event-based studies often is a task in which the participant has to respond to changes in the visual field, for example, the words of the ongoing task are printed normally in black, and when the words come up in blue, the participant is to press F1 and otherwise to respond with Y or N for the ongoing task. The prospective memory task in the time-based paradigm asks participants to respond at specific intervals, for instance every 5 minutes, by pressing a certain key ('press F1 every 5 minutes'). In the time-based paradigm, participants are provided with a clock that enables them to check the time and decide if the time is right to execute the PM task. Forgetting in time-based PM tasks is the absence of the required action at the specified time, and in event-based PM tasks forgetting is the absence of a the required action to the cue.

Because this thesis focused on supporting prospective memory in daily life, the ecological validity of the methodology is regarded as an important issue. We are interested in information about how prospective memory can best be supported in real world situations, and therefore we aim to mimic the real world situation of prospective memory tasks. The standard PM paradigm was believed to evoke different behavior than the everyday life settings. Several issues surrounding ecological validity in the standard PM paradigm, along with how the methodology could be changed to resemble a more naturalistic setting, are discussed in the following sections.

2.7.1 Use ongoing tasks that take at least 20 seconds

Einstein and McDaniel's (1990) paradigm requires participants to respond immediately to a specific cue. In real life, people may postpone the prospective memory action a few minutes when they are reminded of it because they first want or need to finish (part of) their ongoing task. For example, if Jane wants to ask her colleague something as soon as she meets him, and she sees the colleague passing by her office, she might first finish reading the email she just opened before walking to the office of her colleague. If one has to take medicines at 18 o'clock, but the person is driving home at that time, most likely the person will wait to take the medicines until s/he gets home. Therefore, in everyday life, not executing the intended action

precisely at the intended time does not always reflect forgetting, but might just be a choice to delay the action for a few minutes. Standard prospective memory paradigms leave no room for this possibility of delaying.

Because in everyday life situations people choose to immediately perform a PM task or sometimes to delay it a few minutes, the experimental paradigm should also incorporate the possibility to choose when to execute the PM task. The choice to postpone the execution of an intention may lead to forgetting of the intention. Inserting the possibility of delaying an intention therefore can lead to different behavior than without this possibility. When an intention can be delayed, this would allow a participant to respond within a certain window of time, instead of forcing the participant to respond immediately when the time is right. This window of time subsequently will be called the *window of opportunity*.

Introducing a window of opportunity of for instance 1 minute has consequences for the duration of the ongoing task. Namely, when the duration of a task is very short, it does not seem reasonable to decide halfway to interrupt it and move on the PM task. For instance, a lexical decision task of about 100 milliseconds is not the kind of task someone would interrupt. To offer this possibility of switching to the PM task while one of the ongoing tasks is not completed, would require ongoing tasks of at least 20 seconds.

Besides the fact that a window of opportunity requires ongoing tasks that take a while, it is also more naturalistic to use ongoing tasks that take somewhat longer than a few hundred milliseconds. In general, the duration of tasks executed in the office environment are more a matter of minutes than of milliseconds.

2.7.2 Task switching: use a PM task that takes a while

In naturalistic prospective memory tasks, people have to switch between their tasks. When one sees his or her colleague, one has to stand up and walk to the other office. What becomes clear from this example is that a everyday prospective memory tasks involve task switching in which the PM task takes some time and is executed in another context. Asking participants to press F1 is not a switch of a comparable duration to those everyday PM tasks, as the participant might press the key with the left hand and in the mean time move on with responding on the ongoing tasks with the right hand. Taking a PM task of a longer duration can improve the sense of task switching. Therefore, a requirement for a more naturalistic PM task is that the PM

task should take some time and preferably be executed in a different context, e.g., a different room or a different screen on the computer.

2.7.3 Use attention demanding ongoing tasks

In everyday life, we are most prone to prospective forgetting when we are busily engaged in other activities. An ecologically valid method for studying PM performance would therefore keep the participant 'busily engaged' in the ongoing task. Being busily engaged results in the situation where no cognitive resources are left to remember to execute the PM task in time. Such a situation shows our limited capacities, probably the limited capacities of working memory. One way to mimic this situation of depleted working memory capacity is to use tasks that absorb ones attention. As all attention goes to the ongoing task, no processing capacity is left to evaluate whether other things need to be done. A naturalistic setting therefore incorporates attention demanding ongoing tasks.

2.7.4 Incorporate process measures

In daily life, not executing an intention may be caused by the lack of thoughts about the intention at the appropriate time. It might well be that there were thoughts about the intention during the day, but just not at the right time. The standard prospective memory experiments only look at the outcome of the process: the task is executed at the right time or not. But in this case, no distinction can be made about whether the participant did not about the PM task at all, or just did not think about it at the right time. It also would be interesting and useful to know whether the participant was aware sometime during the experiment of the task that still had to be done. This awareness of the still-to-be-executed task is possibly reflected in process measures. Process measures are measures that are assumed to reflect (or tap into) the cognitive processes underlying task performance (Payne, Bettman, and Johnson, 1993). Looking only at the outcome of the process is not always informative about what happened in between. To give the researcher a better idea of what happened in between, process measures could be incorporated in the experiment.

2.8 Summary of the literature review of prospective memory research

From this literature review, a few main points become clear. Prospective memory is a specific kind of autobiographic memory. It concerns intended future

actions. The characteristic aspect of prospective memory is that retrieval has to occur at a specific moment in time and is self-initiated.

Another characteristic of prospective memory is that it always concerns multi-task situations: the prospective memory task is always embedded in other tasks. Therefore, PM tasks require task switching and monitoring if the right time for executing the PM task has arrived. This monitoring requires cognitive resources, and more specifically, it is likely to be an additional demand on the central executive. The central executive is to direct attention to the appropriate task at hand. When the main task is attention demanding this taxes the ability of the central executive to direct attention away from the main task and to direct it to the PM task. Consequently, when the main task is attention demanding, the likelihood increases that the PM task is forgotten. The problem of prospective memory is not so much that the intention cannot be retrieved, but that the intention is not retrieved at the required moment.

Prospective memory is usually studied in laboratory settings that incorporate a standard method: participants are kept busy with an ongoing task and are supposed to respond occasionally to a specific cue. These traditional PM experiments fall short at a few points in their ecological validity. Issues of ecological validity are of importance for this thesis because the aim is to support prospective memory in real world situations. To solve these problems of ecological validity, the author suggests to use attention demanding ongoing and prospective memory tasks that take at least 20 seconds and to incorporate a window of opportunity in which the PM task can be executed. To gain more insight into the processes of remembering and forgetting intentions, process measures could be incorporated in the experiments.

Because the current laboratory paradigms lack ecological validity, it is hard to generalize findings from prospective memory research to the applied field of reminding technologies. It was suggested that a more naturalistic setting would evoke different behavior. Because reminding technologies are technologies that can be used in everyday settings, it is important to mimic these settings. For people suffering from prospective memory failures, it would be interesting to know how prospective memory can be supported. The 'art' of supporting prospective memory is discussed in literature on reminding technologies, which will be the focus of attention of the next chapter.

3. Literature review of reminding systems research

3.1 Introduction

We are all familiar with the occasional failing of our prospective memory. You might form the intention of buying milk later while eating your breakfast, but in the afternoon you may forget all about the milk. To prevent forgetting, you can use reminders. Older individuals are known to have more trouble with prospective memory than youngsters (West & Craik, 1999). Elderly people are also known to build quite sophisticated systems to remind themselves of things they have to do. Possibly, people are aware when their natural memory system can use some help. Cohen-Mansfield, Creedon, Malone, Kirkpatrick, Dutra, and Herman (2005) conducted a field study among elderly people to see what kind of reminder systems older individuals currently use. The study showed that the participants often used sticky notes or alarm clocks to remind themselves to do something. Another method was to place medicines at a spot they encountered at the time that the medicines had to be taken (e.g., on top of the coffee machine). Every external method² that is used to prevent ourselves from forgetting what we intend to do can be called a reminding system. Whatever kind of reminder system used, it typically changes a time-based task, which is difficult, into an event-based task.

In this chapter, I first will identify user groups who may need reminding systems. The question of why this thesis focuses on technology (as opposed to paper-and-pencil methods) then will be addressed. Furthermore, some existing reminding technologies will be presented. Finally, I will discuss why there is still little knowledge on what technologies work best and why they would work best.

3.2 User groups for reminding systems

There are specific groups that have problems with PM. For the design of new technologies, it is useful to consider which are the target groups who could use supportive systems for PM. Also in reviewing existing memory aiding technologies, it is important to keep in mind at which group the technology was targeted.

A few target groups would especially benefit from reminding technologies, such as elderly people. Given the fact that in the western world the number of elderly is

² Internal methods would be, for example, rehearsal.

growing rapidly, problems with PM performance will become of increasing interest, because so many will suffer from these problems. In The Netherlands, like in other countries, there is a policy to try to support elderly to stay in their own home as long as possible. To prolong independent living, people can benefit from aids that help them overcome their daily (little) problems (Huppert et al., 2000). Besides the fact that normal aging leads to declines in PM, dementia is another phenomenon that is associated with PM declines (Huppert et al., 2000). A third group with PM problems is a very differentiated group of people with neurological deficits, sometimes caused by a disease, but also frequently caused by accidents. The latter group suffers from what is called Traumatic Brain Injury (TBI). A fourth group with PM problems includes virtually anyone who is busy: The fact that PM performance declines with age does not imply that PM performance is close to perfect in younger adults. Research shows that if cognitive demands on the background tasks are high, PM performance suffers (Park et al., 1997). Consequently, healthy younger people also could benefit from support of their prospective memory.

3.3 Why technology?

There are many ways to prevent people from forgetting their intentions, which range from paper-and-pencil methods (e.g., sticky notes), asking other people to remind them, placing reminders at places which are part of their daily routine, alarm clocks, and more advanced technologies. This thesis focuses on technology as a possible solution for memory problems. There are several reasons for this choice, which are listed below.

In everyday life, event-based prospective memory tasks are tasks that have to be executed after encountering a specific event. These events can be created by placing cues or reminders in the environment. These cues or reminders can be initiated by technologies. For example, many people use cooking timers in the kitchen to prompt them when the cake is ready. Therefore, cooking timers may be helpful for reminding of other activities (and indeed, this is the kind of technology older people report to use). In Cohen-Mansfield et al.'s (2005) research, participants (mean age was 78 with a range from 65 to 91) reported that they normally used one to seven memory aids, including calendars, address books, paper notes, cooking timers, alarm clocks, and other people to remind them of the things they foresaw to forget.

Memory aiding technologies can in general be classified as a compensatory strategy, that is, these technologies can compensate for memory deficits. Cognitive prosthetics for example can function as such a compensatory strategy that changes the participants' environment, with the goal being to improve the functional skills³ of the patient (Kirsch and Levine, 1978, in Cole, 1999). Another way for memory rehabilitation is restitution-oriented therapy (Evans, 2006). However, according to Evans (2006), no evidence is yet available from research that shows the effectiveness of this kind of therapies. Because research shows that compensatory strategies can be effective in supporting memory, as we will see later on in this paper, and because the aim of this paper is to gain more insight into how PM can effectively be supported, compensatory strategies will be the focus of current paper.

Memory aiding technologies range from paper-and-pencil methods to state-of-the-art technologies like PDAs. The question is whether advanced technologies are preferable to the old-fashioned methods. One advantage of advanced technologies is that they can cue people at a specific time, and at the same time include information about what has to be done⁴. Another advantage of electronic devices is that the acknowledgment of cues can be monitored, both by outsiders like caregivers and by the patient himself / herself⁵. Acknowledgement of cues is recorded in the system and can be looked up later on, for example when one doubts whether s/he already took the medication today, one can look up whether s/he responded to the prompt (which can serve as an indication of whether or not the medication was taken).

Cohen-Mansfield and colleagues' (2005) research showed some other reasons for why electronic devices would be preferable. Participants indicated that they used paper notes, alarm clocks, calendars, and all other kinds of reminders. However, they were interested in using new devices, as they reported problems such as forgetting to look, update or use notes, calendar and so forth (15% of the participants), and losing or misplacing the reminder (6% of the participants). Setting up complex reminder

³ Functional skills are for instance being able to provide yourself with dinner, independently, or being able to take your medicine without support of other people.

⁴ Timing can also be provided by a watch that rings at preset times. Hersh and Treadgold (1994) rightly noted that watches do not provide explanatory read-out. Paper-and-pencil methods lack in the fact that they do not provide an accurate alarm-timing cue. Combinations of course can be useful, but can be burdensome. Cohen-Mansfield et al. (2005) showed that some participants chose to go through great lengths in setting up complex reminding systems. Participants indicated to prefer electronic aids that include both timing and information about the to-be-performed activity.

⁵ By 'acknowledgment of cues' it is meant that the person responds to the cue by indicating to the system that s/he saw the reminder. The reminding system asks for a response and records the response.

systems appears to be quite common. An electronic device could therefore be easier and more user-friendly in reaching the goal (i.e., by preventing the forgetting of intentions). Other benefits could be automated scheduling and alerting, consistency of procedures, feedback over use and non-use (also towards caregivers) and the availability for timed-prompts.

3.4 Some available technologies in aiding memory

Most of the currently available memory-aiding technologies are not specifically aimed at problems with prospective memory. However, because scheduling and reminding problems (which can be considered as PM problems) are typically addressed by memory-aiding technologies, I will review a broader scope of technologies, including those not specifically built for PM problems. Besides general memory-aiding technologies, another interesting set of technologies are the cognitive prosthetics, which are aimed at compensating for all kinds of cognitive impairments⁶. A few examples of this set of technologies will be given in this section to indicate the range of technologies already available. Cognitive prosthetics are relevant for the current study when they incorporate systems for scheduling, planning and reminding.

Some applications already have been developed to help people with a traumatic brain injury (TBI) who also have problems with their prospective memory. Designing technological aids for memory impaired people is a challenge however, as they might; a) forget how to use the aid, b) are often unable to program their memory aid, c) use the devices in unsystematic ways, and d) are sometimes embarrassed by having to use memory aids (Wilson et al., 1997).

Although the use of technology seems problematic, there are some examples of successful electronic memory aids. One of these systems is the NeuroPage, developed by Hersh and Treadgold (1994), which is a portable paging system that has a screen and can be attached to a belt. Reminders are inserted via a computer. It has an audible alarm (adaptations to vibrate if required are possible), and it shows an explanatory message. Wilson et al. (1997) conducted the first pilot study with the NeuroPage. All 15 of the participants benefited from NeuroPage, with a mean success (percentages express the percentage of tasks that the participant successfully remembered to

⁶ One can argue that memory-aiding technologies are a subset of the general category *cognitive prosthetics*. However, because cognitive prosthetics is a term that is used for technologies that incorporate more than just memory aids, I use the term cognitive prosthetics for technologies that provide more than only memory support.

complete a PM task) in the baseline period of 37% without the pager, 86% in the treatment phase⁷ and 75% after the treatment phase in the absence of the pager but after 7 weeks of training (the pager was removed from the subjects after 7 weeks of using it). The most used reminders were 1) 'good morning, it is (day, date)', 2) 'take your medication now', 3) 'fill in your diary', 4) 'don't forget your ... (keys/bags/folders, etc)', and 5) 'make your packed lunch'. The 1997 study included TBIs, only one of whom lived independently by himself. Because the pilot study was considered successful, a broader group was taken into account. In the similar study in 2001 of Wilson and colleagues, 143 participants participated, with differing memory problems. Less than 50% of the target behaviours were successfully achieved in the baseline period. In the period that they used the pager, 76% of the target behaviours were successfully accomplished.

A system quite similar to NeuroPage is the ISAAC. ISAAC has as extra functionality that it is possible to save information that the patient often forgets, such as the names of grandchildren, or important phone numbers. Another feature of ISAAC is data-logging: all interactions with the system are saved. This data-logging feature provides information to the caregivers about whether the user has responded to the prompts given by the system and whether the user often used the snooze button⁸. The advantage of data-logging for the user is the ability to look up whether an action has been completed; for instance, whether pills already have been taken that day. Or, more accurately, the user can see in the system whether s/he acknowledged the cue. Gorman, Dayle, Hood, and Rumrell (2003) were the first to review the use of this system, and their target group for ISAAC was patients with neurofunctional impairments. Although the support of ISAAC for the patients seems promising, no empirical evidence is provided in the article for the supposed benefits of the system, only anecdotal evidence was provided in the article. The authors acknowledged this in their conclusion by mentioning that a well designed experimental investigation still has to be undertaken.

Essential Steps software is technology that belongs in the category 'cognitive prosthetics.' Among other things, Essential Steps includes a scheduling system. Other options are a word processor, a telephone book and controlling personal finances. The

⁷ The treatment phase solely consisted of using the NeuroPage

⁸ A snooze button is a button to indicate that the person wants to be reminded later again of the same to-be-remembered action.

first to review the working of Essential Steps was Bergman (2003). The case studies of users were very positive regarding the additive value of Essential Steps for TBIs with severe cognitive impairments. An important lesson in the article of Bergman is that memory problems and impaired perception of time often go together, as many users of Essential Steps appeared to have both memory problems and problems with knowing which time it was (for instance leading to taking the medication meant for the evening twice in the morning). Time-based prospective memory tasks may require both a good memory and a correct perception of time.

A system that seems specifically suitable for older adults is the Voice Organizer. A voice organizer works as follows: an individual records a cue (e.g., the older person her/himself), and sets a time for this reminder. When the initiated time comes, the organizer beeps and, after pressing a button, the individual hears the original message/cue about what to do. The advantages are that no programming skills are required (except for setting the timer) and no screen or interface is needed. Screens or interfaces often imply a lot of learning before using the system. Oriani et al. (2003) described the use of such a system, with their target group being patients with Alzheimer disease. Their aim was to reduce PM problems with an electronic memory aid. The researchers used a within-subjects design, which allowed them to draw stronger conclusions. They had three recall conditions: free recall, recall aided by a written list, and recall aided by a voice organizer (they call it EMA: electronic memory aid). The voice organizer led to significantly more recall than both other conditions. Interestingly, there was no significant difference found between free recall and recall aided by the written list. This result is worth mentioning because it implies that paper-and-pencil methods for reminding people of intentions do not lead to better PM performance than when individuals have to do without these methods.

There are also more generally used (i.e., used by 'normals') reminding systems currently available. Portable Digital Assistants (PDAs) for example can be used as aids for prospective memory. Szymkowiak, Morrison, Gregor, Shah, Evans and Wilson (2005) evaluated the use of a PDA specifically adjusted for memory-impaired users in a rehabilitation clinic. Specific problems for individuals with memory impairments appear to be usability problems. That is, menu-structures can be problematic for people with memory impairments because menu structures hide part of the features (and therefore require some memory). Reminders could be implemented in the PDA. Furthermore, the PDA offered the possibility of monitoring

the use of the PDA, a feature important for caregivers, because responses to prompts were stored in the system.

Another commonly used technology to remind people of appointments is a so-called reminding system like one can find in MS Outlook or at Yahoo.com. O'Connell, Mateer and Kerns (2003) described the use of the Yahoo calendar by a Korsakoff patient (the Wernicke-Korsakoff's syndrome is accompanied by PM problems). O'Connell and colleagues chose the calendar for supporting the prospective memory of their patient because it was, according to them, easy to program, able to repeat cues, had a flexible schedule for repeating prompts, and contained the option of sending messages to an alphanumeric pager. The last feature was one of the most important features because the patient was already used to having a pager. The patient responded to most cues immediately, except when the prompt arrived when he was engaged in other activities. The researchers concluded that the calendar was effective strategy for supporting the memory of this patient.

3.5 *Critical comments on reminding systems research*

The previous section reviewed several research studies which evaluate the use of some specific reminding systems. Although the results appear to be promising, these studies lack in several ways.

First of all, most studies only review the use of one system, which allows for no comparisons between systems. Of the systems reviewed in this paper, only the evaluation of the Voice organizer incorporate a comparison, namely with paper-and-pencil. Only one of the papers reviewed by Sohlberg et al. (in press) contained a comparison between two systems. Because there is hardly any comparison study available, it remains unclear which system should be used in which situations.

Furthermore, the systems are often not evaluated by an experiment that has control groups. The studies in which systems for TBIs are evaluated use within-subjects designs, and therefore the improvement in prospective memory performance in these cases may not only be due to the used reminding system, but also could be caused by a natural healing process. As Sohlberg et al. (in press) noted, the study of Wilson et al. (2001) is the only well designed⁹ experimental study in evaluating

⁹ Sohlberg et al. (in press) categorized the reviewed studies into three levels of evidence using a classification from the Centre of Evidence-Based Medicine, with the first level as the level with the

electronic memory-aiding technologies. Many other studies use only a few participants and did not include a control group. Most research that has been conducted are pilot studies. These pilot studies sometimes merely seem aimed at fund raising for better experiments: "It is our hope that funding sources will soon recognize the potential power of cognitive prosthetic systems (...) A well designed experimental investigation of the ISAAC system with adequate sample size is needed." (p.66, Gorman et al., 2003). These articles lack critical comments on the evaluated product. More objective evaluations, by using experimental designs that can be replicated, seem to be missing.

Even if several reminding systems are compared by assigning them to different participants, there would still remain uncertainty about how to design an effective reminder system. This is because all systems have a different interface, and thus differences in effectiveness may also be caused by differences in usability. Although some attempts have been made, currently no exhaustive list of usability requirements for the design of technologies for cognitively disabled people exist.¹⁰ Because no such list exists, it is still unclear whether regular reminding systems (like PDA's and Outlook/Yahoo calendar kind of artifacts) aid cognitively impaired people with their PM problems.

At first glance, it may seem positive that *many* individuals could be helped with technologies aiding prospective memory, but this also creates a problem. Because several technologies have been tested on different target groups, it is not clear whether cueing strategies work the same for everyone. O'Connell et al. (2003) make this point by recommending future research to distinguish which cueing strategies work for which deficits.

Another problematic issue in the area of reminding systems is that systems are designed in a trial-and-error way. The systems are created and then tested on people with PM problems. This way of designing immediately leads to the problem of usability, which makes it hard to say whether the way of cueing is not correct for supporting prospective memory, or the usability is just not good enough. In this thesis I propose to take a fundamentally different approach. I propose to start with research in the prospective memory aimed at finding out what kind of cueing helps to lessen

best quality. The term *well-designed* refers to this first level, meaning that a study included prospective, randomized controlled trials.

¹⁰ For those who are interested in some usability requirements for the design of cognitive prosthetics, see Gorman et al. (2003), Cole (1999), Cohen-Mansfield et al. (2005), and Inglis et al. (2003).

PM problems. Once such a basic understanding is achieved, the findings could possibly be implemented in a wide range of technologies.

3.6 Summary of the literature review of reminding systems research

In sum, many people could benefit from using reminder systems: for example, elderly people, people suffering from dementia, people with neurological deficits and busy office workers. Electronic devices are preferred over paper-and-pencil methods when it comes to reminding, especially because timing and information about what to do can be integrated into one system.

Quite a number of evaluation studies have been conducted on electronic reminder systems. These studies show promising results. However, almost without exception, the studies lack in several ways. They only evaluate one system, which does not allow for comparisons between currently available systems. Another point in which the studies lack is when TBI patients are used. In these cases, only within-subjects designs are used, while the improvements might be due to a natural healing process and are not the result of using a reminding system. Furthermore, only small sample sizes are used in most studies.

From the evaluation studies, it is also not clear whether the (in)effectiveness of the device is a result of usability problems, or that more basic parts of prospective memory are not supported in the right way by the device. Therefore it is suggested that research should be conducted to find out how prospective memory works and how it can best be supported on a general level. How such research can be conducted and what questions could be addressed is the topic of the next chapter.

4. Combining research on prospective memory and reminding systems

4.1 Introduction

If you want to know how to effectively support prospective memory you could turn either to literature on prospective memory, or to literature on reminding systems. However, both research fields fall short in answering the question how prospective memory can effectively be supported (see Chapter 2 and 3).

Prospective memory literature offers some indications on how prospective memory works by showing cases in which prospective memory fails. Although this approach is fruitful from a theoretical point of view, it is not yet directly useful from the application point of view. Theories on prospective memory do not tell how to prevent prospective memory failures. The other research field of relevance in this context, reminding systems, is aimed at overcoming prospective memory failures. However, research on reminding systems fails to come to general conclusions on how the systems support prospective memory.

In this chapter, a short account will be given for how the two lines of research can be combined and what questions could be addressed in a combined approach. This thesis will thereafter move to discuss an experiment that addresses one of the questions.

4.2 Combined research

First of all, we must acknowledge that existing reminding systems seem to work to some extent, at least according to the studies evaluating the use of these systems. Automatically however, we come to the question of why and how do these systems work. This question should be answered if one wants to build new effective systems. If the reasons underlying the (in)effectiveness of reminder systems remain unclear, only conclusions can be drawn about the effectiveness of specific systems in specific situations.

One step towards answering the question of why the existing systems work is to start by comparing the existing systems. It would be interesting to know which features they have in common, and which features are unique for particular systems. Another possibility would be to have users try several different systems, and let them indicate which of the systems is their favorite and why. If users are able to indicate

which basic features of the reminding systems are helpful in reminding them then a next step would be to design an experiment to test these basic features in a controlled environment. An experiment allows independent manipulation of the features. Another advantage of experiments is that design and usability issues can be left out of consideration, because all reminders in the studies can have the same layout. By using the same layout, the effect of the layout cancels out in the comparison between the setting of different parameters of the reminders. In this way, first more fundamental issues in supporting prospective memory can be investigated.

The two lines of research could also be brought together in another way. Prospective memory experiments could be enriched with more naturalistic reminders, instead of artificial events/cues like words turning blue. Commonly used reminders not only remind the user that something should be done at that moment, but also provide information about what should be done. The more naturalistic reminders could be incorporated in a more naturalistic paradigm.

In sum, from whichever direction we proceed, studying how reminders can effectively support prospective memory results in naturalistic experiments incorporating the basic features of reminding systems. This would involve experiments in which prospective memory tasks are embedded in other tasks in such a way that it reflects everyday prospective memory tasks better.

4.3 Research questions that could be addressed

The question may arise regarding what kind of research questions could be addressed in a combined study of prospective memory and reminding systems. To give the reader some idea of the scope of the area still unstudied, some indications of research questions that could be addressed will follow.

In theory, reminding systems work easy enough: you schedule a task, and when the time arrives, an alarm goes off and you fulfill the task. However, in everyday life, we face a more complicated world. What will I do if the alarm goes off while I am driving? Do I stop the car and immediately take my medicines? Probably I will not stop the car, but drive on until I reach my destination and take the pills there. Thus, one question is whether people will immediately turn to the PM task when prompted, or will they first finish (part) of what they were doing? And if they choose to delay the PM task, will they then forget to complete the PM task?

Another interesting question is whether participants are aware of the fact that they may forget the PM task. Specifically, would they use the option of setting a reminder (which takes time of course) or just trust their memory, and are they accurate in assessing whether it is worth the cost of setting a reminder?

What happens if you allow a participant to use a 'snooze'-button? The MS Outlook reminders always offer the opportunity of 'remind me later,' and also 'when' that later is (in 5 minutes, 10 minutes, 1 hour, 1 day etcetera). Does 'snoozing' lead to better memory for the to-be-performed action, or just to irritation?

Research questions could also be derived from general memory theories. Take for example the encoding specificity principle¹¹. Does it also hold for prospective memory? This is an interesting question, because it might lead to the conclusion that I need a reminder for taking my medication when I leave my home, but when I would stay in the home, no reminder is needed. Is prospective memory so to speak location transferable?

Having summed up a couple of the possible research questions, we will now turn to the research question addressed in this thesis.

¹¹ The encoding specificity principle (Wiseman & Tulving, 1976) describes the phenomenon that memory is improved when (contextual) information available during encoding is also available at the moment of retrieval.

5. Introduction to the experiment

5.1 Introduction

As discussed in the previous chapter, prospective memory experiments could be conducted that incorporate the basic features of reminder systems. Such experiments may provide answers valuable for prospective memory research and for the development of reminder systems. To provide information applicable for the design of reminding systems, more naturalistic prospective memory tasks are needed as discussed in Chapter 2. The experiment in this research study therefore incorporated a window of opportunity, ongoing tasks of at least 20 seconds, prospective memory tasks that take at least the same amount of time, and process measures. The experiment incorporated a reminder, because all systems reviewed in Chapter 3 had a reminder in which both timing and information about the intention were programmed.

The experiment conducted in this research study strives to answer a question which has both theoretical and practical importance. The basic feature which is manipulated in the experiment is timing of reminders. Section 5.2 explains the practical importance and Section 5.3 the theoretical importance of the issue of the timing of reminders.

5.2 Timing of reminders: practical importance

In the office environment, people make use of technologies to remind themselves of things they intend to do. A program like MS Outlook offers the opportunity to schedule meetings and at the same time set an alarm that goes off 15 minutes before the meeting. This fifteen minutes is the default option. There is however no evidence that 15 minutes is the most optimal timing of the alarm. Fifteen minutes may be enough to forget the to-be-remembered task again. On the other hand, fifteen minutes may be a suitable period of time to finish part of what one was doing.

5.3 Timing of reminders: theoretical importance

Both timing of the moment of retrieval and elapsed time after encoding are essential for memory. The miraculous thing of memory is that it enables people to bring into mind times past. Memory is, so to say, a bridge to other times and places. Trying to bring memories into mind is however not always successful.

Studies in autobiographic memory show that people tend to forget things when the time between encoding and retrieval increases (for a review see Roediger, Marsh & Lee, 2002). This forgetting may be because old memories are 'erased,' or maybe because older memories are just not accessible anymore or are just harder to retrieve. Maybe the reason for this phenomenon is not so much that time passes, but that other, newer memories come in between. This is what has become known as the interference theory (Neath & Surprenant, 2003). As time passes, we experience new things and thus create new memories. Whether time or new experiences are the reason of forgetting old memories, the result is the same: we tend to forget things as time passes.

The studies in autobiographic memory (reviewed by Roediger, Marsh and Lee, 2002) that show an increased probability of not being able to retrieve information with increasing time, only concern retrospective memory. Whether this finding that people tend to forget things when the period between encoding and retrieval increases also holds for prospective memory is still unknown. It may be that as the period between formation and executing the intention increases, the likelihood increases that the intention is forgotten (see Figure 5.1). If prospective memory performance declines when time passes after the formation of an intention, then it would follow the same pattern as retrospective memory. On the other hand, it may be that a plan becomes more central in our thoughts when the time left before it decreases. In that case, forgetting would become *less* likely when the period of time after formation of the intention increases.

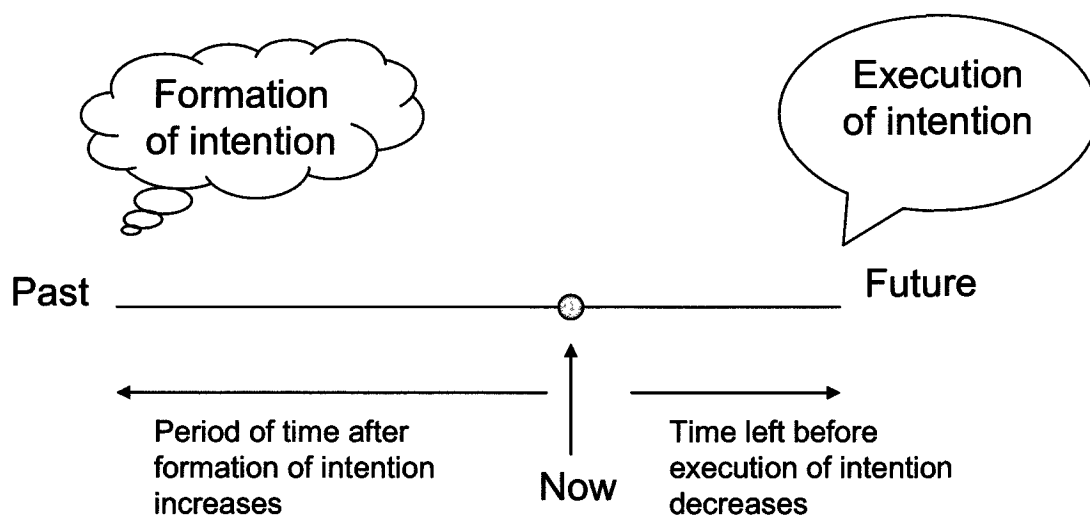


Figure 5.1 Time path between the formation and the execution of an intention

The idea that an intention becomes more central in our thoughts is illustrated by the following anecdote: When one receives an invitation for a wedding, one can form the intention to go to the wedding. The invitation is usually received a few months before the wedding, but it is only a few days before the wedding that we become concerned about what to wear and at what time we should leave the house to be in time for the ceremony. In other words, the intention of attending the wedding ceremony seems to become more central in our thoughts as the time before the execution of the intention decreases. This claim is supported by the finding of Park et al. (1997) that participants who did not forget the PM task showed an increase in clock checking frequency as the time before execution of the time-based prospective memory task decreased.

Being reminded of an intention can prevent forgetting of an intention. However if the to-be-remembered task is not executed immediately after receiving the reminder, forgetting of the intention may still occur. Receiving the reminder may be regarded as a “refreshing of the memory” for the intention. One of the aims of the current study is to investigate whether this forgetting after receiving a reminding occurs, and whether the probability of forgetting is influenced by time.

5.4 *A time-based prospective memory task and reminders*

Reminders are used to prevent people from forgetting a time-based task. Because our interest lies in how people deal with reminders, time-based prospective memory tasks were used in this study. To ‘help’ the participants, they receive a reminder a few minutes before they are to start the prospective memory task. Because the tasks are time-based, the participants were provided with a clock. The time between receiving a reminder and being able to execute the PM task will be referred to here as the *delay*. The central question is: what is the effect on performance of the length of a delay between receiving a reminder and being able to execute the prospective task?

Both the ongoing task performance and the prospective memory performance were used as measures of performance. Furthermore, the role of checking the clock during the ongoing task was investigated. Receiving a reminder shortly before the PM task has to be executed is thought to be helpful for remembering to do the PM task. In MS Outlook, 15 minutes (15 minutes is the default option) before the intended action has to be executed, an alarm goes off. One might ask whether that is the right default option. As suggested before, in general, people tend to forget things when time

passes. Therefore it may be that longer delays lead to higher chances of forgetting the PM task (Hypothesis 1). Furthermore, after receiving a reminder, people have to remind themselves of the intended action. This self-reminding could have negative effects for ongoing task performance. Because in longer delays people have to self-remind longer, overall ongoing task performance may be worse for long delays than for short delays (Hypothesis 2).

A long delay may increase the number of times an individual has to check whether the time is right to execute the PM task. Consequently, it may be that longer delays are associated with a higher number of clock checks during the delay than short delays (Hypothesis 3). These clock checks may possibly lead to interference and worse performance on the ongoing task (Hypothesis 4). In all, the question is how sensitive performance is for a delay between receiving a reminder and executing an intended action. The next chapter will introduce the reader to the methodology used for answering the research question.

6. Method

6.1 Introduction

The methodology described in this Section is designed to test four hypotheses:

1. Longer delays lead to higher chances of forgetting of the PM task.
2. Longer delays lead to worse performance on the ongoing task.
3. Longer delays lead to more clock checks.
4. Monitoring the clock leads to worse performance on the ongoing task.

These hypotheses imply that the experiment involves both ongoing tasks and prospective memory tasks (described in Section 6.4). How these two are combined in the experiment will be discussed in Section 6.3. The lay-out of the different elements will be discussed in Section 6.5 and 6.6. Section 6.7 describes the design, Section 6.8 the procedure and Section 6.9 the measurements. But first some information about the participants and overview of the experiment will be given in Section 6.2 and 6.3.

6.2 Participants

Fifty-eight participants participated in the study. They ranged in age between 16 and 32 years ($M = 23.01$, $SD = 3.09$) and were recruited from the Eindhoven University of Technology. The majority of the participants ($N=53$, 91.4%) were Master or Bachelor students, and the remaining participants were either PhD students ($N=4$) or enrolled in a post-Masters program ($N=1$). Most were male participants ($N=49$). All participants received 5 euros for participating. Three participants indicated they had a color sight deficit; two of them had a green-red distortion and the other participant had a distortion for dark colors. Because the results showed no differences in performance between the participants with normal sight and the ones with the color deficits, results of all participants were used in the analyses.

6.3 General structure of the experiment

The experiment was computer-based and ran in Authorware 6.5. The program started with instructions on the experiment. The participants were familiarized with the different types of tasks. Furthermore, they were instructed about *how* and *when* they were supposed to switch between the ongoing task and the PM task (a more detailed explanation on the instructions follows in section 6.9). Following the

experiment, participants were asked a few questions about their age, gender and how they experienced the experiment in hindsight.

6.4 Experimental set up

The experiment consisted of two types of tasks, namely picture tasks and number tasks (a more detailed explanation of both tasks follows in section 6.5). Participants were instructed to do as many picture tasks as possible and at a regular interval of seven minutes they were to switch to a number task and execute this task. The picture tasks served as the ongoing task of the experiment. Switching to the number task was regarded as the prospective memory task.

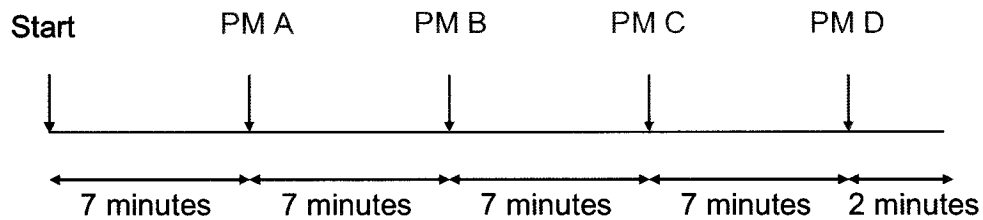


Figure 6.1 General time line of the experiment. The number tasks were to be executed at the point of the arrows: task A could be executed 7 minutes after the start of the experiment.

Participants were told that the number tasks had to be performed at an interval of approximately seven minutes, but that they would receive a reminder a few minutes before every number task. This reminder would inform them of the exact time that they could start a specific number task. We were interested in whether participants would interrupt an ongoing task to switch to a number task, or first finish the ongoing task that they were engaged in. Therefore, the participants were given a window of opportunity (a time frame of one minute) in which they could start a number task. This results in the time line of the experiment displayed in Figure 6.2.

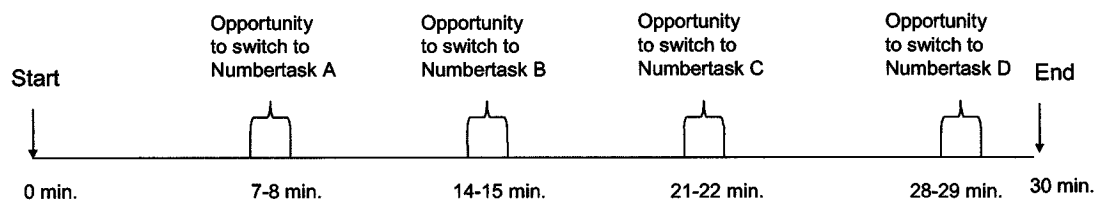


Figure 6.2 Detailed time line of the measurement phase of the experiment: participants could switch to the number tasks during the specified windows of opportunity.

6.5 Ongoing and prospective memory tasks

The ongoing task, called the “picture task,” in this experiment was a mental rotation task. Every task consisted of two pictures displayed simultaneously on the screen (see Figure 6.3). In total, 216 pairs of pictures were generated in Matlab. Each picture consisted of 11 x 11 little squares that together formed one big square. Furthermore, each picture contained two or three colors. Using different colors for different sets of pictures was thought to make the tasks more pleasant. The little squares received a color by random assignment. The second picture was a copy of the first one, but in half of the cases one of the little squares in the big square received a different color (this color had already been used in the picture, so no new colors

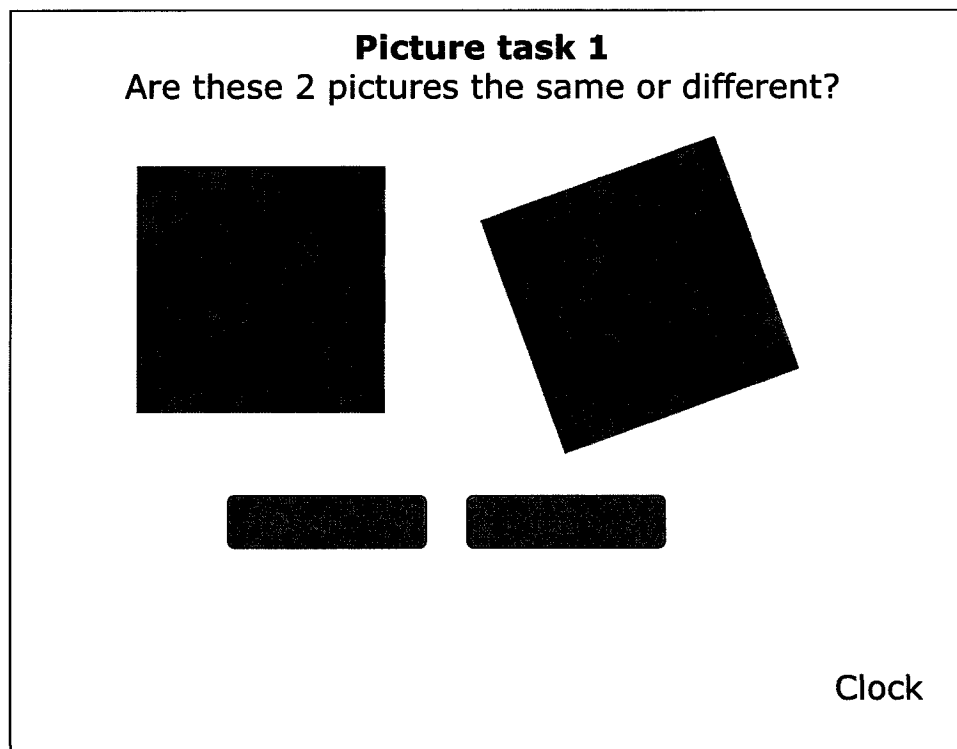


Figure 6.3 Layout of the main screen. The ongoing task is displayed.

introduced to the picture; see Figure 6.3). Furthermore, the picture on the right side of the screen was rotated slightly (20, 40 or 60 degrees). Participants had to judge for every pair of pictures, whether they were different or the same.

The difficulty of the ongoing tasks was manipulated systematically by changing some of the parameters of the pictures. These parameters can be used as predictors in analyses of the reaction time and correctness of the picture tasks. By incorporating these parameters in the statistical analyses, variance due to differences between picture tasks is captured¹². One of the parameters was the number of colors used in the picture (two or three) with tasks incorporating three colors being harder than tasks incorporating two colors. Another parameter is the rotation angle (20, 40 or 60 degrees) of the second picture, with increasing task difficulty for increasing rotation angles. The number of changes in the second picture was either zero or one, with one change being easier to detect than no change. The proportion of one color is another parameter of task difficulty, as it is easier to detect a difference between two pictures when the first picture almost completely consists of one color.

The prospective memory task in the experiment was a number task. It does not matter what kind of PM task participants have to perform, because the main interest is just whether they remember to do it. However, to mask the purpose of the experiment for the participants, a real task was introduced that had to be executed at specified times. This number task worked as follows; 50 random numbers between 0 and 9 were displayed on the screen, and the task was to count the number of occurrences of a particular digit (e.g., count the number of 3's, on the screen). When participants finished this number task, they could return to the ongoing tasks.

6.6 Reminders

Preceding each number task, participants received one reminder. The reminder was a text box that was placed in front of the ongoing task. This method of reminding was used to force participants to read the reminder. The text box disappeared when participants clicked on the button 'read,' which was placed inside the text box. The reminder appeared for example five minutes before the start of the window of opportunity for the number task.

¹² A pilot study was conducted to test the effect of the stimuli parameters. 52 Participants participated. 49% of variance of reaction time could be explained by the stimuli parameters.

6.7 Screen layout

Normally, a prospective memory task requires task switching. To give the experiment the look and feel of regular task switching, the different types of tasks were to be performed on different screens within the same computer program. By pressing buttons on the bottom of the screen, the participant could move from the main screen to the number task screens (this is comparable with moving from a text edit program to a calculation program on a Windows computer interface). Each number task screen had its own button, and to move back to the ongoing task screen, the participant had to press a button labeled 'main screen.'

The buttons on the main screen were made invisible, and they would only appear when the cursor was moved to the corner in the left-hand of the screen (see Figure 6.4). The reason for hiding the buttons was to make sure that participants were not reminded of the number tasks by the visibility of the buttons.

The clock was located in the bottom right-hand corner of the main screen and was marked by the word 'clock.' In the same way as the buttons were made invisible, the clock was made invisible; when the cursor moved over the word 'clock,' real time was displayed. The reason for hiding this clock was to enable the researcher to know when and how often the clock was checked.

The screens of the number tasks were only available within a set period of time, namely the preset window of opportunity of the specific tasks. When the button of a specific number task was pressed before the start of the window of opportunity of that number task, another screen appeared with the message: "You are too early, go back to the main task." To discourage participants from checking whether the time was right for a specific number task, it took a number of seconds before this message would appear (simulating time to "load" the screen). If participants tried to open the screen of a number task for which the window of opportunity already had passed, a message appeared saying "You are late, go back to the main task."

After choosing 'same' or 'different', the screen layout changed slightly. The pictures and the buttons 'same' and 'different' disappeared and a button 'Next' appeared. When the participant pressed this 'Next' button, a new picture task appeared on the screen. It was possible to check the clock and press the buttons for the PM task on this intermediate screen.

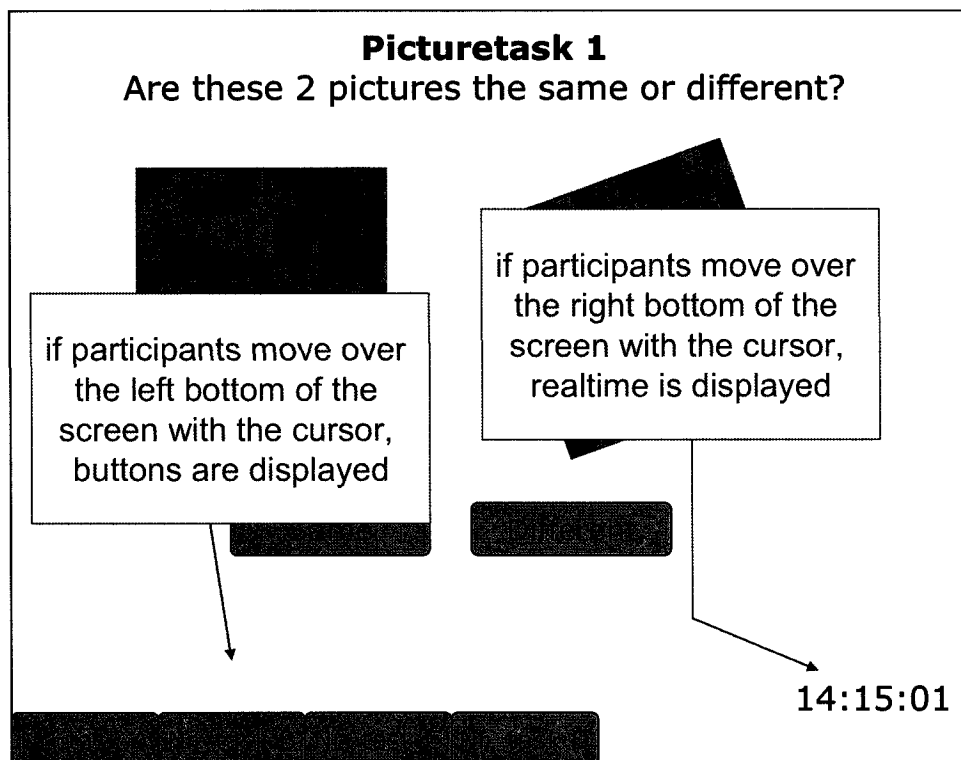


Figure 6.4 Layout of the main screen. The buttons for the PM task and the clock were only visible when moving with the cursor over special areas of the screen. The buttons for the PM tasks did not change throughout the experiment: the participant could not see at the buttons that the task had already been done or that the window of opportunity for that task had passed.

6.8 Design

The experiment was a within-subjects design with 4 conditions: 1) no delay between reminder and the start of the window of opportunity for a specific PM task, 2) a delay of 1 minute, 3) a delay of 3 minutes, and 4) a delay of 5 minutes. The order of the conditions was counterbalanced, resulting in 24 between-subjects ordering conditions. Placement of the answer buttons ‘different’ and ‘same’ was also counterbalanced between participants: half of the subjects received the ‘same’-button on the left side of the screen and half of the subjects received the ‘different’-button on the left side of the screen.

6.9 Procedure

Upon entering the room where the experiment was run, participants were asked to hand in their cell phones and watches to prevent them from being able to look at their own clocks. Participants were tested in individual cubicles, and the researcher stressed

that if the instructions shown on the computer were not clear then the participants should step out of their cubicles and ask for help. The instructions on the computer informed the participants that they were to perform one of the number tasks approximately every 7 minutes. Further, they were told that they would receive one reminder for each number task, and that this reminder would tell them the exact time left before they could start with the number task (i.e., the time left before the beginning of the window of opportunity for that specific task). Importantly, participants were informed that the reminder could come from 0 to 5 minutes before the start of the window of opportunity. Instructions furthermore stressed that both the PM and ongoing tasks were important and that both should be performed correctly. Additionally, participants were instructed to do the ongoing tasks as fast as possible. This speeded-response instruction was to try to make them devote all their cognitive resources to the task at hand. After these instructions, and after any questions were answered, the experiment began. The experiment took approximately 30 minutes per participant. When the experiment had finished, the participants answered five demographic questions and one other question: "If you have not executed one of the number tasks, can you explain why not?" After the experiment participants were asked not to talk to others about the contents of the experiment for two weeks, and they received an email debriefing them about two weeks after the completion of the experiment.

6.10 Measurements

Testing the hypotheses requires the measurement of three types of behavior: ongoing task performance, prospective memory task performance, and clock checking behavior.

Ongoing task performance was measured both by the time spent on each picture task (each pair of pictures) and the correctness of the same/different judgment. Besides these measures of performance, the time at which a picture task started and at which it ended was recorded. During the picture tasks, the participant could check the clock or move to a number task screen. Two different measures of RT can be used: the RT including the time spent checking the clock and moving early to the number task screen (a variable which will be called 'Real RT') and the RT without the time spent watching the clock and moving to the number task screen early (a variable

which will be called 'Processing time'). These two measures can be used to answer two different questions, namely:

1. Is the total time needed for the tasks influenced by Length of delay?
2. Is the time needed to process the picture task influenced by Length of delay?

The first question is interesting for the applied field of reminding systems as it is not only interesting to know whether office workers become slower on their ongoing task because of limited processing capacity, but also whether they are slowed down by clock checking. Clock checking may be necessary to be in time for the PM task. The second question is interesting for the theoretical field of prospective memory because the question here is whether self-reminding impairs ongoing task performance because of the limited processing capacity.

Prospective memory task performance was measured by the timing of moving to the number screens. All attempts of moving to number screens were recorded. In this way, part of the prospective memory process was captured. Because moving to the number task screens at the wrong time was discouraged, it was postulated that attempts to move to the number screens reflected that the participant thought that the time was right to go there.

Clock checking behavior was registered by recording every time that the cursor moved over the clock. Both timing and duration of the clock checks were saved. These measures of clock checking behavior were used as an estimate of when, and how often, the participant thought of the prospective memory task.

7. Results

7.1 Introduction

The experiment not only produced data on outcome measures, but also process data. In the analyses, four process measures were used: number and timing of clock checks, and number and timing of attempts to switch to a number task screen. First, the attempts to switch to a number task screen will be discussed. The results reveal that not remembering to perform the number task *in time* does not imply that the participant had no thoughts about performing this task *at other moments during experiment*. Following this discussion, results on the three aspects of the research question and how they relate to each other will be discussed: prospective memory performance, checking whether the time is right and ongoing task performance.

7.2 General remarks about the analyses

The design of the experiment allows for both within-subjects and between-subjects analyses. The data on ongoing task performance allow for a detailed analysis, namely trial by trial. To give an indication of the size of N for the different levels of analyses:

- The between-subjects analyses have $N=58$, because 58 participants participated.
- The within-subjects analyses concern the 4 different conditions. The experiment can be split into 4 parts of about seven minutes, each time finishing either after the end of the window of opportunity for the PM task, or after the participant has executed the PM task. One of the 58 participants indicated that he only understood the instructions about moving to the PM screen after missing the second one. His first two blocks of seven minutes are excluded from the analyses. This leaves us with $58 \times 4 - 2 = 230$ blocks. Therefore the within-subjects analyses have $N=230$.
- The trial-by-trial analyses have $N=3985$. The number of trials (ongoing tasks) is variable within blocks because it is dependent on the speed of the participant. Mean number is 17 per participant per block of seven minutes.

In the analyses, mixed models, which are models that incorporate variance of mixed sources, will be used to test the hypotheses. Mixed models have as an advantage that

it is allowed to have an unequal number of observations per condition. Because participants differed in their speed of accomplishing ongoing tasks, different participants have a different number of observations per block of seven minutes. The most important characteristic of a mixed model is that it distinguishes both fixed and random variance sources. Fixed variance sources are the predictors in the model. The random variance source used in the models in this study is the between subjects variance. The model assumes that all participants are affected by the fixed factors in the same way, but that they may differ in their personal mean. The model further assumes that the means of the participants are randomly distributed, following a normal distribution. By capturing in this way the between-subjects variance, the model is in the end a within-subjects model. The model tests whether the fixed factors have a significant effect on the dependent variable. The effect size of the effects can be read from the maximum likelihood estimates: an estimate of zero indicates no effect. Maximum likelihood estimates (MLEs or Restricted Maximum Likelihood estimates, REMLEs) in a mixed model are analogous to what beta estimates are in a standard regression model (more on this kind of model can be found in Singer, 1998).

7.3 *Prospective forgetting: no thoughts about the PM task at all?*

Forgetting to execute an intended action does not necessarily imply that the intention was completely forgotten; that is, it may just indicate that the intention simply was not remembered at the right moment. For example, you may intend to post a postcard today, and have thoughts about it all day, but forget to do it when you pass the mailbox.

All attempts to switch to a specific number task were registered. Such attempts indicate that the participant thought about the number task. Failures to attempt to switch to a number task *within the appropriate window of opportunity* are regarded as prospective forgetting. As discussed previously (in Section 2.7.4), it is of theoretical interest to see whether the participants had thoughts about the prospective memory task during the experiment, even when they forget to execute it at the right time.

The attempt to switch to a number task can be categorized in two steps (see also Figure 7.1). First a distinction can be made between attempts that are in time and those that are not in time. The latter category can be divided further into two subcategories: early and late responses, respectively attempting to switch to a number task before the window of opportunity of that task or after.

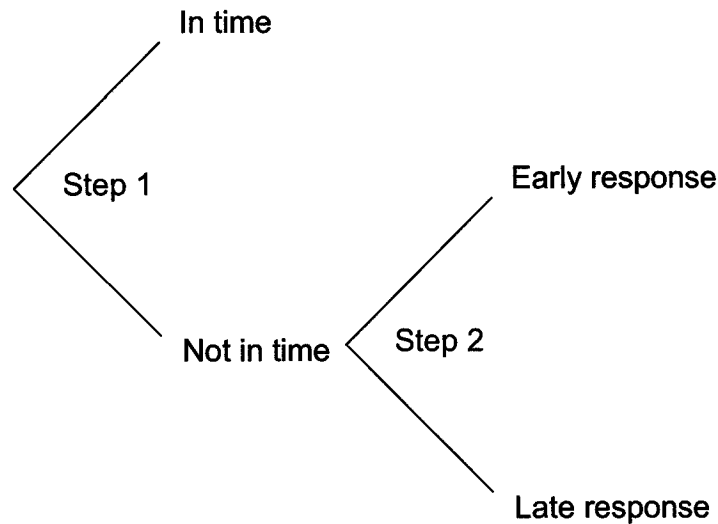


Figure 7.1 Clicks towards number task screens can split into three categories. The first step is to distinguish clicks that occur inside the window of opportunity ('in time') and those that occur outside ('not in time'). The second step makes a distinction in timing of 'not in time' responses: clicks that occur before the window of opportunity are categorized as 'early responses' and those that occur after the window of opportunity are called 'late responses'.

Of the 230 possibilities for executing a PM task, 12 times a participant was not in time with executing the PM task. A remarkably high percentage of participants showed late responses when they were not in time for the number task, namely 9 out of 12 instances of 'not being in time.' Evidently, prospective forgetting in the sense of 'not being in time' does not imply that the participant had no thoughts about the prospective memory task at all.

In the remainder of this Chapter, the term 'forgetting' will be used for blocks in which the participant was not in time for the number task of that specific block¹³, and 'remembering' for blocks in which the participant was in time for the number task for that specific block.

¹³ The term forgetting includes cases in which participants went too early and/or late to the PM task and cases in which the participant showed no attempts to switch to the PM task.

7.4 How does length of delay influence prospective forgetting?

One of the main questions of the current study was whether length of delay would affect prospective forgetting. As can be seen in Figure 7.2 the number of instances of forgetting seemed to increase with longer delays.

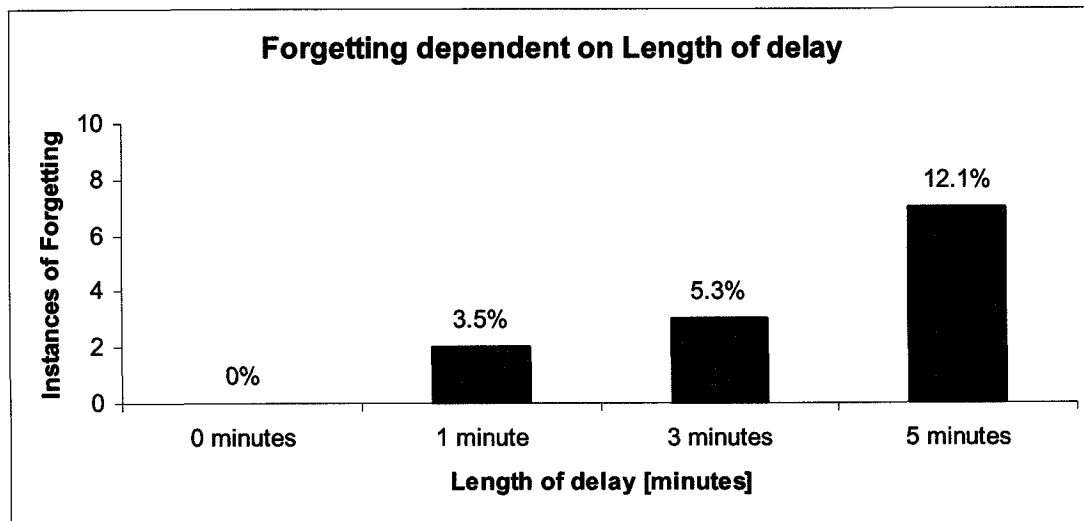


Figure 7.2 Distribution of instances of forgetting over the different delays.

This effect was tested in a mixed model for nominal data (Analysis 1). The dependent variable was Remembering (yes or no), indicating that the subject was in time for the PM task or not. Independent variables in the model were Length of delay, Order of blocks¹⁴ and a fixed intercept¹⁵. A random Subject factor was also introduced, which was only marginally significant ($p=.066$), indicating that participants differed marginally in their amount of forgetting. The factor of interest, Length of delay had a negative effect on Remembering ($z=-2.30$, $p=.021$, $MLE=-.55$), with longer delays having higher chances of forgetting. The fixed intercept was significant ($z=3.80$, $p<.001$, $MLE=5.39$), meaning that for the average delay, the probability of remembering is estimated to be higher than zero. There was no significant effect of Order of blocks ($p=.98$).

¹⁴ The variable Order of blocks was introduced to account for order effects. It could for instance be that participants forgot the PM task in their first block, but not in the other blocks. The variable ranges from 1 to 4.

¹⁵ A fixed intercept was always included in the analyses. When one draws the graph of a regression function, the fixed intercept is the value of the y-axis at which the function crosses the y-axis. In a linear regression function, the fixed intercept is the b in the equation: $\hat{Y} = aX + b$, in which \hat{Y} is the predicted variable (dependent) and X the predicting variable (independent).

7.5 How does length of delay influence checking whether the time is right for executing the PM task?

Checking whether the time was right for the PM task could be done in two different ways: by checking the clock (participants then had to combine the information of the clock with the information they remember about at what time the reminder was received and how many minutes then had been left) and by moving to the number task screen to see whether it was already available. Both ways will be discussed in this section.

7.5.1 Total amount of clock checks during a block

The number of clock checks during a block ranged between 0 and 17 ($M=4.98$). The distribution of clock checks in blocks of seven minutes is displayed in Figure 7.3. The number of clock checks seemed to increase with the length of delay.

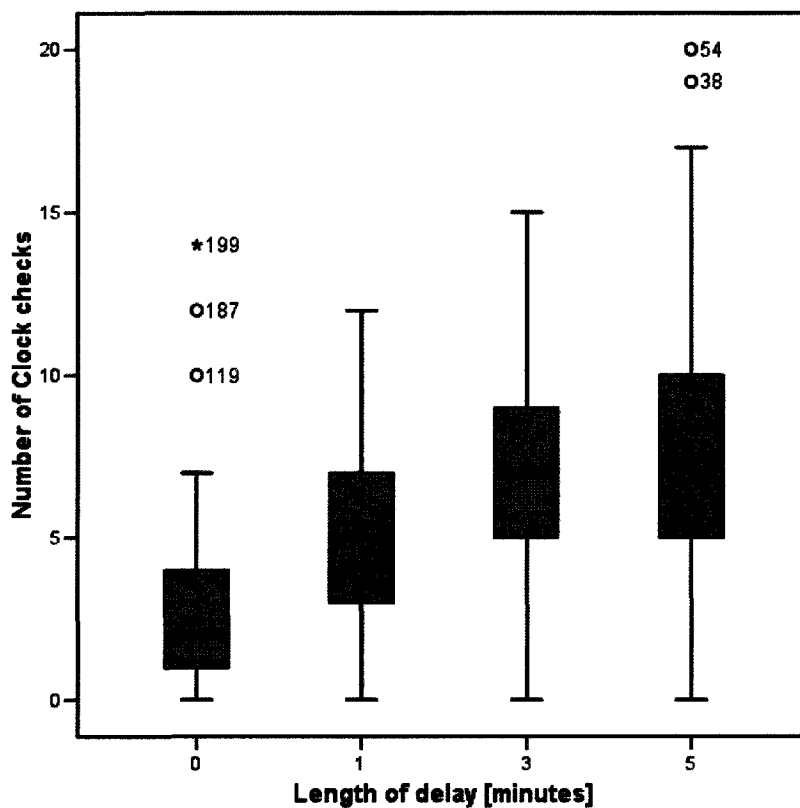


Figure 7.3 Box plots showing the distribution of number of clock checks per block of seven minutes.

This pattern was tested in a mixed Poisson regression model (Analysis 2) with 5 fixed factors and 1 random Subject factor. The dependent variable was Number of clock

checks during a block of 7 minutes. Because Number of clock checks is a count variable, the assumption of normality does not hold, and this is the reason for choosing a Poisson distribution (Long, 1997). The independent variables were Length of Delay, Remembering, Interaction between Remembering and Length of delay, Order of Blocks and a fixed intercept. The random factor reached significance ($p < .0001$), meaning that participants significantly differed in their clock checking behavior. The fixed intercept also reached significance ($z = 5.70$, $p < .001$, $MLE = 1.13$), meaning that clock checking was on average significantly above zero. There was a positive main effect of Length of delay ($z = 11.4$, $p < .001$, $MLE = .18$), indicating that longer delays go with more frequent clock checking. The interaction of Remembering and Length of delay was significant ($z = 3.32$, $p < .0001$, $MLE = .29$), which shows that when people remembered to execute a PM task the increase of clock checking with longer delays was steeper than when they forgot to execute the PM task. This pattern is not surprising because it was assumed that clock checking is needed to be in time for the PM task, and apparently the PM task in which the delay is longer is harder to fulfill (the chance of not being in time is higher for these PM tasks) and consequently more clock checking may be needed to be in time for the PM task.

7.5.2 Pattern of clock checking during a block

Besides a difference in absolute number of clock checks during a block of 7 minutes, the pattern of clock checking during a block may also be different between blocks. It may be that clock checking frequency increases over time during a block (as found by Park et al., 1997), and that this increase is steeper for blocks with shorter delays because it may be harder to estimate the duration of one minute than of five minutes (or possibly the other way around).

To be able to study the pattern of clock checks over time during a block, the clock checks were summed within every 1 minute interval within a specific block. This resulted in maximally seven values¹⁶ per participant per block. Participants could switch to the PM task during the seventh minute, therefore this seventh minute was not a complete minute of 60 seconds. Therefore, the seventh minute is dropped from the analyses. To control for the effect of receiving the reminder, clock checks immediately following the reminder were eliminated from the analysis. A clock check

¹⁶ Maximally seven observations because some participants switched at the start of the seventh minute to the number task screen, where no clock was available.

was removed if the clock check was the first registered behavior after reading the reminder within five seconds from reading the reminder (148 clock checks were removed in total). These clock checks were regarded as a response to receiving the reminder. A maximum distance in time of five seconds between reading the reminder and checking the clock was used to prevent excluding cases from the analysis in which the participant first looked at the ongoing task for a minute (not registered behavior) and then checked the clock, because in that case a direct relationship between receiving the reminder and checking the clock is not very likely.

The overall pattern of clock checking during the blocks, collapsed over delay conditions, is presented in Figure 7.4. What becomes apparent from the graph is that participants checked the clock most frequently in the first minute.

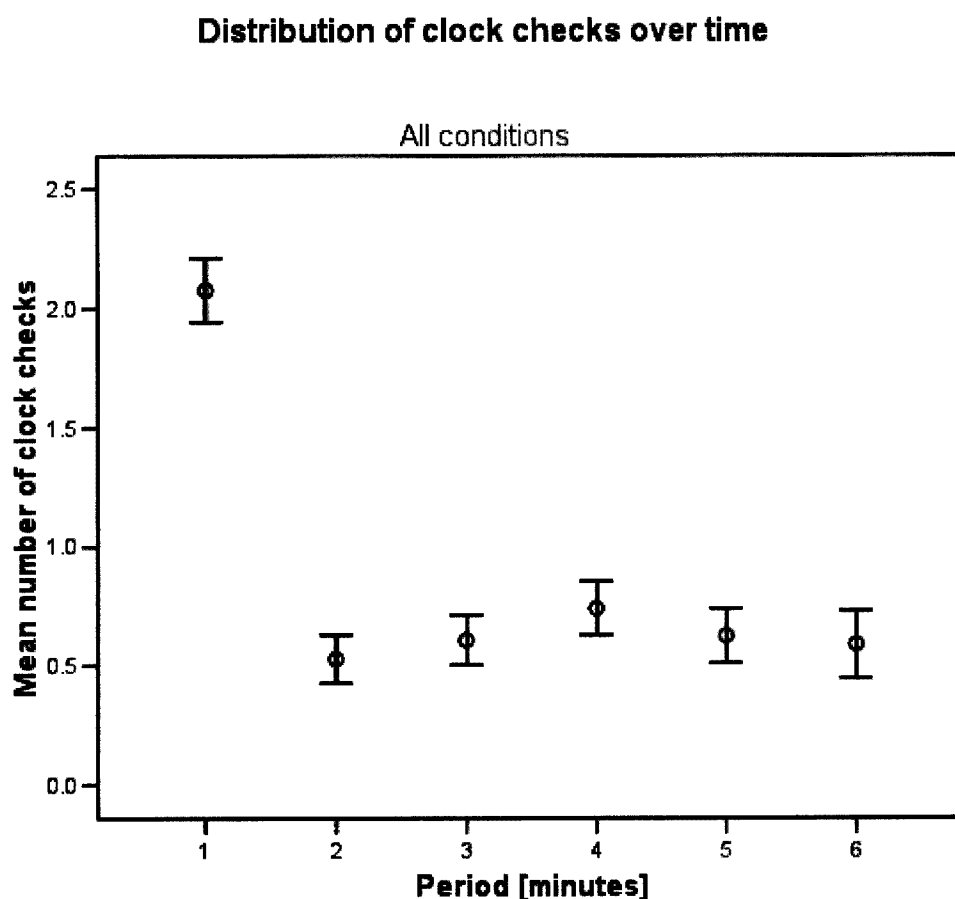
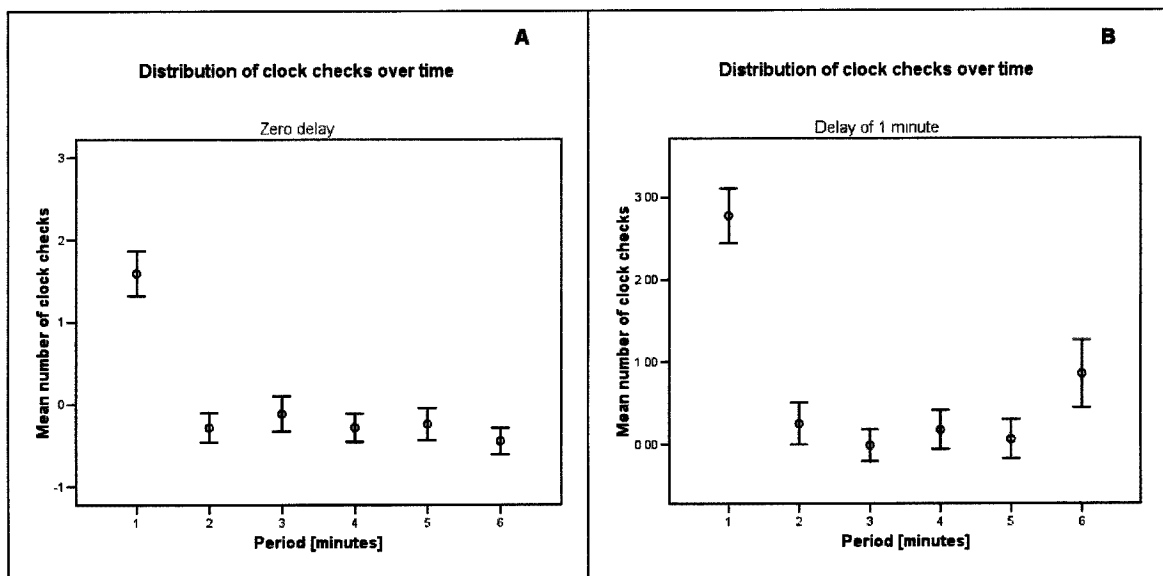


Figure 7.4: Pattern of clock checking during a block of 7 minutes. Within-subjects confidence intervals (see Cousineau, 2005) on the number of clock checks during 1 minute.

The hypothesis to be tested is whether the pattern of clock checking is dependent on length of delay. A mixed Poisson regression model (Analysis 3) was used to test which factors affect the clock checking pattern. The number of clock checks during one minute was the dependent variable. Because Number of clock checks is a count variable, Poisson regression was used. One random Subject factor was introduced as an independent variable, together with 11 fixed factors. The fixed factors were: (1) fixed intercept, (2) Length of delay, (3) Order of periods, (4) First minute¹⁷, (5) Order of blocks, (6) Remembering, (7) Length of delay x Order of periods, (8) Order of blocks x Order of period, (9) three-way interaction Length of delay x Order of period x Remembering, (10) Length of delay x Remembering, (11) Order of periods x Remembering, and (12) First minute x Length of delay. The results showed that there was no linear trend in clock checking over time within blocks in general, because Order of periods (or the order of minutes within a block) did not reach significance. It could have been that there is no linear trend on average over the blocks, but that some blocks with a long delay showed a negative slope and other delays show a positive slope, which cancel out on average. This is however not the case, because the interaction between Length of delay and Order of period has no significant effect on clock checking per minute.



¹⁷ First minute was used as a variable because it was clear from the graphs that clock checking was especially frequent in the first minute. The question is whether the number of clock checks increased beyond this first minute effect, therefore this variable is included in the model.

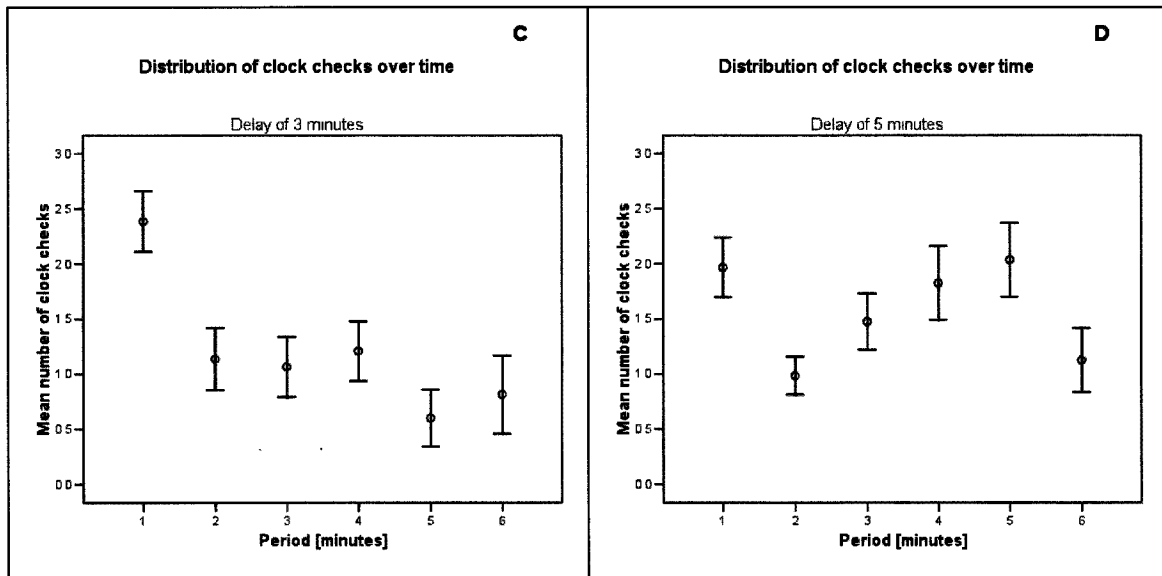


Figure 7.5 Distribution of clock checks over time, with in Part A, B, C and D respectively the conditions with a zero delay, a delay of one, a delay of three and a delay of five minutes. Error bars represent 95% within-subjects confidence intervals on the number of clock checks during one minute..

Another factor of interest, namely Length of delay reached significance ($z=13.0$, $p<.001$, $MLE=0.21$), which means that longer delays go with a higher mean frequency of clock checking. A third factor, the interaction between Length of delay and First minute had a significant negative effect on clock checking per minute ($z=-4.12$, $p<.001$, $MLE=-0.18$), meaning that in longer delays the difference between the clock checking frequency in the first minute compared to the rest of the block decreases. This can also be seen in Figure 7.5: the number of clock checks in the first minute is relatively low for blocks with a delay of five minutes, whereas the number of clock checks in the rest of a block with a delay of five minutes is relatively high. Consequently, the difference between the number of clock checks in the first minute versus the number of clock checks in the other minutes is smaller for longer delays. There is no apparent reason for this effect, because the delay conditions did not differ in the first minute. The pattern found by Park et al., namely that those who forgot the PM task showed a flat curve and those who remembered the PM task showed an increasing curve was not replicated: there was no significant interaction between Remembering and Order of periods.

Table 7.1: results of mixed Poisson regression model on clock checking frequency per minute ($N=1356$, of 57 subjects) (Results of Analysis 3)

Variable	Estimate	SE	Z	p-value
Intercept	-0.34	0.03	-11.49	<.001
Length of delay	0.21	0.02	12.96	<.001
Order of periods	-0.01	0.03	-0.23	n.s. (0.82)
First minute	0.62	0.09	7.01	<.001
Order of blocks	-0.04	0.03	-1.44	n.s. (.15)
Remembering	-0.07	0.18	-0.36	n.s. (.72)
Interaction: Length of delay x Order of periods	0.00	0.01	0.01	n.s. (.99)
Interaction: Order of periods x order of blocks	-0.13	0.01	-8.77	<.001
Interaction: Order of period x Length of delay x Remembering	0.01	0.05	0.12	n.s. (.91)
Interaction: Length of delay x Remembering	0.30	0.09	3.37	<.001
Interaction: Order of periods x Remembering	-0.06	0.10	-0.57	n.s. (.57)
Interaction: First minute x Length of delay	-0.18	0.04	-4.12	<.001

In sum, longer delays come at a certain cost when it concerns clock checking. The clock is checked more often in 7 minutes when the reminder comes early (delay of 5 minutes) than when the reminder comes relatively late (delay of 1 minute). This pattern can be seen in Figure 7.3. The pattern of clock checking is also in favor of short delays: the clock checking frequency per minute is higher for longer delays (see Figure 7.5), except for the first minute. Clock checking occurs frequently in blocks with longer delays and especially when the PM task is not forgotten in that block.

7.5.3 How early is an early response and how late a late response?

The distribution of Early and Late responses over time are displayed in Figures 7.6 and 7.7. Looking at Figure 7.6, it appears that most Early responses occur in the last minute before the PM task. However, for Late responses (Figure 7.7), it appears that most occur within the first few minutes after the window of opportunity of a PM task. One participant was even 20 minutes late, and some were more than 10 minutes early. Most likely, those people just hit the button by accident.

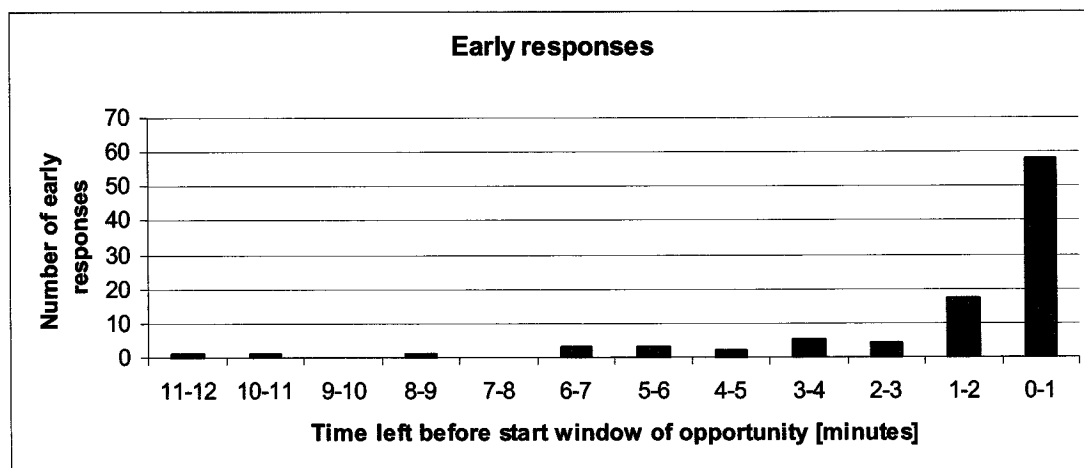


Figure 7.6 Distribution of time between early responses and onset of window of opportunity

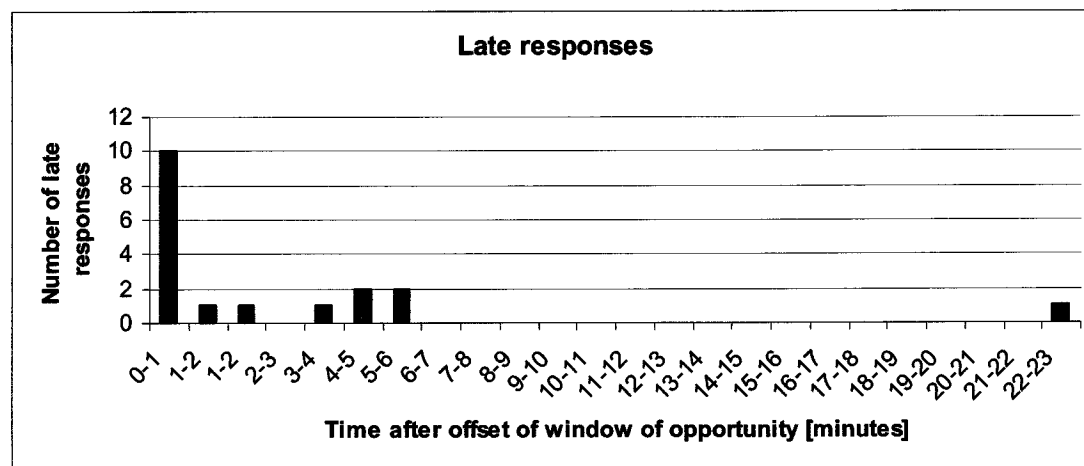


Figure 7.7 Distribution of time between offset of window of opportunity and late responses

7.5.4 The effect of length of delay on early and late responses.

Clicking on the button for the number task can be regarded as a form of checking whether the time is right for that specific number task. It was hypothesized that this type of checking is dependent on Length of delay. Table 7.2 shows the distribution of Early and Late responses over the different lengths of delay. The number of Late responses is not affected by length of delay. The number of Early responses, however does seem to increase with increasing length of delay.

Table 7.2: Number of early and late responses distributed over the different delays.

	Delay 0 min.	Delay 1 min.	Delay 3 min.	Delay 5 min.
Early responses	10	26	26	33
Late Responses	5	4	4	5

A mixed Poisson regression model (Analysis 4), was used to test whether the Number of early responses was dependent on Length of delay, with Number of early responses as the dependent variable. The independent variables were Order of blocks, Length of delay and a fixed intercept. A random Subject variable was added to account for between subject variability. All components reached significance, with as variable of interest Length of delay and its effect on Number of early responses ($p < .01$, MLE = 0.14). Apparently, longer delays come with a certain cost: Participants more often feel a need to check whether it is already time to start with the PM task.

7.5.5 Could early responses serve as an indicator of remembering the PM task in time?

The occurrence of Early responses may reflect that the participant is aware that a certain PM task still has to be executed. It may also indicate that the participant thought that the right time had arrived to execute the number task. In that sense, the occurrence of an early response may be a predictor of remembering (being in time for the PM task). However, the data showed that this is not the case: When every single delay (N=230) is first categorized as 'forgetting' versus 'remembering', there are 12 delays that are categorized as forgetting and 218 as remembering. In 7 of the 12

forgetting delays, at least 1 instance of an early response occurred. In 57 of the 218 remembering delays, at least 1 instance of an early response occurred. Because 7 out of 12 instances is larger than 57 out of 128 instances, it seems that showing an early response does not predict remembering.

7.6 *How does length of delay influence ongoing task performance?*

The third component of this research study is ongoing task performance. Did length of delay have an impact on how well participants were able to perform their main task? Ongoing task performance can be captured in two ways: correctness and reaction time (RT). Both are not only possibly affected by Length of delay, Remembering and order effects, but also by the difficulty of the task at hand. Therefore, task difficulty of the individual ongoing tasks should be taken into account. Although the tasks were randomly selected, it could be that the majority of the different tasks are executed during a block with the longest delay. Therefore, aggregating the data of the separate tasks would possibly insert biases. For this reason, only trial by trial analyses will be executed, in which task difficulty is captured in the explanatory variables.

7.6.1 *Descriptive statistics on ongoing task performance*

Total number of picture tasks performed per participant ranged between 31 and 113 ($M=68.72$, $SD=19.55$), and this variability demonstrates that within-subjects analyses are more appropriate when considering RT. The correctness over all trials done by the participant ranged from 63% to 100% correct¹⁸ ($M=90.2\%$, $SD=7.6\%$). The average reaction time of participants on picture tasks ranged from 8.21 to 39.2 seconds ($M=21.82$ s, $SD=6.66$ s).

7.6.2 *Correctness trial by trial*

A mixed model was used (Analysis 5) to investigate whether correctness was influenced by length of delay, and several parameters of the stimuli were introduced to correct for task difficulty (namely: rotation angle, number of colors, number of changes in the picture being 0 or 1, and the proportion of one color). A nominal logistic model was used with Correctness (yes/no) as the dependent variable. To

¹⁸ Interesting to note: One of the subjects who reported a color sight deficit (green-red distortion) had 100% of the ongoing tasks correct.

capture between-subjects differences on Correctness, a random Subject factor was included in the model. It appeared that the most interesting factors, like Remembering ($p=.58$) and Length of delay ($p=.72$) did not have a significant impact on Correctness. Some parameters of picture stimuli had a significant impact on Correctness, namely Number of changes and Rotation angle. Number of changes had a significant effect on Correctness ($Chi-square=255.77$, $p<.001$, $REMLE=-2.16$), indicating that performance was worse on ongoing tasks involving a change than ongoing tasks involving no change. The rotation angle of the second picture had a positive effect on Correctness ($Chi-square=13.12$, $p<.001$, $REMLE [40-20]=-0.19$ and $REMLE [60-40]=-0.44$): correctness was higher for ongoing tasks with a larger rotation angle. The Log of the reaction time had a positive significant effect on Correctness ($Chi-square=156.23$, $p<.001$, $REMLE=2.23$): on trials where the participant was slow, the chances were also higher that the participant gave the wrong answer. Table 7.3 summarizes the whole model.

Table 7.3 Results of Analysis 5

Variable	Estimate	SE	p-value
Remembering	[no] -0.10	.18	n.s. (.57)
Length of delay	[1-0] -0.28 [3-1] 0.38 [5-3] -0.49	[1-0] 0.18 [3-1] 0.49 [5-3] 0.50	n.s. (.73)
Number of changes	[0] -2.16	0.13	<.001
Number of colors			n.s. (.49)
Rotation angle	[40-20] -0.19 [60-40] -0.45	[40-20] 0.17 [60-40] 0.18	<.01
Proportion of one colour			n.s. (.49)
Receiving a reminder			n.s. (.94)
Order of blocks			n.s. (.35)
Order of trials within a block			n.s. (.75)
Interaction: Order of blocks x Order of trials within a block			n.s. (.14)
Interaction: Length of delay x Order of blocks			n.s. (.79)

Logarithm of the reaction time	2.23	0.18	<.001
Intercept	-22.6	1.85	<.001

7.6.3 Reaction time trial by trial

Performance on the ongoing task could be measured in two ways, namely correctness and reaction time on the picture tasks. The effect of Length of delay on reaction time was studied in a mixed model, with the natural logarithm of the RT as the dependent variable. If the natural logarithm is used, the assumption of normality holds, otherwise the distribution is skewed to the right.

Two measures of RT can be used in the analyses, as explained in Section 6.10: Processing time and Real RT. The first measure was used in Analysis 6A, the second measure was used in Analysis 6B.

The first analysis tested whether Length of delay had an effect on Processing time. For this purpose, a mixed model was used (Analysis 6A), including 18 fixed variables and one random Subject effect. The dependent variable in this analysis was the log of 'Processing time'. The variable of interest, Length of delay, was not significant ($p=.77$), meaning that Length of delay had no impact on Processing time. Another variable of interest, namely Remembering, also did not show a significant impact on Processing time ($p=.16$), nor did the interaction of Remembering and Length of delay ($p=.12$). However, what is interesting is that Frequency of clock checking during a trial led to a significant increase in RT ($F(1, 3530)=28.5$, $p<.0001$, $MLE=0.07$), as did Moving to a PM screen during a trial ($F(1, 3530)=43.3$, $p<.0001$, $MLE=-0.13$). When participants check the clock one time during a trial¹⁹, this adds .07 to the Log reaction time, which means 1.34 sec for the average trial²⁰. When a participant moves to a PM screen during a trial, this adds 0.13 to the Log reaction time, which means an extra 1.23 sec for the average trial. As we know from earlier analyses, these factors are related to Length of delay. However, when these factors are removed as explaining variables, there was still no significant influence of Length of delay on RT. Both analyses (6A and 6B) show similar effects for some of the parameters. Those parameters will be discussed at the end of the section. All results of Analysis 6A can be found in Table 7.4.

¹⁹ Beforehand, it was expected that participants would check the clock between trials. However, 86.4% of all clock checks were performed *during* a trial.

²⁰ Note that in the dependent variable Processing time the time spent to look at the clock is not included. 1.34 seconds comes on top of the time it takes to see what time it is.

The second analysis tested whether Length of delay had an effect on Real RT. A mixed model was used consisting of 17 fixed variables as explanatory variables and one random factor account for the Subject effect (Analysis 6B). The dependent variable of this model was 'Real RT'. The same variables were used as in Analysis 6A, only this time 'Moving to a PM screen' and 'Clock checking frequency' are removed, whereas a new factor was introduced: 'Before or after receiving the reminder.' The 'Before or after receiving the reminder' factor reached significance; Real RT was longer for trials after receiving the reminder than before. ($F(1, 3306) = 4.6, p=.03, MLE=-0.03$). This result was expected because checking the clock takes time and is probably behavior that occurs more often after receiving the reminder. Thus clock checking slowed down Real RT after receiving the reminder. The moment at which the reminder is received during a block is dependent on the length of the delay of that block. The proportion of trials after receiving the reminder is higher for blocks with a long delay than with a short delay (see Figure 7.8). Consequently, a block with a long delay contains relatively more trials with a longer RT (trials after receiving a reminder took more time). One would expect that in general, longer delays are associated with longer RT in general. If the variable 'Before or after receiving the reminder' is removed from the analysis, such an effect of Length of delay could appear. This variable was removed from model and a new analysis was performed. However, the factor of interest, Length of delay did not show a significant effect on RT. Apparently, the effect is too small to carry over to Length of delay.

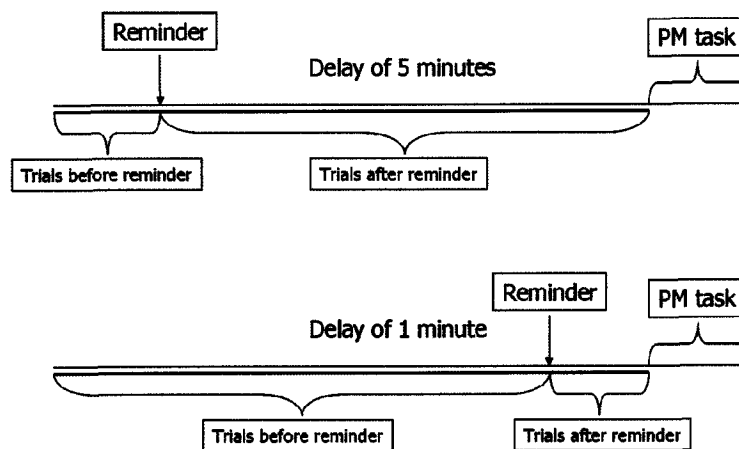


Figure 7.8: Relatively more trials fall after the reminder than before when the delay is 5 minutes. In case of a delay of 1 minute, relatively more trials fall before the reminder is received than after.

To account for task difficulty, several parameters of the picture stimuli were included in both models. The absence of a change in the picture led to longer RTs than a task which included a change (6A: $F(1, 3530)=14.6, p<.0001, MLE=.11$; 6B: $F(1, 3304)=18.5, p<.0001, MLE=.11$). An increasing rotation angle led to an increase in RT ($F(2, 3530)=26.3, p<.0001, MLE[40-20]=.065, MLE[60-40]=.161$; 6B: $F(2, 3304)=20.1, p<.0001, MLE[40-20]=.065, MLE[60-40]=.116$). Trials with three colors took more time than trials with two colors (6A: $F(1, 3530)=132, p<.0001, MLE=-.152$; 6B: $F(1, 3304)=158, p<.0001, MLE=-.149$). The location of the button 'same' on the screen (at the left or at the right side) had a significant effect on RT, with the button on the left side being associated with shorter reaction times (6A: $F(1, 3530)=5.60, p<.05, MLE=-.085$; 6B: $F(1, 3304)=8.56, p<.01, MLE=-.010$). This variable was a between-subjects measure and thus the effect shows a significant difference between participants which is not meaningful for this study. Furthermore, both analyses show order effects, as both the order of the trials within a block (6A: $F(1, 3530)=25.6, p<.001, MLE=-.008$; 6B: $F(1, 3304)=3.20, p=.07, MLE=-.003$) and the order of blocks had a (marginally) significant effect on RT (6A: $F(1, 3530)=114, p<.001, MLE=-.073$; 6B: $F(1, 3304)=166, p<.001, MLE=-.080$). This appears to be a learning effect because the reaction time decreases with later trials and later blocks.

The complete regression models including all variables can be found in the Table 7.4, where also the maximum likelihood estimates are listed.

Table 7.4: Results of Analysis 6A and 6B. Significant outcomes are printed in red. Degrees of freedom for the model are the same in both models, and can be found in column 2. An x indicates that the variable was not included in this specific model. A dot indicates that the variable contains 0 degrees of freedom in this specific model.

Variable	Model 6A On Ln[Processing time]					Model 6B On Ln[real RT]			
	DF	DF total	Est.	F Ratio	Prob > F	DF total	Est.	F Ratio	Prob > F
Random subject variable	57	3530			Shrunk	3304			Shrunk
Intercept			9.828				10.250		
Length of delay	1	3530	.005	0.150	0.70	3304	-.001	0.006	0.94
Clock checking frequency during trial	1	3530	.072	29.0	<.0001	x	x	X	x
Number of changes in stimulus	1	3530	[0].113	14.6	0.0001	3304	[0].113	18.5	<.0001
Number of colors of stimulus	1	3530	[2] -.152	132	<.0001	3304	[2].149	158	<.0001
Rotation angle of stimulus	2	3530	[40-20].065 [60-40].161	26.3	<.0001	3304	[40-20].065 [60-40].116	20.1	<.0001
Proportion of one color	1	3530	-.001	0.020	.89	3304	.007	1.40	0.24
Button 'same'	1	3530	[left]-.085	5.60	0.02	3304	[left]-.101	8.56	0.004
Moving to PM task during trial	1	3530	[not]-.132	44.4	<.0001	x		X	x
Remembering	1	3530	[not].036	1.83	0.18	3304	[not].019	0.651	0.42
Correctness	1	3530	[not].072	4.19	0.04	3304	[not].104	10.9	0.001
Interaction: Number of changes x Correctness	1	3530	[not][not] -.188	40.6	<.0001	3304	[not][not] -.176	44.7	<.0001
Interaction: Number of colours x Correctness	1	3530	[2][not] -.001	0.011	0.92	3304	[2][not] -.007	0.359	0.55

Variable	Model 6A On Ln[Processing time]					Model 6B On Ln[real RT]			
	DF	DF total	Est.	F Ratio	Prob > F	DF total	Est.	F Ratio	Prob > F
Interaction: Rotation angle x Correctness	2	3530	[40-20][not] -.010 [60-40][not] .040	0.841	0.43	3304	[40-20][not] -.009 [60-40][not] -.012	0.267	0.77
Interaction: Proportion of one color x Correctness	1	3530	[not]-.12	3.69	0.05		[not]-.002	0.113	0.74
Order of trials within a block	1	3530	-.008	25.3	<.0001	3304	-.003	3.20	0.07
Receiving a reminder during a block	1	3530	[no]-.100	31.5	<.0001
Before versus after reminder	1	x	x	X	x	3304	[before] -.050	18.0	<.0001
Order of blocks	1	3530	-.073	114	<.0001	3304	-.080	166	<.0001
Interaction: Order of blocks x Length of delay	1	3530	-.005	1.12	0.29	3304	-.005	1.78	0.18
Interaction: Order of trials within a block x Length of delay	1	3530	.001	3.00	0.08	3304	.001	1.99	0.16
Interaction: Remembering and Length of delay	1	3530	[not].020	2.85	0.09	3304	.013	1.61	0.20

8. Discussion

The experiment in this thesis was conducted to explore what the effect on performance was of length of a delay between receiving a reminder and executing a prospective memory task. Both ongoing task performance and prospective memory performance were expected to decline with increasing length of delay. Furthermore, it was expected that checking whether the time is right would be detrimental for ongoing task performance but beneficial for prospective memory performance. Therefore, these three aspects were taken into account in answering the research question: prospective memory performance, performance on the ongoing task and checking whether the time was right for the PM task. The results on those three aspects will first be discussed separately, and then all three are taken together to answer the main question.

The data showed that prospective memory performance was worse at longer delays; that is, forgetting rates were higher for longer delays. This pattern is in line with hypothesis 1. This pattern of results is important because beforehand, it was not known whether inserting a delay between receiving a reminder and being able to execute a PM task made a difference on prospective memory performance. This is a valuable finding for the design of reminding systems, as it shows that introducing a long delay can have negative effects on PM performance. This finding is also valuable for PM research, because it was not yet known whether and how PM performance was affected by time. These results showed that the chances of forgetting a task after receiving a reminder increased with time. This pattern is similar to retrospective memory performance, which also tends to show a decline over time. The size of the effect of receiving a reminder on PM performance is however not yet established. All conditions in the experiment included a reminder. It may be that there is no difference in PM performance between receiving a reminder 5 minutes before the PM task or no reminder at all. The effect of receiving a reminder versus no reminder may be the subject of a follow-up study. Such a study could provide arguments for the use of reminder systems.

Clock checking was also found to occur more often in blocks with a long delay. These results are in line with hypothesis 3: longer delays go with more frequent clock checking. This result was expected because it is more useful to check the clock after receiving the reminder than before, and in blocks with a long delay there is more time

after receiving the reminder than in blocks with a short delay (and thus more opportunity to check the clock after receiving the reminder). However, not only the absolute number of clock checks in a block of seven minutes was affected by the length of delay. That is, the clock checking frequency *per minute* was also higher for longer delays than for short delays. Clock checking frequency, therefore, was also *relatively* higher for longer delays. This finding is of interest for the design of reminding systems as it shows that using a long delay between receiving a reminder and the possibility to execute the PM task leads to more frequent clock checking. The finding that relatively more clock checks occurred in blocks with a long delay is also of interest for prospective memory research. It suggests that it may be harder to estimate how long a 5 minutes delay takes than to estimate the duration of an one minute delay and consequently more frequent clock checking is needed in longer delays. Although the clock ticks minutes away at a constant and regular pace, the perception of time makes people feel that the pace at which time goes by differs between situations. Expressions like 'time flies when you are having fun' illustrate this idea that time perception is different in different situations. The elderly and people suffering from Alzheimer's disease have a different time perception than younger, healthy adults (Carrasco, Guillem, & Redolat, 2000; Craik & Hay, 1999 in Einstein et al, 1995), and they have often problems with prospective memory. Possibly, time perception and prospective memory are related (a suggestion also made by Block & Zakay, 2006). Time perception may also be a moderator in the relationship between ongoing task performance and prospective memory: an accurate time perception may be needed for good prospective memory performance and at the same time this time perception is affected by ongoing task performance. Being busily engaged may also give the sense that time flies, a reason for underestimating the time spent on the main task. Therefore, the role of time perception in prospective memory tasks should be a subject of further study.

The other aspect concerning performance in situations in which a PM task has to be remembered is ongoing task performance. Ongoing task performance was measured both by correctness of responses and the reaction time at the picture tasks. No effect of length of delay was found on correctness. Two questions can be addressed when considering reaction time. The first question is of interest for the research field of prospective memory, namely whether reaction time is impaired by self-reminding. To answer this question, the effect of length of delay on the time a

participant needed to process a picture task was studied. This 'processing time' was slowed down when a reminder was received, when the clock was checked, and when the participant moved during that trial toward a number task screen. For checking the clock and moving to a PM task, some motor tasks were needed that take time such as eye movements and moving the cursor. The time required for these actions was included in the variable Processing time. Consequently, it is not surprising that when a participant checked the clock or moved to a PM task during a trial, that the trial took more time even after correcting for the time spent watching the clock and time spent at the number task screen. For checking the clock, two eye movements are needed (back and forth). Such a saccade generally takes 100 ms (Sekuler & Blake, 2002). Moving the cursor over a distance of around 20 cm towards a target with a width of 2 cm requires around 600 ms (Oel, Smidt, & Smitt, 2001). The effects are around the size of these movements (1.23 and 1.34 seconds). No effect of length of delay was found on Processing time. It was expected that ongoing task performance would worsen after receiving the reminder, because participants should then remind themselves. No effect of such self-reminding was found in this study. A possible explanation for the absence of results on the ongoing task is that the PM task and the ongoing task require different resources. It was assumed that successful PM performance depends on working memory. The chosen ongoing task required participants to keep in mind part of the picture on the left and compare it with that part of the picture on the right. Keeping in mind information and comparing it with new information requires working memory capacity. The absence of results on ongoing task performance is not due to the fact that different resources were needed that could run in parallel, because both the PM task and the ongoing tasks required the same resource. According to the TAP hypothesis the tasks should be similar to not interfere with each other. The tasks are however dissimilar, because self-reminding is an internal process whereas the ongoing task required the participant to combine information from the environment with information from memory. Consequently, the TAP hypothesis can not provide an adequate explanation for the absence of an effect of self-reminding on the ongoing task. Another explanation of the absence of results on ongoing task performance lies in the duration of the ongoing tasks. The current study used attention demanding ongoing tasks of about 20 seconds each. The attention demanding ongoing tasks usually used in other research only last a few hundreds milliseconds each. In that case, only a split second of divided attention is enough to

induce large effects on RT (Cohen & Gollwitzer, in press; Smith, 2003). The current experiment used tasks of a longer duration and larger variability in RT between the tasks. Because the variability in RT was in this experiment a matter of seconds, short moments of divided attention in the range of milliseconds could not be detected. It seems that these tasks with longer duration are less sensitive to changes in attention. Further study is needed to verify this conclusion. Although short duration tasks enable the researchers to show self-reminding, the currently used long duration tasks seem to show that self-reminding needs not be disruptive for ongoing task performance on more naturalistic tasks. This is an important finding for reminding system research because it may be that in regular office tasks, ongoing task performance is not influenced by self-reminding. There are several reasons for considering the tasks used in this study to be naturalistic tasks. Longer ongoing task can be considered more naturalistic because everyday office tasks generally take minutes instead of milliseconds. Furthermore, the tasks used as ongoing tasks in this experiment required the participant to search for and combine information. Searching and combining information are tasks that are regularly performed in the office environment. The tasks used in this study add valuable insights on the impact of self-reminding on ongoing task performance. The current study shows that tasks that take relatively more time seem to be more robust to switches of attention.

The second question regarding reaction time is a practical one, namely whether participants can do less ongoing tasks in blocks with a longer delay. This is of interest for the design of reminding systems, because it would tell us something about the effects of the delay of a reminder on productivity. In blocks with a long delay, more frequent clock checking and movements towards the PM task were registered. These actions may be necessary to be in time for the PM task, and may reduce the number of ongoing tasks a person can perform. In this case, Real reaction time was used, and this 'real reaction time' slowed down after the reminder was received, confirming Hypothesis 4. This slowing down, however did not transfer to an effect of length of delay on RT, which was expected according to Hypothesis 2. Apparently, the effect of slower responses after receiving a reminder is small. This finding suggests that it does not make a difference whether the reminder is received early or late with regard to ongoing task performance. It appears that participants were able to both monitor the clock and not decrease overall ongoing task performance. A possible explanation for

this effect is that people are aware of when clock checking is least disruptive. It may be that participants check the clock at times that they were already distracted.

All in all, longer delays go with more forgetting of the prospective memory task, a finding that supports the use of short delays. Although the size of the effect does not seem to be large, one should keep in mind that these results spring from an experimental situation that requires people only to be concerned about two tasks. Outside the laboratory, people have to deal with a large amount of tasks. Prospective forgetting may thus be more frequent outside the laboratory. Longer delays also go with a higher frequency of checking the clock in absolute terms (comparing blocks of 7 minutes with a reminder early or late in this block) and in relative terms (clock checking frequency per minute). Longer delays also go with more early responses: participants feel a need to check externally whether the time is right to move to the number task. These two types of external checking slow down ongoing task performance. However, this effect of slowing down of responses is not that large that in a block of seven minutes a difference is found in reaction time between receiving a reminder early or late in the block. Consequently, when it concerns ongoing task performance, it does not matter whether a short or long delay is used. In sum, short delays are better than long delays in a situation where ongoing tasks of considerable duration are used and a reminder is received maximally 5 minutes before the possibility to execute the PM task.

A last interesting point concerns the registration of the attempts of participants to switch to the PM task. It seems from the results that participants thought about the PM task during the experiment, a fact that could not have been shown by the standard paradigm. The idea that the participants thought about the PM task is based on the finding that participants almost always checked a number task screen, and I assumed that this reflects that the participant thought the time was right to move to the number task. Although they almost always checked a number task screen, they did not always move 'in time' to this task. This shows that prospective forgetting in the sense of not being in time to execute a prospective memory task, does not imply that there were no thoughts at all about this special task. The paradigm of Einstein and McDaniel (1990) only distinguishes 'in time'- responses versus 'no responses.' In their paradigm, prospective remembering seems like a black and white picture: a task is either remembered or forgotten. However, in reality, remembering and forgetting appear to

fluctuate over time. What is forgotten at one moment, could be remembered a moment later.

9. Conclusion

The current study served two goals: a general and a specific one. The general goal was to show how research in prospective memory and reminder systems can be combined, and to provide an example of how reminders can be used in a prospective memory experiment. The experiment resulted in knowledge of interest for the field of prospective memory and knowledge of interest for the design of reminder systems. The specific goal was to answer the question ‘what is the effect on performance of length of a delay between receiving a reminder and executing a prospective memory task?’

Based on the data from the experiment, short delays should be preferred over long delays. PM performance is worse with longer delays, but the effect is not large. Possibly, the laboratory setting is not as demanding as regular office work situations. For practical matters, a delay of 5 minutes between receiving a reminder and executing a prospective memory task may not be problematic, depending on the situation. In this study only delays between 0 and 5 minutes were used, and further research is needed to see whether the effects that were found increase when delays of about 15 minutes are used (which is the default option of MS Outlook).

Interesting for the theoretical field of prospective memory is that prospective forgetting seems to increase with increasing time after receiving a reminder. Possibly, the forgetting rates when a reminder comes 5 minutes before the PM task are equal to those without a reminder. Furthermore, the study showed that ongoing task performance is not necessarily impaired by self-reminding, a finding possibly due to the longer duration of the ongoing task compared to the standard PM paradigm.

In summary, the current study shows that it is possible to run experiments which produce results useful for both prospective memory research and research on reminding systems. Introducing reminders in ecologically valid prospective memory experiments appears to be a fruitful way combining both fields. Combining those fields may be necessary for the development of effective reminder systems. And after all, wouldn't we all like to have a reminding system that prevents us from forgetting by reminding us *at the right time?*

References

- Baddeley, A. (1997). *Human memory: Theory and Practice*. East Sussex, UK: Psychology Press.
- Bergman, M.M. (2003). The Essential Steps: A cognitive orthotic. *NeuroRehabilitation, 18*, 31-46.
- Block, R.A., & Zakay, D. (2006). Prospective remembering involves time estimation and memory processes. In: J. Glicksohn, & M.S. Myslobodsky (Eds.). *Timing the future: The case for a time-based prospective memory*. (pp. 25-49). River Edge, NJ, US: World Scientific Publishing Co
- Carrasco, M.C., Guillem, M.J. & Redolat, R. (2000). Estimation of short temporal intervals. *Experimental Aging Research, 26*, 139-151.
- Cohen, A., Dixon, R.A., Lindsay, D.S. & Masson, M.E.J. (2003). The effect of perceptual distinctiveness on the prospective and retrospective components of prospective memory in young and old adults. *Canadian Journal of Experimental Psychology, 57*, 274—289.
- Cohen, A., & Gollwitzer, P.M. (in press). The cost of remembering to remember: cognitive load and implementation intentions influence ongoing task performance. In: M. Kliegel, M.A. McDaniel and G.O. Einstein (Eds.), *Prospective memory, Cognitive, Neuroscience, Developmental, and Applied perspectives*. Lawrence Erlbaum Associates.
- Cohen-Mansfield, J. Creedon, M.A., Malone, T.B., Kirkpatrick, M.J., Dutra, L.A. & Herman, R.P. (2005). Electronic memory aids for community-dwelling elderly persons: attitudes, preferences, and potential utilization. *The Journal of Applied Gerontology, 24*, 3-20.

- Cole, E. (1999). Cognitive prosthetics: an overview to a method of treatment. *NeuroRehabilitation*, 12, 39-51.
- Cousineau, D. (2005). Confidence intervals in within-subjects designs: a simpler solution to Loftus and Masson's method. *Tutorial in Quantitative Methods for Psychology*, 1, p. 42-45.
- Craik, F.I.M., & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior*, 11, 671-684.
- Einstein, G. O. & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 115-141). Mahwah, NJ: Lawrence Erlbaum Associates.
- Einstein, G.O., McDaniel, M.A., Manzi, M., Cochran, B. & Baker, M. (2000). Prospective memory and aging: forgetting intentions over short delays. *Psychology and Aging*, 15, 671-683.
- Einstein, G.O, McDaniel, M.A., Richardson, S.L., Guynn, M.J. & Cunfer, A.R. (1995). Aging and Prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 21, 996-1007
- Einstein, G.O., Smith, R.E., McDaniel, M.A. & Shaw, P. (1997). Aging and Prospective memory: The influence of increased task demands at encoding and retrieval. *Psychology and Aging*, 12, 479-488.
- Eysenck, M.W. & Keane, M.T. (2002). *Cognitive Psychology: A student's handbook*. East Sussex: Psychology Press Ltd.
- Evans, J.J. (2006). Memory rehabilitation – should we be aiming for restoration or for compensation? *Journal of Neurology*, 253, 520-521.

- Gorman, P., Dayle, R., Hood, C. & Rumrell, L. (2003). Effectiveness of the ISAAC cognitive prosthetic system for improving rehabilitation outcomes with neurofunctional impairment. *NeuroRehabilitation*, 18, 57-67.
- Hersh, N.A. & Treadgold, L.G. (1994). NeuroPage: the rehabilitation of memory dysfunction by prosthetic memory and cueing. *Neurorehabilitation*, 4, 187-197.
- Huppert, F.A., Johnson, T. & Nickson, J. (2000). High prevalence of prospective memory impairment in the elderly and in early-stage dementia: findings from a population-based study. *Applied Cognitive Psychology*, 14, 63-81.
- Inglis, E.A., Szymkowiak, A., Gregor, P., Newell, A.F., Hine, N., Shah, P., Wilson, B.A. & Evans, J. (2003). Issues surrounding the user-centred development of a new interactive memory aid. *Universal Access in the Information Society*, 2, 226-234.
- Long, J.S. (1997). *Regression models for categorical and limited dependent variables*, Sage Publications, London.
- Marsh, R. L. & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 24, 336-349.
- Maylor, E.A. (1993). Aging and forgetting in prospective and retrospective memory tasks. *Psychology and Aging*, 8, 420-428.
- McDaniel, M.A. & Einstein, G.O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, 14, 127-144.

- McDaniel, M. A., Robinson-Riegler, B., & Einstein, G. O. (1998). Prospective remembering: Perceptually driven or conceptually driven processes? *Memory & Cognition*, *26*, 121-134.
- Neath, I., & Surprenant, A. M. (2003). *Human memory: An introduction to research, data, and theory, second edition*. Pacific Grove, CA: Brooks/Cole.
- O'Connell, M.E., Mateer, C.A. & Kerns, K.A. (2003). Prosthetic systems for addressing problems with initiation: Guidelines for selection, training, and measuring efficacy. *NeuroRehabilitation*, *18*, 9-20.
- Oel, P., Smidt, P., & Smitt, A. (2001). Time prediction of mouse-based cursor movements. *Proceedings of Joint AFIHM-BCS Conference on Human-Computer Interaction IHM-HCI'2001*. Lille, France, Sept. 10-14, 2001. Volume II, 37-40. Cépaduès-Éditions, Toulouse, 2001
- Oriani, M., Moniz-Cook, E., Binetti, G., Zanieri, G., Frisoni, G.B, Geroldi, C., De Vreese, L.P. & Zanetti, O. (2003). An electronic memory aid to support prospective memory in early stages of Alzheimer's disease: a pilot study. *Aging & Mental Health*, *7*, 22-27.
- Park, D.C., Hertzog, C., Kidder, D.P., Morrell, R.W. & Mayhorn, C.B. (1997). Effect of age on event-based and time-based prospective memory. *Psychology and Aging*, *12*, 314-327.
- Payne, J.W., Bettman, J.R., & Johnson, E.J. (1993). *The adaptive Decision Maker*. Cambridge University Press, New York.
- Roediger, H.L., Marsh, E.J., & Lee, S.C. (2002). Kinds of Memory. In: *Stevens' Handbook of experimental psychology, Vol. 2: Memory and Cognitive Processes*, 1-41.

- Roediger, H.L., III, Weldon, M.S., & Challis, B.H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H.L. Roediger III & F.I.M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving*, (pp 3-41), Hillsdale, NJ: Erlbaum
- Sekuler, R., & Blake, R. (2002). *Perception*. New York: McGraw-Hill.
- Singer, J.D. (1998). Using SAS PROC MIX to fit multilevel models, hierarchical models, and individual growth models. *Journal of Educational and Behavioral Statistics*, 24, 323-355.
- Smith, R.E. (2003). The cost of remembering to remember in event-based prospective memory: investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 347-361.
- Sohlberg, M.M., Kennedy, Avery, J., M., Coelho, C., Turkstra, L., M., Ylvisaker, Yorkston, K. (in press) Practice guidelines for external aids for memory rehabilitation, *Journal of Medical Speech Language Pathology* [scheduled for Vol 15(1) 2007].
- Szymkowiak, A., Morrison, K., Gregor, P., Shah, P., Evans, J.J., Wilson, B.A. (2005). A memory aid with remote communication using distributed technology. *Personal and Ubiquitous Computing*, 9, 1-5.
- Tulving, E. & Thomson, D.M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, 80, 359-380.
- West, R. & Craik, F.I.M. (1999). Age-related decline in prospective memory: the role of cue accessibility and cue sensitivity. *Psychology and Aging*, 14, 264-272.

- Wilson, B.A., Emslie, H.C., Quirk, K. & Evans, J.J. (2001). Reducing everyday memory and planning problems by means of a paging system: a randomised control crossover study. *Journal of Neurology, Neurosurgery, and Psychiatry*, 70, 477-482.
- Wilson, B.A., Evans, J.J., Emslie, H. & Malinek, V. (1997). Evaluation of NeuroPage: a new memory aid. *Journal of Neurology, Neurosurgery, and Psychiatry*, 63, 113-115.
- Wiseman, S. & Tulving, E. (1976). Encoding specificity: Relations between recall superiority and recognition failure. *Journal of Experimental Psychology: Human Learning and Memory*, 2, 349-361.



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