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Smartwatch aids time-based prospective memory in Korsakoff syndrome: a case study

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ABSTRACT

Prospective memory (PM) is the ability to remember to carry out an intention in the future. PM is particularly impaired in Korsakoff syndrome (KS). We investigated the benefit of a smartwatch and smartphone compared to no aid in supporting time accuracy and PM task performance in KS. Time accuracy was improved with a smartwatch compared to the other conditions. Furthermore, the smartwatch and phone conditions were more effective than no aid in assisting memory for task content. Together these results suggest that using an external memory aid is beneficial for successful PM in KS.

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Introduction

Prospective memory (PM) refers to remembering to carry out a planned intention at a future occasion, the occasion being at a particular time (time-based PM), or at the occurrence of an event (event-based PM), e.g., seeing a friend. Time-based PM allows us to schedule and conduct activities that are to be carried out at appropriate times. It can be more challenging than event-based PM since it relies more heavily on self-initiated processes (Craik, Klix, & Hagendorf, 1986; d'Ydewalle, Luwel, & Brunfaut, 1999).

A patient group with striking PM deficits are those with Korsakoff syndrome (KS). KS patients perform poorly on event-based PM tasks (Altgassen, Ariese, Wester, & Kessels, 2016; Brunfaut, Vanoverberghe, & d'Ydewalle, 2000), however, less information is available regarding their time-based PM abilities. The first PM study conducted in KS ran a time-based PM task as a pilot experiment. This condition was not completed however, since the task was too demanding (Brunfaut et al., 2000). Previous studies (Mimura, Kinsbourne, & O'Connor, 2000; Shaw & Aggleton, 1994) have shown that KS patients are impaired in their ability to make temporal judgements, both underestimating and overestimating the estimated time (El Haj et al., 2016). Deficits in episodic memory may contribute to this impairment, since time estimation may rely on the retrieval of events that occurred during the time intervals (Mimura et al., 2000). With poor time estimation in these patients (de Joode, van Boxtel, Hartjes, Verhey, & Van Heugten, 2013), unassisted time-based PM tasks would be especially challenging. In addition to episodic memory deficits, KS is characterised by global deficits in executive functioning. Importantly, PM is known to heavily rely on episodic memory and executive functions (Einstein & McDaniel, 1990); two processes which are severely impaired in this patient population (Brion, Pitel, Beaunieux, & Maurage, 2014; Fama, Marsh, & Sullivan, 2004).

External memory aids are particularly useful in supporting PM in neurological patients and in healthy individuals (Cicerone et al.,

2005). These aids can be applied for managing our daily lives, planning appointments, and keeping track of our weekly schedule (de Joode, van Heugten, Verhey, & van Boxtel, 2010). Previous studies have investigated the benefit of external memory aids in assisting with PM tasks in cases of KS (see Oudman, Nijboer, Postma, Wijnia, & Van der Stigchel, 2015 for a review), however the results are still very limited. Two earlier studies investigated the effects of using a diary in KS to support PM. Davies and Binks (1983) tested the effects of using PM prompt cards (i.e., 'open the window') on remembering future events in one patient diagnosed with KS. Both the patient and the partner were involved in the training process, and eventually the patient was able to apply notion cards to help him go to future events. Morgan, McSharry, and Sireling (1990) compared the effects of a digital paging system and verbal commands in attending group meetings in a KS patient. Both conditions resulted in more than 80% attendance rate of the patient, suggesting that both verbal commands and digital paging could help attendance (Morgan et al., 1990). To examine the effects of a digital planning device in KS, de Joode et al. (2013) studied the difference between a personal digital assistant (PDA) and a memory watch in supporting PM for daily activities. Quantitative analysis was not possible, potentially due to the vast amount of missing observations. A limited qualitative analysis suggested that the PDA was favoured over the watch by both the patient and the care staff. Supporting the need for more research: no valid case-controlled studies have been performed. Missing observations and patient dropouts have proved to be problematic factors affecting previous case studies examining similar interventions. For example, one study suffered from clinician's unintentional loss of scoring forms of the outcome variable and inconsistent scoring routines from staff members in the clinic (de Joode et al., 2013). Another study had to be stopped mid-way at the request of the patient (Svanberg & Evans, 2013). Introducing novel interventions in KS patients may be complicated by the severity of executive and memory deficits. Therefore, due to

these complications, there remains little quantitative evidence that memory aids can support PM tasks in this patient group.

In light of the lack of evidence for the applicability for memory aids in KS, the present case study investigated the beneficial effect of a “MyWepp” smartwatch, a commercially available wearable electronic device, on aiding PM tasks. This watch could serve as a comfortable and robust alternative to other memory aids. The MyWepp device presents pictorial and verbal commands on previously externally set times, to support PM in the patient. The aim of the present study was to provide quantitative evidence as to whether an external memory device can prove beneficial in supporting time-based PM tasks in a case of KS.

Case report

Our patient was a 56-year-old Dutch man diagnosed with KS (Mr. W.). He met the Diagnostic criteria of the DSM-5 for the alcohol-induced major neurocognitive disorder (American Psychiatric Association, 2013), and the criteria for KS as described by Kopelman (2002). He had been detoxified for more than a year and was in the chronic, amnesic state of KS, not in the state of Wernicke delirium during the time of testing. Previously, he had an episode of acute Wernicke Encephalopathy, and was treated with parenteral thiamine. Despite this treatment he went on to develop KS, as reflected in chronic declarative amnesia, and mild executive deficits (see Table 1 for assessment results). The neurologist report stated that he suffered “strong atrophy of the brain” during initial hospitalization based on MRI. His estimated alcohol consumption per-day was two bottles of liquor.

Before the onset of Wernicke Encephalopathy, he was very high functioning having previously obtained a PhD in Chemistry and worked abroad as an internal manager of an oil company. Mr. W. now lives in a full-time care facility for KS patients. He has very good social skills and regularly visited with his family members who live nearby the facility. He was aware of his PM struggles and would often make jokes about forgetting to carry out the tasks of the study.

Method

Materials and procedure

A list of tasks was presented to the patient on each testing day morning (before breakfast). This list contained a description of the tasks to be performed on that day as well as the designated times (quarterly, half or hourly times were used). Each day consisted of four tasks. Examples of the tasks are presented in Table 2.

The first condition allowed the patient to use his smart phone in order to set reminders for the tasks. The second condition required the patient to rely only on his own memory and no external devices where available. In the third condition, the MyWepp watch was provided to the patient. Only the necessary functions were available on the device: namely, the task reminders and clock; no other apps or files were available. The patient was given detailed verbal instructions of how to use the device and was familiarised with the watch prior to taking part in the study. For the experiment, task reminders were programmed into the watch by the researcher. This was

Table 1. Demographic variables and neuropsychological test results of the case study patient diagnosed with Korsakoff syndrome.

Construct	Score	Classification
Handedness ^a		right
CAMDEX total score ^b	82*	very low
CAMDEX memory section	21*	very low
CAMDEX non-memory section	61	normal
CAMDEX domain scores		
Orientation	5*	very low
Language	28	normal
Memory	16*	very low
Attention	7	normal
Praxis	6	normal
Perception	9	normal
MMSE ^c	21*	very low
WAIS-IV total ^d	127	high
BADS total score ^e	18	average
BADS Rule Shifting	0 errors	high
BADS Action-Plan Test	5 points	high
BADS Key Search Task	14 points	high
BADS Temporal Judgement	3 points	average
BADS Zoo Map Test	4 points*	very low
BADS Six Elements	3 points	average

* = Score below cut-off value, CAMDEX = Cambridge Examination for Mental Disorders – Revised, MMSE = Mini Mental State Examination, WAIS-IV = Wechsler Adult Intelligence Scale-4, BADS = Behavioural Assessment of Dysexecutive Syndrome

^a Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971)

^b Section B CAMDEX scores, screening instrument for dementia. Normed for 65 years and older (Roth et al., 1986)

^c Raw score on the Mini Mental State Examination, a short screening instrument for dementia (Folstein, Folstein, & McHugh, 1975)

^d Total IQ score on the Wechsler Adult Intelligence Scale, version IV (Wechsler, 2008)

^e Scores and classification according to the Behavioural Assessment of Dysexecutive Syndrome, a test for Executive Functioning.

Table 2. Examples of PM tasks assigned to the patient.

Prospective memory tasks
“Send a picture of today’s paper at 9:45”
“Send a picture of a plant at 14:15”
“Send a message to Beth at 17:30”
“Send a picture of shoes at 19:00”

done in order to decrease noise during the experiment. An administrative system accompanies the smartwatch, this allows caregivers to program reminders into the watch wirelessly and remotely from a laptop or similar device. At the set times the watch beeped, vibrated and showed a notification with the task description, accompanied with ‘green tick box’ and ‘red cross box’. The patient was required to click the appropriate box indicating whether the task had been completed or not.

An episodic memory test was given at the end of each testing week. This was a pen and paper test and contained six questions. It was a target recognition task in which the patient had to indicate which pictures or task descriptions (selected from the list of PM tasks) were his or assigned to him, and which were distractors.

The patient was tested on three conditions over three weeks. Each condition was assigned for three testing days, these took place on the Monday, Tuesday and Wednesday of each week. On each morning of the testing days, the patient was instructed to try to remember the task content and the times that they were assigned. This took approximately 5 min-

utes. The tasks all required Mr. W. to send (via 'WhatsApp') either a message or a picture of a common object (no personal pictures) to the researcher (see Table 2). Each were designed so that they were easily achievable wherever the patient was, i.e., if he was at work or out for a walk.

The first condition, known as the 'As-per-usual condition' allowed the patient to complete the PM tasks in any way that he normally would. During this condition Mr. W. made use of his mobile phone, setting reminders for each task as he would with real-life PM appointments. Since the patient only used a mobile phone in the first week, it is later referred to as the 'Phone condition'. The second condition was a 'No-aid condition'. During this week, the patient was required to complete the PM tasks with no external aids. This was accomplished by monitoring the patient as he was presented the daily tasks to ensure that no notes were taken nor was he able to use his phone at this time. The final week consisted of the 'Watch condition', this was similar to the second week, however, the patient was informed that the watch was programmed with the task description and that a reminder would be presented five minutes prior the designated time of the task.

Retrospective memory task

At the end of each week, the patient completed a retrospective episodic memory test based on that week. This resulted in a total of three tests, each made-up of six questions. During the test, the patient was presented with six pictures or task descriptions that were taken by him or assigned to him in that week. Alongside these were distractor items or task descriptions. The patient had to indicate which items were his. The hits rate was calculated as the dependent variable.

Analysis

A total of 36 tasks were assigned, 12 per condition. Two dependent variables were indexed: PM time accuracy (in minutes), this was calculated as minutes difference from the assigned time, and precision of the PM task (correct or incorrect). One observation during the Watch condition was excluded due to a technical issue preventing the task from being presented. The analysis was carried out using Rstudio 1.1.456. The Shapiro-Wilk test informed us that the data was skewed [$p = 0.000$] and the Breusch-Pagan test informed us that there was equal variance across conditions [$p = 0.294$]. Therefore, we compared PM time accuracy between the three conditions using the Kruskal–Wallis (K-W) test, a non-parametric alternative to a one-way ANOVA. The precision of the task (correct or incorrect) was a simple binary outcome measure, therefore this dependent variable was analysed using a chi-square test of independence.

Results

Time accuracy on prospective memory task

Time accuracy refers to absolute minute difference away from the designated PM time. The K-W test showed a significant difference between conditions [$\chi^2(2) = 8.261, p = 0.016$], suggesting that time accuracy was not equal over the three conditions. Moreover,

a post-hoc Dunn test with Bonferroni correction revealed that one pair of conditions differed: the Watch condition and the No aid condition [$Z(2) = 2.869, p = 0.012$] and Cohen's effect size value [$d = 1.1$] suggested a high practical significance. There was no difference between the Phone condition and the No aid condition [$Z(2) = 1.554, p = 0.120$], or between the Phone condition and Watch condition [$Z(2) = 1.348, p = 0.178$]. Table 3 depicts the descriptive statistics for time accuracy over the three conditions. Together these results suggest the Watch condition was particularly effective in supporting the time component of these tasks.

Precision of the content of prospective memory task

The content of the PM task refers to what the task entails, and the precision of this component refers to whether this was carried out correctly or incorrectly. For example, if the task was to "send a picture of a car", the task would be "correct" if a car appeared in the picture sent. Pictures of any other objects or no pictures would be termed "incorrect". The chi-square test of independence found a significant difference between the number of correct and incorrect tasks carried out over conditions [$\chi^2(2) = 20.205, p = 0.000$]. Tests of individual comparisons revealed that the patient was significantly more successful during the Watch condition (100% accuracy) compared to the No-aid condition (16.7%) [$\chi^2(1) = 13.004, p = 0.000$], and in the Phone condition (83.3%) compared to the No-aid condition [$\chi^2(1) = 8.167, p = 0.004$]. Performance between the Watch condition and Phone condition did not differ [$\chi^2(1) = 0.457, p = 0.499$]. In the No-aid condition, the patient would remember that a task had to be carried out, however, the content of the task carried out in this condition was rarely correct. These results suggest that the availability of an external memory aid is significantly more effective than no aid in benefiting memory for the content of the PM task. (Figure 1)

Exploratory analysis on practice effects

In order to explore a possible practice effect, we compared the performance over the three days in each condition, we did this using three separate K-W tests. This revealed there to be no significant improvement over the three days in any condition; Phone condition [$\chi^2(2) = 2.933, p = 0.231$], No aid condition [$\chi^2(2) = 1.075, p = 0.584$], and Watch condition [$\chi^2(2) = 0.655, p = 0.721$]. Therefore, we may conclude that the patient did not improve in his timeliness of completing the task over the course of the testing period.

Discussion

The aim of the current study was to analyse the effectiveness of a smartwatch as an external memory aid for PM tasks in

Table 3. Descriptive statistics of time accuracy of the prospective memory tasks per condition.

Condition	mean (min)	SD (min)	median (min)
Phone	30.7	51.3	12
No-aid	65.2	58.1	48
Watch	16.5	23.7	5

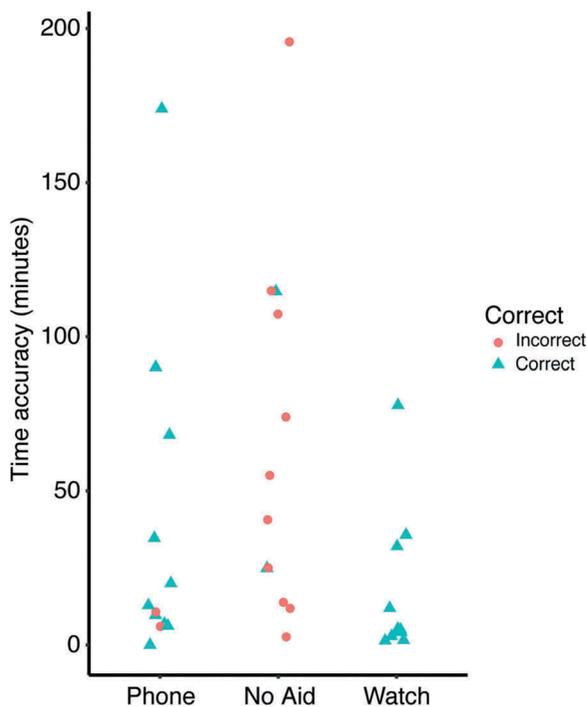


Figure 1. [To view this figure in color, please see the online version of this journal.] Depicts the results of both analyses.

a case of Korsakoff Syndrome. The results indicated that time accuracy of the PM task was significantly better when the patient was able to use the smartwatch as an external memory aid compared when no aid was available. Interestingly, the phone condition, where the patient's mobile phone was used to support the PM tasks, did not differ to the no aid condition. These results suggest that the smartwatch was superior in assisting the 'when' component of the PM tasks.

Our second measurement was the accuracy of the PM task. Specifically, this concerned whether the task was carried out correctly or incorrectly. Our results show that this "what" component was significantly more accurate when an external memory aid was available, whether it be a phone or a smartwatch. Together, these findings suggest that the combination of time accuracy and task precision was significantly improved when the MyWepp watch was available as an external memory aid.

Earlier studies have indicated that KS patients' PM can be supported by prompt cards (Davies & Binks, 1983), diary reminders (Brunfaut et al., 2000), digital pagers and verbal assistance (Morgan et al., 1990). The current study, however, is the first to demonstrate that a smartwatch significantly profits PM performance in KS regarding both timing and correctness of PM performance. The previous findings of de Joode et al. (2013), were only able to conclude qualitatively (through observations and subjective impressions) that PDAs were effective in supporting PM, since the study was hindered by missing measurements and inter-rater reliability. In comparison, this study relied on objective and easily measurable timed observations, and was successfully carried out to the full testing period. This study, therefore, enhances these previous findings with significant quantitative results and informs us that these memory aids may be clinically important for KS patients' PM.

This study has three limitations worth mentioning. Firstly, although the patient in the current study met the diagnostic criteria for KS as described by Kopelman (2002) he is a high functioning individual and is very competent with technical devices. It is possible that KS patients require a basic degree of cognitive functions as well as motivation in order to successfully incorporate an external memory aid in their daily life (Walvoort, Wester, & Egger, 2013). Our case is comparable to KS patients in terms of his planning impairments as indicated by the BADS task 5 (Zoo Map Test) in Table 1, however, further research must be conducted in order to establish whether KS patients with varying levels of cognitive impairments would benefit differently from the use of the MyWepp watch as an assistive memory aid. The second limitation concerns the programming of the PM tasks. The phone condition was initially a measure of his PM functioning in an 'as per usual setting, therefore, Mr. W. was given the list of tasks and directly programmed them into the phone himself. In the watch condition, the researchers programmed the tasks. Based on the level of functioning in this patient, it is unlikely that he did not program the tasks accurately, however, in future studies it would be desirable to keep these factors constant and have the patient program all devices where possible. The third limitation only came to light towards the end of the testing period. This was that the patient did not find comfort in wearing wristwatches. The smartwatch, therefore, instead of being positioned on the patient's wrist, was constantly kept in his pocket. This meant that the screen face, where the task was being displayed, was not readily visible. Since the device is to be used as a watch, this could have negatively affected performance in the tasks. In future patient studies it would be important that the individual taking part is comfortable with wearing a wrist watch at least for the extent of the testing period.

The current study has demonstrated that an individual with KS can improve on both the 'what' and the 'when' components of a PM task when an external memory aid is available; where the latter is particularly profited by the use of a smartwatch. Importantly, our findings show that basic use of a mobile phone as a PM reminder can aid memory for task content, establishing that a regular phone is preferred to no external aid, however, that a smartwatch is superior in accomplishing both precise and timely tasks. Important clinical applications for the smartwatch could develop since high functioning patients could learn to use the administrative system themselves and therefore manage their own routine. In patients where this may not be possible, caregivers are able to program the device remotely.

In conclusion, the challenges related to time-based PM: remembering what the task is and when to carry it out, can be overcome with the use of assistive technology. Though this was evident in a single patient, there is potential for further studies extending similar results in larger groups of KS patients. The conclusions from this case study complement previous findings and add to the limited research regarding external PM aids in Korsakoff syndrome. Promoting PM is a gateway to more independent living for KS patients and further research on a larger scale would allow us to harness the full benefit from these new technological devices in memory rehabilitation in this patient group.

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