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ORIGINAL RESEARCH

Effects of Introducing the Bbrainklok as a Digital External Memory Aid on Prospective Memory, Apathy and Autonomy in Individuals with Korsakoff's Syndrome

Sterre Smits[1,2], Erik Oudman[1,2], Mareike Altgassen[3], Lisa van Rijswijk[1,2], Albert Postma[1,2]

[1]Experimental Psychology, Utrecht University, Helmholtz Institute, Utrecht, the Netherlands; [2]Slingedael Korsakoff Center, Lelie Care Group, Rotterdam, the Netherlands; [3]Department of Psychology, Johannes Gutenberg University Mainz, Mainz, Germany

Correspondence: Sterre Smits, Email e.a.m.smits@uu.nl

Introduction: Korsakoff's syndrome (KS) is a neuropsychiatric disorder caused by severe thiamine deficiency resulting from malnutrition, typically as a consequence of structural alcohol abuse. It is characterized by profound cognitive and behavioral impairments, including deficits in prospective memory (PM), the ability to remember to perform an intended task, and high levels of apathy. These deficits significantly impact daily functioning and perceived autonomy.

Methods: This study investigated the effects of introducing the Bbrainklok, an external digital memory aid, on PM performance, apathy and autonomy in individuals with KS. Sixteen individuals with KS or other alcohol-induced major cognitive disorder, residing in a long-term care facility, participated in a nine-week intervention study. Bayesian analyses compared a null hypothesis (no change) with two alternatives: early change (H1) and gradual change (H2).

Results: Apathy levels decreased following the introduction of the Bbrainklok, while improvements in prospective memory performance were more variable across participants. Autonomy showed small and inconsistent changes over time, precluding firm conclusions regarding intervention-related effects. Importantly, the beneficial effects of the Bbrainklok appeared to be independent of cognitive functioning and baseline apathy, suggesting that the device is accessible even for individuals with lower cognitive or motivational capacity. Focus groups with care staff confirmed that the Bbrainklok was experienced as reliable, user-friendly, and helpful in providing daily structure. Participants themselves also generally reported a pleasant experience with the Bbrainklok reminders.

Conclusion: Overall, the findings highlight the potential of a digital external memory aid, the Bbrainklok, as an accessible and user-friendly assistive technology to enhance structure and engagement in individuals with KS living in long-term care.

Keywords: Korsakoff's syndrome, prospective memory, apathy, autonomy, external memory aid

Introduction

With the rapid advancement of technology, electronic aids such as smartphones and smartwatches have become integral tools for managing everyday life.[1] These devices support a wide range of cognitive activities by helping users organize their schedules, remember appointments and store information. Given these functions, electronic aids can be considered as a form of external cognitive support that may also benefit individuals with (cognitive) deficits in memory, planning, attention or motivation.

In recent years, a growing body of research has explored the use of electronic memory aids in populations with cognitive decline. Within dementia research, for instance, such tools have shown promising potential to improve prospective memory (PM) performance.[2–4] PM refers to the ability to remember to carry out intended actions in the future (eg., remembering to attend a dentist appointment) and relies on well-functioning episodic memory and executive functioning.[5] Successful PM is essential for independent functioning, as failures in this domain can jeopardize

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professional activities (eg., forgetting about a presentation that you had to prepare), social relationships (eg., forgetting you were meeting a friend) and even your health[6,7] (eg., forgetting to take your medication).

A patient group known for pronounced PM deficits is individuals with Korsakoff's syndrome (KS).KS is a chronic neuropsychiatric disorder caused by thiamine deficiency, typically following chronic alcohol abuse.[8,9] It is characterized by profound cognitive and behavioral impairments that significantly impact daily functioning. Severe episodic memory impairment is a core feature of KS, and additional deficits in executive functioning are common, including difficulties with planning, inhibition, cognitive flexibility and working memory.[8] Given the significant impairments in both episodic memory and executive functioning in KS, several studies have investigated PM functioning in this population. Consistently, findings indicate significant PM deficits in individuals with KS.[10–14] As a result of these impairments, many individuals with KS are unable to live independently.[15,16] Consequently, a large proportion reside in long-term care facilities where such assistance in daily functioning can be provided.

Beyond cognitive challenges, KS is associated with a range of behavioral symptoms, such as apathy, agitation and aggression. Among these, apathy is often regarded as one of the most prominent and debilitating.[17,18] Apathy is characterized by a persistent deficit of motivation, feelings, emotions, and/or interests, leading to a significant reduction in self-initiated, goal-directed behaviors. Apathy can lead to dangerous situations, as individuals with KS may fail to respond appropriately to urgent circumstances or neglect everyday responsibilities (eg., forgetting to extinguish a cigarette). Care staff working closely with individuals with KS report that apathy negatively influences individuals' ability to lead an autonomous and structured life.[19] Furthermore, apathy is associated with increased healthcare costs and significant caregiver distress.[20] These studies emphasize the substantial burden apathy places on both individuals with KS and their caregivers.

Importantly, in older adults, including individuals with mild cognitive impairment and dementia, there appears to be a dynamic, reciprocal relationship between PM deficits and apathy. Esposito et al (2012), reported that PM impairments can contribute to apathy by disrupting plan execution, responses to cues, intention-action translation, task switching, and multitasking. Conversely, lack of interest, a component of apathy, can diminish engagement with intended tasks, lower effort investment, and reduce the likelihood that intentions are actively maintained or acted upon. Thus, PM deficits and apathy can reinforce each other in a cycle of reduced initiative and goal-directed behavior.

This interaction between PM and apathy may lead individuals with KS to rely heavily on repeated prompts and external motivation to complete daily activities. In long term care facilities, individuals with KS receive reminders for daily tasks by care staff. However, many individuals with KS exhibit limited insight into their deficits.[21] As such, they may perceive reminders as unnecessary. They might belief that they have already performed the task, can remember to do it independently or lack interest in performing the task. These (perceived) "unnecessary" reminders can lead to frustration, agitation or even aggression.[22] Furthermore, excessive reliance on caregivers may diminish individuals' sense of autonomy and independence.[23]

Notably, despite evidence of a reciprocal relationship between PM deficits and apathy, no studies have systematically evaluated interventions targeting both outcomes in individuals with KS. Interventions specifically designed to reduce apathy in individuals with KS remain underexplored. However, a recent systematic review by van Dorst et al[24] provided a transdiagnostic overview of non-pharmacological interventions for apathy across different populations that share symptom-level characteristics with KS. The review concluded that successful interventions do not rely on intrinsic motivation, but rather on external stimulation such as cueing and behavioral activation. These insights suggest that external prompts and structured cues could be an effective strategy to help reduce apathy, particularly in individuals who struggle with reduced internal motivation. Conversely, there is increasing literature for interventions to support PM. Structured interventions such as errorless learning[21,25] and external memory aids, like prompt cards and digital calendars, have shown positive effects on PM performance and feeling of autonomy.[1,21,26–33] In particular, digital external memory aids have emerged as promising tools.

In digital memory aid intervention studies, PM is typically operationalized as performance on structured, time-based tasks embedded in daily routines rather than laboratory-based cognitive tests. This approach reflects the functional nature of PM impairments in KS. Among these digital memory aids, smartwatches have emerged as a promising tool. Lloyd et al[28] reported that smartwatches were more effective than phones or no aid, and Smits et al,[32,33] using independent

cohorts, showed that smartwatches are even as effective as verbal reminders in supporting PM in KS. Nevertheless, evidence also suggests that smartwatches may not be suitable for all users: Smits et al[32,33] observed that individuals with lower cognitive functioning and higher apathy benefited less from smartwatch reminders than those with higher cognitive functioning and lower apathy.

The variable suitability of current digital aids underscores the broader challenges faced by individuals with KS. The syndrome's chronic and largely irreversible nature means that cognitive and behavioral symptoms, including apathy and confabulation, tend to remain stable over time.[34,35] Quality of life in long-term care is consistently reported as moderate to poor, and many individuals experience profound social and emotional loneliness.[36,37] Given this long-term, static course and the absence of effective treatments,[38] there is a pressing need for interventions that can foster engagement, autonomy, and meaningful activity within long-term care settings.

One promising alternative that may address some of the limitations observed in existing digital external memory aids is the Bbrainklok (https://bbrain.eu/). This is a tablet designed to support daily structure through consistent and multimodal cueing. It features a large, fixed display showing both the current time and a clear overview of the daily schedule. Tasks are announced visually and audibly. Unlike the smartwatches, the Bbrainklok does not require the user to wear the device; it can be placed in a prominent location within the living space of the user and passively deliver salient cues that may help prompt goal-directed behavior, even in those with lower levels of cognitive functioning or diminished initiative. By eliminating the need for interaction, learning or device management, it may impose less cognitive load. This reduced demand may be particularly suitable for individuals with KS, and may thereby enhance ecological usability in everyday contexts. To date, empirical evidence supporting these assumed benefits is however lacking. Therefore, in the current study, we aimed to evaluate the effects of introducing a digital external memory aid, the Bbrainklok, on PM performance, apathy and the feeling of autonomy in individuals with KS.

Previous research comparing verbal reminders, given in-person by the researcher, and smartwatch-based external memory aids in individuals with KS found that both modalities supported PM performance to a comparable extent. However, only verbal reminders led to PM improvement over time, while performance in the smartwatch condition remained stable across the assessed four days.[32,33] This difference may be attributed to familiarity: individuals with KS are regularly exposed to verbal cueing in care settings, whereas the smartwatch was a novel device requiring adjustment. These findings suggest that the effectiveness of external memory aids may depend not only on their presence, but also on users' familiarity and how long they have been using them.

In the current study, PM performance was assessed daily during a three-week baseline period (without the Bbrainklok), followed by a six-week intervention period in which the Bbrainklok was implemented. To explore whether prolonged use of a digital aid like the Bbrainklok can similarly lead to improvements in PM performance over time, we will conduct a Bayesian analysis with one null hypothesis and two alternative hypotheses reflecting different trajectories over time:

- Null hypothesis (H0): There is no change in PM performance over time; baseline (B), time point 1 (T1), and time point 2 (T2) scores are equal.
  - (B = T1 = T2).
- Alternative hypothesis 1 (H1): PM performance improves after introduction of the Bbrainklok and remains stable thereafter; baseline scores are lower than both T1 and T2, which do not differ from each other.
  - (B < T1 = T2).
- Alternative hypothesis 2 (H2): PM performance improves progressively across all time points; baseline scores are lower than T1, which in turn are lower than T2.
  - (B < T1 < T2).

Apathy and autonomy were assessed every three week (at baseline, mid-intervention, and post-intervention). Empirical evidence regarding the temporal course of apathy reduction in response to memory-based interventions in KS is currently

scarce. To our knowledge, no studies have systematically examined whether improvements in apathy emerge immediately or unfold gradually over time following the introduction of assistive technology. However, Oey et al[39] investigated behavioral effects of light intervention in people with KS. They compared behavioral symptoms between a three week baseline period and a six-week intervention phase, in which individuals with KS were exposed to a dawn simulation system in their bedrooms, which gradually increased light intensity to a preset maximum. Their results showed that apathy decreased between baseline and the first three weeks of intervention and even further in the second three weeks of the intervention. Although this intervention differs fundamentally from a memory aid, the observed gradual pattern of behavioral change suggests that improvements in apathy in KS may not necessarily plateau early but may continue to develop over time.

With regard to autonomy, empirical evidence on the effects of assistive technology on perceived autonomy in individuals with KS is limited. Although autonomy has not been systematically examined as an outcome in prior memory-aid studies, qualitative findings suggest that some participants report feeling more independent when supported by external memory aids.[32,33] Given the established relationship between PM, apathy, and goal-directed behavior,[40] improvements in PM and/or reductions in apathy may plausibly translate into increased perceived autonomy. On this basis, both early and gradual improvement trajectories were considered theoretically plausible for autonomy, despite the limited direct empirical evidence.

Therefore, we applied a similar Bayesian model to autonomy and apathy outcomes, comparing a stable, early-change and gradual change hypothesis:

- Null hypothesis (H0): There is no change in perceived autonomy and apathy levels over time; baseline, T1, and T2 scores are equal for both variables.
  - (Bau = T1au = T2au & Bap = T1ap = T2ap)

- Alternative hypothesis 1 (H1): Autonomy increases and apathy decreases after the Bbrainklok is introduced, with no further change after T1; baseline autonomy is lower than T1 and T2, which are equal.
  - (Bau < T1au = T2au & Bap > T1ap = T2ap)

- Alternative hypothesis 2 (H2): There is a continuous improvement in autonomy and a continuous reduction in apathy over time; baseline autonomy is lower than T1, which is lower than T2.
  - (Bau < T1au < T2au & Bap > T1ap > T2ap)

Method

This study employed a mixed-methods design combining quantitative and qualitative approaches. The quantitative component consisted of a three-week baseline phase (without the Bbrainklok), followed by a six-week intervention phase in which the Bbrainklok was implemented. PM was assessed daily and analyzed using a single-case design at the individual level, whereas apathy and autonomy were assessed at three time points (baseline, mid-intervention, and post-intervention) and analyzed at the group level. The qualitative component consisted of focus groups with care staff. A more detailed description of the procedure is provided below.

Participants

Eighteen patients residing at the Korsakoff centre Slingedael in Rotterdam, the Netherlands, participated in this study. Two participants withdrew consent during the study due to dissatisfaction with the memory aid, and in accordance with ethical guidelines their data were not included in the analyses, resulting in a final sample of sixteen participants (four female, twelve male, Table 1). Of these sixteen, thirteen met the diagnostic criteria of KS as outlined by Kopelman,[41] characterized by disproportionate memory dysfunction identified through neuropsychological assessment following an acute episode of Wernicke Encephalopathy. For three participants, the etiology was less clear, all were diagnosed with an Alcohol-induced Major Neurocognitive Disorder, Amnestic-Confabulatory Type (DSM 5: 291.1), and were recommended for placement in a Korsakoff care facility. Although the DSM-5 category substantially overlaps with the clinical

Table 1 Demographic Characteristics 16 Participants Diagnosed with Korsakoff's Syndrome or Alcohol-Induced Major Neurocognitive Disorder

Participant	Sex	Age	Level of Education[a]	Diagnosis	Years of Diagnosis till Study Inclusion	MoCA[b]	Word Fluency (Profession/ Animal; Percentile) [c]	Letter Fluency (Percentile) [c]	HADS[d]	Self-reported drinking habits [e]
1	Female	58	4	KS	14	10*	P: <1 A: <1	<2	A: 9 D: 7	NA
2	Female	68	5	Alcohol-induced MND	NA	24	P: 16–50 A: 50-84	84-98	A: 0 D: 3	NA
3	Male	71	3	KS	4	12*	P: <2 A: 2-5	<2	A: 17 D: 11	1 bottle strong liquor a day
4	Male	79	3	KS	2	19*	P: 50–84 A: 16	2	A: 5 D: 6	Less than 1 bottle strong liquor a day
5	Male	70	3	KS	12	19*	P: 5 A: <2	16-50	A: 2 D: 6	NA
6	Male	73	3	KS	5	21*	P: 16–50 A: 16-50	84-98	A: 2 D: 2	4-5 ½ liter cans of beer a day
7	Male	72	7	KS	5	22	P: 50–84 A: 84-93	16-50	A: 1 D: 2	1,5 liter beer a day (10% alcohol)
8	Male	65	4	KS	1	21*	P: <2 A: 5-16	5-16	A: 4 D: 3	NA
9	Male	80	4	KS	27	16*	P: <2 A: <2	>2	A: 0 D: 2	NA
10	Male	69	4	KS	13	15*	P: 5 A: <2	2-5	A: 0 D: 0	NA
11	Female	68	4	KS	NA	14*	P: 2–5 A: <2	16	A: 5 D: 1	NA
12	Female	63	4	Alcohol-induced MND	10	14*	P: 5 A: 5-16	16-50	A: 1 D: 1	NA
13	Male	56	5	KS	2	20*	P: 5–16 A: 50	2-5	A: 2 D: 7	2-3 beers a day

(*Continued*)

Table 1 (Continued).

Participant	Sex	Age	Level of Education[a]	Diagnosis	Years of Diagnosis till Study Inclusion	MoCA[b]	Word Fluency (Profession/ Animal; Percentile) [c]	Letter Fluency (Percentile) [c]	HADS[d]	Self-reported drinking habits [e]
14	Male	66	4	Alcohol-induced MND	1	17*	P: 5–16 A: 2-5	5-16	A: 2 D: 1	10-12 beers a day
15	Male	57	NA	KS	16	20*	P: NA A:NA	NA	A: 0 D: 4	NA
16	Male	65	6	KS	1	22	P: <2 A: 5	>98	A: 4 D: 2	2 bottles of wine

Notes: [a]Level of education is based on the Verhage scale (1964); low-educational level (1–4), mid-educational level (5) and high-educational level (6–7). [b]A MoCA- score below the cut-off of 22/23 (*) is considered optimal for distinguishing individuals with KS from cognitively intact controls.[42] [c]Percentile ranges were interpreted as follows: >98 = exceptionally high score, 91–97 = above average score, 75–90 = high average score, 25–74 = average score, 9–24 = low average score, 2–8 = below average score, <2 = exceptionally low score.[43] [d]HADS scores of 0–7 indicate no anxiety or depression, 8–10 suggest possible anxiety or depression, and 11–21 reflect probable anxiety or depressive disorder.[44] [e] Self-reported drinking habits was assessed at intake at the Korsakoff's centre.

Abbreviations: KS, Korsakoff's syndrome; MND, Major neurocognitive disorder; NA, Information not available.

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description of KS, the DSM-5 classification is etiologically framed within alcohol-related neurocognitive disorder, whereas the clinical diagnosis of KS emphasizes the chronic amnestic syndrome following thiamine deficiency and Wernicke's encephalopathy.[16] In practice, these classifications often refer to highly similar clinical presentations. Therefore we have decided to include both patient groups. The average age of the participants was 67.5 years old (SD = 6.1). Participants were excluded if they were illiterate or insufficient in understanding the Dutch language and if they did not regularly attend each meal (breakfast, lunch and dinner). Importantly, the latter criterion referred to structural non-participation in communal meals (eg. eating in their room or declining specific meals), rather than occasional non-attendance due to forgetting. The study was approved by the Ethics Review Board (FETC) of the Faculty of Social and Behavioral Sciences, Utrecht University, the Netherlands (FETC Registration 24–0089). All procedures involving human participants were conducted in accordance with institutional ethical standards and the principles of the Declaration of Helsinki.

Materials

Neuropsychological Assessment

In order to compare the current levels of cognitive functioning between participants, we administered a neuropsychological assessment, including three standardized tests, the week before starting baseline PM assessment (Table 1).

Montreal Cognitive Assessment (MoCA)

To assess overall level of cognitive functioning we administered the Montreal Cognitive Assessment (MoCA), which yields a total score ranging from 0 to 30. The MoCA is a brief screening instrument combining the assessment on 8 different domains of cognitive functioning: visuospatial/executive functioning, naming, memory, attention, language, abstract reasoning, delayed recall, and orientation.[45] It is designed to assess mild cognitive impairment and dementia, which has also been identified as a reliable tool with good discriminatory power for detecting KS when using a cut-off score of 22/23.[42]

Verbal Fluency

Executive functioning was further assessed using the "Verbal Fluency test", in which participants were asked to report as many words within one minute, either beginning with a specific letter (phonemic fluency) or belonging to a semantic category (semantic fluency; animals/profession). The dependent measure is the number of correct words. The outcome reflects the ability to initiate a mental search and retrieve information from the lexicon or semantic memory system, as well as overall executive functioning, such as attention, cognitive flexibility, inhibition, and processing speed.[46,47]

Hospital Anxiety and Depression Scale (HADS)

Symptoms of anxiety and depression were measured using the Hospital Anxiety and Depression Scale (HADS.[44] The HADS is a 14-item self-report questionnaire comprising two subscales (anxiety and depression). Each item is rated on a 4-point Likert scale, with subscale scores ranging from 0 to 21; higher scores indicate greater symptom severity. The HADS is considered suitable for populations with cognitive or physical impairments, as it minimizes confounding from somatic symptoms.[48]

PM Measurement

PM performance was operationalized as independent meal attendance, reflecting an ecologically valid measure of PM functioning in daily life. The aim was not to assess underlying PM capacity using standardized cognitive tests, but to examine whether the Bbrainklok could support PM-dependent behavior in a real-world care context. Evidence from dementia research[49] suggests that even routine activities rely on intact PM functioning, supporting the use of everyday tasks as indicators of functional PM.

PM performance was measured over a period of nine weeks, consisting of three baseline weeks and six intervention weeks. Care staff recorded attendance at each meal (breakfast, lunch, and dinner; except Sunday breakfast, when

participants could sleep in). The dependent measure was the PM attendance score per meal: independent attendance (scored as 1), picked-up by care staff (scored as 2), or not applicable (scored as 3; eg., if the participant was already in the living room or away on an outing).

Autonomy

Autonomy was measured using the Autonomy Scale Amsterdam (ASA), which was completed by the individuals with Korsakoff syndrome (KS) together with the researcher. The ASA was used to measure autonomy in a group of psychiatric patients[50] and consists of six separate but interacting dimensions of (i) Self-integration, (ii) Engagement with life, (iii) Goal-directedness, (iv) Self-control, (v) External constraints and (vi) Social support. Items are rated on a 11-point scale (0–10), with higher scores indicating greater autonomy, resulting in a total score ranging from 0 (no autonomy) to 210 (complete autonomy). The ASA is a reliable scale with strong internal consistency (α =0.90).

Apathy

Apathy was measured using the APADEM-NH (APAthy in DEMentia, Nursing Home) scale. This instrument was developed specifically to assess apathy in institutionalized patients with neurodegenerative dementia. It accounts for the special characteristics of the most severe stages of the illness and the distinctiveness of the institutional environment such as group-living or professional caregiving.[51] The APADEM-NH assesses the patient's state of apathy through an interview with a professional caregiver who has a good level of knowledge (eg., caring for the patient on a regular basis) of the cognitive and functional status of the patient. Caregivers were instructed to rate apathy symptoms based on the patient's behavior during the previous week. Due to the visible implementation of the Bbrainklok in the living environment, raters were not blinded to the intervention phase. The scale includes 26 items distributed in three dimensions: Deficit of Thinking and Self-Generated behaviors (DT): 13 items, Emotional Blunting (EB): 7 items, and Cognitive Inertia (CI): 6 items. Each item is scored on a 4-point scale, where 0 = no limitation (the resident always performs the task spontaneously or responds to the stimulus), 1 = mild limitation (performance or responses improve with slight prompting), 2 = moderate limitation (performance or responses improve only with substantial prompting), and 3 = severe limitation (no response despite prompting). Subscale and total scores were computed, ranging between 0 and 78, with higher scores reflecting greater apathy. The APADEM-NH has shown good feasibility and reliability (Cronbach's α: DT =0.88, EB =0.83, CI =0.88) and is valid for distinguishing apathy from depression in institutionalized patients with mild to severe dementia.

Bbrainklok

The tablet used in this study was the Bbrainklok Model 2024 Family tablet, developed by Bbrain.eu (Figure 1). The Bbrainklok is a technological aid designed to support older adults by assisting with time perception and aimed to prolong independent living at home. It provides reminders for daily tasks such as taking medication. The device can be programmed remotely and, in its full version, allows users to view their agenda, receive messaged, photos and video calls. However, in this study, only the agenda, time and task reminder functions were used to reduce cognitive load and minimize complexity.

Weekly Check-in

Each week of the intervention, when participants were using the Bbrainklok, we asked participants to rate the pleasantness of the Bbrainklok on a 5-point Likert scale ranging from 1 ("very unpleasant") to 5 ("very pleasant"). They were also asked whether they would like to receive reminders for additional tasks. At the end of the intervention, participants were given the option to keep the Bbrainklok if they prefer.

Evaluation Care Staff

Care staff evaluated the Bbrainklok by filling out a questionnaire (Appendix A) about their experience. They were also asked to participate in a focus group to provide further feedback on their impressions of the Bbrainklok (Appendix B).

Figure 1 Bbrainklok home screen. Translation from Dutch: "Dinsdag ochtend" = "Tuesday morning".

Procedure

Sixteen individuals diagnosed with KS participated in this study (Table 1). The study was conducted across two cohorts, taking place between September and November 2024 (participant 1–12), and again between March and June 2025 (participant 13–16). Before participation, individuals received an information letter and provided written informed consent. In addition, each participant's legal guardian gave written consent for general research participation at the Korsakoff centre and was informed about this specific study, providing verbal approval.

To assess the effects of the Bbrainklok as a digital external memory aid on PM, autonomy and apathy, we implemented a structured assessment protocol consisting of a three-week baseline and a six-week intervention phase (Figure 2).

One week prior to the start of the baseline phase, participants completed the neuropsychological assessment, including the MoCA, (letter/word) fluency and the HADS. During the baseline phase, no external reminders were provided. PM performance was measured by care staff, who recorded for each meal (breakfast, lunch, and dinner) whether participants attended independently, had to be picked up from their rooms, or if the observation was not applicable. This resulted in a total of 60 data points per participant. This total accounted for the missed breakfast on Sundays because participants are allowed to sleep in that day. On the last day of the baseline phase autonomy and apathy were first assessed.

Following the initial three weeks, we entered a six-week testing phase, during which external reminders were provided by the Bbrainklok. Participants received a reminder five minutes before each scheduled meal. On the first day of the intervention, the researcher introduced the Bbrainklok and explained how it provided reminders for daily tasks. This first day served as a training session, during which the researcher helped the participants get used to the clock and the reminders given on this device; no PM data was collected on this day. Care staff then resumed assessing PM performance of the participants. This resulted in a total of 117 data points per participant, accounting for the training day and missed Sunday breakfasts.

Autonomy and apathy were measured two additional times during the interventions phase; halfway through the intervention (after three weeks) and at the end of the intervention (after six weeks), ensuring consistent three-week intervals between measurements. Furthermore, a weekly check-in was conducted in which individuals with KS rated the Bbrainklok on a Likert-scale ranging from 1 (very unpleasant) to 5 (very pleasant), and were also asked to provide a short

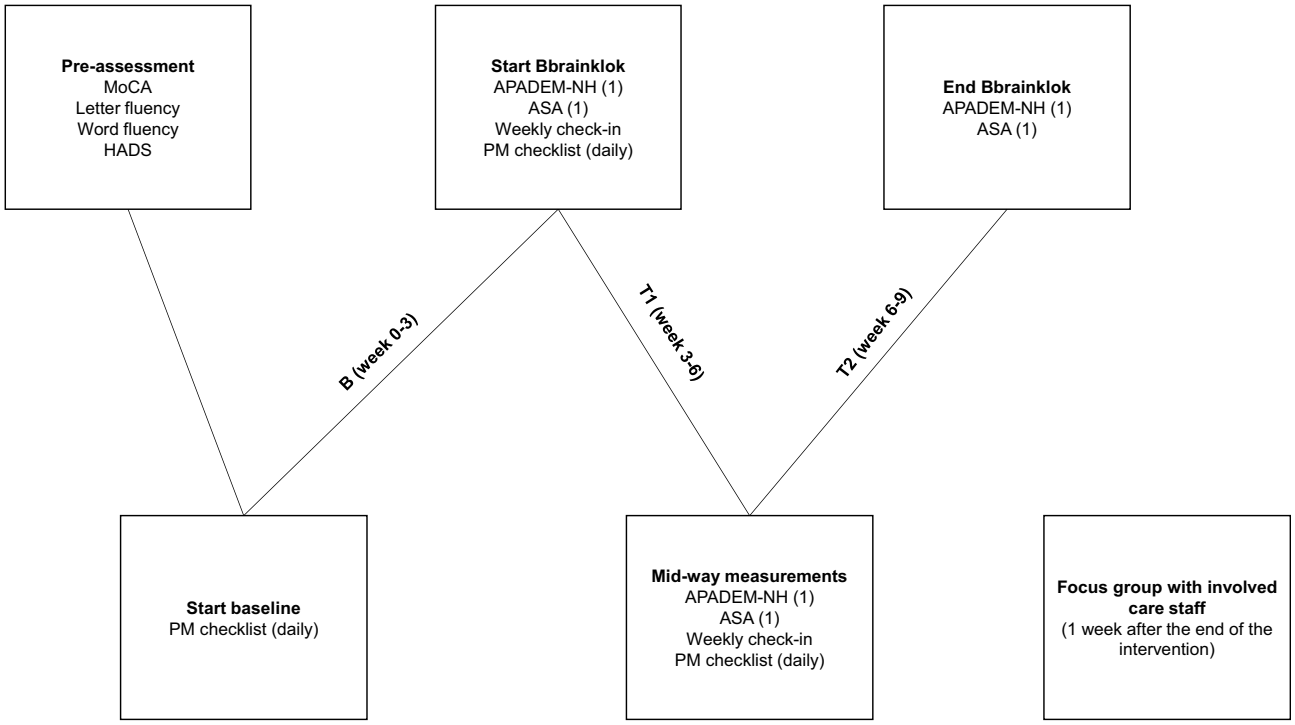

Figure 2 Visualization study design.

verbal response about their experience. In the second study cohort, only Likert ratings were administered; verbal responses were not collected by the researcher.

After completing the intervention, we asked participants whether they wished to keep the Bbrainklok. Additionally care staff were asked to complete a questionnaire regarding their experience with the Bbrainklok, and focus groups were conducted with caregivers to obtain verbal feedback on their experience.

Missing Data

For PM measurements, missing data were not imputed; analyses were conducted with available data only. For autonomy and apathy measurements, if one of the three assessments was missing, the remaining data points were used; if two or more assessments were missing, the participant was excluded from the analyses. For the weekly Likert scale responses, missing values were imputed using the last observation carried forward approach.[52]

Data Analysis

To evaluate the effects of the Bbrainklok on PM performance, we conducted Bayesian analyses in RStudio (version 4.3.2) using the "multinomineq" package. This approach allows us to compare multiple hypothesis directly, each reflecting different patterns of change over time.[53,54] In contrast to traditional null hypothesis significance testing, Bayesian methods enable researchers to assess the relative support for competing hypotheses based on observed data. This approach is particularly suitable for studies with small sample sizes.

We compared three hypotheses regarding PM scores across baseline (B), the first half of the intervention (T1), and the second half of the intervention (T2): H0 (B = T1 = T2), H1 (B < T1 = T2), and H2 (B < T1 < T2). For each participant, Bayes factors for inequality-constrained models were calculated using the "bf_binom" function with 10,000 iterations. Posterior model probabilities (PMPs) were subsequently computed to determine the most likely hypothesis for each individual. PMPs sum to 1 across the tested hypothesis and reflect the relative support for each hypothesis; the hypothesis with the highest PMP is considered most supported.[53,54] However, even when a PMP is very low (eg. 0.03 compared to 0.96) this does not imply that the corresponding hypothesis can be definitely ruled out. PMPs are interpreted

as continuous measures of uncertainty and are not compared against fixed threshold values. In addition to these specified hypotheses, a PMP was also calculated for the unconstrained hypothesis (Hu), which represents the best possible model fit without constraints, to allow comparison against the specified models.[53–55] Comparing PMPs for H0, H1, H2, and Hu allows us to evaluate which trajectory is most consistent with the data.

To investigate changes in apathy and autonomy, we conducted Bayesian analyses in RStudio (version 4.3.2) using the "lavaan" and "bain" packages. First, we specified a saturated structural equation model in "lavaan" that included the six repeated-measures variables (Au1, Au2, Au3, Ap1, Ap2, Ap3), allowing them to correlate freely. Means for each time point were estimated using full information maximum likelihood (FIML) to handle missing data. Bayesian hypothesis testing in "bain" compared three hypotheses: H0 (stable scores: Au1 = Au2 = Au3 & Ap1 = Ap2 = Ap3), H1 (initial improvement/reduction: Au1 < Au2 = Au3 & Ap1 > Ap2 = Ap3), and H2 (continuous improvement/reduction: Au1 < Au2 < Au3 & Ap1 > Ap2 > Ap3). In addition to these specified hypotheses, "bain" also provides PMP values for the unconstrained hypothesis (Hu) and the complement hypothesis (Hc), which includes all possible outcomes not covered by the specified hypotheses.[53–55]

Exploratory Analysis

In addition to the confirmatory analyses, we explored how the Bbrainklok was experienced by individuals with KS and their care givers.

To assess participants' experiences, weekly Likert-scale ratings of perceived pleasantness were averaged per individual across the intervention period. This resulted in a mean pleasantness score for each participant.

Care staff experiences were assessed using both quantitative and qualitative methods. First, care staff completed a Likert-scale questionnaire at the end of the intervention evaluating the usefulness and acceptance of the Bbrainklok. Responses were summarized descriptively using mean scores to provide insights into staff perceptions of the tablet's utility. Second, transcripts from four focus groups (N=9) and one individual interview (N=1) were analyzed. Two researchers independently coded the transcripts using thematic content analysis, using NVivo 14. An inductive approach was used to allow themes to emerge from the data without imposing predefined categories. Codes and themes were iteratively refined through discussion until consensus was reached. Given the relatively small number of participants in the focus groups, the goal was not to achieve data saturation but rather to explore a range of perspectives and generate preliminary insights into staff experiences with the Bbrainklok.

Additional exploratory analyses are reported in the appendix (Appendix I–K). First, we examined whether perceived pleasantness of the Bbrainklok changed over time, to explore whether users required an adjustment period before experiencing the device as beneficial. Second, correlational analyses were conducted to investigate whether baseline cognitive functioning (overall cognition and executive functioning) and apathy were associated with improvements in prospective memory (PM) performance between baseline and T2. PM performance was operationalized as the percentage of times individuals came independently, calculated separately for baseline, T1 and T2; the difference between these two percentages was then used as the outcome measure in the correlation analyses. A Shapiro–Wilk test confirmed that PM, MoCA, semantic fluency, letter fluency and apathy scores did not deviate significantly from normality ($p > 0.05$), allowing us to use Pearson's product–moment correlation to examine the relationships between these variables.

These analyses were motivated by implementation considerations. Prior research on external memory aids, such as smartwatches, suggests that effectiveness may depend on individual characteristics, including cognitive functioning and motivational levels (Smits et al, 2022, 2025). Examining these associations in the current study allows for preliminary insights into which individuals may benefit most from the Bbrainklok and whether its effectiveness is moderated by baseline functioning. Given their exploratory nature and limited statistical power, these analyses should be interpreted cautiously and are intended to inform future research and clinical decision-making rather than to provide definitive conclusions.

Results

Prospective Memory

For each participant, a baseline percentage of independently attend meals was calculated (see Table 2), as this provides essential context for interpreting the PMP findings. The mean baseline attendance was 75.1%, (SD= 20%). This indicates limited room for improvement for a substantial portion of the sample and suggests the potential presence of ceiling effects, which will be addressed in the Discussion.

PMP scores were computed for all three competing hypotheses (Figure 3, Appendix C). Overall H0 (no change in PM performance across baseline, T1 and T2) received the most support for 50% of the participants (8/16), suggesting that most patients did not experience measurable improvements in PM performance during the intervention phase. This stability is consistent with the high baseline performance levels. Nevertheless, 31.25% of the participants (5/16) showed strongest support for a change hypothesis (H1: 18.75%; H2: 12.5%). Notably, in several cases the PMP for H1 was close to that of H0, suggesting that early improvement was often a plausible alternative even when H0 received slightly greater support. Across participants, H1 generally received more overall support than H2, indicating that when change was observed, it more frequently reflected early rather than gradual improvement. Overall, in most participants, H0 received strongest support, indicating no change in PM performance. However, the variability in supported hypotheses underscores the heterogeneity of individual responses to the intervention.

Apathy and Autonomy

For the group-level analysis of perceived autonomy and apathy scores, three participants had a single missing apathy score, which was tolerated as adequate data remained for reliable analysis. One participant was excluded because of three consecutive missing data points, resulting in a final sample of fifteen participants. Bayesian hypothesis testing was conducted at group level using all available raw scores within the structural equation model. Accordingly, the reported PMPs reflect relative support for each trajectory at the group level, rather than averaged individual PMPs. PMP values showed strongest support for H1 (PMP =0.413) and H2 (PMP=0.329), indicating an initial improvement in autonomy and a concurrent initial reduction in apathy. For some participants, these changes stabilized after the first three weeks, whereas for others they continued to improve or decrease further. In contrast, the model assuming no changes over time, (H0, PMP=0.066) received little support.

Table 2 Raw Scores PM Performance per Participant

Participant	B (Independent/total,%)	T1 (Independent/total,%)	T2 (Independent/total,%)
1	37/38 (97%)	46/51 (90%)	49/50 (98%)
2	48/49 (98%)	48/49 (98%)	50/50 (100%)
3	24/46 (43%)	27/44 (61%)	31/51 (61%)
4	40/48 (83%)	40/48 (80%)	44/54 (98%)
5	23/47 (49%)	33/50 (66%)	43/53 (81%)
6	27/31 (86%)	24/24 (100%)	23/24 (100%)
7	31/36 (86%)	27/27 (100%)	23/23 (100%)
8	17/46 (37%)	26/39 (67%)	16/32 (50%)
9	14/17 (92%)	11/12 (92%)	5/6 (83%)
10	23/24 (96%)	14/21 (67%)	8/12 (67%)
11	21/24 (88%)	22/23 (97%)	13/16 (81%)
12	19/31 (61%)	19/27 (70%)	14/21 (67%)
13	29/45 (64%)	30/49 (61%)	40/51 (78%)
14	36/41 (88%)	25/33 (85%)	36/39 (92%)
15	33/53 (62%)	36/47 (77%)	10/19 (53%)
16	32/45 (71%)	36/43 (84%)	38/19 (97%)

Notes: Total = the total number of observed meal occasions within the phase (maximum = 60 per phase; values may be lower due to missing or non-applicable observations). Independent = the number of meals attended without assistance. % = the percentage of independently attended meals relative to the total number of observed meal occasions within that phase.

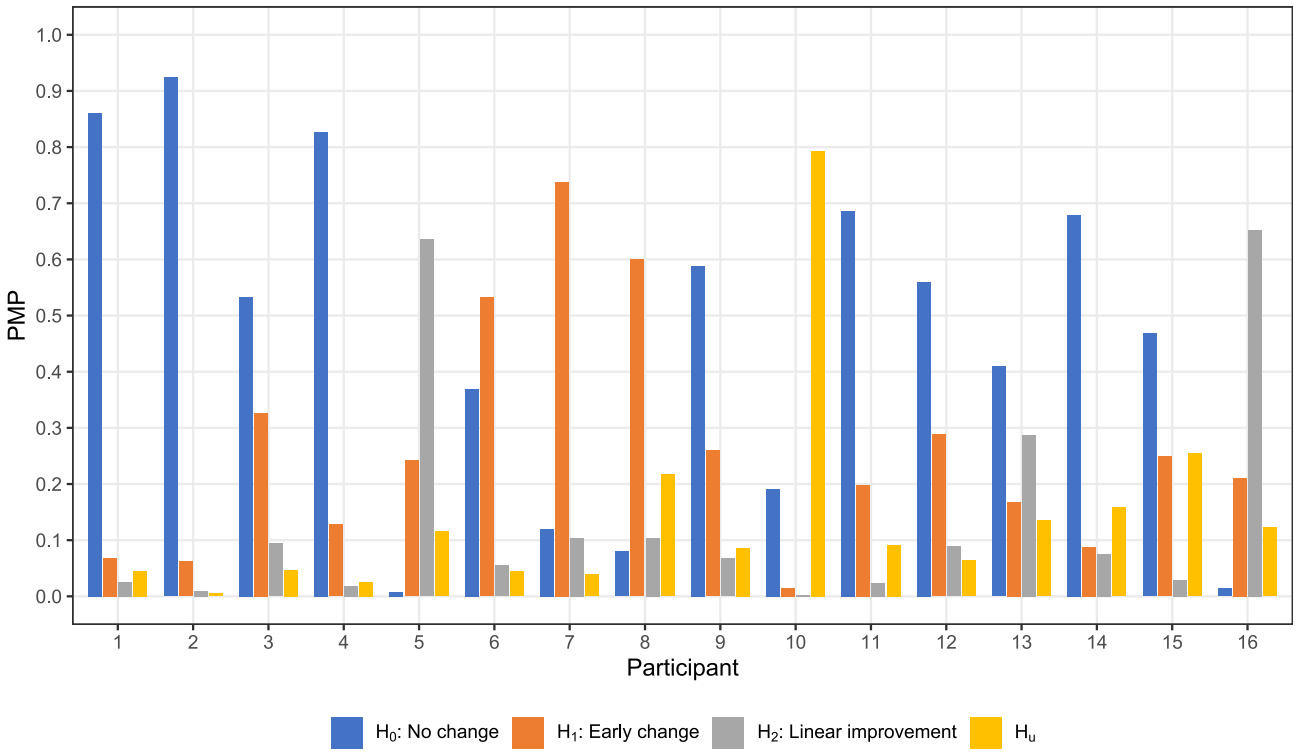

Figure 3 Individual posterior model probabilities for each hypothesis. H0 represents no change in PM performance over time. H1 represents an early change, with improvement between baseline and T1 followed by stabilization between T1 and T2. H2 represents linear improvement across baseline, T1, and T2. Hu is the unconstrained hypothesis, representing the best possible model fit without restrictions, and serves as a benchmark for comparing the constrained models.

With regard to apathy, Figure 4 illustrates the average trend across baseline, T1 and T2. Mean apathy scores decreased primarily between baseline and T1, suggesting an initial reduction, followed by smaller and more variable changes between T1 and T2 (see individual difference in Appendix D). Although the average changes shown in Figure 4 appear small, the Bayesian comparison indicates that a perfectly stable trajectory (H0) was less consistent with the observed data than models allowing early or gradual change.

Visual inspection of Figure 5 shows that mean autonomy scores decreased slightly from baseline to T1, indicating a temporary reduction in perceived autonomy. Between T1 and T2, scores returned close to baseline, resulting in no overall improvement across the six-week intervention. Individual scores (Appendix D) showed substantial variability.

Overall, the early-change (H1) and gradual-change (H2) models received the strongest support at the group level. However, this pattern was primarily driven by reductions in apathy. Although the gradual-change model (H2) also received moderate support, this was partly attributable to the increase in autonomy between T1 and T2, which reflected a return to baseline rather than a sustained gain. In other words, the apparent support for gradual improvement in autonomy does not indicate meaningful net change. The additional support for the complement hypothesis (Hc; PMP =0.193) further suggests that the observed autonomy trajectory was not fully captured by the predefined improvement models. Taken together, the evidence indicates modest early reductions in apathy, whereas autonomy changes were small, variable, and not sustained.

Pleasantness Ratings of Individuals with KS Using the Bbrainklok

Descriptive results

Appendix E and Figures 6 and 7 show the mean responses of the individuals regarding the pleasantness of the Bbrainklok, rated on a Likert-scale from 1 (very unpleasant) to 5 (very pleasant). Only two participants reported average scores below 3, indicating an unpleasant experience. This was reflected in their verbal comments, such as “I don’t like it.” and “ Nothing special. It does not give any results. It is more of a burden.”. In contrast, the remaining 14 participants

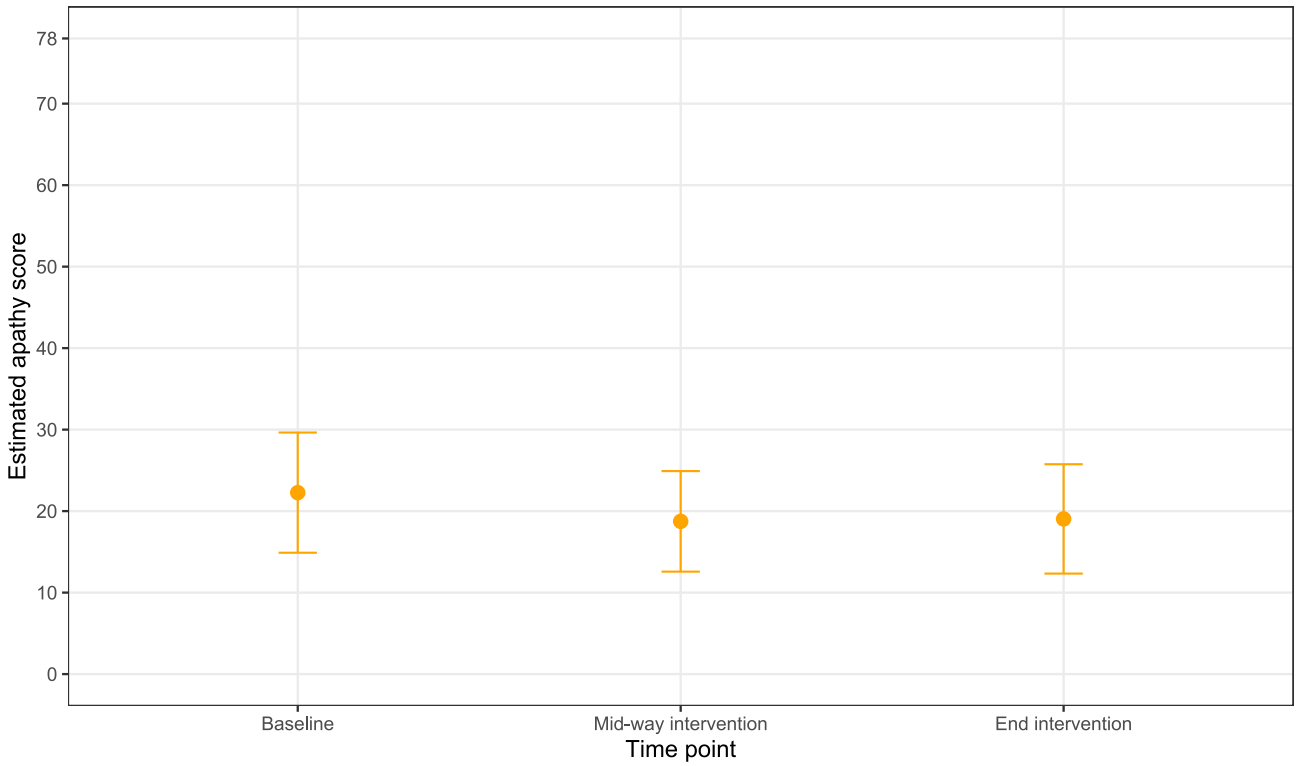

Figure 4 Estimated group-level apathy scores across the study period (baseline, mid-way, and end of intervention). Error bars represent the standard error of the mean and indicate variability across participants. Scores on the "Apathy in Dementia, Nursing Home" questionnaire range from 0 to 78, with higher scores reflecting greater apathy.

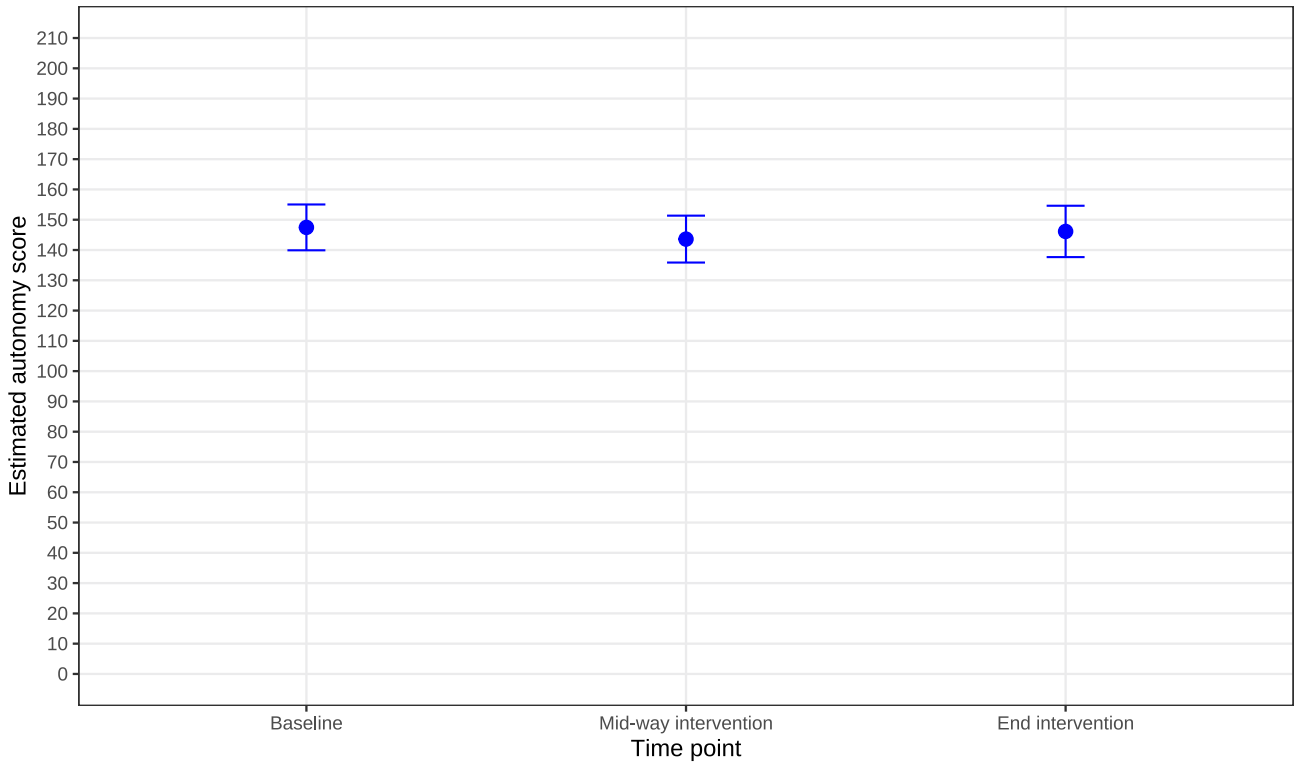

Figure 5 Estimated group-level autonomy scores across the study period (baseline, mid-way, and end of intervention). Error bars represent the standard error of the mean and indicate variability across participants. Scores on the Autonomy Scale Amsterdam range from 0 to 210, with higher scores reflecting greater autonomy.

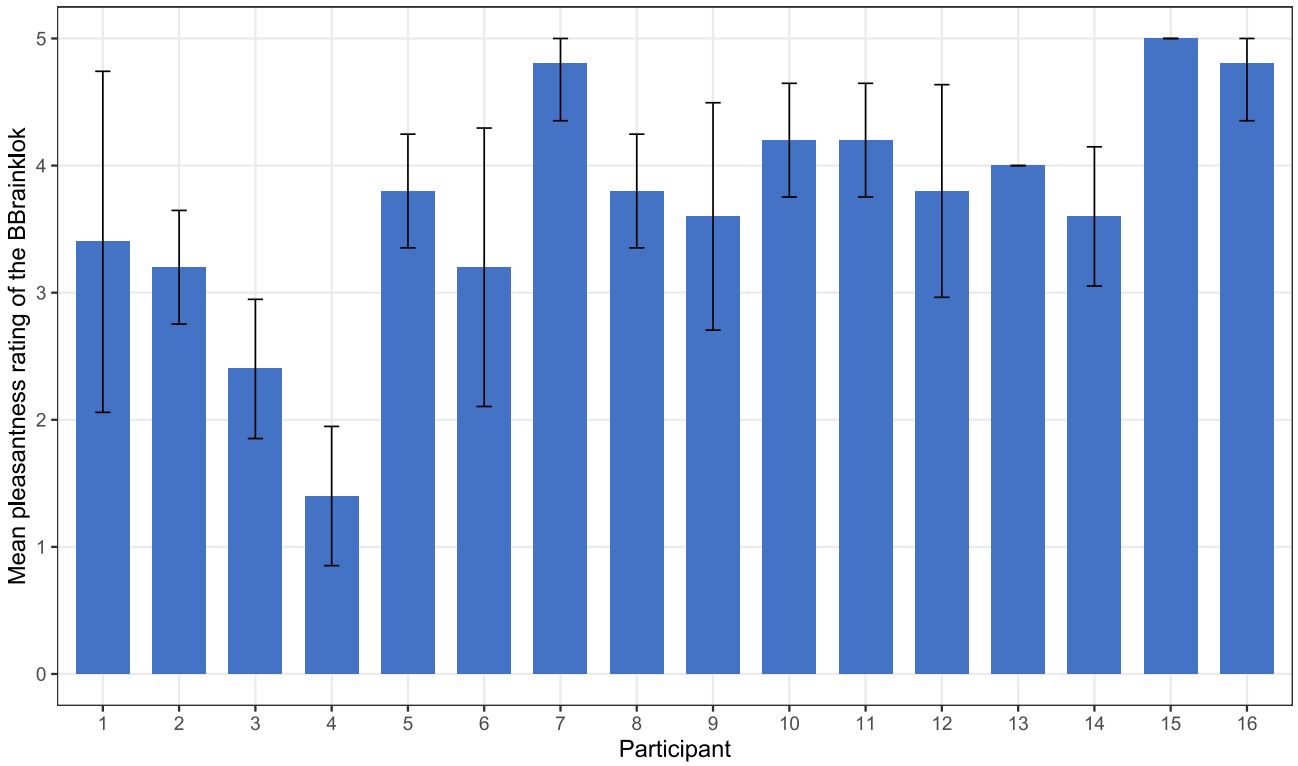

Figure 6 Mean pleasantness ratings of the Bbrainklok for each of the 16 participants, with error bars representing standard deviations. Ratings were provided on a 5-point Likert scale (1 = very unpleasant, 5 = very pleasant). Error bars represent the standard deviation and reflect variability in ratings per participant.

reported overall neutral to very pleasant experiences with the Bbrainklok. Consistent with these ratings, many participants provided positive verbal responses such as "Fine, I often look at it. It is an improvement." or "It's good to look at. It gives me information. I enjoy it." Others expressed more neutral view, for example "I'm fine with it but it does not benefit me. I'm already at breakfast before the alarm." An overview of all verbal responses can be found in Appendix F.

Experience Care Staff with the Bbrainklok

Descriptives

Care staff completed a Likert-scale questionnaire (0 = not at all to 4 = very much so) assessing the perceived usefulness and acceptance of the Bbrainklok (see Appendix G). Fourteen carers participated in this evaluation. Individual responses are presented in Appendix G, and the mean scores are summarized in Figure 8.

Note that the response option "Neutral" on the Likert scale used in this study was not optimally worded. It was adopted from an existing scale in which "Neutral" represents a mid-level response in a range (eg., "Very poor" to "Very good"). In the present context, this wording may have suggested a slightly higher level of endorsement than "A little," although the ordinal position of the options likely ensured consistent interpretation by respondents.

Qualitative Analysis

The qualitative analyses explore staff member's experiences with the use of the Bbrainklok in daily care, as well as their observation of how individuals with KS responded to the device (Appendix H). Questions were organized around five themes: overall experience, interaction, user-friendliness, observed residents' experience and implementation (Appendix B).

Overall Experience

Most care staff expressed a positive attitude toward the Bbrainklok. Only one caregiver reporting a neutral impression because reminders were limited to meals, which were considered less difficult to remember than other tasks. Staff generally indicated that they trusted the Bbrainklok as a memory aid and often no longer needed to collect participants.

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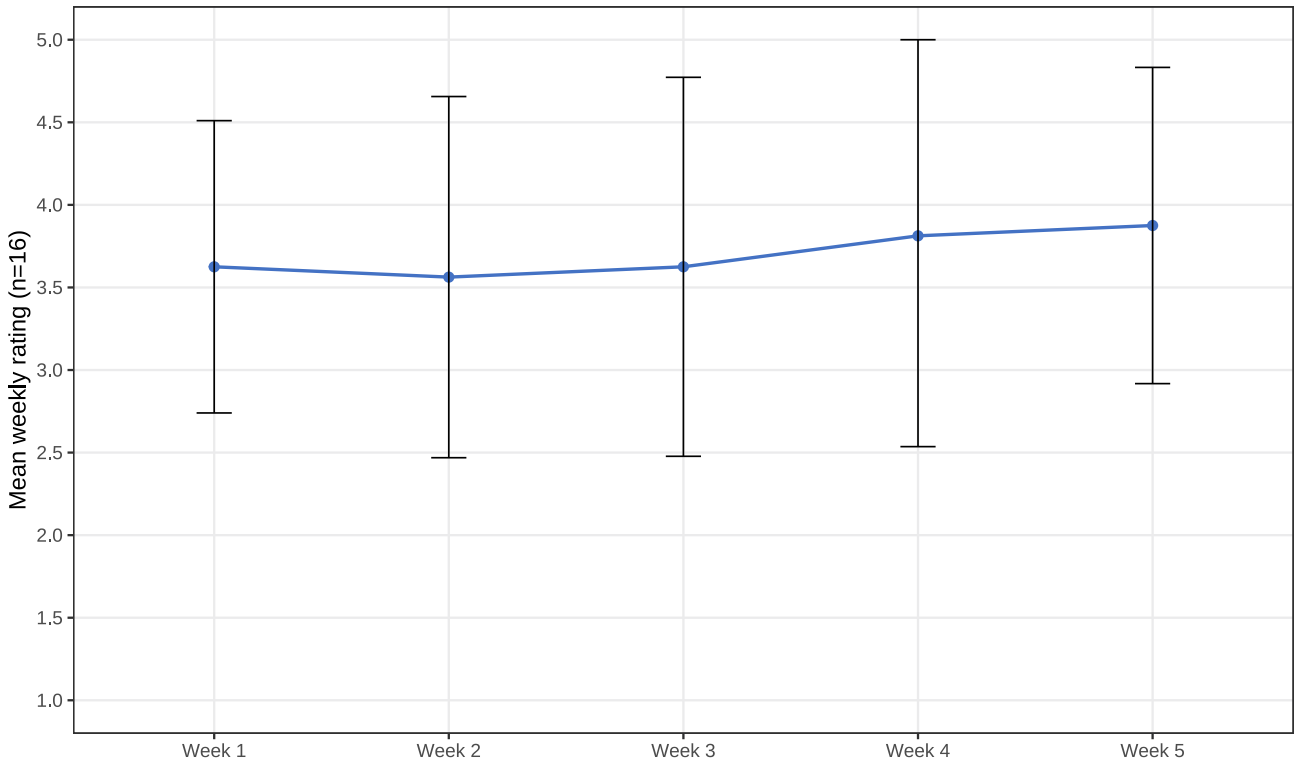

Figure 7 Mean weekly rating across five weeks for 16 participants. Ratings were given on a 5-point Likert scale (1 = very unpleasant, 5 = very pleasant). Error bars represent the standard deviation and reflect variability in ratings per participant.

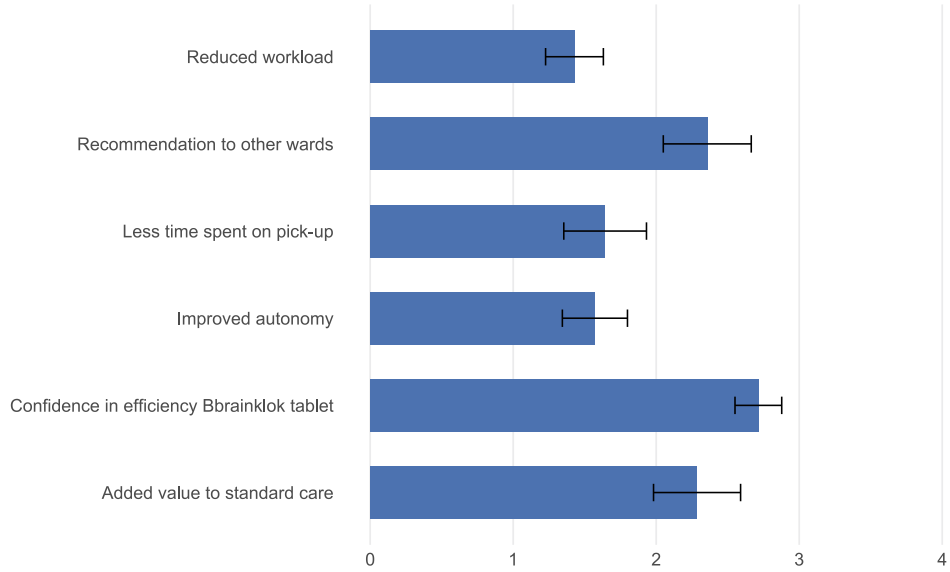

Figure 8 Mean care staff questionnaire rating for the Bbrainklok based on a 5-point Likert scale (0= not at all, 4= very much so). Error bars represent the standard deviation and reflect variability in ratings per participant.

However, one caregiver reported still preferring to pick up the resident to ensure attendance. Staff observed difference in how residents responded to the Bbrainklok in terms of PM performance: some required fewer reminders and attended appointments independently, whereas others continued to need prompting. A useful insight from the focus group was that the Bbrainklok appeared especially valuable for residents who spent much of their time in their room or bed. These

individuals were more likely to notice and respond to the reminders. By contrast, more active individuals with KS often missed the reminders, making the device less effective for them.

Interaction

Staff noted changes in interaction with some residents. Certain individuals asked fewer open questions and instead sought confirmation, for example asking "Lunch is at one, right?" instead of "What time is lunch?". For others, no change in interaction was observed, as they continued to rely on reminders from caregivers. No changes in interaction between care staff members themselves were reported.

User-Friendliness

Care staff considered the Bbrainklok easy to use and described it as a clear device. They valued the large display of the time, the overview of daily tasks and the combination of written and spoken reminders. The "nightstand", where lights were automatically dimmed after a certain time, was also appreciated. Feedback primarily concerned practical limitations: the tablet must remain on a charger and therefore cannot be moved, which restricted flexibility.

Residents' Experiences

Caregivers reported both positive and negative responses from residents. Some individuals found the device pleasant, while others considered it annoying or childish. Two participants discontinued use because they disliked the tablet. Interestingly, some residents who initially reacted negatively later reported acceptance after becoming accustomed to it. Staff also observed differences in residents' awareness of the device's purpose. While some understood its function, others could not explain what the clock was for when asked.

Implementation

At this stage, staff did not report a reduction in workload, noting that collecting residents for meals did not require substantial time. However, they emphasized that if reminders were extended to a wider range of tasks, the potential for time savings would increase. Several design suggestions were made, including a larger version for individuals with impaired vision and adding a to-do list function that allows resident to tick off completed tasks. Staff also emphasized the importance of tailoring the device settings (eg., brightness and volume) to residents' preferences from the start. Staff also expressed interest in using additional features of the Bbrainklok, such as family contact and picture integration. At the same time, they raised concerns about feasibility. In particular, they noted that implementation could be difficult if residents were required to cover the costs themselves and questioned whether the device could be transferred if a resident relocated. A recurring theme concerned comparisons between the Bbrainklok and the smartwatch. Care staff emphasized that the Bbrainklok was particularly suitable for residents who spent much of their time in their room or in bed, as its large display and fixed location provided a clear overview of daily tasks. By contrast, the smartwatch was seen as more appropriate for active residents, offering greater mobility and timely prompts throughout the day. Staff concluded that the two devices could complement each other. The Bbrainklok offers structure and a visible daily overview, while the smartwatch facilities greater independence for residents who are more mobile. Several caregivers therefore considered a combined approach the most promising solution.

Discussion

This study aimed to evaluate whether a digital external memory aid, the Bbrainklok, can enhance PM performance, reduce apathy and thereby improve autonomy in individuals with KS living in a long-term care facility. The clearest finding was a decrease in apathy, particularly during the early phase of use. Although the magnitude of this reduction was modest at the group level, it was relatively consistent compared to the other outcomes. In contrast, PM performance remained stable for approximately half of the sample and improved only in a subset, while autonomy showed small and inconsistent changes that returned to baseline levels.

The limited PM gains contrast with earlier studies reporting more consistent improvements following external memory aids.[1,25,27–33] A likely explanation lies in the task context. Meal attendance is highly routinized and supported by strong internal cues such as hunger,[56] resulting in high baseline attendance rates (Table 2) that likely restricted

observable improvement. Importantly, participants with a low baseline attendance demonstrated clearer improvements patterns, suggesting that intervention effects may depend on initial functional level. This finding underscores the importance of individualized implementation and indicated that the Bbrainklok may be particularly beneficial for residents with lower baseline PM performance. Although most participants did not show measurable improvement, gains observed in a subset remain clinically relevant. Given the substantial PM deficits characteristic of KS,[10–14] even small improvements in daily task completion may meaningfully support structure and independence in everyday life. Future implementation efforts should therefore consider extending the use of the Bbrainklok to other daily-life PM tasks that are less strongly embedded in routine.

The reduction in apathy is notable, as targeted apathy interventions in KS remain scare. The findings aligns with the conclusions from van Dorst et al[24] who argued that effective interventions in this population may rely less on intrinsic motivation and more on external stimulation, such as cueing and behavioral activation. Although the observed effects were modest, even small reductions in apathy may be clinically meaningful for individuals with KS and their caregivers. Given the substantial burden that apathy places on both residents and care staff,[19,20] and the current lack of targeted interventions in this population, even modest improvements are of clinical relevance. However, given the limited magnitude of change, these findings should be interpreted cautiously and replicated in larger samples.

Perceived autonomy was included as a secondary outcome, as improvements in PM functioning and reductions in apathy were expected to contribute to greater autonomy. However, autonomy was not affected by the BBrainklok intervention. Instead, an initial decrease was observed, followed by a return to baseline levels. This suggests that perceived autonomy may be less sensitive to isolated task support than to broader psychosocial factors.[50] Unlike prior studies reporting autonomy gains with assistive technology,[57] the present study relied on self-report rather than proxy ratings, which may account for discrepancies.[25] These findings highlight that functional task success does not autonomically translate into enhance subjective autonomy.

Sustained use is a common challenge in memory rehabilitation, as individuals often discontinue digital aids once formal support ends.[38] Devices like the Bbrainklok, which are intuitive, minimally demanding, and seamlessly integrated into daily routines, are therefore crucial for sustainable use. Focus group findings confirmed that care staff valued its large display, clear overview, and ease of use, reinforcing its potential as a reliable, long-term aid in care settings. Additionally both residents and care staff reported an overall positive experience with the Bbrainklok, which is especially important for sustainable implementation in care settings.[58] Acceptance appeared to increase over time, suggesting that a brief adjustment period may facilitate uptake when introducing new assistive technologies.

With respect to individual differences and patient suitability, several patterns emerged. Staff noted that the Bbrainklok was particularly useful for residents who spend much of their time in their rooms. More active residents were more likely to miss cues due to the device's fixed location. Those individuals may require complementary technologies such as smartwatches. Exploratory analyses did not reveal clear associations between baseline cognitive functioning or apathy and intervention-related PM improvement, although limited statistical power and ceiling effects restricts firm conclusions. If replicated, this pattern may indicate that the Bbrainklok is applicable across a relatively broad range of cognitive and motivational profiles, rather than only those with relatively preserved functioning.

Several limitations should be acknowledged. PM performance data were incomplete (15–80% missing per participant), as care staff occasionally forgot to record attendance due to staff changes or busy periods. To address this, we used Bayesian analysis, which can handle incomplete data by jointly estimating missing values and model parameters, thereby retaining available information while accounting for uncertainty.[59] Additionally, The absence of an age- and gender-matched control groups also limits comparison. However, previous studies have shown ceiling effects in control groups,[11,14] suggesting that including one here would have added little interpretive value.

A further limitation concerns the administration of the apathy questionnaire. In the first study phase (November), care staff completed all three ratings (baseline, T1, T2) on the same form, allowing them to see previous responses. In the second phase (March), separate forms were used for each time point, resulting in greater variability and suggesting improved reliability. Notably, even with the initial limitation, apathy still decreased in most participants, strengthening the robustness of this finding.

Finally, ceiling effects constrained the potential to detect PM improvement, as several participants already attended meals independently at high rates (over 85% of the time). Because meal attendance is strongly supported by routine and internal cues such as hunger,[56] future studies should examine tasks with weaker internal cueing and greater variability to better assess intervention effects.

Strengths of this study include its robust design and relatively long intervention period, as most technological interventions in KS have been evaluated only over brief time frames.[1,28,29,32] Moreover, many digital intervention studies in KS rely on single-case designs, whereas the current study included a comparatively larger sample, enhancing the reliability and generalizability of the findings.[60] In addition to objective outcome measures, the study incorporated perspectives from both individuals with KS and their care staff. This provided valuable insight the usability and perceived usefulness of the Bbrainklok in long-term care settings. By combining functional PM outcomes with measures of autonomy, apathy, user-friendliness, the study adopted a multidimensional evaluation approach, thereby strengthening its ecological validity and practical relevance for clinical implementation.

Conclusion

This study set out to evaluate whether a digital external memory aid, the Bbrainklok, could enhance PM, reduce apathy and improve autonomy over time in individuals with KS or alcohol-induced major cognitive disorder. The most consistent findings was a modest reduction in apathy, alongside high user acceptability among both residents and care staff. In contrast, PM performance remained stable for most participants, with only a subset showing patterns consistent with early improvement. Autonomy scores showed small and inconsistent change, with no clear overall improvement across the intervention period.

Although benefits were not uniform, the Bbrainklok may provide meaningful support for certain residents, particularly those who are less active and spend substantial time in their rooms. Its intuitive, low-demand design and positive evaluations from both users and caregivers suggest favorable conditions for successful implementation in long-term care settings. Overall, the results position the Bbrainklok as a feasible and accessible tool to support engagement, daily structure, and perceived independence in individuals with KS.

Declaration to Participate

Informed consent was obtained from all individual participants included in the study. Verbal informed consent was obtained for the legal guardian.

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Disclosure

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