Use of an electronic pillbox by older adults with mild Alzheimer's disease: Impact on medication administration and adherence

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M. Tellier, C. Auger, N. Bier, L. Demers. Use of an electronic pillbox by older adults with mild Alzheimer's disease: Impact on medication administration and adherence. Gerontechnology 2020;19(1):66-76; https://doi.org/10.4017/gt.2020.19.1.007.00 **Background** Medication management is a key concern for people with Alzheimer's disease (AD) and their family caregivers in the home environment. Using an electronic pillbox or multicompartment medication device (eMMD) could help them on a daily basis. **Research aim** The aim of this study was to teach older adults with mild AD how to use an eMMD and evaluate the impact of its use on independence with medication administration and medication adherence. **Method** We conducted a multiple baseline single-case study with an A1BA2 design across tasks (A1 = no training, no eMMD; B = training with eMMD; A2 = no training, daily use of eMMD). Four participants with AD learned how to use an eMMD by following a training program involving specific learning strategies. Independence with medication administration was scored on a 5-point scale observation chart and analyzed visually and quantitatively using Tau. Medication adherence was measured using the automated data generated by the eMMD over the 12 weeks post-training. **Results** All participants were able to learn to use the eMMD within 11 training sessions. Score variability and trends showed an increase in independence with medication administration between A1 and A2. Tau yielded significant ($p < 0.05$) effect sizes. Medication adherence was over 80% for the 12 weeks post-training. **Conclusion** This study suggests that engaging older adults with mild AD in using an eMMD can improve medication management. The results also reinforce the relevance of technology research and development focusing on this population.

Keywords: Alzheimer disease, medication management, electronic pillbox, errorless learning

Introduction

People with Alzheimer's disease (AD) and their family caregivers face the daily challenge of medication administration at home (Kaasalainen et al., 2011). Independence with medication administration, i.e., the ability to take medication by oneself, is one of the main responsibilities assumed by family caregivers (Brodaty & Green, 2002; Fortinsky, 2001; While, Duane, Beanland, & Koch, 2013). The performance of this complex task, which requires remembering to perform an action over time, is affected by the beginning of the disease (Petersen et al., 2014). Independence with medication administration has a direct impact on adherence, which is the degree to which actual medication administration corresponds with that prescribed by a health professional (Advinha, Lopes, & de Oliveira-Martins, 2017; Cooper et al., 2005; Sabaté, 2003). Non-adherence is a particular concern in the case of people with dementia (Okuno, Yanagi, & Tomura, 2001; Ruscin & Semla, 1996) since it has an impact on their use of health services (Arlt, Lindner, Rösler, & von Renteln-Kruse, 2008).

In the older population in general, the use of an electronic pillbox or multicompartment medication device (eMMD) improves medication administration by organizing the medication ac-

cording to a prescribed schedule and issuing verbal and/or audible signals when it is time to take it. A systematic review examining medication adherence with the use of an eMMD by older adults without any cognitive disorders reported adherence rates varying between 78% and 98% across the 22 studies identified; the gold standard for good adherence is 80% (Miguel-Cruz, Felipe Bohórquez, & Aya Parra, 2018). Another literature review looked at the effectiveness of eMMDs in a community-dwelling population without any cognitive disorders (Paterson, Kinnear, Bond, & McKinstry, 2017) and identified 6 studies showing that eMMDs can improve adherence in this population (Paterson et al., 2017).

To date, studies looking at technologies for Alzheimer's disease and other dementia have not considered people with dementia as direct users of medication management devices. A systematic review conducted in 2017, identified 539 intelligent assistive technology for dementia (Ienca et al., 2017). Of these, only 3 were addressing medication management and all 3 were classified as distributed systems i.e., part of the intelligent environment and not used directly by individuals with dementia. No data on the impact on adherence was available.

To raise the level of evidence of the effectiveness of eMMDs for medication administration used by people with AD, it is important to define the context of use and evaluate usability in this population (Paterson et al., 2017). In addition, the training strategies must be defined (Bartfai & Boman, 2014). In fact, persons with AD need specific training to learn how and when to use their assistive technology. Also, implementing strategies must be determined in order to ensure that the technology will be used on a day to day and long-term basis (Imbeault et al., 2013). Our team developed an intervention protocol that guides clinicians when teaching people with mild AD to use an eMMD. The intervention takes place in the home environment and is supported by evidence-based cognitive intervention to support learning of people with dementia, including errorless learning methods (Clare et al., 2010; Sohlberg, 2012).

The general aim of the present study was to explore, in a real-world setting, an intervention protocol for eMMD usage in early AD. More specifically, the objectives were: (1) to support learning of eMMD usage in mild AD with the use of a protocol based on evidence-based practice in the field; and (2) to explore the impact of its use on independence with medication administration and adherence.

Method

Study design and hypotheses

We conducted multiple single case studies. More specifically, we used an A1BA2, multiple baseline design across tasks. This design is indicated when studying a new intervention (Ottenbacher, 1986) because it can be personalized according to the participants' cognitive profile and progress and the observed effects can be contextualized. Phase A1 (5 sessions - no training, no eMMD) was used to establish the baseline for degree of independence with medication administration. It also enabled the participant to get used to the eMMD . In phase B (training; a number of sessions varied depending on the participant's progress, use of eMMD only during training sessions), the participant learned to use the eMMD. The degree of independence with medication administration without the eMMD was measured and the technology was removed from the participant's home between sessions. In phase A2 (5 sessions - no training, use of eMMD daily), the participant's degree of independence with medication administration was evaluated in a situation involving daily use of the eMMD. Also, adherence data were collected starting in this phase and continuing up to 12 weeks post-training. The untrained task was measured at the same frequency as medication administration (trained task), i.e., once per session in the 3 phases. Sessions were held once a week in phases A1 and A2 and twice a week in phase B.

The study hypotheses were that there would be: i) improvement in independence with medication administration between phases A1 and A2; ii) no change in independence for the untrained task between phases A1 and A2; and ii) a medication adherence rate of at least 80% post-training.

Participants

To be eligible for the study, participants had to have been diagnosed with probable early-stage (mild) AD by their doctor according to DSM-5 criteria and have a problem with medication administration (support of a caregiver needed and/or history of a missed dose and/or mixed medication). Participants had to be aged 65 years or older and take medications in pill form because this was the only format supported by the technology used (eMMD). Candidates with a diagnosed mental illness were excluded. All participants were able to sign a consent form. Considering the intensity of the intervention protocol and the exploratory nature of the study, 4 participants were recruited. Potential candidates were identified through team discussions at a primary care memory clinic in Laval, Canada. The nurse in charge of the clinic made the initial contact and a researcher obtained a signed consent. Participants were informed that they could keep the eMMD after the end of the study. A neuropsychologist administered an assessment battery to establish a detailed cognitive profile of the participants (*Table 1*). The descriptive data collected

Table 1. Test results of Neuropsychologist assessment battery

Neuropsychological tests	Participants			
	1	2	3	4
Episodic Memory				
Rey-Osterrieth Complex Figure Test Copy (/36)	31	16*	1*	13*
Immediate recall (/36)	0.5*	2.5*	0*	4.5
Delayed recall (/36)	0*	2.5*	0*	4*
Delayed recognition (/24)	15*	17	14*	17
DMS 48				
Immediate recall (/48)	20*	44	48	45
Delayed recall (/48)	28*	36*	43	44
Rey Auditory Verbal Learning Test (/15)				
Recall 1	2	3	6	4
Recall 2	3	4	6	3
Recall 3	4	7	5	4
Recall 4	7	5	6	4
Recall 5	8	5	3*	4
B list	3	3	1*	4
Immediate recall	6	4	4*	0*
Delayed recall	0*	4	6	0*
Recognition	ND	11	14	9
Semantic Memory				
Pyramid and Palm Tree Test (/52)	43*	46	40*	46
Boston Naming Test –30 items version	24	20	27	29
Verbal Fluency				
Lexical (letter – P)	6	3	4*	4
Lexical (letter – F)	6	5	5	8
Lexical (letter – L)	4	1	3	7
Category (animal)	7*	13	4*	12
Executive Functions				
Trail Making				
Part A (in sec)	51.15	74.93	139.02*	90.95*
Part B (in sec)	168.22	206.56*	227.00*	69.93*
Stroop– condition 1 (time)	37.87	47.67	100.55*	68.33*
Stroop– condition 2 (time)	24.60	35.91	64.03*	38.01*
Stroop– condition 3 (time)	180.00*	118.78*	74.12*	129.89*
Stroop– condition 4 (time)	117.52	73.78	152.18*	112.48
Working Memory				
Digit Span				
Forward span max	5	4	5	4
Backward span max	3	3	3	3

∗Results below the threshold of 2 standard deviations according to age and level of schooling or below the cut-off.
Rey-Osterrieth Complex Figure Test (Meyers & Meyers, 1996); DMS 48 (Barbeau et al., 2004); Rey Auditory Verbal Learning Test (Lezak, 1976); Pyramids and Palm Trees (Howard & Patterson, 1992; French norms by Callahan et al., 2010); Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983; Verbal fluency (French norms by Rouleau, 2011); Trail Making Test A and B (Reitan, 1958); Stroop Test (Version Victoria; Spreen & Strauss, 1991); Digit span and letter-number sequencing WAIS–III (Wechsler, 1997a).

from the assessment helped to better understand individual results. All participants showed some impairments in episodic memory and executive functions, which is consistent with the onset of AD type of dementia.

Participant #1

Participant #1 (P1) was a 75-year-old man who was living alone at the time of the study; he was diagnosed with probable AD 1 year earlier. His general cognitive profile is presented in *Table 1*. P1 showed executive as well as episodic memory deficits. He also showed signs of semantic memory deficits. Before using the eMMD, he took his medication twice a day, in the morning and at bedtime, using a pill dispenser prepared by the pharmacy each week. His daughter called each time to remind him to take his medication and tell him which compartment to open.

Participant #2

Participant #2 (P2) was a retired 74-year-old widow, who lives with her son at the time of the study. She was diagnosed with probable AD 4 months earlier. *Table 1* shows that she presented executive function deficits, as well as deficits in visual

Table 2. Scoring guide for degree of independence with medication administration

Score	Meaning
4 = Independent	User takes the right medication at the right time.
3 = Independent with difficulty	User takes the right medication at the right time but with difficulty, e.g., drops the pill on the floor.
2 = Verbal assistance	User requires verbal instructions, e.g., "It's time to take your medication."
1 = Verbal and physical assistance	User requires verbal instructions and physical help, e.g., "It's time to take your medication" and help with opening the container.
0 = Dependent	Someone else gives the medication.

episodic memory. She was taking her medication 3 times a day, in the morning, at dinner and at bedtime. Before using the eMMD, she used a pill dispenser prepared by the pharmacy and delivered to her home each week. Her son was supervising her medication administration to avoid oversights.

Participant #3

Participant #3 (P3) was a married, retired 81-year-old woman. She was diagnosed with probable AD 3 years earlier. *Table 1* shows that she presented executive function deficits, as well as significant difficulties in episodic memory. She also showed signs of semantic memory deficits. At the time of the study, she was using a pill dispenser prepared and delivered by the pharmacy each week and took her medication twice a day, in the morning and evening. P3 was requiring assistance from her husband to supervise the medication administration schedule (morning and bedtime) and handle the regular pill dispenser (select the right compartment and open it).

Participant #4

Participant #4 (P4) was a 71-year-old retired man, who was living with his partner at the time of the study. He was diagnosed with probable AD a year earlier. *Table 1* shows that he presented executive functions and episodic memory deficits. He was using a weekly pill dispenser prepared by the pharmacy, which the couple went to pick up. His partner was supervising the medication administration schedule (morning, lunch, afternoon, dinner, bedtime) and the pill dispenser manipulation (select the right compartment).

Description of the training

This intervention protocol was built on cognitive rehabilitation, evidence-based practices for persons with severe cognitive deficits (Clare et al., 2000; Clare, Woods, Moniz Cook, Orrell, & Spector, 2003; de Werd, Boelen, Rikkert, & Kessels, 2013, 2015; Haskins et al., 2012; Sohlberg & Mateer, 1989; Sohlberg & Turkstra, 2011). The training was based on the three-step intervention method of Sohlberg & Mateers (1989) and supported by errorless learning methods (Clare et al., 2010). In the current study, learning is broken down into 5 steps related to the usage of the eMMD. To avoid errors, the protocol informed the clinician to be vigilant in detecting any errors that could be made and correct them immediately by physically guiding the person (errorless learning principles). During the first training session, the participant was encouraged to use the eMMD intuitively, i.e., without any verbal or physical assistance. The goal of this session was to determine if: (1) training is necessary, and (2) if so, at what step it should start. Then, the intervention began with 2 training sessions held at the participant's home at the same time each week. To support the clinician in the use of errorless learning, a decision tree identified the type of help to be provided for each step (verbal and/or physical) and how supervision was reduced gradually (vanishing cues) until the participant became independent. The training ended when the participant was able to complete the 5 steps in using the eMMD independently, during 3 consecutive sessions. The intervention protocol is available upon request to the author.

Electronic pillbox

The commercially available eMMD used in this study (DoPill® https://www.domedic.ca/) was originally designed for people with Parkinson's Disease. It was chosen because its functionalities are compatible with the need to support prospective memory functions in AD. The eMMD consists of a connector and 28 compartments covered with a membrane that detects events. It is filled by the pharmacist and each compartment can contain several medications (pills). When it is time to take the medication, the eMMD sends a sound alert and a green light indicates the compartment containing the medication to take. The user must lift the plastic film to take the medication from the compartment. If the person does not react, reminders will be repeated every 15 minutes, up to 3 times. In the event of an error, the eMMD sends a more insistent alarm. The eMMD generates data automatically (medication taken correctly, taken late, error or omission), and the data are communicated by text or email through the connector to a health professional or family caregiver (or to the first author in the case of this study). Users only have to plug the 28 compartments device and the connector into a power outlet.

Measures

Independence with the trained task (A1, B, A2)

Independence with medication administration is defined as the physical and cognitive ability

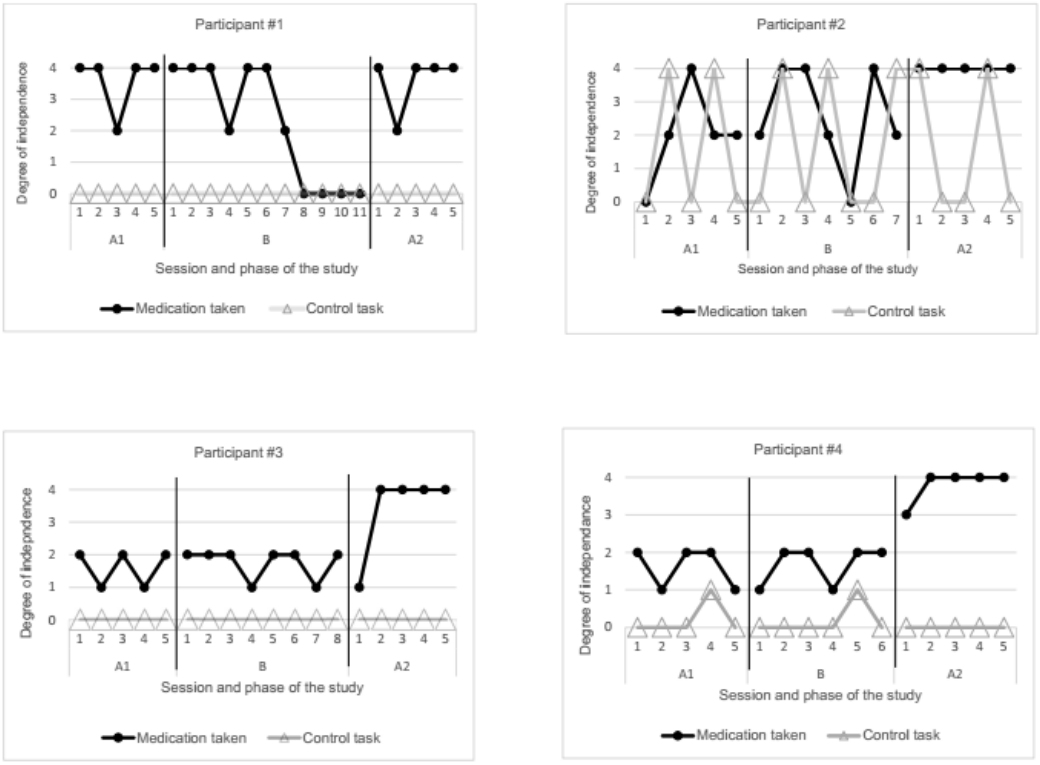

Figure 1. Degree of independence with medication administration and untrained task

to execute the steps necessary to take (swallow) medication. It was measured once per session using a 5-point ordinal scale (*Table 2*) adapted from the Activities of Daily Living Profile (Dutil, Bottari, & Auger, 2017). A distinction between verbal assistance, and physical and verbal assistance, was added to the original scoring scale to refine the degree of independence.

Independence with the untrained task (A1, B, A2)
An untrained task was used to reduce internal validity bias, including maturation and measure repetition that are inherent to single case studies (Matyas & Greenwood, 1996). It consisted of having the participant telephone the day before the session to confirm the appointment. Making an appointment is supported by similar cognitive functions as the trained task regarding procedural (repetition of a series of motor steps) and prospective memory (remembering to do a task in the future). Independence in the untrained task was evaluated using the same scoring scale and at the same frequency as the medication administration task.

Medication adherence (A2 and continuing up to 12 weeks post-training)
Adherence is the degree to which actual medication administration corresponds to that prescribed by a health professional. It was evaluated from the log automatically generated by the eMMD (taken correctly, taken late, error or omission). The raw data were then aggregated on a dichotomous scale, with Yes for medication taken correctly (on time/late), and No for medication taken incorrectly (error/omission). Taking it late was considered medication taken correctly since the person took the medication correctly after being reminded by the alarm.

Researcher's log (A1, B, A2)
In each session, the researcher noted observations concerning the intervention and/or use of the eMMD. These included elements to consider when conducting a session such as the participant's behavior (fatigue, pain, confusion), mood and comments, or an event that occurred that could have affected the participant's concentration. The researcher also noted situations that required to adapt the intervention protocol, such as canceling a session because of a health problem.

Family caregiver's journal (A1, B, A2)
The family caregiver used a journal to record events that happened when the researcher was not present, such as a new medication or meeting with a new health professional, how medication administration generally proceeded outside of the sessions, and the participant's overall condition. The family caregiver could also note necessary information related to the control task

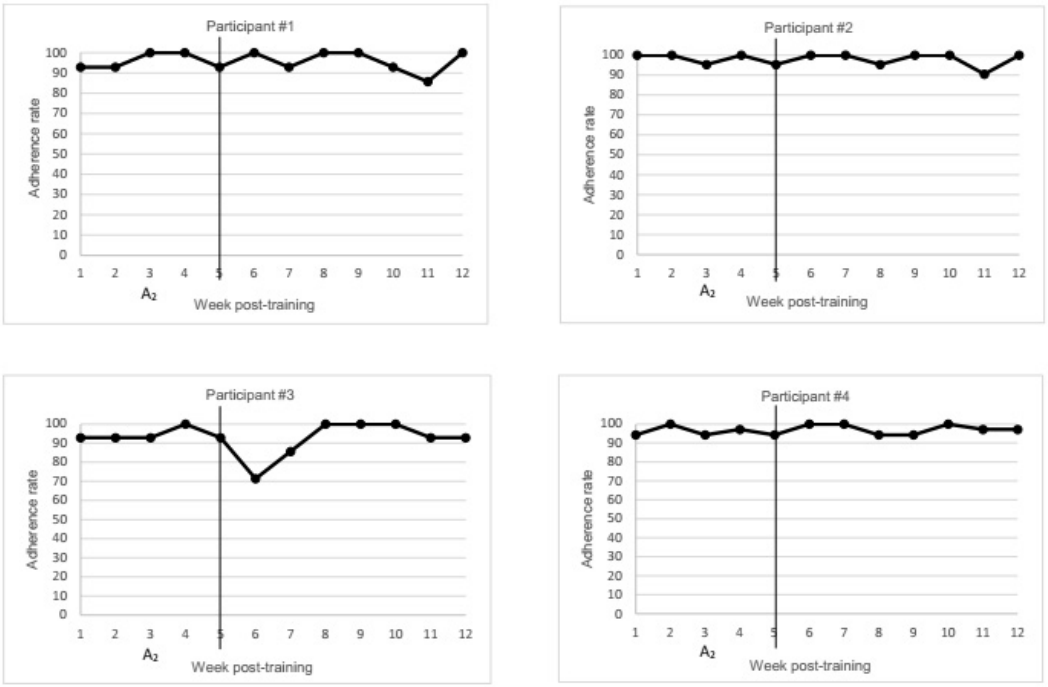

Figure 2. Adherence to medication during the 12 weeks post-intervention

(call the day before the appointment), including details of the help provided, in order to be able to score the degree of independence.

Procedure

All sessions were held by the same researcher and scheduled according to the participant's preferred time of day. Depending on the participant, it was either during the morning or lunch medication intake. The researcher went to the participant's home 15 minutes prior to medication administration. At the beginning of the session, the researcher instructed the participant: *"When it's time, take your medication as usual."* At the end of each session, the participant was told: *"The day before your next appointment, please confirm it by calling this number."* In every session of phase A1, the evaluator measured the degree of independence with medication administration as it is normally done. Each session lasted approximately 30 minutes. A report was kept of medical appointments and the participant's general condition in case something had changed since the previous session. The eMMD was shown to the participants so they could get used to it. In phase B, the number of sessions varied depending on each participant's learning period. Similarly, to phase A, a report of events that had occurred since the last session was completed with the family caregiver. After measuring the degree of independence with medication administration, the training started with 4-5 trials per session according to the participant's tolerance level. Each session lasted approximately 45 minutes. In phase A2, a favourable location for the eMMD was identified in collaboration with the individual to ensure that he could hear the alarm, such as the kitchen counter if medication intake was at mealtime. The same procedure was followed as during A1, except that medication administration was done using the eMMD on a daily basis.

Analysis

First, we analyzed the scores for independence with medication administration and the untrained task collected in phases A1 and A2. A visual analysis was done using the criteria for change proposed by Ottenbacher (1986), namely that measures varied within the same phase (2 changes of at least 1 point on the scoring scale) and that the trend changed between phases. Then a Tau (individual and with all participants combined) was calculated to support the results of the visual analysis (Parker, Vannest, Davis, & Sauber, 2011). Tau is a non-parametric statistic that measures the non-overlap between 2 series of data. It varies from -1 to 1. In our study, a value of -1 means that all the scores in A2 are lower than in A1 while a value of 1 means that all the scores are higher in A2 than in A1. A value of 0 indicates a complete overlap, i.e., no change between scores in A2 and A1. In our study, Tau was calculated with a Web-based calculator (Vannest, Parker, Gonen, & Adiguzel, 2011). This non-parametric statistic allows us to identify and correct for the natural tendency that

Table 3. Ratings of visual inspection and results of analyses of degree of independence with medication administration and untrained task

Participants	Tasks	Ratings of Visual Inspection			Results of analyses	
		Variability A_1	Variability A_2	Trend change between A_1 and A_2	Tau-U	p value
#1	Medication administration	No	No	No	0	1
#2		Yes	No	Yes	0.8	0.04*
#3		Yes	No	Yes	0.68	0.08
#4		Yes	No	Yes	1	0.009*
#1	Untrained task	No	No	No	0	1
#2		Yes	Yes	No	0	1
#3		No	No	No	0	1
#4		No	No	No	-0.2	0.6

Legend: *p value <0.05 indicates significant change between A_1 and A_2.
Variability: Yes = at least 2 changes in independence score in same phase
Trend change: Yes = shift in independence scores between A_1 and A_2

can be present in the baseline phase by using a Tau-U, which avoids overestimating the results attributed to the intervention. However, this was not needed in our study. Finally, adherence was calculated as the ratio between the total number of answers indicating medication taken correctly (Yes) per week and the total number of medications prescribed by a health professional. A ratio higher than 80% was considered good, based on Miguel-Cruz et al. (2018).

Results

The individual results for each case are discussed first, followed by the whole sample of 4 participants. Individual independent session scores for medication administration and the untrained task are illustrated in *Figure 1* for each phase (A1, B, A2) and each participant. Ratings of visual inspection (observed variability indicated by Yes or No) of the *Figure 1* graphs for phase A1 and A2 are in *Table 3*. In *Table 3*, these visual inspections are presented with the calculated Tau values that combine non-overlap between phase A1 and A2 for medication administration and untrained task. The weekly adherence rates for each of the participants over the 12 weeks following the training phase (A2 and up) are illustrated in *Figure 2*. The results for each participant are presented below.

Participant #1

In phase B, his daughter noted that the family doctor changed his medication and medication schedule. P1 mastered the eMMD after 11 training sessions, which consisted primarily of learning how to open the plastic film to get the pills.

The visual analysis showed stable scores for independence with medication administration between phases A1 and A2. No variability or trend change was observed and this was confirmed by a Tau of 0 (p=1). However, the visual analysis in phase B (during the training) revealed substantial variability. A decline in independence was observed in weeks 8, 9, 10 and 11, which coincided with the change in medication noted in the journal. For the untrained task, no variability or trend change was reported. Concerning adherence, the rate for medication taken correctly was above 80% every week (86% and over). The eMMD data revealed 1 error in taking medication in weeks 1, 2, 5, 7 and 10, and 2 errors in week 11. Since Participant #1 took his medication twice a day, this corresponded to 7 errors out of 168 uses of the eMMD.

Participant #2

In phase B, Participant #2 mastered the eMMD after 7 training sessions, which consisted primarily of learning how to open the plastic film to get the pills. During the study, she started a strategy to support her in remembering the control task: she put a post-it note on the fridge to remember to call to confirm the appointment. However, she often eats at her daughter's house and was seeing it only when she was staying home for supper.

The visual analysis showed variability in the data in A1, but no significant trend was detected by the Tau. In A2, no variability was visually detected as the scores were stable at 4 (independent). A trend change between the 2 phases was confirmed by a Tau of 0.8 ($p<0.05$), indicating that 80% of the A2 data were higher than in A1. For the untrained task, no trend change was observed. The adherence rate with the eMMD was over 90% during the 12-week period. Out of the 21 times per week that medication was taken (3 times a day), the log showed 1 error in weeks 3, 5 and 8, and 2 errors in week 11, for a total of 5 errors out of 252 uses of the eMMD.

Participant #3

In phase A2 of the study, the family caregiver's journal indicated that the diagnosis for P3 was changed to moderate AD and that she had pneumonia with episodes of confusion for about 10 days. She mastered the eMMD after 8 training sessions, which consisted primarily of learning

how to open the plastic film to get the pills.

In phase A1, medication administration independence scores varied but they stabilized towards independence in phase A2. However, the trend change observed between phases A2 and A1 was not confirmed by the Tau statistic since the result of .68 (p=0.08) was not statistically significant. The untrained task was stable in phases A1 and A2, and no significant trend change was observed (Tau-U=0; p=1). The eMMD medication adherence score was above 80% for 10 of the 12 follow-up weeks. The 2 weeks when adherence fell below 80% coincided with the health problem noted in the journal. P3 obtained the maximum adherence score for 4 weeks (weeks 4, 8, 9 and 10). For the remaining 8 weeks, the weekly number of errors varied between 1 and 4 out of 14, totaling 12 errors out of 168 uses of the eMMD.

Participant #4

The family caregiver's journal indicated that P4 had a heart attack and had to be hospitalized for 2 months at the beginning of phase A2. This phase was thus interrupted and resumed after he returned home, once his state of health had stabilized. An additional training session was required to help him reactivate his knowledge. In phase B, he mastered the eMMD after 7 training sessions, which consisted primarily of learning how to open the plastic film to get the pills.

In phase A1, the independence with medication administration score varied but it stabilized in phase A2. A statistically significant trend change was observed (Tau-U=1; p<0.05) with greater independence post-training. No significant trend change was observed for the untrained task (Tau =-0.2; p=0.6). Adherence was above 80% during the 12 weeks post-intervention. Out of the 35 times, medication was taken per week, 1 error was observed in weeks 3, 5 and 8, and 2 errors in week 11, for a total of 5 errors out of 420 uses of the eMMD for Participant #4.

Combination of data from the 4 participants

The data from the 4 participants were combined by using Tau again, with a web-based application (Vannest et al., 2011). The results showed variability in the scores for independence with medication administration in A1 for 3 of the 4 participants (#2, #3 and #4), which disappears in A2. There was a change in trend between phases A1 and A2 for these same participants. No change was observed for the untrained task for all participants. A combined Tau for the 4 participants of 0.62 (p<0.05) indicates that 62% of the independence scores after the eMMD was introduced (in A2) were higher than before the eMMD was introduced (in A1). For the untrained task, a combined Tau of -0.05 (p=0.794) was obtained, pointing to the absence of change for the whole sample.

Discussion

The main objective of this study was to evaluate the impact of an eMMD on the independence of older adults with AD, more specifically on medication administration and adherence. The training was done with the help of a structured intervention and the 4 participants were able to incorporate the eMMD in their routine after 7 to 11 training sessions. Our results showed a significant overall improvement in independence with medication administration while independence in the untrained task did not change. Also, all our participants maintained good adherence, i.e., above the 80% cut-off proposed by Miguel-Cruz et al. (2018), in the 12 weeks following the end of the training. Two factors that could explain these results are discussed below, namely the use of errorless methods and the functionalities of the technology.

The use of errorless learning methods could explain the success of the training in our study. Errorless learning is considered as an evidence-based practice in persons with severe memory deficits, such as in AD (Clare et al., 2010; Li & Liu, 2012). To our knowledge, this method has never been used in combination with an eMMD. Our results hence support studies that have shown the importance of using a structured learning phase when using technology to help cognition in AD (Imbeault et al., 2013). Our results also suggest the relevance of using errorless learning methods for medication administration. Our intervention supported exclusively the sequence of actions to execute when using the eMMD, regardless of the contextual details (Clare & Jones, 2008). Also, our hypothesis with respect to the untrained task was confirmed, suggesting the importance of using learning methods with this population.

Also, as shown in a study by Imbeault et al. (2016) using an electronic agenda, the usage of a technological device in AD can be maintained on a long-term period when learning and transfer in a real-life setting are well supported. In fact, although the 4 participants in the present study had a degenerative disease, they were able to maintain an adherence rate of over 80% for at least 12 weeks. One of them had to interrupt his training for 2 months but a single training session reactivated the routinized actions and he was able to move onto phase A2. Also, one of the participants showed a significant progression of the disease, without any observed effect on her medication adherence. Therefore, our results suggest that when older adults with cognitive deficits are well trained to use the eMMD, its usage can be maintained over a long period of time, despite the progression of the disease.

The functionalities of the eMMD could have also contributed to the positive results obtained in the present study. The functionalities of a technology have a direct impact on the user's ability to interact with the device and ease of use minimizes the training required (Lehoux, Sicotte, & Denis, 1999; Norman, 2002). For example, a good design has signals that direct the user's attention and makes the actions to take explicit (Norman, 1989; Woolgar, 1990). The eMMD provides very clear sensory signals. A sound alarm tells the users to approach the technology to remind them it is time to take their medication. A visual signal (green flashing light) shows users which compartment to open. When the correct compartment is opened, the alarm stops. However, the eMMD design does not indicate how to open the compartment (i.e. lift the plastic film). The 4 participants' training focused specifically on this step of the task, clearly demonstrating the importance of a good design to support usability of a technology. However, since a single step seemed problematic, it would be interesting to test the feasibility of the training by non-professionals such as formal and informal caregivers.

Strengths and limitations

Our choice of multiple single-case designs proved to be well adapted to heterogeneous cognitive and functional profiles of older adults in the early stages of AD. It enabled us to link the participants' characteristics and the results obtained, which is crucial information for implementing an intervention in a clinical environment. In addition, each participant was his/her own control, which allowed observing the potential impact of a particular characteristic, such as the presence of a family caregiver. To avoid a reactive effect, we created optimal conditions by having a stable schedule and a single evaluator. Another limitation of this study is that we were not able to add a return to baseline and then a re-introduction of the eMMD to confirm the effect of the device on medication administration and adherence. This option was not ethically feasible because it would have meant taking the eMMD away in a task considered critical for a person with AD. Another strength was the use of an untrained task to control the possibility of internal validity bias, supporting the efficacy of the intervention protocol. In addition, adherence was measured consistently post-intervention (A2) with the eMMD. It would have been relevant to also measure adherence during A1 and B. However, a systematic measure of adherence was not feasible without daily use of the eMMD. Finally, our study suggests that eMMDs have the potential to support medication management in early AD, but those results will have to be confirmed by studying the intervention protocol with a larger number of participants and for a longer follow-up period.

Conclusion

Medication administration is a key concern for people with AD and their family caregivers. This study shows that older adults with mild AD are able to learn how to use an eMMD to improve their independence with medication administration and maintain good adherence. The results also suggest that if training on technology begins at the onset of AD, it is possible to develop automated actions. Directly engaging older adults with AD in implementing technology at home is one way to re-empower them. Our results shed new light on the management of older people with probable early-stage AD and reinforce the relevance of technology research and development focusing on this population.

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