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Effects of Practice Testing with Corrective Feedback on Long-Term BPSD Knowledge in Dementia Caregivers: Randomized Controlled Trial

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Abstract

Background

Caregivers help manage the behavioral and psychological symptoms that people living with dementia experience. However, caregivers' knowledge is imperfect, and available resources (e.g., online webpages) can promote low-quality learning that is ineffective.

Objectives

We evaluated an evidence-based, self-guided, digital learning intervention aimed at improving caregivers' knowledge and long-term retention of dementia care information.

Methods

A pre-registered, randomized-controlled experiment was conducted with 64 caregivers of people living with dementia. Caregivers learned about managing symptoms of dementia via practice testing with detailed, corrective feedback, which was contrasted against two active control comparisons – practice testing without feedback and rereading.

Results

Practice testing with detailed, corrective feedback intervention enhanced immediate learning and knowledge on a 2-day delayed test relative to both active control comparison conditions. Benefits of the digital intervention were observed on a 1-year-delayed test relative to the re-read active control comparison. Caregivers rated this intervention favorably.

Conclusions

Practice testing with detailed, corrective feedback is an effective intervention for targeting caregivers' dementia-related knowledge. Psychoeducational interventions should implement testing with feedback.

Trial Registration:

ClinicalTrials.gov, **NCT07377318**.

Introduction

Many people living with Alzheimer's Disease and Related Dementia (ADRD) are cared for by informal caregivers such as family members (Alzheimer's Association, 2024; Thompson et al., 2007). Providing care to those living with ADRD requires significant time and involves performing demanding tasks (Chu et al., 2000) like managing the behavioral and psychological symptoms of dementia (BPSD). Many caregivers face challenges in providing care partially owing to gaps in their knowledge about dementia (Jorge et al., 2021; Proctor et al., 2002; Robinson et al., 2014). For instance, some caregivers lack knowledge about the symptoms of dementia, how to help provide care to someone living with dementia, and how the disease progresses (Jorge et al., 2021). These gaps in caregiver knowledge can lead to suboptimal outcomes such as reduced adherence to treatment plans (Chodosh et al., 2007). Compounding this issue, caregivers have trouble accessing in-person medical education due to limited mobility, lack of care assistance, or transportation. Thus, we developed a novel digital tool that uses an evidence-based learning strategy to support caregivers' learning and understanding of information that is critical to caring for those living with dementia.

Caregivers report a lack of easily accessible information that improves their knowledge of ADRD, as well as a lack of information about the skills needed to provide care to someone living with ADRD (Sztramko et al., 2021; Alzheimer's Association, 2024). Informal caregivers express a need for ADRD knowledge, report concern about deficits in knowledge about ADRD, and that a significant portion of their caregiving time is spent seeking out information (e.g., Fortinsky & Hathaway, 1990; Penrod & Dellasega, 1998; Ringer et al., 2020). Often, caregivers obtain dementia-related information from healthcare appointments with medical professionals, discussions with other caregivers, and searching online (Kim et al., 2021; Tang et al., 2023). However, caregivers experience multiple barriers to health education about ADRD. Many caregiver classes are provided by healthcare professionals (Gaugler et al., 2015), making these opportunities unavailable to some caregivers and placing high demand on healthcare providers. Additionally, many health education classes are offered in-person, constraining access and placing a burden on caregivers to find transportation and find care for their person living with dementia if they cannot go with them. In contrast, digital education can improve accessibility because it can be administered remotely. Indeed, caregivers who have completed internet-based intervention studies have typically viewed the format positively (e.g., Gaugler et al., 2015; Hattink et al.,2015; for a review, see Ottaviani et al., 2021). Our digital health intervention is specifically designed to be self-administered, which reduces burden on healthcare providers, and to allows for flexible implementation so that caregivers can use it in the way and at the time that is most convenient for them.

Unfortunately, standard methods of digital or in-person health education about ADRD for caregivers encourage passive learning strategies such as rereading or surface level review, which contributes to poor treatment outcomes (Kessels, 2003). The most effective health education interventions present guidelines about caring for someone living with ADRD by readings texts or watching videos (Blom & Pot, 2011; Blom et al., 2015; Pot et al., 2019; Scott et al., 2022). For instance, iSupport, Mastery Over Dementia (or MoD), and iGeriCare typically present information to caregivers via texts or videos, and sometimes caregivers answer questions (Pot et al., 2019; Pot, 2010; Blom et al., 2015; for reviews, see Cheng & Zhang, 2020; Pleasant et al., 2020; Sztramko et al., 2021). Getting information in the form of

texts and videos can result in caregivers using low-impact learning strategies such as rereading or rewatching when studying dementia-related content (Brame, 2014). Thus, even though these interventions provide an accessible and flexible method for disseminating important knowledge to caregivers, they are restricted by caregivers' ability to effectively self-regulate their learning. Caregivers can also prematurely disengage from studying and spend limited time reviewing challenging material, limiting knowledge retention. These issues can be reduced by grounding digital training for caregivers in principles from the science of learning.

The science of learning emphasizes the importance of using evidence-based cognitive strategies during study for long-term maintenance of knowledge (Ariel, Babineau, & Tauber, 2023; Carpenter, Pan & Butler, 2022; Dunlosky et al., 2013). One intervention that may enhance caregivers' ADRD knowledge is practice testing. During practice testing, people attempt to retrieve previously learned information from memory (Roediger & Karpicke, 2006). For example, following a doctor's appointment where a treatment plan for a psychological symptom (e.g., delusions) was discussed, caregivers might attempt to recall information about what triggers the symptom and how to manage it at home. Prior work shows that practice testing leads to superior long-term memory relative to simply rereading material (e.g., reading a website; for a review, see Agarwal et al., 2021). Further, receiving detailed, corrective feedback after practice testing can enhance the effect of practice testing on learning (Yang et al., 2021) by reinforcing correct responses and correcting errors for incorrect responses (Butler & Roediger, 2008; Roediger & Butler, 2011). For instance, after attempting to recall the treatment plan for delusions, caregivers may check their responses against information they have received (e.g., via a website or doctor). Checking their responses for accuracy would serve as corrective feedback (i.e., correct or incorrect) and may provide supportive details that explain why they should manage the symptoms a certain way. This process of engaging in retrieval and receiving detailed, corrective feedback would then allow caregivers to update their knowledge accordingly and enhance their memory for the relevant information. As important, the science of learning approach to digital education for caregivers will allow us to determine the specific learning mechanisms that enhance caregivers' knowledge.

Prior work on practice testing has exclusively focused on non-caregivers, so the degree to which practice testing supports caregivers' retention of dementia-related knowledge is unknown. Moreover, although some interventions such as iSupport and MoD can involve asking caregivers questions and providing feedback, they do not do so in a systematic way, sometimes rely on another party (e.g., Pot et al., 2015), and do not examine caregivers' subsequent long-term retention of material. Thus, there is a need to systematically explore the degree to which caregivers may benefit from a self-guided digital tool that uses practice testing to retain this benefit over time, as well as to evaluate the circumstances under which practice testing most benefits their learning to support optimal care (e.g., with or without detailed, corrective feedback).

We examined whether structured practice testing with or without detailed, corrective feedback improves caregivers' learning of the behavioral and psychological symptoms of dementia relative to an active control comparison with an online learning tool that does not require supervision by healthcare providers

or another party. Caregivers learned 12 categories of BPSD by reading about each in a web-page format (as would be freely available to caregivers via websites such as the Alzheimer's Association) and then engaging in rereading (i.e., active control), practice testing, or practice testing with detailed corrective feedback. Caregivers' knowledge was tested immediately after the intervention, two days later, and one year later. We hypothesized that testing with feedback would produce superior short-term and long-term retention relative to practice testing without feedback and relative to rereading, and that practice testing without feedback would produce superior retention relative to rereading.

Method

This randomized controlled trial was registered on ClinicalTrials.gov (Project CARE-D: Online Caregiver Education for Dementia; Identifier: NCT07377318; first submitted January 14, 2026). The hypotheses, study design, and analysis plan were also preregistered on the Open Science Framework (OSF): https://osf.io/xt38q/overview. Study materials, de-identified data, and analysis code are available through the OSF repository. This study is reported in accordance with the CONSORT 2025 guidelines (Hopewell et al., 2025). Participants were blind to the study hypotheses.

Design and participants

Learning strategy (reread, testing, testing with feedback) was manipulated within-participant. Our dependent variables were immediate test performance, two-day delayed test performance, and one-year delayed test performance.

Assignment of the 12 behavioral and psychological symptom categories to the three learning conditions (rereading, practice testing, and practice testing with corrective feedback) was randomized separately for each participant using a custom JavaScript algorithm implemented within the experimental software. The algorithm used JavaScript's built-in pseudorandom number generator to generate a constrained randomization procedure such that four symptom categories were assigned to each learning condition. Randomization and condition assignment occurred automatically within the software without investigator involvement, and participants were unaware of the assignment sequence prior to presentation of the learning materials.

All potential participants were first screened for eligibility by responding to 5 questions. Two questions were about use of English (Is English your first or native language? How long (in years) have you spoken English?) and one question was about location (Are you physically located in the United States?) The remaining 2 questions were about ADRD caregiver status. Participants responded to, "Do you assist, provide care, and/or make health care decisions for someone?" by selecting yes or no. Subsequently, participants responded to, "What is the chronic condition of the person you assist, provide care, and/or make health decisions?" from a list of 11 options [Stroke, Lou Gehrig's disease (ALS), Multiple Sclerosis (MS), Chronic Renal Failure, Dementia (Alzheimer's disease, Frontotemporal dementia, Lewy Body dementia, Parkinson's disease, etc.), Post-Traumatic Stress Disorder (PTSD), Chronic Obstructive

Pulmonary Disease (COPD), Diabetes, Coronary Heart Disease, Cancer, or I do not care for someone with a chronic condition]. Only participants who self-identified as a first or native English speaker, located in the United States, and a caregiver specifically for a person with dementia were enrolled in the experiment. Participants were also required to have a 95–100 approval rating on the Prolific platform, an index of prior participation quality.

We assessed 1,688 people for eligibility to participate; of those, 1,564 did not meet the requirements for the study because they were not caregivers for a person living with dementia (PLwD). Of the remaining 124 who were eligible, 55 decided not to participate, data did not save for 3, and 1 took too long to complete the study and timed out. One participant reported not currently providing care to someone and was thus excluded. Participants (hereafter, referred to as caregivers) included a total of 64 caregivers for PLwD, recruited from Prolific (www.prolific.com; 2024), which is an online data collection platform (see Table 1 for demographic information). Sample size was selected anticipating a 12% attrition rate (Sztramko, et al., 2021) and from simulations to ensure a high-powered experiment. Recruitment occurred from May to August 2025. Caregiver characteristics are presented in Table 2. A total of 64 caregivers participated in session one and 62 participated in session two. Of the 57 eligible caregivers who were still on Prolific one year later (7 were no longer on Prolific), 37 completed session three. A CONSORT flow diagram illustrating participant recruitment, retention, and analysis is presented in Fig. 1.

Table 1

Demographic Data (N = 64)

Characteristic	n	M (SD) or %
Age (years)	64	41.03 (11.83)
Range: 19–66		
Gender		
Women	36	56.3%
Men	24	37.5%
Non-binary	1	1.6%
Not specified	3	4.7%
Race/Ethnicity		
White	45	70.3%
Black	3	4.7%
Asian	4	6.3%
American Indian	3	4.7%
Hispanic/Latino	3	4.7%
Two or more races	3	4.7%
Not specified	3	4.7%
Education		
High school diploma	22	34.4%
Trade school	10	15.6%
Bachelor's degree	21	32.8%
Master's degree	6	9.4%
Doctoral degree	2	3.1%
Not specified	3	4.7%

Table 2
Caregiver Characteristics (N = 64)

Characteristic	n	%
Relationship to Care Recipient		
Parent	29	45.3%
Other family member	24	37.5%
Friend/non-relative	4	6.3%
Sibling	1	1.6%
Child	1	1.6%
Spouse	1	1.6%
Other	1	1.6%
Not specified	3	4.7%
Years as Caregiver		
Less than 1 year	7	10.9%
1–2 years	22	34.4%
3–4 years	27	42.2%
5–6 years	4	6.3%
7 + years	4	6.3%
Hours of Care per Week		
Less than 5 hours	8	12.5%
5–14 hours	26	40.6%
15–20 hours	18	28.1%
21–34 hours	6	9.4%
35 + hours	6	9.4%
Type of Dementia		
Alzheimer's disease	24	37.5%
Multiple types	21	32.8%
Frontotemporal dementia	5	7.8%
Vascular dementia	4	6.3%

Characteristic	n	%
Relationship to Care Recipient		
Not sure	3	4.7%
Parkinson's disease	2	3.1%
Lewy body dementia	1	1.6%
Traumatic brain injury	1	1.6%
Not specified	3	4.7%

Figure 1

CONSORT Flow Diagram

Materials

Learning materials and scales for this experiment are available via OSF (https://osf.io/2upx9/?view_only=324ec5eb15684d5aa4386dd04b427268). Learning materials included information about 12 behavioral and psychological symptoms of dementia (BPSD). Symptom categories included aberrant motor ability, agitation and aggression, anxiety, apathy, appetite and eating disorders, delusions, depression and dysphoria, disinhibition, elation and euphoria, hallucinations, irritability and lability, and nighttime behavior disturbances. All materials were created using the National Institute on Aging, the Alzheimer's Society, and the Alzheimer's Association websites, which are freely and publicly available to caregivers. Information for the study and reread trials was presented in a text format to simulate reading information from a webpage when getting ADRD information online (Fig. 2). For the testing conditions, information was presented as multiple-choice questions such as, "Your loved one sometimes believes things strongly that are not true, for example thinking that someone has stolen their keys when they can't find them. What can you do about these experiences?" with four multiple-choice options, one of which was correct. For the testing with feedback condition, caregivers received detailed and corrective feedback for correct and incorrect answers. For the prior example, if the question was answered correctly by selecting, "Take their concern seriously", the feedback read, "Yes, that is correct. Sometimes people with dementia strongly believe things that are not true. These thoughts are known as delusions. Even though the delusions are not true, they feel very real to the person. Stay calm, acknowledge how they feel, and reassure the person that you are taking their concern seriously." If the question was answered incorrectly by selecting, "Because you know this is not true, you can dismiss the concern", feedback read, "No, that is not correct. It is important not to dismiss what the person is saying or feeling just because they have dementia. Instead, stay calm, acknowledge how they feel, and reassure the person that you are taking their concern seriously." The content was counterbalanced between learning conditions so that caregivers learned the same information with the 12 BPSD randomly assigned to

learning condition. For example, some caregivers learned about the symptoms of delusions associated with dementia via rereading, others learned this same information via testing without feedback, and others learned this same information via testing with feedback. Learning materials were divided such that each caregiver learned four symptom categories with rereading, four symptom categories with testing, and four symptom categories with testing with feedback. Each symptom category had four corresponding questions for a total of 48 questions that appeared on the immediate and delayed tests. Thirty-two questions were used during practice testing – 16 for testing and 16 for testing with feedback. The remaining 16 questions (4 per symptom category) corresponded to the rereading condition.

Figure 2

Overview of the Study and Learning Phase in Session 1

To measure caregivers' subjective assessments about practice testing and receiving feedback when using the self-guided, online learning program, we used an 18-item scale that we adapted for the caregiver context (Venkatesh & Bala, 2008). This scale was used because it assesses factors that influence individuals' acceptance and adoption of technological tools (in this case, our online learning program). Each item on the measure was rated on a Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). The scale consisted of multiple subscales including perceived usefulness (e.g., Using the program with this strategy increases the number of symptoms I can manage.), perceived ease of use (e.g., I find the program when using this strategy to be easy to use.), perceived enjoyment (e.g., I find using the program with this strategy to be enjoyable.), behavioral intentions (e.g., Given that I had access to the program that uses this strategy, I predict that I would use it.), job relevance (e.g., In my role assisting a PLwD, using this program with this strategy is relevant.), and output quality (e.g., The quality of the knowledge I get from the program when using this strategy is high.). We did not include the subscales for computer self-efficacy, perceptions of external control, computer playfulness, computer anxiety, objective usability, subjective norm, voluntariness, image, or result demonstrability (Venketesh & Bala, 2008). We also removed scale questions that were not relevant for our experiment. Specifically, we removed one item from the perceived ease of use scale (I find it easy to get the program to do what I want it to do.), one item from the behavioral intentions scale (Assuming I had access to the program, I intend to use it.), and we changed "system" in each item to "program with this strategy." Participants were given the following instructions:

You learned about how to manage different behavioral and psychological symptoms of dementia using different strategies. You restudied symptoms by rereading the texts or by practice testing with multiple choice questions. Some of the multiple-choice questions had feedback and others did not. Please rate how much you agree with each statement below as it pertains to your experience using the program from today to learn by answering questions and receiving feedback. You should only base your responses on what you think about using the program to restudy with this specific strategy (i.e., learning by answering questions and receiving feedback).

Subscale scoring was completed by summing the scores and dividing by the total number of items for that subscale. No items on the scale required reverse coding. Overall usability was then calculated by summing the scores on each of the subscales and dividing by the total number of items on the measure (18).

Procedure

Session one

After passing the screening and providing consent, caregivers were informed that they would learn about managing BPSD by studying the material in different ways. Next, caregivers were informed that they would read about 12 BPSD and that they should try their best to read each text as if they were researching the material on their own. Caregivers then studied each of the 12 BPSD, one-by-one, in a webpage format, at their own pace. Next, caregivers studied all 12 BPSD in the learning phase, at their own pace, using rereading, testing, or testing with feedback (Fig. 2). The order of learning strategy was randomized per caregiver, and caregivers went through the learning phase a total of three times. Strategy was consistent between trials such that if hallucination concepts were studied using testing in the first trial, they were also studied using testing in the subsequent two trials. The learning phase was blocked such that caregivers studied or answered all questions about one BPSD (e.g., hallucinations) before moving onto the next BPSD (e.g., apathy). Following the learning phase, caregivers completed attention check 1 (i.e., multiple-choice question with five options, “What is your favorite meal of the day? We would like you to ignore this question and just select the last option labeled Brinner”) and Raven’s progressive matrices as a filler task (Raven et al., 1998). Caregivers had up to 10 minutes to complete the Raven’s progressive matrices task and self-paced within those 10 minutes. Next, caregivers completed attention check 2 (i.e., When you were in high school, how hard did you work on your studies? In answering this question, please ignore what the question is asking and just select the first option indicating that you do not really remember.) before moving onto the self-paced immediate test.

On the immediate test, caregivers answered 48 multiple-choice questions about each of the 12 symptom categories (4 questions each). Questions were presented in a blocked fashion such that caregivers answered all 4 questions about one of the symptom categories before moving onto the next symptom category. Question order was randomized within each symptom category. Caregivers then completed attention check 3 (i.e., What is your favorite color? In answering this question, please ignore what the question is asking and just select the option Green.) and the 18-item usability measure (adapted from Venkatesh & Bala, 2008). Finally, caregivers provided demographic information, were thanked, and reminded of their session 2 appointment. The median time to complete session one was 2 hours and 30 minutes.

Session two

Session two was released two days after session one, and most caregivers completed it at that time (21 caregivers completed it 3–10 days later). Caregivers were informed that they would be tested again on the information they learned in the previous session. Next, caregivers completed the two-day-delayed test by answering the same 48 multiple-choice questions as on the immediate test. The two-day-delayed test was self-paced, and caregivers answered questions in a blocked fashion such that they answered all 4 questions about one of the symptom categories before moving onto the next. Question order was randomized within each symptom category. Finally, caregivers completed some additional measures consistent with a larger protocol, and were thanked and debriefed. The median time to complete session two was 1 hour.

Session three

A total of 37 caregivers from the original sample participated in session three. On average, session three was completed 325.35 days (*SD* = 37.03) after session one (range: 238 to 383 days). Caregivers were informed that they would be tested on the information they learned in the first session that occurred one year prior. Next, caregivers completed the one-year-delayed test by answering the same 48 multiple-choice questions as on the immediate and two-day-delayed test. The one-year-delayed test was self-paced, and caregivers answered questions in a blocked fashion such that they answered all 4 questions about one of the symptom categories before moving onto the next. Question order was randomized within each symptom category.

Given the minimal-risk nature of the online educational intervention, no formal adverse event monitoring was conducted. At the end of the study, participants were invited to provide open-ended feedback, including comments, concerns, or any unintended effects related to their participation. Participants could discontinue participation at any time without penalty.

Results

Data and code for all analyses are available here: https://osf.io/2upx9/?view_only=324ec5eb15684d5aa4386dd04b427268. Analyses were conducted using all available data for each outcome (available-case analysis). Participants who did not complete a given follow-up assessment were excluded only from analyses involving that assessment, and missing outcome data were not imputed. No adverse events or unintended effects related to the intervention were reported by participants during the study. We first present performance on the practice tests across learning blocks for the test condition and the test with feedback condition. We then present immediate (10-minute delay), two-day-delayed test performance, and one-year-delayed test performance. Finally, we present descriptive statistics for the usability measure.

Performance during learning

We conducted a linear mixed effects model using learning block (1, 2, 3) and learning condition (test, test with feedback) as interacting fixed effects and caregiver as a random effect to examine proportion

correct on practice tests during the learning phase. The rereading condition could not be included in this analysis because no questions were answered during learning. There was a significant main effect of condition on performance during learning, $F(1,315) = 115.29$, $p < .001$, $\eta_p^2 = .27$. There was also a significant main effect of block on performance during learning, $F(2,315) = 32.12$, $p < .001$, $\eta_p^2 = .17$. These effects were qualified by a significant interaction between condition and block on performance during learning, $F(2,315) = 24.22$, $p < .001$, $\eta_p^2 = .13$. Follow-up comparisons using the Bonferroni correction revealed that performance did not improve across blocks in the test condition, $ts < 1$, $ps \geq .999$. However, in the test with feedback condition, performance during learning was higher on blocks two ($M = .84$, $SE = .02$), $t(189) = 4.90$, $p < .001$, $d = .87$, and three ($M = .88$, $SE = .02$), $t(189) = 6.65$, $p < .001$, $d = 1.15$, than on block one ($M = .70$, $SE = .02$); performance did not differ between blocks two and three, $t(189) = 1.68$, $p = .330$ (Figure 3).

Figure 3

Mean Proportion Correct During Learning in Each Block

Note. Error bars reflect ± 1 standard error of the mean.

Immediate test performance

We conducted a linear mixed effects model using learning condition (reread, test, test with feedback) as a fixed effect and caregiver as a random effect to examine proportion correct on the immediate test. There was a significant effect of condition on immediate test performance, $F(2,128) = 94.64$, $p < .001$, $\eta_p^2 = .60$. Follow up comparisons using the Bonferroni correction revealed that performance was higher in the test with feedback condition ($M = .92$, $SE = .02$) than in the reread condition ($M = .73$, SE = .02), $p < .001$, $d = 1.91$, and the test condition that did not receive feedback ($M = .70$, $SE = .02$), $p < .001$, $d = 2.26$ (Figure 4). Performance did not differ between the reread condition and the test condition, $p = .500$.

Figure 4

Mean Performance on the Immediate and Delayed Tests in Each Condition

Note. Error bars reflect ± 1 standard error of the mean.

Two-day delayed test performance

We conducted a linear mixed effects model using learning condition (reread, test, test with feedback) as a fixed effect and caregiver as a random effect to examine proportion correct on the two-day-delayed test.[1] There was a significant effect of condition on delayed test performance, $F(2,120) = 50.59$, $p < .001$, $\eta_p^2 = .46$. Follow up comparisons using the Bonferroni correction revealed that performance was higher in the test with feedback condition ($M = .88$, $SE = .02$) than in the reread condition ($M = .74$, SE = .02), $p <$

.001, d = 1.37, and the test condition (M = .71, SE = .02), p < .001, d = 1.73 (Figure 4). Performance did not differ between the reread condition and the test condition, p = .230.

One-year delayed test performance

We conducted a linear mixed effects model using learning condition (reread, test, test with feedback) as a fixed effect and caregiver as a random effect to examine proportion correct on the one-year-delayed test. There was a significant effect of condition on test performance, $F(2,72) = 5.15$, p = .008, η_p^2 = .13. Follow up comparisons using the Bonferroni correction revealed that performance was significantly higher in the test with feedback condition (M = .73, SE = .03) than in the reread condition (M = .65, SE = .03), p < .032, d = 0.70 (Figure 4). There was also trend such that performance was marginally higher in the test with feedback condition compared to the test condition (M = .66, SE = .03), p = .066, d = .57. There was no difference in performance between the restudy condition and test condition, p > .999.

Usability measure

Usability scores and scores on each of the subscales ranged from 1 (strongly disagree) to 7 (strongly agree) with scores of 5 and above indicating agreement, 3 and below indicating disagreement, and 4 indicating neutral (neither disagree nor agree). All means exceeded 5 on the agreement scale revealing that caregivers generally approved of the practice testing with feedback learning intervention (see Table 3). We then conducted exploratory one-sample t-tests to examine if average overall usability and the average score on each subscale was significantly greater than 5, indicating agreement. Scores on overall usability were significantly greater than 5, $t(63) = 9.52$, p < .001, d = 1.19. Scores on perceived usefulness, $t(63) = 11.13$, p < .001, d = 1.39, perceived ease of use, $t(63) = 5.99$, p < .001, d = .75, perceived enjoyment, $t(63) = 2.82$, p = .003, d = .35, behavioral intentions, $t(63) = 5.70$, p < .001, d = .71, job relevance, $t(63) = 11.78$, p < .001, d = 1.47, and output quality, $t(63) = 10.62$, p < .001, d = 1.33, also significantly exceeded 5.

Table 3

Mean Ratings on the Usability Measure

	M	*SD*	Range
Overall Usability	5.92	.78	3.94 – 7.00
Perceived Usefulness	6.15	.83	4.00 – 7.00
Perceived Ease of Use	5.62	.83	4.00 – 7.00
Perceived Enjoyment	5.45	1.28	2.00 – 7.00
Behavioral Intentions	5.79	1.11	3.00 – 7.00
Job Relevance	6.22	.83	4.33 – 7.00
Output Quality	6.17	.89	4.00 – 7.00

General Discussion

The reported experiment is the first to systematically evaluate the impact of a digital educational tool that incorporates structured practice testing on caregivers' learning about the behavioral and psychological symptoms of dementia over an extended period (immediately, two days later, and one year later). Our digital intervention adhered to principles from the science of learning to structure practice testing with detailed, corrective feedback enhanced caregivers' learning in the short-term (i.e., on the immediate test), in the long-term (i.e., on the two-day-delayed test), and impressively into the future (one-year delayed test). These outcomes are consistent with the broader literature on practice testing (e.g., Roediger & Karpicke, 2006; for a review, see Agarwal et al., 2021). Moreover, ADRD knowledge retained by caregivers was substantially enhanced with the retrieval practice intervention (i.e., d = 2.27 for immediate test performance and d = 1.40 for delayed test performance), revealing an approximate 20% immediate gain in knowledge, a 15% gain two days later, and an 8% gain one year later.

The sustained knowledge retention observed in our study has clinically meaningful implications for dementia care. The 8% retention advantage observed one year later represents a meaningful improvement in caregiver's ability to respond appropriately to challenging behaviors. Accurate knowledge about BPSD supports caregivers' self-regulation by providing them with evidence-based tools and strategies to effectively manage symptoms as they arise. Caregivers who retain this knowledge are better positioned to identify environmental triggers, implement person-centered communication strategies (e.g., validating emotional experiences rather than correcting factual inaccuracies, focusing on feelings rather than behaviors, etc.), and differentiate behaviors that require medical attention versus those manageable with non-pharmacological approaches. This enhanced self-regulatory capacity can potentially improve the quality of life for both caregivers and PLwD

Practice testing with feedback enhanced learning relative to a rereading condition, which suggests that caregivers may use ineffective learning strategies when learning about dementia by simply rereading available information (cf. Brame, 2014). In fact, our data indicates that rereading was not any more effective than reading each text only once. Consider performance for the testing conditions during block

one (Figure 3). Final performance in the reading condition was nearly identical to performance in block 1 for each of the testing conditions suggesting that rereading each text two additional times produced no additional gains to learning. These findings align with prior research that indicates rereading alone to be ineffective strategy for learning educational texts (Callender & McDaniel, 2009). Thus, psychoeducational interventions should be designed to discourage passive, repetitive reading and instead, incorporate active learning strategies; practice testing with feedback is one viable alternative that can promote durable learning of essential caregiving information.

Consistent with prior research, feedback during learning was a critical factor for supporting caregivers' short-term learning and long-term retention (Yang et al., 2021; Butler & Roediger, 2008; Roediger & Butler, 2011). It is likely that feedback after practice testing helped caregivers correct health misconceptions, update their knowledge, and minimize errors relative to practice testing that was not supported with corrective feedback (cf. Sitzman et a., 2022; Tse et al., 2010). Correcting misconceptions is especially important for BPSD management because misconceptions like interpreting behaviors as intentional or believing confrontation is an appropriate response to a challenging behavior can lead to approaches that escalate distress for both the PLwD and the caregiver. Corrective feedback supports caregivers' self-regulation by helping them develop accurate mental models for why behaviors occur and equipping them with appropriate response strategies. This self-regulatory knowledge provides the foundation for caregivers to monitor their own reactions, select appropriate strategies, and adjust responses based on the PLwD's needs. Performance during learning also supports this point because performance increased significantly from the first block to the second and third when caregivers used practice testing with feedback. By contrast, practice testing without feedback did not benefit learning on the immediate or two-day-delayed test compared to rereading. These outcomes provide important insights relevant for the development of psychoeducational interventions aimed at enhancing caregiver knowledge.

We identified practice testing with corrective feedback to be a powerful digital health intervention for enhancing caregivers' knowledge of behavioral and psychological symptoms of dementia. This may explain, at least in part, the diverse outcomes observed in research on psychoeducational research with caregivers (e.g., Butler et al., 2020; Thompson et al., 2002; for reviews, see Cheng & Zhang, 2020; Pleasant et al., 2020; Sztramko et al., 2021). In other available online training programs for caregivers, practice testing is not systematically employed; some interventions incorporate practice testing with feedback whereas others do not (or do so to a lesser degree), and some require another party such as a coach (i.e., not entirely self-guided). Our outcomes provide evidence that practice testing with feedback is a crucial factor in determining the effectiveness of psychoeducational programs and can be one way that caregivers can effectively learn about ADRD without supervision of a healthcare provider or another party. Moreover, our digital tool can be used by caregivers remotely, at a time that is most convenient for them. We encourage researchers to ensure that main points in their caregiver interventions are reinforced with structured practice testing that includes detailed, corrective feedback, as doing so can enhance caregivers' knowledge of ADRD.

Caregivers positively rated the digital health intervention. Many caregivers provided positive comments about their experience such as, *"I actually learned a lot. This information will be helpful. Thank you."*, *"I enjoyed this."* and *"This was the best study I have ever done. I feel like I actually learned some things and the teaching method was great. Seriously, it was impressive."* This is important because people are unlikely to engage with educational tools that they find to be aversive or too demanding, even if they benefit from them (e.g., Rathnayake et al., 2018). No caregivers left negative comments about the intervention or expressed concerns that the testing with feedback intervention was confusing, cumbersome, boring, or overly demanding. One reason why caregivers may have endorsed practice testing with feedback is because people report preferring to receive feedback after testing their knowledge (Ariel et al., 2024). Indeed, multiple caregivers left comments indicating this preference, e.g., *"Personally, the multiple-choice questions with feedback is what I learned best from. Questions without feedback is unhelpful to me because I don't know if what I selected is correct."* and *"The questions without feedback were not helpful to my learning. I was unsure if I had the right answer."*

Limitations and future directions

Caregivers had three blocks of learning prior to taking the immediate and delayed tests. Although learning significantly increased from block one to two, suggesting that caregivers should practice test their knowledge and receive feedback multiple times when learning ADRD material, an important future direction is to identify optimal dosage that achieves time efficiency and effectiveness. We found that three blocks of learning produce few gains relative to two blocks of learning, suggesting that two blocks might be sufficient to improve learning up to two days later. As well, research with non-caregivers has found successfully recalling information three times to be ideal for long-term learning (Ariel et al., 2024; Rawson & Dunlosky, 2011). However, caregivers did not reach maximum performance by the end of block three, so there is room for improvement. This issue was noted by one caregiver who left the comment, *"I think restudying three times isn't enough, maybe 4 or 5."* It will also be important to identify optimal dosages of practice testing based on caregiver characteristics and other dementia care information.

Although the caregivers rated the current digital health intervention positively, one limitation of our measure is that caregivers only rated the usability of the testing with feedback condition, so their experiences cannot be compared against the other learning conditions. An important direction for the future will be to develop other metrics and adopt a mixed-method approach to evaluate the acceptability of practice testing compared to other learning strategies while including caregivers' engagement and desire to use the intervention in the future. Additionally, future work could assess the extent to which caregivers use this type of intervention compared to other types of psychoeducational interventions.

We did not measure the extent to which practice testing with feedback impacts caregivers' daily health choices when managing the behavioral and psychological symptoms of dementia. We also did not assess the effects of enhanced knowledge following the digital intervention on measures of caregivers' wellbeing. These are critical avenues for future research. Specifically, future research should

directly evaluate the effects of enhanced knowledge from testing with detailed, corrective feedback on the health and wellbeing of caregivers and PLwD, as well as on the quality of care for PLwD. Previous research indicates that psychoeducation interventions that target knowledge for managing BPSD can reduce caregiver stress and burden (Cheng & Zhang, 2020; Pleasant et al., 2020; Sztramko et al., 2021); testing with feedback may be one way of doing so. In this vein, test-enhanced learning interventions have broad educational efficacy, perhaps with the potential to improve a variety of health outcomes. This learning intervention may also improve adherence to treatment plans by targeting relevant care knowledge (e.g. medication management, diet and nutrition, healthcare navigation, treatment plans, social engagement and cognitive stimulation strategies).

Conclusion

Our digital health intervention that applied practice testing with detailed, corrective feedback is effective for improving caregivers' short-term and long-term knowledge of how to manage the behavioral and psychological symptoms of dementia. The digital delivery format offers scalability and accessibility advantages that could help address the growing need for caregiver education as dementia prevalence increases globally. Caregivers rated this online learning program positively, though more research is needed to establish how gains in knowledge impact the quality of care and the wellbeing of caregivers and PLwD. We recommend that psychoeducational interventions for caregivers of PLwD include practice testing with detailed, corrective feedback to foster robust learning of dementia-related information.

Declarations

Ethics Approval and Consent to Participate

All participants provided electronic consent prior to inclusion in the study. The study was approved by the Institutional Review Board of Texas Christian University (protocol code 2024 – 153, approved 26 April 2024).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contribution

MDS oversaw data collection, conducted analyses, wrote first paper drafts, assisted with caregiver recruitment and screening, and edited the manuscript. RA conducted all programming and provided feedback on the manuscript. MH assisted with data collection, assisted with caregiver recruitment and screening, wrote a McNair Scholar paper, and gave undergraduate student presentations. LH reviewed all dementia content for medical accuracy and clarity and assisted with caregiver recruitment. SKT obtained and managed funding, mentored student co-authors, oversaw caregiver recruitment and screening, and provided feedback on the manuscript. All authors approved the final manuscript.

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Data Availability

All data and analytic code are available at https://osf.io/2upx9/?view_only=324ec5eb15684d5aa4386dd04b427268.

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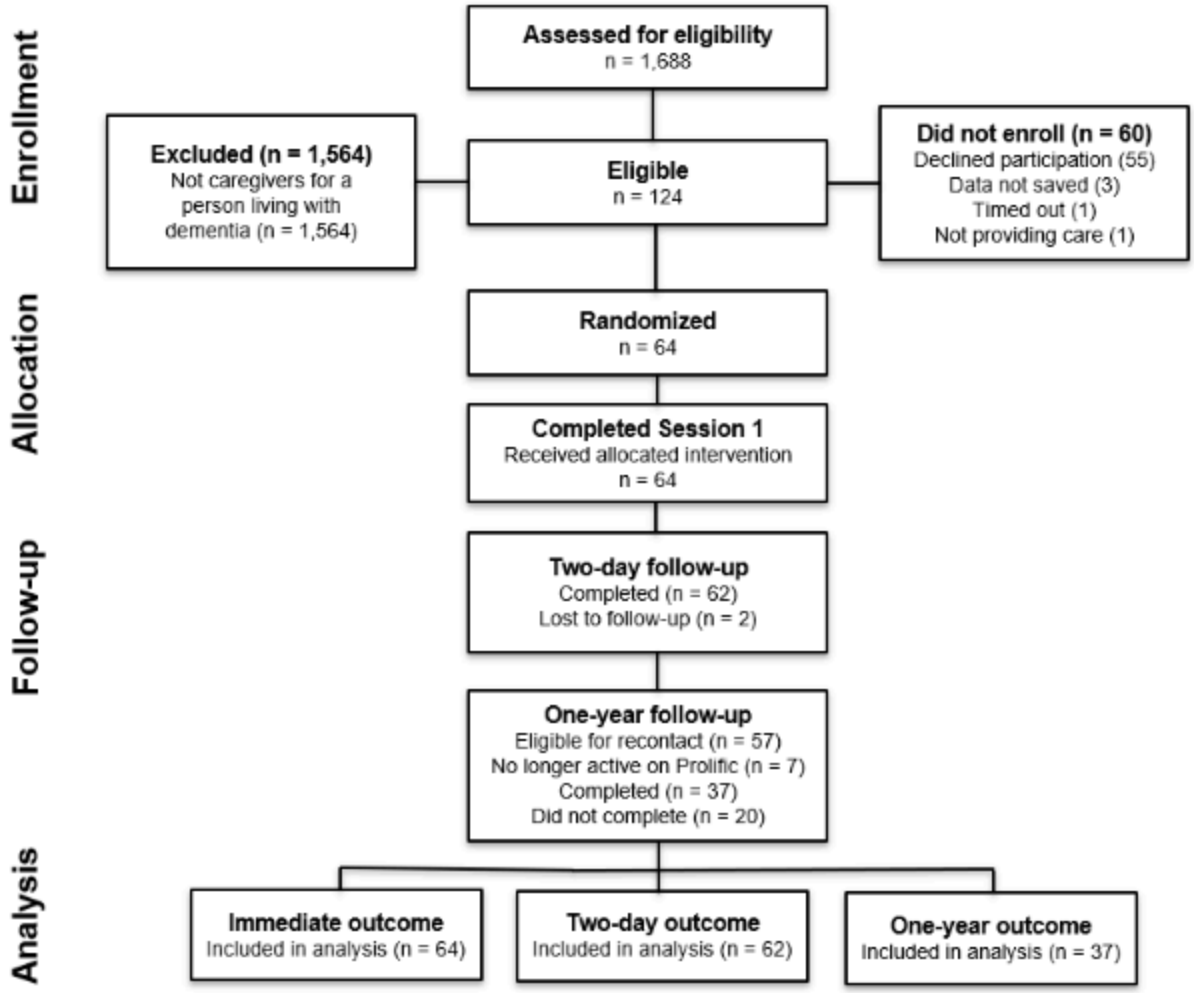
Footnotes

1. Three caregivers did not complete the two-day-delayed test or usability measure. Thus, data for the two-day-delayed test and usability were collected from 62 caregivers.

Figures



Note. Seven participants could not be recontacted for the one-year follow-up because they were no longer active on the Prolific platform.

Figure 1

CONSORT Flow Diagram

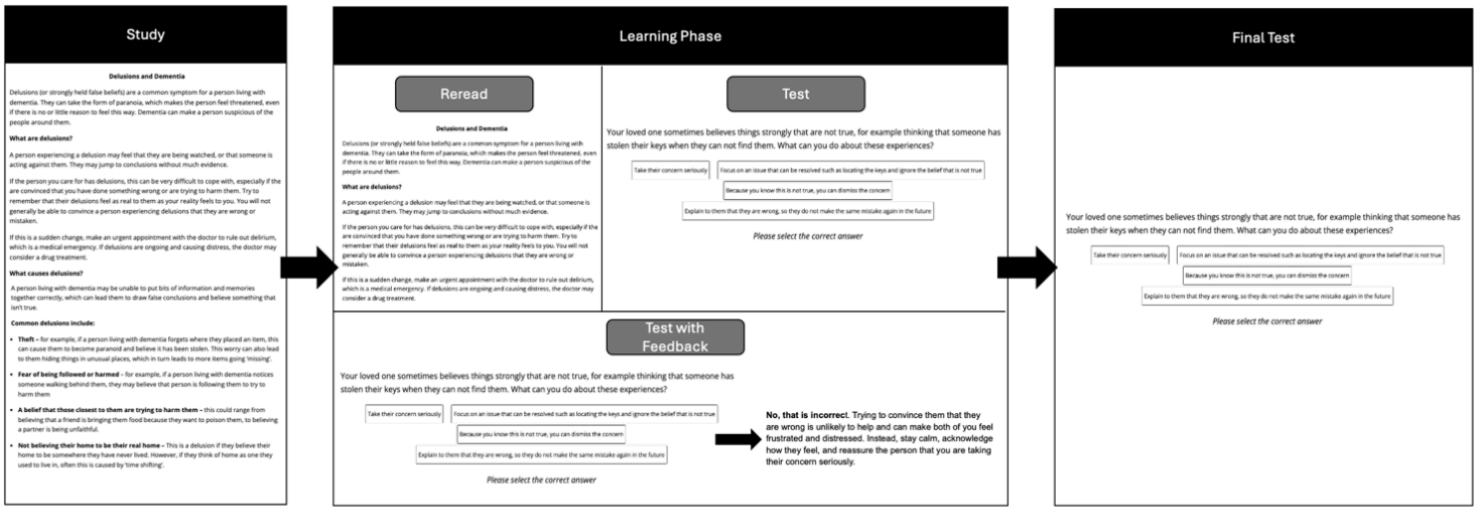


Figure 2

Overview of the Study and Learning Phase in Session 1

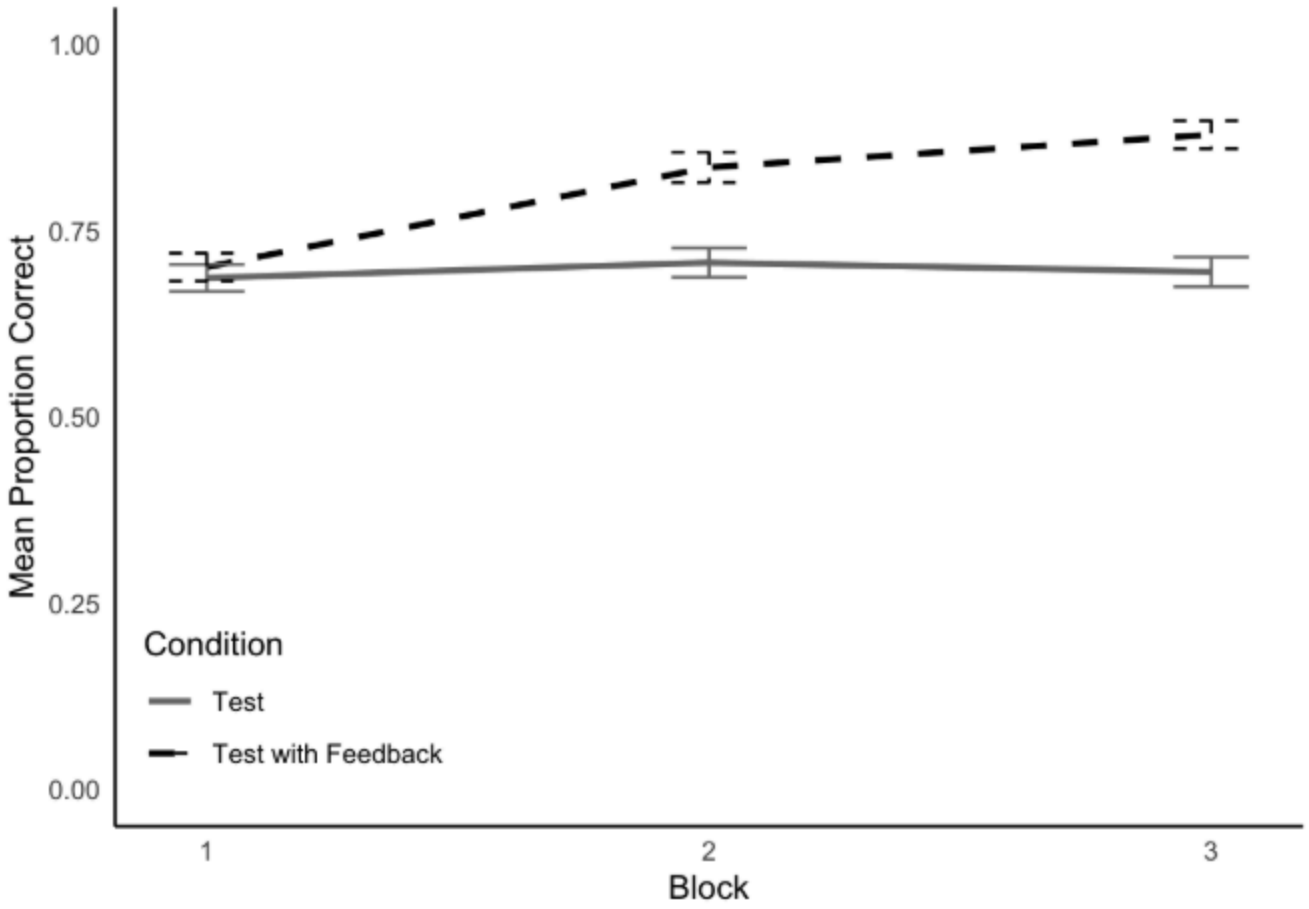


Figure 3

Mean Proportion Correct During Learning in Each Block

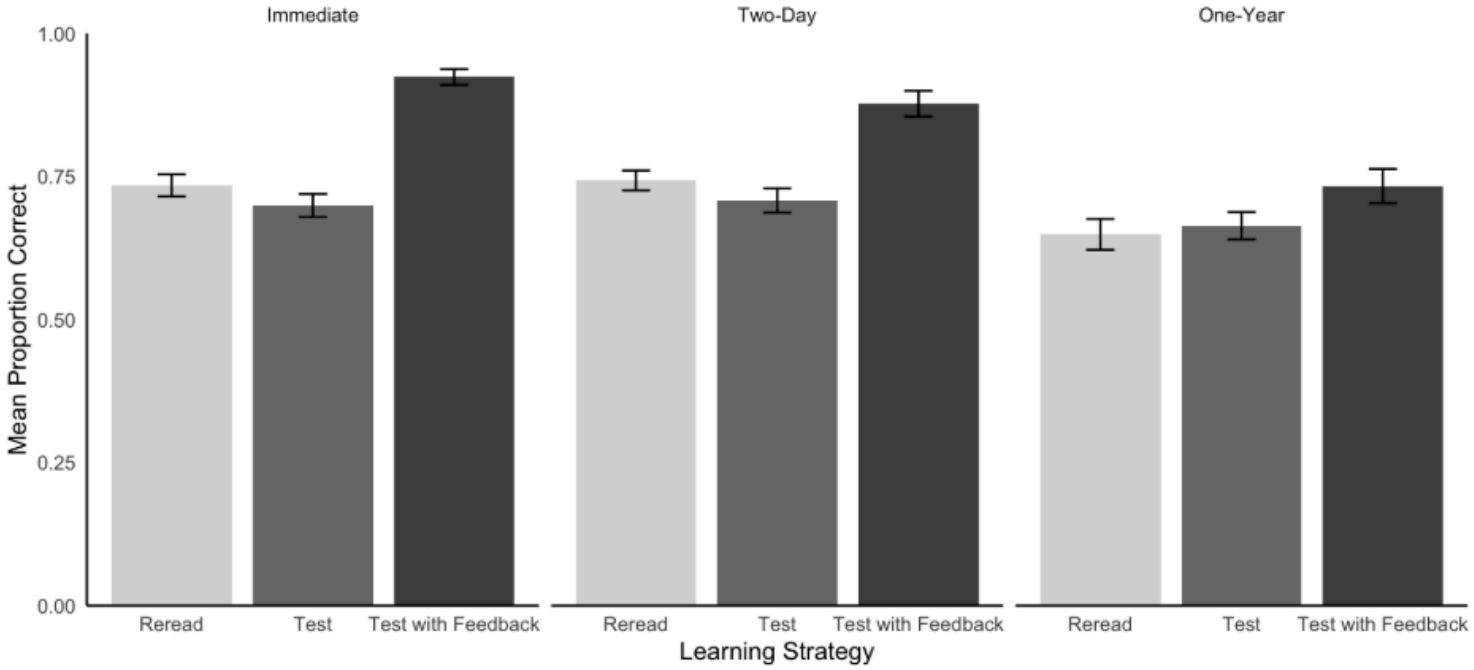


Figure 4

Mean Performance on the Immediate and Delayed Tests in Each Condition

Supplementary Files

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- CONSORT2025editablechecklist1.docx