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Assistive technology: Visual mapping combined with mobile software can enhance quality of life and ability to carry out activities of daily living in individuals with impaired memory

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Abstract.
BACKGROUND: There is growing evidence that assistive digital technology can enhance quality of life (QOL) for individuals with various forms of cognitive impairment, including dementia.
OBJECTIVE: Assess whether the use of a visual mapping software program to manage activities of daily living would have a positive impact on QOL scores and on cognitive scores in a group of dementia residents in an adult living community.
METHODS: We compared quality-of-life scores and cognitive function scores before and after using the assistive technology for three months.
RESULTS: 1. QOL scores significantly improved in the memory impaired residents, as measured by a self-report questionnaire. 2. Caregivers also reported significantly improved QOL scores in the residents, and the caregivers reported more improved scores than the residents did. 3. Net Promoter Scores for residents and caregivers showed that using visual maps was highly satisfying; they would continue using this technology. 4. Memory-impaired residents showed significantly improved scores in cognitive areas reflecting improved ability to focus and pay attention.
CONCLUSIONS: In addition to the positive findings in QOL and cognition, assistive technologies applied to dementia care are easy to access, easy to use, have little risk of side effects, and are relatively low in cost.

Keywords: Memory, mind mapping, hippocampus, neostriatum, declarative memory, procedural memory, habit memory

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1. Introduction

Alzheimer's disease and Alzheimer's disease related dementias (AD/ADRD) are age-associated neurodegenerative diseases that are reaching epidemic proportions as a result of an aging world population. Progression of AD includes losses in memory, orientation, independent decision-making capacity, and abilities for self-care. Impressive gains in our understanding of AD pathogenesis have not yet translated into pharmacological therapies that halt disease progression. Evidence-based behavioral approaches are rapidly becoming recognized as methods to provide effective neurocognitive and therapeutic support for AD/ADRD individuals and their caregivers [1]. Behavioral approaches include lifestyle modifications, reducing physical and psychological barriers for completing activities of daily living (ADLs), and improving communication with and amongst caregivers.

There is growing evidence that assistive digital technology, when combined with behavioral approaches, can be useful interventions that help individuals with various forms of cognitive impairment, including dementia [2–5]. An example of assistive technology is the development of mind mapping software programs for creating a visual map of instructions or procedures. In its simplest form, a visual map is a series of connected pictures illustrating the sequential steps for undertaking and successfully completing an activity of daily living (ADL) like bathing, dressing, or brushing teeth. Visual mapping software is already successfully applied to a wide range of areas in education, management, and medicine. This includes pre-operative instructions for patients, discharge instructions for patients, and assistive medication labels [6,7]. The use of visual mapping is also reported to improve caregiver teamwork in the care of individuals with dementia [8]. A landmark book by Dr. George Huba, a psychologist diagnosed over 7 years ago with fronto-temporal dementia (FTD), describes his use of visual mapping to successfully organize, schedule, and accomplish his daily goals and ADLs [9]. Inherent advantages of assistive technologies such as software for visual mapping are ease of distribution and high accessibility, little to no side effect profile, and low cost.

For the feasibility study described here we assessed the effectiveness of visual mapping as an assistive technology for memory-impaired individuals. The innovative idea of using visual mapping to assist memory-impaired individuals is based on two relatively recent neuroscience systems-level findings: First, certain brain regions (e.g., the neostratum) are less likely to be affected by the neuropathology (e.g., plaques and tangles) that characterize the early stages of AD [13]. Second, the neostriatum and related spared brain regions are involved in the development of non-conscious procedures, skills and habits [14] that underlie routine behaviors associated with many ADLs. We asked four addressable questions: 1. Can the use of visual maps enhance quality of life (QoL) of memory impaired individuals? 2. Do caregivers perceive positive QoL changes in individuals under their care as a result of the use of visual maps? 3. Was the experience using visual maps satisfying to the extent that individuals with impaired memory and their caregivers would continue to use this assistive technology and would recommend the use of visual maps to others? 4. Can the use of visual maps enhance cognitive function in memory-impaired individuals?

2. Methods

We combined a visual mapping software program with a series of visual map templates and loaded the software and the templates on mobile tablet devices to create the assistive technology used here. The visual maps consisted of pictures and keywords presented in a step-by-step sequence to assist memory-impaired patients and caregivers in organizing and successfully accomplishing their activities of daily

Table 1
Resident participant demographics

Resident	Diagnosis	Age	Sex
1	AD	90	M
2	MCI	92	F
3	ADRD	83	F
4	ADRD	68	F
5	AD	83	M
6	ADRD	75	F
7	AD	76	F

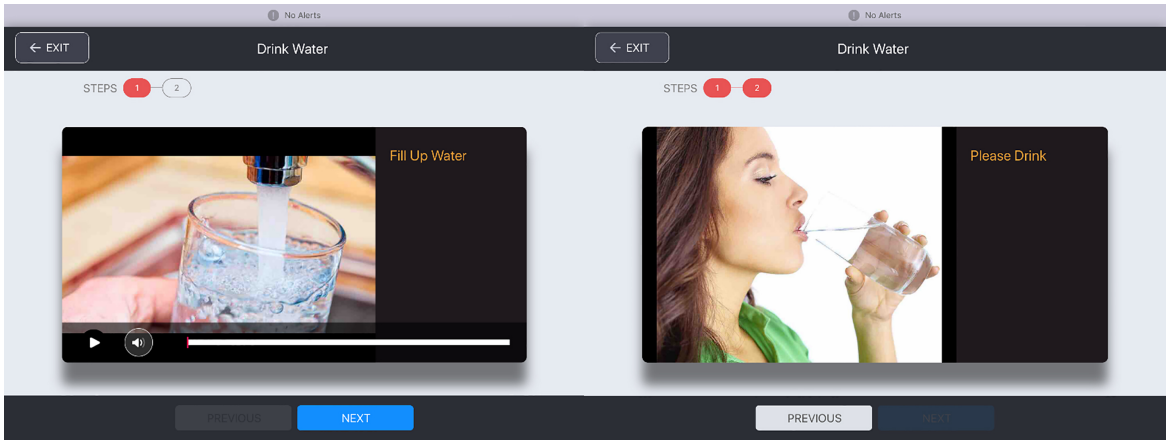

Fig. 1. An example of a visual map for the Drinking Water activity of daily living (ADL), showing two sequential steps. Each step appears individually and sequentially on the tablet screen, controlled by the user's touch screen. When an ADL is completed, the home screen appears showing the next scheduled ADL.

living (Fig. 1). The study was conducted at an Atlanta-based adult living community with a resident population of approximately 80 individuals. A professional staff of trained and certified supervisors and caregivers oversee a range of care plans at the adult living community that include independent living, managed care, and dementia care.

2.1. Participants

The adult living community staff selected a group of ten memory-impaired individuals. Inclusion criteria were full-time residency, medical record diagnosis of mild cognitive impairment (MCI), Alzheimer's disease (AD), or Alzheimer's disease related dementia (ADRD), ability to comprehend and carry on general conversation, and ability to carry out one-step commands. Exclusion criteria were history of chronic drug or alcohol abuse, a diagnosis of schizophrenia, or evidence of severely impaired vision. Three resident participants did not complete the study (two individuals died, and one left the study due to family conflicts). Table 1 shows the demographic data for the seven individuals (mean age = 81 years) who completed the study and whose findings are presented here. As described in the Study Design, two caregiver/supervisors who oversaw the daily care of the ten residents also participated throughout the four-month study.

2.2. Study design

This small-n feasibility study used a longitudinal, non-randomized, single-arm, repeated measures

design where pre- and post-intervention measures were obtained. In the pre-intervention baseline condition, assessments of residents were done prior to the use of visual maps. In the post-intervention condition re-assessments of residents were done immediately after three months of using visual maps. Additionally, post-intervention data were collected both from residents and caregivers using an 18-question Exit Interview and a 2-question Net Promoter Index (NPI) score. The residents served as their own controls (single arm, repeated measures).

2.2.1. Pre-intervention baseline condition (∼ 1 week duration)

Caregivers: The two supervisor/caregivers were provided smart tablet devices dedicated for use in this study and preloaded with visual mapping software and a customized template library of ADL visual maps. Caregivers were trained by technical staff on the use of the visual mapping software, including how to access a library of 40 map templates that depicted a wide range of activities of daily living (ADLs). Caregivers were also trained on how to modify and personalize the template maps by replacing generic photos with photos of the actual room or items of the resident for whom the maps were created (Fig. 1). The built-in smart device camera was used for this process so that new photos could easily be imported into a map. *Residents:* Clinically trained staff personnel conducted the pre-study assessment of all ten residents using five standardized neuropsychological assessments. Residents were administered the assessments in the same order: 1. Generalized Anxiety Disorder (GAD7 – seven items assessed severity of anxiety disorder). 2. Personal Health Questionnaire (PHQ8 – eight items assessed energy, appetite, nervousness, depression). 3. Quality of Sleep/Pain (QSP5 – five items assessed quality of sleep, discomfort from pain). 4. Quality of Life (GQL8 – eight items selected from the Wisconsin University Quality of Life Questionnaire assessed enjoyment, leisure, mood). 5. Repeatable Battery for Assessment of Neuropsychological Status (RBANS; Form A). For the four questionnaires, all items were in the form of statements to be answered on a 0–3 scale (e.g., "Over the last two weeks how often have you been bothered by feeling nervous, anxious or on edge?" 0. Not at all, 1. Several days, 2. Over half the days, 3. Nearly every day). Residents were administered the tests orally (the staff person stated the question and the multiple-choice answers, then recorded and confirmed with residents their choices on the questionnaire sheet. To allow completion of the full battery within a one-hour session, abbreviated versions were used for some of the standardized assessments (indicated above in parentheses). The RBANS was administered in its complete form, and it was administered interactively, directed by the RBANS manual.

2.2.2. Intervention with visual maps (∼ 3 months duration)

During this period, caregivers worked with residents on a variety of ADLs, using the maps developed for helping them routinely accomplish their activities more effectively. Caregivers maintained their regular daily contact with residents, and they were available for assistance in creating or modifying the visual maps. Additionally, technical staff held weekly office hours on site, and they were available to residents and caregivers to "troubleshoot" any smart device malfunctions or other technical problems throughout the three-month study period.

2.2.3. Post-intervention condition

At the end of three months of using visual maps, residents were re-assessed using the same battery administered in the Pre-Intervention condition (the RBANS Form B was used for the retest). The same staff person carried out the pre and post assessments. Two additional assessments were administered at the end of the three months, both to the residents and to their caregivers: 1. An 18-item overall-quality-of-life questionnaire (QoL18) assessed whether change (positive or negative) occurred as a result of

Table 2
Pre- and post-intervention assessment scores (0/0) for the neuropsychological test battery

Resident	GAD7 pre/ post/±	PHQ8 pre/ post/±	QSQ5 pre/ post/±	QLQ8 pre/ post/±	RBANS immediate memory pre/post/±	RBANS visuospatial pre/post/±	RBANS language pre/post/±	RBANS attention pre/post/±	RBANS delayed memory pre/post/±	RBANS total scale score pre/post/±
1	5/2 −	5/2 −	1/2 +	8/11 +	78/76 −	81/87 +	80/68 +	106/109 +	60/48 −	76/72 +
2	2/1 −	2/3 +	6/1 −	4/6 +	61/69 +	53/60 +	99/80 −	56/72 +	56/82 +	55/65 +
3	16/1 −	10/1 −	9/2 −	−2/4 +	57/67 +	60/58 −	103/99 −	85/68 −	48/48 =	61/58 −
4	2/0 −	4/1 −	6/0 −	0/8 +	40/49 +	60/53 −	61/51 −	60/75 +	44/40 −	45/48 +
5	0/0 =	1/1 =	0 / 0 =	6 / 12 +	57/53 −	87/81 −	54/68 +	88/79 −	44/48 +	56/56 =
6	1/4 +	2/1 −	2/2 =	6/3 −	40/44 +	56/50 −	40/47 +	53/72+	40/40 =	43/46 +
7	2/3 +	2/3 +	5/3 −	−2/3 +	40/40 =	50/50 =	74/78 +	53/79 +	40/40 =	47/50 +
Mean	4.0/1.6 −	3.7/1.7 −	4.1/1.4 −	2.9/6.7 +	53/57 +	64/63 −	73/70 −	72/79 +	47/49 +	46/56 +

Scores are averaged across the seven residents for each assessment test. (− indicates a decline in performance score, + indicates improvement in performance score, = indicates no change in performance score). Of the four neuropsychology tests, only the Quality of Life (QLQ8) test showed significant improvement scores ($p < 0.01$). For The RBANS, six of the seven residents showed improved Total Scale scores, but this did not reach significance ($p > 0.05$). Many residents' scores on the Immediate Memory and Attention subtests of the RBANS significantly improved ($p's < 0.05$).

using the MHS for three months. The questionnaire was administered orally to the residents in a Likert scale, self-rating format (5. Much better, 4. Better, 3. Not much change, 2. Worse, 1. Much worse). The caregivers completed multiple QOL18 questionnaires, each with respect to a particular resident under their care. 2. A 2-item "Yes"/"No" Net Promoter Score (NPS) assessed residents' and caregivers' overall user-experience 1. Would you recommend this assistive technology to your friends/colleagues? 2. If there was a follow-up study using this assistive technology, would you participate?

3. Results

As shown in Table 2, there were no significant differences between the residents' mean pre/post scores on three of the neuropsychological assessments (GAD7, PHQ8, and QSQ5; all p values > 0.05). However, on the fourth assessment (QLQ8, Quality of Life), six of the seven residents showed increased post-scores compared to their pre-scores (mean pre-score for 7 residents = 2.9, mean post-score = 6.7, $t = 2.81$, $p < 0.01$).

The RBANS test generates 5 Subtest Scale Scores plus a Total Scale Score (Table 2). The seven residents showed an average increase of 10 Total Scale Score points between their pre (mean = 46.14 points) and post (mean = 56.42 points) performance. Although this difference did not reach statistical significance ($t = 0.96$, $p > 0.10$), closer analysis revealed that only one of the seven residents evidenced a poorer post Total Scale Score. None of the five Subtest Scale Scores showed significant differences between pre/post performance (all $p's > 0.05$). More detailed analyses revealed that on the Immediate Memory subtest, four residents (2,3,4,6) showed an average improvement of 6.25 points, and on the Attention subtest, five residents (1,2,4,6,7) showed an average improvement of 15.80 points (p's for both subsets of residents < 0.05). Improved post-scores on these two subtests were the major contributor to the improved post Total Scale Score outcome. No other subtests evidenced any such improvements.

Mean scores from the 18-question Exit Interview for all seven residents were compared to a null hypothesis mean score of 3.00 (indicating no change). Residents' mean scores for the 18 questions ranged from 3.21–4.68 (Fig. 2A). The overall mean score for all seven residents was 3.74, ($t = 3.65$), $p < 0.001$. Scores for the caregivers, who evaluated the seven residents, were also highly positive and

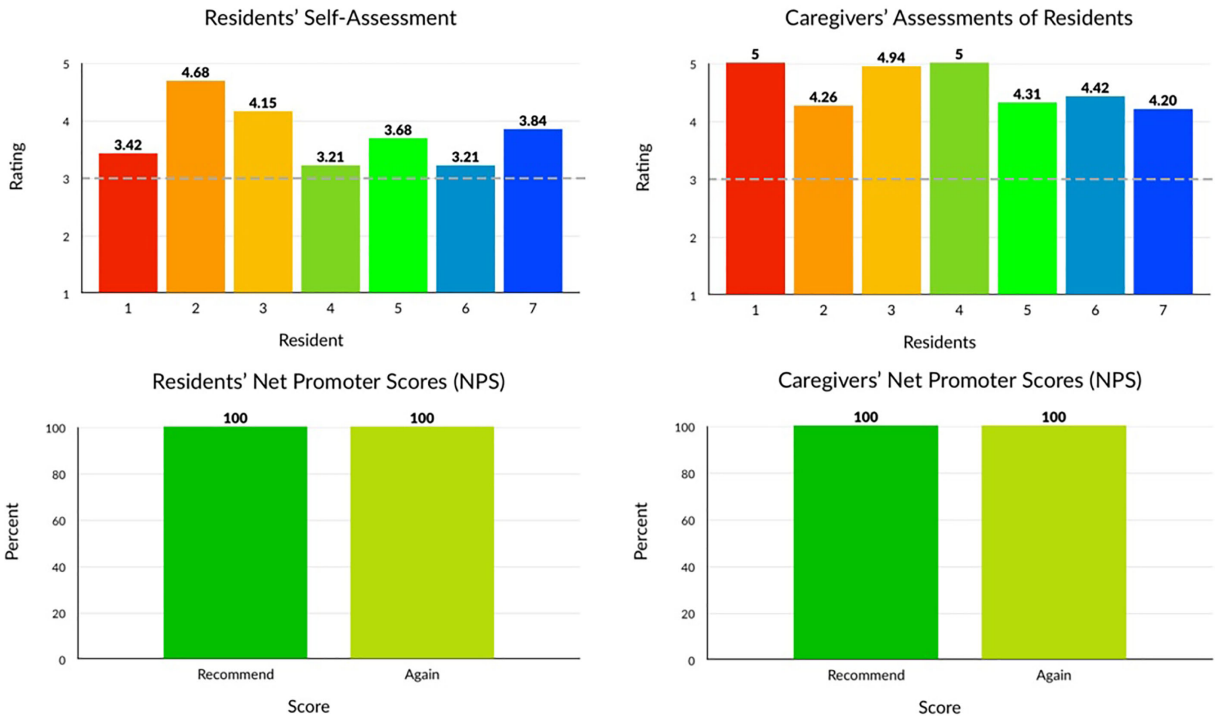

Fig. 2. (Top) Mean quality of life Exit Interview scores for each of the seven residents (left) and for the two supervisor/caregivers (right). The residents self-rated themselves and the caregivers rated the specific residents in their care. Scores are the responses on a 1–5 scale (1 = much worse, 2 = worse, 3 = no change [Null hypothesis], 4 = better, 5 = much better), averaged across 18 quality of life questions. Residents and caregivers evidenced significant improvement in quality of life scores (compared against 'no change") following three months of using visual maps ($p's < 0.001$). (Bottom) Net Promoter Scores for residents (left) and caregivers (right). For each of the two Net promotor questions, residents and caregivers answered "Yes" 100% of the time.

significant. The caregivers mean scores for the seven residents ranged from 4.20–5.00. The overall mean caregiver scores for all seven residents was 4.59, ($t = 11.33$), $p < 0.001$ (Fig. 2B). Scores from the 2-question Net Promoter Index were consistently high and similar both for residents and caregivers. The mean percent of "Yes" responses across the 2 questions both for the seven residents and for the two caregivers was 100%. No residents or caregivers gave any "No" responses (Fig. 2C and D).

4. Discussion

The findings from this study successfully addressed four questions concerning the feasibility of using assistive technology with memory-impaired individuals:

1. Can the use of visual maps enhance quality of life (QoL) for memory impaired individuals? Of the four tests in the neuropsychology battery (GAD7, PHQ8, QSQ5, QLQ8), only the Quality of Life Questionnaire (QLQ8) showed evidence of positive change following three months of using visual maps. The findings from the GAD7, PHQ8, and QSQ5 evidenced no significant pre/post changes. These results from the latter tests were not surprising, because the residents scored low in terms of their endorsement on a wide range of conditions, including anxiety disorder, nervousness, physical complaints, and sleep disorder. The statistically significant positive findings from the QLQ8

were entirely consistent with the statistically significant positive outcome of the 18-question Exit Interview answered by the residents (Fig. 2A). Taken together, these findings from the residents provide strong and statistically significant evidence that the use of assistive technology in the form of visual maps and mobile device software can, within a duration of only three months, enhance the quality of life of individuals who have impaired memory, including those with MCI, AD and AD-related dementia.

2. Do caregivers perceive positive QoL changes in individuals in their care as a result of the use of visual maps? The findings from the caregivers' 18-question Exit Interview, in which caregivers answered questions about the specific individual of the seven study-residents in their care, showed strong positive and statistically significant evidence that caregivers perceived positive changes in their residents across a wide range of quality of life measures (Fig. 2B). Moreover, caregivers frequently gave greater positive change scores for specific residents than the positive scores the residents gave themselves. By one view, the caregiver ratings could be viewed as a more objective measure of change and the self-ratings of the residents as a more subjective measure. Taken together, these findings point to the fact that following a relatively short duration of working with visual maps and smart device software, caregivers perceive and report strong positive QoL changes in the residents under their care.
3. Was the experience using visual maps satisfying to the extent that individuals with impaired memory and their caregivers would continue to use this assistive technology and would recommend the use of visual maps to others? The Net promoter Score (NPS) is a metric used in customer experience assessment programs to measure customer satisfaction and potential for growth [10]. Typically, participants are asked one question, i.e., how likely they are to recommend their products or services to their friends, family, or network. To obtain a more comprehensive view, the NPS in the present study used two yes/no questions (Fig. 2C and D) asked of both resident participants and their caregivers. Responses from the residents and the caregivers were unanimous, with 100% "Yes" responses for both questions. Thus, the findings very strongly point to the answer that the use of assistive technology was a positive experience for the residents and for the caregivers, they would recommend it, and they would again engage with it if the opportunity arose in the future.
4. Can the use of visual maps enhance cognitive function in memory-impaired individuals? The scores from the five RBANS subtests scales did not evidence statistically significant improvement from the pre-measurement (baseline) to the post-measurement (after the 3-month experience with the MHS). Nevertheless, two findings stand out as relevant to this question. First, the seven residents, on average, increased their pre/post RBANS Total Scale Score by approximately 10 points. Moreover, only one of the seven residents showed a decreased pre/post score (five residents showed improved scores, and one showed no change). Thus, although not statistically significant, there is a clear trend toward improvement in overall cognitive function as measured by the RBANS Total Scale score. Second, for two subtests, Immediate Memory and Attention, over half the residents showed statistically significant improved pre/post scores that averaged between 6 to nearly 16 points. None of the other subtests evidenced any reliable pre/post changes.

The findings of a trend in improved overall cognitive performance, and evidence of significantly improved pre/post scores on immediate memory and attention were unexpected. All but one of the resident participants had a diagnosis of dementia, that is, almost all had cognitive impairment that severely limited their ability to function and were presumed to continue deteriorating. Both of the Immediate Memory and the Attention RBANS subtests emphasize focus and concentration. It has been hypothesized that the use of visual maps provides a way for individuals to better see the connections between different components of an event [11,12]. The several months of using visual maps to help carry out ADLs requires the

individual to focus, pay attention to, and concentrate on the pictures, their sequence, and their relationship to the specific ADL. This intentional activity requires effort, occurs repeatedly, and could in turn, enhance the individual's ability to pay attention and focus better than previously, despite their advancing dementia. It would be important to explore, and potentially exploit, this possibility conferred through digital assistive technology in future research. In addition to the findings of positive impacts on QOL and aspects of cognition, assistive technologies have inherent benefits in that they can be easy to access, easy to use, have little risk of side effects, and are relatively low in cost. Thus, assistive technology can be an important intervention for dementia healthcare.

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Conflict of interest

None to report.

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