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Feasibility Study of an Augmented Reality System for People with Dementia

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Abstract

While augmented reality (AR) can be valuable in therapy with people with dementia (PwD), when designing an AR system for PwD, it is important to understand how PwD interact with to such systems. Here we discuss an experiment that aims to study how PwD can complete a set of activities using a variety of human - computer interaction techniques in an AR environment. During our analysis, we will answer 4 research questions: (RQ1) How autonomous are PwD while using the proposed system? (RQ2) How engaging is the system? (RQ3) How proficient are PwD in doing the proposed activities using errorful and errorless approaches? (RQ4) How useful is the proposed system as perceived by therapists? There were 7 people diagnosed with dementia participating in the study. We also invited 3 health professionals to provide feedback regarding the overall usefulness of the AR system for stimulation purposes in PwD who are at initial to intermediate stages of dementia.The experiment showed that, in general, participants did enjoy doing the activities and were able to complete them independently. As far for the therapists, they showed interest in using the system for stimulation purposes in the future interventions. However, the experiment also revealed that it is important to adapt the activities to the patient's profile.

CCS Concepts

• ***Computing methodologies*** → *Marker detection and occlusion;* • ***Hardware*** → *Projector and webcam;*

1. Introduction

Dementia is an incurable neurodegenerative disease that is accompanied with neuropsychiatric symptoms such as memory loss, anxiety, agitation, depression, and other issues and has a negative impact on cognitive, emotional and physical abilities of individuals suffering from this disease [Ala18]. Dementia is an umbrella term that compresses different types and pathologies such as Alzheimer's disease, frontotemporal dementia, vascular dementia, Lewy body dementia, and mixed dementia [Ala18, Kor02]. Independently of the type of dementia, as the disease progresses, people with dementia (PwD) become increasingly more dependent on third parties to perform activities of daily living (ADL's) [Ala18] leading to the early institutionalization of such population. Moreover, the lack of physical and human resources in nursing homes represents an additional factor that increases the risk of depression and burnout syndrome among caregivers of PwD [DOA09, LRHB12, Fla18].

The inability to find more efficient solutions to treat dementia leads, not only to extra weight in societal costs [WGA*17], but also additional emotional and physical weight to family, caregivers and health professionals [MS09]. Although pharmaceutical approaches have been developed to mitigate the harmful consequences of dementia, their impact on the disease is limited, and it is often accompanied by side-effects [Wo10]. In order to reduce some of the costs and emotional burden of the disease, there is a growing need for alternative and complementary approaches [HWC*10]. The application of non-pharmaceutical methods has been proposed to stimulate not only cognitive and physical domains but also ADL's [HWC*10].

Existing scientific literature suggests that music and reminiscence related activities can alleviate some neuropsychiatric symptoms such as depressive symptomatology, provide cognitive and emotional wellbeing and stimulate autobiographical memories [WSJ*05, STL*14, EHPA12]. Besides being fun, these activities can be led by either formal or informal caregivers. Indeed, serious games have been developed using the benefits of music and reminiscence to stimulate PwD [BJP10].

Similarly to traditional methods, serious games can be used on a variety of therapeutic contexts such as physical and psychological well-being, promotion of ADL's training, as screening tools and for educational purposes [WBGS13].

While the majority of serious games are not specifically designed for the individual needs of PwD as many of these game designers use "a One Size Fits All approach" [Hay18], some serious

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games have already been developed specifically for PwD,to train ADL's, cognition and among other purposes [HdVIMS18, McC12, FRY*15, BPK*15, MB13].

A significant advantage that serious games have over traditional methods is that serious games can enhance motivation among PwD [KAA*14], which are important factors, especially, during clinical interventions. If PwD are engaged in game-like tasks, they will focus less on the clinical aspects, which are a source of emotional stress. Recently, AR technologies have gained much attention to address dementia-related issues [Hay18]. Work has been done using AR in a variety of contexts for PwD such as in a cognitive screening tool [BM16] or to provide reminiscence related experiences augmented with multimedia content such as photos and videos. For instance, this technology allows the blending of real objects with virtual content on a mobile device when walking near them [MBR15].

Unfortunately, there is an absence of feasibility and efficacy studies with these novel approaches [KAA*14]. Thus, it becomes important to validate, together with health professionals, the efficacy and effectiveness of digital systems explicitly designed for stimulation purposes with PwD [KAA*14].

Here, we discuss a study we have performed using our AR system for PwD, which includes several game-like AR activities. The novelty of this study is that it provides the scientific community a deeper understanding of how PwD complete a set of activities while using a variety of human-computer interaction techniques through an AR system. Moreover, we invited therapists to interact with the system to assess the usefulness of the proposed tool in their daily practice. Throughout our experiment, we will answer four research questions (RQ).

RQ1 – How autonomous are PwD while using the proposed system?
RQ2 – How engaging is the system?
RQ3 – How proficient are PwD in doing the proposed activities using errorful and errorless approaches?
RQ4 – How useful is the proposed system as perceived by therapists?

Figure 1: *Circular timer and marker. A blue circular timer is activated after occluding the marker with the finger, full body or random physical objects.*

Figure 2: *System configuration(s). (1) Table projection setup with a projector and a tripod. (2) Floor projection setup through a high-intensity projector and a tripod. (3) A PsEye camera which is collocated with the projectors to track and identify the projected markers A, B, C and D.*

2. Methods

Our AR system for PwD consists of a set of activities with AR features that were created using the Unity 3D Game Engine (Unity Technologies, San Francisco). We use an LG PW800 projector (Life's Good, Seul) to display the activities on a table, a Dell S330w projector (Dell inc., Texas) to display activities on the floor , and a PsEye webcam (Sony Corporation, Sony City). While our AR system contains several different activities, all activities have some common characteristics. They all use virtual content projected on a table surface or the floor, as well as markers and a tracking system to enable the interaction of physical objects with the virtual content.

Markers are the interactive elements that participants can interact with using their limbs or with physical objects (figure 1 shows a marker under the user's hand). In order to track the markers, the Analysis and Tracking System (AnTS) was used (Bermúdez i Badia, S. (2004-2014). AnTS (Version 2.x) [software]. Retrieved from https://neurorehabilitation.m-iti.org/tools/). AnTS is a visual tracking software that can track several markers simultaneously through a webcam. Interaction can happen through the tracking of a physical object tagged with a marker or through virtual markers. In the latter case, as opposed to more traditional tracking approaches, markers are not physical and attached to the limbs or interactive objects but were digitally projected on the table surface.

Interaction can be triggered when the projected marker is occluded to the camera (by a hand, foot or an object) and the AnTS will stop detecting it. Hence, our system supports different types of interaction: through touch (hand and feet), through untagged objects, and through interactive physical markers.

The actions associated with each marker are triggered after occluding them for 4 seconds A clock-like circular timer around the marker would provide feedback on the 4 second. selection period (figure 1). To facilitate communication and the identification of the

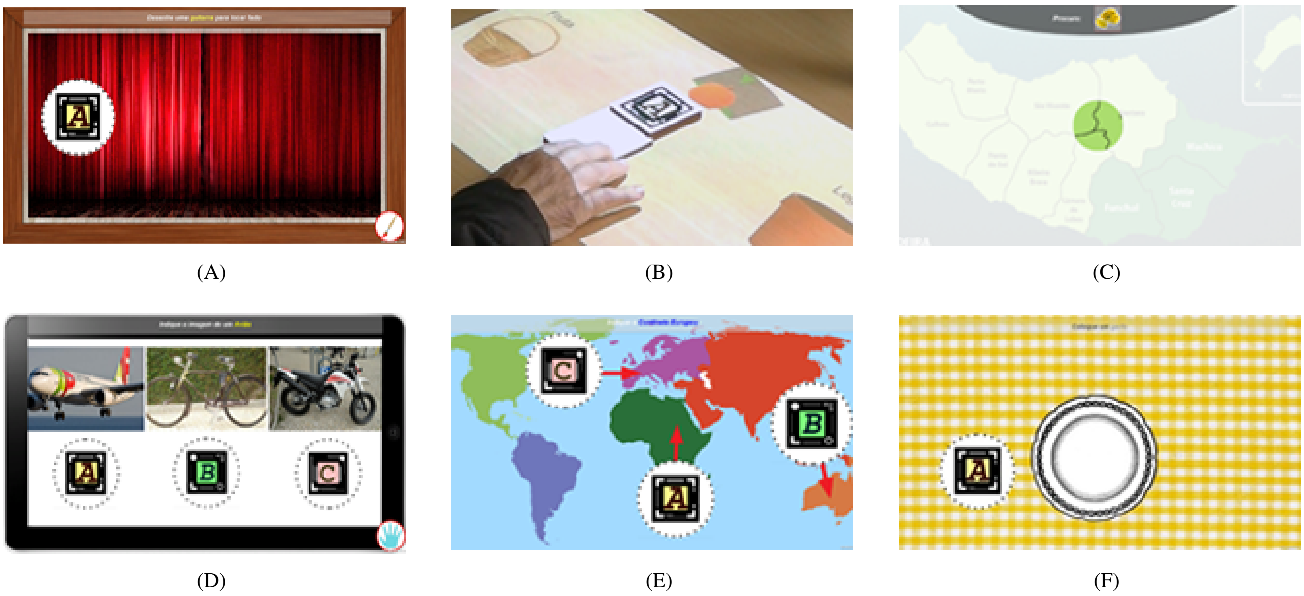

Figure 3: *Activities. (A) Participants had to fill the gaps through physical drawings. (B) Participants uses physical object to interact with virtual objects in activity and drag these to the correct container.(C) Participants had to find a variety of objects, which were only visible to the human eye through the physical device.(D) Participants had to choose the correct answer among* 2 *wrong options using upper limbs. (E) Participants had to select the correct answer among* 2 *wrong answers using full body. (F) Participants had to set a table using real-life objects.*

markers by both participants and researcher during the study, we designed personalized markers and identified them with letters of the alphabet. The setup of the experiment is illustrated in figure 2.

2.1. Activities

Using AR technology, we developed 6 interactive activities with different interaction modalities to target different physical abilities (i.e., gross and fine motor skills) and cognitive competencies (i.e., executive functions, attention, memory, and association). For all activities, During the activities, music was played in the background. For most of the activities, well known Portuguese songs were played to entertain participants during activity performance. However, in some activities music was used actively to assist participants in their decision making. In this experiment, we implemented two types of approaches: errorless and errorful activities (Table 1). We define errorless as an activity that does not provide negative feedback to remediate wrong actions and errorful as activities that provides negative feedback via audio message - 'Ohh, try again'- during erroneous decision making. However, participants were congratulated after finishing each task. Below we describe the characteristics of all 6 activities in detail.

Activity 1. Creative Painting

Competences trained. Memory and, fine and gross motor skills
Activity Description. This is a puzzlelike activity were participants must draw to complete a painting that is projected on a table (figure 3.A). This is a two-person activity where therapists or a researcher and participants work together. For this activity, PwD can use paper, cardboard, color pencils and a pen, or any combination. Participants must (1) draw flowers, (2) draw the national symbol of Portuguese independence, (3) draw musical instruments, and (4) draw the national flags.
Interaction. The system displays an incomplete scene on a table, and a virtual marker indicates a missing element that needs to be completed gradually with participants creative creations. After creating a drawing or painting on paper, the participant places the paper in the position indicated by the marker. Then, a timer starts, and after 4 seconds the scene evolves to a new one that needs to be completed with another drawing.

Errorless Activities	Errorful Activities
Creative Painting	Knowledge Quiz: Upper Limb
Search Object	Knowledge Quiz: Full Body
Simulation ADL	Categorization

Table 1: *Errorless and errorful based activities*

Activity 2. Categorization

Competences trained. Associative memory
Activity Description. Participants must categorize as many fruits and vegetables as possible for 5 minutes.
Interaction. A fruit or vegetable appears in the top middle, and two containers - for fruits and vegetables - are displayed on opposite sides. To drag fruits and vegetables, participants use a physical

controller tagged with a marker that allows selecting virtual objects (figure 3.B). Vegetables and fruits become selected after placing the controller on them for 4 seconds and then can be displaced to their corresponding container using the physical marker. Once the item is placed in a container, a new item appears. Similarly to [FCaiB17], music feedback is integrated to guide participants to the correct container and avoid erroneous decision-making. When a selected object is displaced, the pitch of the background music becomes distorted as the object approaches the wrong container or undistorted as it approaches the correct one.

Activity 3. Search Objects

Competences trained. Attention and memory.
Activity Description. This is an exploration game where participants must find hidden virtual objects typical from Madeira Island in a map of the island. These include a typical beverage, a headpiece, a musical instrument, fruit, and traditional Madeiran bread. The goal is to find as many objects as possible in 5 minutes (figure 3.C).
Interaction. The participants must use a real physical object and search for the virtual objects mentioned above. Participants have to find the object based on musical distortion: music pitch distortion increases with as the distance to the object increases. After finding an object in the map, a timer is activated, and the participant must hold it for 4 seconds to select it.

Activities 4 and 5. Knowledge Quiz (Full-Body and Hand)

Competences trained. Memory
Activity Description. Participants must select the correct answer among three possibilities. The questions were presented in written form and reinforced verbally by the researcher.
Interaction. This activity can be used with two types of interaction: selecting answers by placing a hand (figure 3.D) or both feet (figure 3.E) on the corresponding marker for 4 seconds. If the interaction is done with hands, the activity is projected on the table. If the interaction is performed with feet, then the activity is projected on the floor. In either activity, when participants chose a wrong answer, the pitch of the background music becomes distorted for 4 seconds. However, if the answer is correct music is unaffected. After participants choose the correct answer, the next task is initiated after a 5 second pause.

Activity 6. Simulation Activity of Daily Living (ADL)

Competences trained. Memory and selective attention
Activity Description. This is another puzzle-like experience based on activities of daily living. This activity requires using real objects like cutlery among other objects. We developed activities that require setting the table, add earrings to a woman's picture, shave the beard of a man, add a watch and bracelets, place objects accordingly to their colors and, finally, complete a sequence of cards in descending order.
Interaction. Participants are required to identify and place the correct physical object on a marker. Every time the participant places an object on a marker, new markers appear in the game. The system detects the presence of an object on top of the AR marker but does not identify which object it is. By doing so, therapists are not limited only to specific predetermined objects. After all objects are correctly placed in the scene, a new scene is presented until all scenes are completed (figure 3.F). As this is an errorless activity, participants are assisted if they choose the wrong object.

ID	Gender	Age	Schooling	Dementia	MMSE
1	Female	78	3 Years	AD	23
2	Female	77	4 Years	AD	25
3	Female	77	4 Years	VD	17
4	Female	70	4 Years	AD	24
5	Female	85	4 Years	AD	16
6	Female	78	4 Years	AD	18
7	Male	63	4 Years	FD	21

Table 2: *Demographic Information. AD - Alzheimer's disease. VD– Vascular Dementia. FD– Frontotemporal Dementia.*

2.2. Participants

We recruited 7 participants (1 male) of 73.57 ± 7.87 years old from a daycare center in Funchal, Portugal. The average mini-mental examination score (MMSE) of participants was of 20.57 ± 3.6. All participants included in this study were diagnosed with dementia (Alzheimer's disease, frontotemporal dementia or vascular dementia) as presented in table 2. All participants were at initial to moderate stages of dementia.

Additionally, three health professionals also participated in the study, and a psychologist interacted with the participants while using the system. A music therapist and a psychomotricity therapist interacted with the system and evaluated it independently without participants. The psychologist is a 39-year-old male with four years of work experience. The music therapists is a 26-year-old female with one year of work experience, while the psychomotricity therapist is a 28-year-old female with 6-month work experience.

We followed a within-subjects experimental design. To avoid learning effects, participants were divided into two groups, and the activities were counterbalanced by assigning them to 2 different subsets of activities. Subset A included creative painting, knowledge quiz using hand and searching objects, while subset B included simulations of ADL, knowledge quiz using full-body and categorization. Each participant was randomly allocated to do A-B or B-A.

2.3. Procedure

Before the beginning of the experimental trial, all participants (or legal representative) required to sign an informed consent. Additionally, we collected information regarding participants profile such as schooling, type of dementia and MMSE.

The experimental sessions were filmed to compute the number of assistance and technical issues with the system. Before performing each activity, all participants had to complete a tutorial where they received instructions regarding interaction and goal.

The experimental sessions were conducted by either a researcher or a psychologist of the care center, who aided whenever a participant was struggling to complete a task (where a task is each trial run of an activity). Taking into consideration that PwD suffer from memory loss, at the end of each activity (with several trial runs), participants were interviewed regarding their perception of autonomy and engagement during the performance of the activity.

In a second phase, the two therapists were invited to interact independently with the system and watched videos of the psychologist interacting with the participants while using the system. Then they were interviewed and asked to complete some questionnaires.

2.4. Instruments and Metrics

To answer RQ1 (perceived autonomy) and RQ2 (engagement), we performed semi-structured interviews about the participants' self-perception and compared the answers with objective data extracted from the video recordings. The answers to our questions were assessed as positive (+1), neutral (0), negative (-1) or not applicable. Additionally, we performed a correlation between MMSE and participants engagement with the activities. To address RQ3 (proficiently), we extracted three different metrics during task performance with both errorful and errorless activities:

Time – we measured the time (in seconds) needed for participants to finish each task.

Success rate – for the errorful based activities we counted the number of times a participant was successful in performing each task. As for errorless based activities, we considered the success rate as 100%.

Issues – we counted the number of technical issues occurred for each task.

Additionally, all therapists were invited to answer a semi-structured interview regarding the interaction, difficulty, immersiveness of the system, and filled a set of questionnaires to assess not only RQ1 and RQ2, but also RQ4 (usefulness):

System Usability Scale (SUS) – it is a quick and low-cost 10 item Liker scale that evaluates system usability [Bro96].

Intrinsic Motivation Inventory (IMI) – it is a tool that evaluates the subjective experience related to an activity [MDT89]. Within the IMI, we used the Activity Perception Questionnaire which evaluates participant's interest/enjoyment, value/usefulness and perceived choice of an activity.

We also presented them with a visual analog 7 points scale that evaluated the appropriateness of the system for PwD at initial to moderated stages. This evaluates difficulty, utility, motivation, adequacy, and interest.

2.5. Data Analysis

IBM SPSS Statistics Version 24 (IBM, New York, United States of America) was used for the statistical analysis. Taking into consideration that we had a small sample size we performed a non-parametric statistical analysis. We used the Wilcoxon signed rank test for pairwise comparisons. Descriptive statistics are presented as medians (Mdn) and interquartile range (IQR), except for demographic data, MMSE engagement and time spent doing the tasks, which are presented as means (M) and standard deviations (STD).

Rank	Interview	Rank	Observations
1	Knowledge Quiz: Upper Limb	1	Knowledge Quiz:Upper Limb
2*	Simulation ADL	2	Simulation ADL
2*	Knowledge Quiz: Full Body	3	Knowledge Quiz: Full Body
4	Categorization	4	Search objects
5	Search Object	5	Categorization

Table 3: *Assistance provided to participants. The activities are ranked in crescent order from least (Rank 1) to most (Rank 5) assistance provided. * asterisk indicates the tie ranking of participants responses.*

3. Results

All participants finished all activities. Participant 5, however, was excused from doing the knowledge quiz upper limb activity due to motor related issues. She also participated in the creative painting activity, but she did contribute in the drawings. Thus, the latter activity was not used to compute her performance metrics.

Also, the number of overall assistance provided to participants in the Creative Painting activity was not considered in the final results as it is completed with a second person.

3.1. RQ1 - Perceived autonomy of participants while doing the tasks

We used the participants' self-report to assess their perception of autonomy. It was reported that 45.7% of the tasks were completed autonomously, 28.6% of the tasks were completed with some help,and 25.7% of the tasks could not be completed without help. However, this perception contrasts with the data collected in the video recordings where, in general, all participants required some degree of assistance to perform the activities. We calculated the mean number of assistance provided per task. Overall, participants required, at least, one assistance per task ($M = 1.21 \pm 0.673$).

By doing a narrower analysis, the activity that required the least assistance was the Knowledge Quiz: Upper Limb task, while the activities that require the most assistance was Categorization and Search Objects. The activities are ranked in crescent order of number of needed assistances (Table 3).

Concerning the number of assistance provided in each task, we analyzed if there is a significant difference between assistance given in an errorful vs. errorless approach. A pairwise comparison indicated that the number of assistance provided in errorless ($Mdn = 7.50 \pm 1.5$) and errorful ($Mdn = 8.50 \pm 4.07$) based activities was not significant.

3.2. RQ2 - Participants engagement while doing the activities

We quantified engagement levels based on the interviews of the participants. All activities were rated as highly engaging ($M = 3.6$). We ranked activities engagement based on the participant's responses. The majority who did the Knowledge Quiz-Full body and Upper-limb activity felt most engaged doing those activities, while feeling less engaged with the Creative Painting activity (see table 4).

Rank	Activity	Engagement%
1	Knowledge Quiz:Full Body	91.7
2	Knowledge Quiz:Upper Limb	91.4
3	Simulation ADL	88.6
4	Categorization	82.9
5	Search Objects	81.4
6	Creative Painting	78.3

Table 4: *Engagement Rank*

Activity	Time	Success%	Issues/Repetition
Knowledge Quiz:Full Body	57.13	67.34	0.42
Knowledge Quiz:Upper Limb	27.31	69.84	0.19
Simulation ADL	85.73	100	0.10
Search Objects	73.63	100	0.21
Categorization	51.41	84.27	0.28
Creative Painting	337.11	100	0.21

Table 5: *Proficiency Measurements*

To study if there was an effect of cognitive abilities in the engagement with the system, we grouped subjects according to the top and bottom 50 percentile of MMSE scores of our sample. We observed that the engagement ratings for the top 50% was higher ($M = 4.17 \pm 1.13$) than for the bottom 50% ($M = 3.27 \pm 1.49$). A Spearman correlation analysis supported these differences and identified a moderate correlation ($r = 0.6$) between MMSE scores and the reported engagement ratings. However, there is no statistical difference ($p = 0.18$).

3.3. RQ3 - How proficient are PwD in doing the proposed activities using errorful and errorless approaches

We evaluated proficiency by measuring time, success rate and the number of issues per repetition of all activities. Within the activities performed, the creative painting took more time ($M = 337.11 \pm 132.31$) and Knowledge Quiz: Upper Limb the least ($M = 27.31 \pm 8.00$).

Regarding the number of issues per repetition, the Knowledge Quiz – full-body activity presented more issues ($M = 0.42$) and Simulations ADL the least. The success rate of the errorful learning activities was higher on average ($M = 74.14\% \pm 0.14$). The activity that presented higher success rate was categorization-task with 84.27%, while the lowest performances were 69.84% in knowledge quiz: upper limb and 67.34% in knowledge quiz: full body. Data are presented in table 5.

To compare if the type of the activity would impact their completion time, we compared the errorless vs. the errorful activities and identified that participants spent 3 times more time in the errorless tasks ($Mdn = 165.35 \pm 76.15$) than in the error-full tasks ($Mdn = 41.64 \pm 18.83$), $Z = -2.366$, $p = 0.018$, $r = -0.6$.

3.4. RQ4 - Perceived usefulness of the system by therapists

The system's usability from the therapist's point of view was found to be 'Good' ($M = 78.33 \pm 14.22$) according to the System Usability Scale. Additionally, we gathered information regarding the therapist's experience with the platform and proposed activities through the activity perception questionnaire. Therapists rated the platform high regarding its usefulness ($M = 6.4$), perceived choice ($M = 6.5$) and enjoyment ($M = 6.5$).

When therapists were asked about their experience with the system for a population at initial to moderate stages of dementia, there was a high acceptance. Therapists showed high interest and motivation in using the platform ($M = 7.0$ and 6.7 respectively). Also, therapists recognized the system utility in stimulating such population ($M = 6.7$). The weaker, yet positively rated, aspects where the adequacy ($M = 5.3$) and difficulty ($M = 4.0$), suggesting that the activities can be better adapted for such population.

4. Discussion

The main goal of this experiment is to study how PwD interact and succeed in fulfilling different tasks while using different human-computer interaction techniques in an AR environment. We also aimed to validate the overall AR system with therapists regarding its usefulness for stimulation purposes by answering several RQs.

Although some of the activities discussed could have been done using touchscreen technology, in AR, it is possible to use real objects to perform the tasks. By doing so, we can capitalize personal, realistic and tangible objects to perform the tasks more efficiently. Another advantage of using AR based projections is that activities can be projected on the floor and stimulate mobility to perform the tasks. Moreover, therapists showed interest in using AR technologies. For example, the psychomotricity therapist was interested in having the system in the sensory stimulation room. Also, the music therapists suggested using real size musical instruments. A similar idea was provided by the psychologist, who suggested using the floor projection to develop a piano activity in which participants could play by using the feet.

Regarding RQ1 related to participants self-perceived autonomy, most participants (45.7%) reported that they did not need any assistance to do the activities. Similar behaviors were in McCallum's study in which PwD required assistance from a second person [McC12]. Moreover, we analyzed if there was any difference in the number of assistance provided between errorless and errorful based activities and we did not find any statistical difference. Although the contradictory information between self-responses and researcher observations, reliability was found as both responses and observations overlap, in the sense that, the quiz knowledge using upper-limbs requested less number of assistance while the searching object and categorization required more assistance from both researcher and psychologist. Nevertheless, it is important to notice that the number of assistance provided to each participant depends on their individual characteristics such as education level, motivation, and cognitive status. However, we faced some technical difficulties with the camera during the experiment, which resulted in some data loss. It was not possible to count the number of assistance provided in some of the activities, and one interview response was missing from our recordings. Furthermore, participant no. 6 denied our request to film the study. Hence, once again we were unable to collect the number of assistance.

Concerning RQ2 – How engaging is the system? –, our results show that participants felt very engaged in performing the activities while using the AR platform. Corroborating the participant's self-reported interviews, the psychologist who is one of their therapists, reported that the patients enjoyed the activities and were engaged. In general, participants found the knowledge quiz full-body more engaging and the creative painting less engaging, although interesting reactions could be observed during this less enjoyed activity. For instance, during the drawing activity, participant 4 said that she felt as she had lost much weight from her shoulders and participant 2 remembered that her mother used to be a painter. While participant 6 did not participate directly in the drawing activity because of feeling insecure, she was able to complete the tasks orally with the researcher assistance. As an example, the first task was to enhance weather conditions to plant flowers and, when she asked about what is necessary to achieve such conditions, the participant replied that it was necessary to have water, fertilizer, and dirt. König *et al* report how serious games can engage participants while doing their task, despite the activity was designed to 'test' PwD in terms of interaction performance [KAA*14]. To explore if the engagement was dependent on the cognitive status of the participants, we made a correlation between engagement and MMSE scores, and despite no statistical difference was found, data suggest a moderate dependency relationship between the two variables.

Regarding RQ3 – How proficient are PwD in doing the proposed activities using errorful and errorless approaches? – in general, there is a high success rate in performing the activities ($M = 87\%$). If we remove errorless tasks, the performance it is still very high ($M = 74\%$), supporting the feasibility of using these tasks in this population. Indeed, PwD are still open to experiment new activities using advanced technological tools and still be successful as seen in [BPK*15,BJP10]. The task with the highest performance was the categorization (with $M = 84.27\%$) while the lowest performance was the knowledge quiz upper–limb and full–body ($M = 69.84\%$ and $M = 67.34\%$, respectively). Regarding the high success rate in the categorization task, it may be due to the number of assistance provided by both researcher and therapist. Many participants had to be reminded that after dragging a virtual object successfully, one must drag the physical piece to the initial position to 'grab' another virtual object. Also, sometimes therapist and researcher would ask participants if the current virtual object was either a 'fruit' or a 'vegetable', which the majority of participants could quickly identify. Interestingly, we observed that the full-body activities required more assistance than the upper-limb ones. This may be due to the fact that the content of the task (geography related questions) may not be the most adequate for PwD; this was suggested by the psychologist who conducted the experiment. Concerning the time spent to finalize activities, the creative painting took longer to finish. We also found statistically significant differences between time spent in errorless and errorful conditions; errorless tasks took 3 times more time. One possible explanation for this is that the time needed to finish these tasks also greatly depends on education, motivation, and cognitive status. Also, it can be due to a lack of experience in doing such tasks while using a novel technology.

Thus, with more training, the time spent in doing the tasks can be reduced. In addition, we found slightly higher technology-related issues in the knowledge quiz full-body activities. These were mostly external factors, for instance, sometimes shadows generated by participants or third parties involuntarily activated markers. Yet again, due to technical issues with the recording device (camera), we lost some data regarding the number of technology-related issues occurred during the experiment.

For our last research question, RQ4 – How useful is the proposed system as perceived by therapists? –, additional data were collected from 3 therapists in different fields. Overall, therapists rated the system with very good usability (78.3) in the SUS questionnaire. Likewise, their experience was highly positive as evaluated by the Activity Perception Questionnaire. We also asked them to fill a non–standardized questionnaire regarding the usage of such a system on a dementia population at initial and intermediate stages. Although therapists attributed a high score regarding utility, motivation, and interest, they gave lower scores regarding difficulty and adequacy. Indeed, during the interview, therapists drew our attention to the fact that some content was not very suitable for some participants. As an example, the psychologist mentioned that performing tasks using full-body was very positive, but a geography-related activity may not have been the most suitable choice, at least, for the participants who participated in the study. Also, the therapist verified that some participants appeared to struggle to find a specific object, aftershave, in the ADLs simulation as it is an item that many participants are not very familiar with. These observations show that it is important to adjust the activities to the individual interests, knowledge, and needs of each person. This concern is equally shared by Hayhurst, who draws our attention to the fact that tasks may not suit all users and that there is a need for user-centered design to target individual needs of PwD [Hay18]. Despite constructive feedback provided by the therapists, only the psychologist used the system with PwD. In future studies, more tests with therapists are required to test the system to obtain more data inquire for future improvement of the system.

5. Conclusion and Future Work

The purpose of this experiment was to study how PwD interact with an AR system while performing a variety of tasks through different interactions. Overall, participants enjoyed doing the activities and were able to complete these with a high success rate. Nevertheless, assistance was occasionally provided to participants to complete the tasks. The number of assistance given is dependent on individual characteristics such as cognitive and physical conditions. Also, during task completion, participants were able to remember and share interesting information regarding past events of their life. This is an important finding as it suggests that the participants were engaged while doing the tasks and that the activities developed can be used for stimulation purposes. Another goal of this study is to gather information to evaluate the usefulness of the AR system for stimulation purposes in PwD at initial to intermediate stages of dementia. According to the results of the questionnaires and interviews, therapists demonstrated high interest in using the system for their therapy sessions in the future. However, therapists showed some concerns regarding the appropriateness of some of the content presented for such population. Given that this is a heterogeneous population with different individual needs, we aim to integrate a UI that allows therapists to personalize the activities to each patient profile.

Thus, in the future, we want to refine the system development further to minimize technology-related issues, as we want to study its clinical impact on a longitudinal study with individuals diagnosed with dementia.

6. Acknowledgment

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