Impact of Combined Music and Reminiscence Cognitive Stimulation in Dementia: A Longitudinal Pilot Study Using *Musiquence*

Luis Ferreira[1[0000-0001-9840-5767]], Mónica Spínola,[2[0000-0002-2931-9221]], Sofia Cavaco[3[0000-0001-7315-4543]] and Sergi Bermúdez I Badia[4[0000-0003-4452-0414]]

[1] Faculdade de Ciências Exatas e de Engenharia, NOVA LINCS, Universidade da Madeira luis.ferreira@staff.uma.pt
[2] Faculdade de Psicologia e de Ciências da Educação, Universidade de Coimbra Rua do Colégio Novo, Coimbra, PORTUGAL. monica.spinola@arditi.pt
[3]NOVA LINCS, Department of Computer Science, Faculdade de Ciência e Tecnologia Universidade de Lisboa, 2829-516 Caparica, Portugal. scavaco@fct.unl.pt
[4]Faculdade de Ciências Exatas e de Engenharia, NOVA LINCS, Universidade da Madeira Funchal, Portugal. sergi.bermudez@uma.pt

Abstract. Dementia is an uncurable neurodegenerative disease that leads to a gradual loss of cognitive capacities and negatively affects emotional state, quality of life, and ability to autonomously perform activities of daily living. Although pharmaceutical approaches can mitigate symptoms in people with dementia, their effect is still limited. Complementary approaches, such as music and reminiscence-related activities, have been proposed for stimulation purposes. Here we present the results of a pilot 14-session longitudinal study with an interactive platform called *Musiquence*, which allows the incorporation of music and reminiscence elements in cognitive stimulation activities, with 8 participants with dementia. In general, the results of the intervention show improvements in all the assessed domains: cognition, anxious and depressive symptomatology, functionality, and quality of life. Preliminary results appear to support the platform's feasibility while providing positive outcomes of clinical efficacy.
Keywords: music, reminiscence, therapeutic outcomes, digital platform, augmented reality, dementia

1 Introduction

Dementia is a neurodegenerative pathology that leads to a gradual loss of cognitive and physical abilities. People with Dementia (PwD) suffer from depression, anxiety, apathy, and cognitive decline [26, 27, 32], among other dementia-related issues (see review [3]). Consequently, PwD become more dependent on third parties to perform activities of daily living (ADLs), which also negatively affects their own and their caregivers' quality of life (QoL) [18, 22]. As there is no cure for dementia, pharmaceutical approaches have been developed to mitigate the disease's progression and alleviate the symptomatology. Nevertheless, pharmaceutical approaches are costly to develop, and

their effect on PwD is limited [20, 23]. Thus, the need for and interest in finding new approaches to complement pharmaceutical ones has been growing.

Among non-pharmacological interventions for PwD, Cognitive Stimulation Therapy has been reported as the most effective [1]. It relies on the positive impact of reality orientation, reminiscence, and validation therapy [31] and stipules that (1) PwD benefit from cognitive stimulation (CS) when mobilized the preserved cognitive functions and (2) being exposed to enriched environments can enhance cognitive reserve and neuroplasticity even in advanced ages. Literature has reported the positive effects of CS on cognition through the maintenance and improvement of cognitive abilities [42]. Also, previous studies using cognitive stimulation therapy have reported an ideal intervention time of 7 weeks with twice-a-week sessions. Beyond that time, there is no evidence of PwD benefiting CS. This type of cognitive intervention can also impact QoL (self-reported and reported by caregivers) and mood (e.g., by reducing depressive symptomatology) [37].

Also, literature has reported the positive effects of incorporating elements such as music, reminiscence and gaming in CS activities [15, 16, 36]. For instance, music has been used in clinical contexts as it has been shown to ameliorate behavior [21], depression, and anxiety [17, 25, 38], communication [5], and autobiographical memory [9] in PwD. Also, research has shown that cognitive improvements are possible through activities that involve music [6, 30, 39]. Like music, reminiscence-related approaches through daily physical items such as photography or household objects can also promote communication and cognitive improvements [42]. Nevertheless, more research is necessary regarding music and reminiscence's effect on PwD [33, 42]. Serious games (SG) are games whose primary purpose goes beyond pure entertainment [8]. For example, SG can be used in many fields such as education, simulation, and health (among others) [40]. In the field of health, SG has been used on a variety of different pathologies like, for example, stroke [29], schizophrenia [13], autism [34], and dementia. Many SG have been developed to be used as cognitive screening tools and stimulate cognitive and physical activities, among other purposes (see review [24]). Thus, to study the potential of using music and reminiscence strategies with PwD in gaming contexts, we developed an interactive platform called *Musiquence*, which implements music and reminiscence on CS activities for PwD [11]. *Musiquence* is compatible with various technologies such as PC, tablet, interactive tables, Leap Motion, Kinect, and augmented reality. It has a Game Editor that allows health professionals (HP) to customize cognitive activities using music and images according to PwD's preferences and needs [11]. In this pilot study, we evaluate the impact of a customized 14-session intervention with *Musiquence* on (1) cognition and (2) quality of life.

2 Methods

Based on results from previous studies [2, 12], in which PwD had positive interactions with AR technologies using different interaction modalities, we opted for a projection-based augmented reality setup for this study as it allows direct interaction input through physical objects and upper limb movements, which facilitates interaction for PwD. To run the system and display the activities on the table, we used a laptop, an Optoma DLP Projection Display (Optoma, New Taipei, Taiwan), and a tripod. A PSEye webcam (Sony, California, USA) was used to detect markers projected on the table. *Musiquence* detects the markers automatically through a tracking system - AnTS [43]. We laid a white paper surface on the table to enhance the contrast between the table and projected activities. Two external speakers were used during the experiment. The setup is shown in Fig. 1.

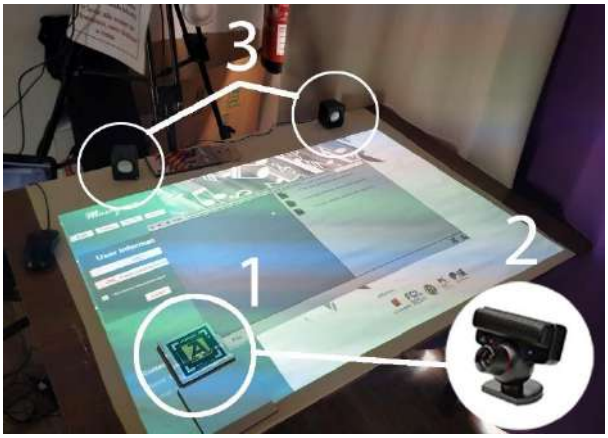


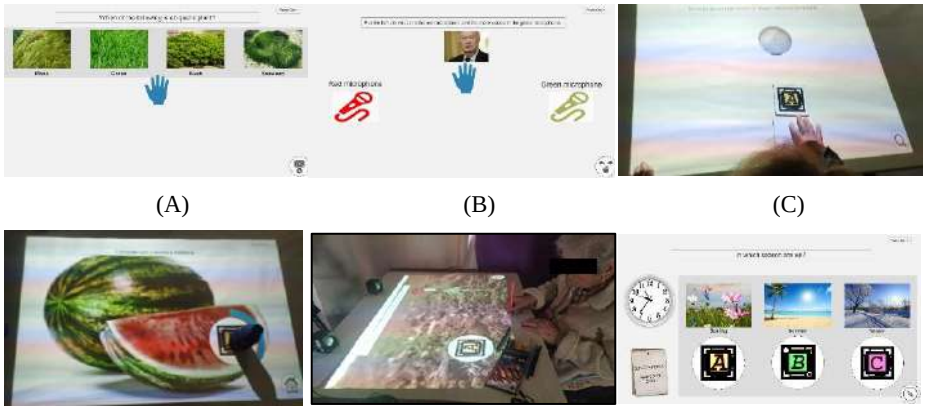
Fig 1. Projection-based augmented reality system. 1) Physical object with a marker attached to it. 2) PSEye camera attached to the projector to track the position of the physical objects. 3) External speakers for the music and feedback. The table was covered with a white sheet of paper to enhance the contrast of the virtual projection.

2.1 Musiquence

Currently, *Musiquence* offers 5 CS activities and one reality orientation activity. The activities were developed using the *Musiquence's* Game Editor; these are game-like activities where participants had to successfully complete each task to proceed in the game. On successful completion of all the tasks, the participants were applauded with the message *"Congratulation! You finished the game."* All activities are described below:

- ***Quiz activity*.** In this activity, PwD must select the correct answer to a given question. It aims to stimulate memory (Fig. 2 - A).

- ***Association activity***. In this activity, participants must associate an answer to the correct container. The activity is designed to stimulate associative memory and executive functioning (decision-making) (Fig. 2 – B).
- ***Search activity.*** Here, participants must find hidden answers using a virtual magnifying glass. The activity is designed to stimulate attention, memory, and executive functioning (planning) (Fig. 2 – C).
- ***Activity of Daily Living.*** Participants must complete a set of daily living-related activities using real objects. It aims to target memory and selective attention (Fig. 2 – D).

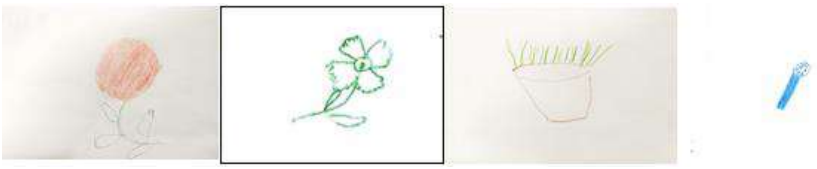


(A) (B) (C)

(D) (E) (F)

Fig. 2. *Musiquence activities*. (A) Quiz activity of "Fowers" theme. The participant had to select the correct answer. (B) Association activity of "Public Figures," theme. The participant had to associate the picture and drag it to the correct container. (C) Search activity of ”Foods" theme. Through the virtual magnifying glass, the participant had to find images of, for example, peppers. (D) Bottles with fruit aromas in the ADL activity of ”Foods" theme. The participant had to recognize and select the correct scent of the fruit and place it on the marker. (E) Creative activity of "Flowers". The participant had to draw the missing piece (e.g., a flower) and place it in the correct location. (F) Reality orientation activity. The participant had to select the right answer, according to the orientation information provided.

- ***Reality Orientation***. This activity aims to assist PwD in recalling the date and place in which they are currently present. It is designed to target orientation faculties (Fig. 2 – F).
- ***Creative Painting activity***. Participants must complete the missing parts of a drawing by adding physical drawings. It is designed to target memory and fine and gross motor skills (Fig. 2 – E). Examples of drawings made in this study are shown in Fig. 3.



(A) (B) (C) (D)

Fig. 3. Here, we show four drawings made by the participants for the Creative Painting activity. (A) "Carnation" drawing to complete a creative activity of the "Festivities" theme. (B) "Clover" drawing to complete a creative activity of the "Flowers" theme. (C) "Wheat" drawing to complete a creative activity of the "Regional Traditions" theme. (D) "Microphone" drawing to complete a creative activity of the "Public Figures" theme.

Interaction. Participants must manipulate a physical object with a marker attached to it to interact with the Quiz, Association, and Search activities (Fig.4). A virtual cursor follows the physical object's position as the participant moves it. To interact with the remaining activities, participants must occlude markers with their hands or a physical object. For example, in the Activity of Daily Living, participants must select the correct physical object among "distractor" objects and place it at the marker location. As for the Creative Painting activity, participants must create physical drawings and place them on the markers of a virtual painting. Lastly, in the orientation activity, participants must select the correct answer by occluding the markers with their hand.

Whenever a selection is performed (the cursor collides with an answer or the markers are occluded), a 4-second timer is activated (Fig. 4). When the timer reaches 0, one of the following types of feedback is provided to the participant. For example, in the Quiz, Orientation, and Association activities - "very good" - is activated when participants select the correct answer, while - "Ohh, try again" – is activated when selecting the wrong answer. In addition, *Musiquence* provides musical cues to the participants when making erroneous decisions while performing tasks [10]; during the 4 seconds, the background music becomes distorted. Similarly, in the Search activity, background music becomes distorted based on distance to aid participants in identifying the hidden images. Correspondingly, the more the participant is further away from the image, the more distorted the music becomes. Regarding the remaining activities (Search activity, Activity of Daily Living, and Creative Painting), only "very good" is activated as there are no wrong answers. Furthermore, the music was played normally without musical cues (except for the Search activity).

Fig. 4. Participant manipulating a physical object with a marker that controls the virtual cursor. The activation of the 4-second timer when selecting an answer.

Content customization. To create the content for the *Musiquence* activities, we performed a participatory design approach with 20 PwD and 19 HP to uncover this population's general preferences. From the interviews with the HP, we gathered a total of 21 themes. From the 21 themes, we selected the 14 most frequent ones. Then, we presented four representative images of each theme with written labels to 20 PwD. PwD selected their favorite ones, resulting in a total of seven favorite themes: Public Figures, Festivities, Flowers, Agriculture, Regional Typical Recipes, Foods, and Regional Traditions. We also collected information regarding musical preferences. 81 Portuguese songs were mentioned, most of these Portuguese from before the year 2000, and from these, we selected the seven most referred by HPs to match the seven preferred themes. These themes and songs were used to create the customized music and reminiscence CS program for PwD.

2.2 Participants

Participants were eligible if (1) they were between initial or intermediate stages of dementia (assessed through MMSE, and formal diagnosis provided by a psychiatrist or neurologist), (2) they were able to use their arms independently, (3) they had a good hearing and visual ability, and (4) had good comprehension skills. Participants did not participate if (1) they were at advanced stages of dementia, (2) if they had diagnoses of previous psychiatric disorders, (3) had severe depressive symptomatology, and (4) if they were bedridden. Participants were recruited from different healthcare centers. Participants 1, 2, 4, and 5 were from the Centro Social e Paroquial da Ribeira Brava (nursing home), participants 6, 7, and 8 were recruited from Casa de Saúde Câmara Pestana (nursing home), and participant 3 was recruited from Centro de Dia Lugar de Memórias (daycare center). Only female participants were included in this pilot study, but we intend to recruit male participants during the longitudinal study. The assessment and intervention sessions were performed at the same place where the participants stayed. The demographic information of the participants is shown in Table 1.

Table 1 – PwD Demographics

ID	Diagnoses	MMSE*	Gender	Age	Schooling**
1	Vascular Dementia	14	Female	86	3
2	Lewy-Body Dementia	26	Female	76	3
3	Alzheimer's Disease	23	Female	80	3
4	Alzheimer's Disease	10	Female	73	4
5	Non-specified dementia	13	Female	83	3
6	Alzheimer's Disease	28	Female	87	12
7	Alzheimer's Disease	15	Female	77	3
8	Alzheimer's Disease	24	Female	74	4

* MMSE values obtained before initiation of the study.

** Schooling values are based on the participants' formal education.

3 Procedure

Our study was approved by Casa de Saúde Câmara Pestana's Ethics Committee, and all participants signed informed consent before initiating the study. Participants were invited to be seated, one at a time, in a quiet room. Before beginning the study, participants had to sign a formal consent. The experimental trial duration was based on the CST principle [1]; we performed 14 sessions, twice per week, of 30 to 45 minutes each, spread over seven weeks. Each week corresponded to a cycle of tasks, meaning that all of the activities available in Musiquence were played once. To which a cycle of tasks corresponded one song and one theme.

The activities were all in Portuguese, and the participants were native speakers. All the participants performed all the tasks in a randomized order. A psychologist was present during all sessions. The experimental sessions were filmed to be later used as complementary data. PwD were assessed before the intervention (pre) and immediately after the intervention (post). The assessment protocol was divided into two sessions of approximately 30 minutes each. In the first two sessions, a certified psychologist performed the pre-neuropsychological assessment (as described in section 4). In the following sessions, PwD were invited to perform the customized music and reminiscence-based CS program using *Musiquence*. The psychologist re-assessed PwD after finishing the intervention sessions (see section 4).

4 Instruments and Metrics

In a population such as PwD, with a neurodegenerative process, the expected evolution over time in cognitive function is a steady decline. Moreover, specific instruments need to be used in PwD as comprehension and expression abilities are strongly affected by their condition. Hence, to evaluate the impact of the customized music and

reminiscence-based CS program in the progression of the condition in PwD, we defined a neuropsychological assessment protocol to assess cognition and QoL. To assess cognition, we used the following instruments:

- ***MMSE***. The MMSE is a 30-point cognitive screening tool validated for dementia [14, 28] that assesses six domains: orientation (time and place), retention, attention and calculation, recall, language, and constructive ability. Higher scores relate to lower deficits [35].
- ***ADAS-Cog*.** It is a Dementia specific brief battery with a 50-score maximum that assesses word recall, naming, commands, constructional praxis, ideational praxis, orientation (time and place), spoken language ability, word-finding difficulty, and comprehension of oral language. Higher scores relate to greater deficits [22].
- ***Kettler Laurent Thierrau (KLT)*.** It is a divided attention assessment tool with 12 lines with 20 squares in which each square differs in the orientation of an exterior line. The participants had four minutes to select as many squares as possible. The selection is based on three examples that are presented on the top of the sheet. The total provides a dispersion index, and Higher scores relate to greater deficits [19].
- ***"Symbol Research" (SR) and "Digit-Symbol Coding" (DSC)*.** Subtests of the Weschler Adult Intelligence Scale (WAIS-III) – SR measures information processing speed and visual perception. The total is obtained by subtracting the errors by the number of hits. DSC measures the speed of processing and executive functioning. The total of hits determines the total score. Greater scores relate to lower deficits [41].
- ***Semantic and Phonemic Verbal Fluency Test***. In semantic fluency, the participant has one minute to say the maximum number of words belonging to each category: foods found in the supermarket and animals. In phonemic fluency, the participant has one minute to say the maximum number of words that begin with each letter: "M," "P," and "R." It assesses processing speed, language production, and executive functions, and the greater the number of words, the better the participant's performance. Greater scores relate to lower deficits [7].
- **Quality of Life-Alzheimer's Disease scale (QoL-AD).** To assess participants' QoL, we used a 13-item assessment scale developed for individuals with Alzheimer's Disease. It allows the assessment of the QoL through self-perception. Higher scores relate to greater perceived quality of life [4].

The same versions of the instruments were used in pre and post interventions by the same order. Also, all the instruments were administrated in one session.

5 Results

All participants finished all the sessions in the seven weeks. To evaluate the impact of our customized music and reminiscence-based CS program on cognition, we used the cognitive and QoL assessment protocol (Table 2).

Table 2 – Pre and Post results of neuropsychological assessments. Results in *bolt* and *underline* indicate improvements in the neuropsychological assessments.

ID	MMSE		*ADAS-Cog*		*QoL-AD*		*KLT*		*WAIS III*				*Semantic Verbal Fluency Test*				*Phonemic Verbal Fluency Test*					
									Symbol re-search		Digit-Symbol Coding		Ani-mals		Foods		M		P		R	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
1	14	**15**	25	**20**	32	23	98.89	**94.45**	5	4	7	5	7	**10**	12	**14**	2	**3**	7	5	4	4
2	26	**27**	14	**10**	30	**36**	97.78	100	7	6	5	**7**	9	9	11	9	2	**3**	6	6	5	5
3	23	23	24	**23**	37	**41**	95.56	100	7	6	8	**10**	7	**10**	15	11	4	**7**	12	10	7	7
4	10	**13**	40	**37**	35	33	100,00	100	8	**9**	2	**4**	6	5	9	5	5	**8**	7	3	4	3
5	13	11	30	37	37	35	94,44	100	4	4	2	**6**	2	1	4	3	0	**1**	0	0	1	0
6	28	26	10	14	21	**22**	81,12	**44,4**	12	8	3	**6**	16	12	13	**18**	5	**6**	9	7	10	9
7	15	13	30	40	25	25	100	**44,4**	3	6	2	2	3	3	1	**3**	1	**2**	2	2	4	2
8	24	21	26	**22**	31	**37**	86,67	**0**	11	10	4	**8**	13	13	16	15	6	6	9	**10**	8	8
mean	19,1	18,6	24,9	25,4	31,0	31,5	93,0	72,9	7,1	6,6	4,1	6,0	7,9	7,9	10,1	9,8	3,1	4,5	6,5	5,4	5,4	4,8
mean post-pre	-0,5		0,5		**0,5**		**-20,1**		-0,5		**1,9**		0,0		-0,4		**1,4**		-1,1		-0,6	

5.1 Assessment of general cognition

Regarding general cognition, as assessed by the MMSE, participants 1, 2, and 4 scored higher in the post-assessment than in the pre-assessment results. In the ADAS-Cog, participants 1, 2, 3, 4, and 8 demonstrated fewer deficits. Participant 3 maintained the results as assessed by the MMES while improving in the ADAS-Cog assessment.

5.2 Assessment of quality-of-life

To assess the impact of our intervention in QoL, we used the QoL-AD assessment tool. Participants 2, 3, 6 and 8 reported improvements in self-perceived QoL, whereas participants 1, 4 and 5 worsened. Participant 7 remained stable.

5.3 Assessment of verbal fluency

As for verbal fluency, as assessed by the Semantic Verbal Fluency Test, participants 1 and 3 were able to mention a higher number of animals. Participants 2, 7, and 8 reported

the same number of animals compared to pre-assessment. The remaining participants worsened. Participants 1, 6, and 7 reported a higher number of foods, while the remaining participants lowered performance. To complement the Semantic Verbal Fluency Test, we used the Phonetic Verbal Fluency Test. The results show that participants 1 to 7 were able to mention a higher number of words starting with "M" in one minute. Participant 8 maintained the same performance when comparing pre-and post-assessment. Considering words starting with "P," only participant 8 enhanced performance, and participants 2, 5, and 7 expressed the same number of words in both assessments. Regarding the letter "R," participants 1, 2, 3 and 8 mentioned the same number of words, while participants 4 to 7 had a lower performance

6 Discussion

Here, we present the results of a pilot 14-session longitudinal study that quantifies the impact of an interactive, customized cognitive stimulation program using *Musiquence* in PwD. In our customized cognitive stimulation program, we aimed to potentiate the effect of reminiscence and music by developing our cognitive stimulation activities based on a participatory design approach in which we collected the favorite themes and songs of PwD living in Madeira Island in Portugal. This set of activities, incorporated on *Musiquence*, aimed to stimulate general cognition. Overall, the results obtained in this study are very promising, as all participants did show improvements in at least two of the cognitive and QoL assessment instruments. Combining customized music and reminiscence elements in a game-like context seems to impact participants' well-being positively. Also, we analyzed (1) specific domains commonly affected by this disease, such as language, executive functioning, and attention, and (2) its larger impact on the PwD's life through the assessment of QoL.

Firstly, our results consistently show that all our participants benefited from the intervention in some aspects. Since our cognitive stimulation program (1) did not aim to train any specific cognitive domain but to stimulate general cognition and (2) our sample of PwD was very heterogeneous, it was expectable that our participants would show different results in the different cognitive domains assessed.

The results are consistent considering the general cognition assessment measures (MMSE and ADAS-Cog). All the participants that improved or maintained their performance of MMSE also improved or maintained their performance on ADAS-Cog. Since the ADAS-Cog assesses cognitive domains impaired explicitly in dementia, it would be expected to observe a cognitive decline in such population. Although participants had a worse mean performance in our general cognition assessment measures, there was only a 0.5 (out of 30) difference in both MMSE and ADAS-Cog. Since an exponential decline of cognitive functioning characterizes dementia, achieving steadiness (no changes in general cognition) is considered a positive outcome. Thus, the

performing of regular music and reminiscence-based activities through SG could be beneficial in achieving cognitive stimulation, as reported, for example, in studies [6, 30].

Regarding the impact of our program in specific cognitive domains, results were not even. For example, despite divided attention (as assessed by KLT) never being the target of our training, several of our activities (i.e., Association and Quiz) demanded some level of this ability. Despite all our participants showing high dispersion indexes on pre-assessment, our results show lower mean dispersion indexes after the intervention. This translates to an improvement in the ability to pay attention to more than one stimulus at a time.

Regarding the attention assessments, most of our participants worsened their performance on SR, showing a mean difference of -0.5 points on post-assessment. Interestingly, our results showed an improved mean difference of about 1.9 points on post-assessment on the DSC. The main difference between these two subtests of WAIS-III relies on how SR demands visual perception abilities, as participants need to discriminate between abstract symbols. Throughout the performance of our activities, participants only had to discriminate familiar, meaningful stimuli. Although these results may also be consistent with visual perception deficits related to dementia [3], we did not observe difficulties from our participants in discriminating the stimuli presented.

As for language, all participants improved or maintained their performance in one or more of our semantic and phonemic verbal fluency assessment measures. Although language aspects were not directly stimulated in any of our activities, communication was present in all our sessions through the Reality Orientation Activity (performed every session before the cognitive stimulation activities). In the other activities (i.e., Quiz, Association, and Search), it was very frequent for the participants to answer and justify their answers before acting on *Musiquence*. Similar reports regarding verbal fluency improvements after musical activities in PwD were verified by Brotons et al. [5]. Again, combining music and reminiscence approaches in a serious game could be beneficial in achieving linguistic outcomes.

Considering self-perceived QoL, results showed a higher mean score of perceived QoL on post-assessment. Although this is a very positive outcome, and previous studies reported enhancement of QoL through CS activities (i.e., reminiscence-related activities) [37], it is important to consider that this may not be directly associated with perceived cognitive improvement. Most of our participants are integrated into nursing homes, where they do not perform many daily activities. At some point in the intervention, most participants were happy to have a weekly routine and perform different activities.

Additional behavioral changes in PwD have been observed during the intervention. For example, in the first sessions, participants generally showed difficulties manipulating the physical object with the attached marker. The marker could not be covered, or

else *Musiquence* would not be able to track it. Throughout the sessions, all our participants learned how to use the physical object without covering the marker, and, in the last sessions, they would do it autonomously, showing some signs of practice learning. Moreover, all participants learned to interact with the virtual environment. In the first sessions, they would move the physical object outside the virtual environment's limits, which resulted in tracking-related problems. In the last sessions, none of our participants needed to be reminded of the virtual environment's limits. Such similar behaviors were seen in a previous study in which we studied different interaction modalities using AR-based setup [2].

Another interesting finding was that all participants could recognize the psychologist that performed the cognitive stimulation intervention, even though they only met during the intervention. Although most participants could not remember the theme of the activities or the type of activities performed, participants were able to associate the psychologist as the person who would take them to perform activities using a computer. For example, participants 2, 6, and 8 were able to remember the psychologist's name and the schedule in which they would perform the activities. Participants reported enjoying performing the activities since the content was familiar to them. Commonly, participants would recall specific memories when performing the activities (e.g., participant 3 recognized a TV host in the activities involving "Public Figures" since it was a TV host she used to watch daily). Participants were also very receptive to the songs used in the activities. All participants sang during the activity performance while recalling memories. For example, when playing the song "Mula da Cooperativa" (a song with a humoristic connotation), participant 1 would laugh, referring that her kids used to sing this song when they were younger. It was common for the participants to appreciate the themes used during the intervention as they reminded them of previous experiences.

7 Conclusion and ongoing work

The results of this study are promising even though our results are heterogeneous. Every participant improved their performance on one or more of the assessed cognitive domains. Moreover, participants enjoyed performing the activities as they sang while remembering the positive aspects of their past. However, this work has some limitations as we do not have a control group, limiting the ability to assess the impact of the intervention and anticipate cognitive decline in this population. To this end, we aim to extend this pilot study with more participants (a total of 16 participants) to provide further evidence regarding the therapeutic effects of Musiquence in the PwD. Also, we plan to gather follow-up results at 3 and 6 months after the cognitive intervention regarding the long-lasting effects that the platform has on such populations.

Acknowledgments

We would like to thank the participants, health professionals, and health institutions – Centro Social e Paroquial da Ribeira Brava and Centro de Dia Lugar de Memórias – for joining the study. This project is supported by the Portuguese Foundation for Science and Technology under project NOVA-LINCS (PEest/UID/CEC/04516/2019) and BRaNT [Belief Revision applied to Neurorehabilitation Therapy (FCT: 02/SAICT/2017)].

References

1. Aguirre E, Hoare Z, Streater A, Spector A, Woods B, Hoe J, Orrell M (2013) Cognitive stimulation therapy (CST) for people with dementia—who benefits most? International journal of geriatric psychiatry 28:284–290
2. Andrade Ferreira LD, Cavaco S, Bermúdez i Badia S (2018) Feasibility Study of an Augmented Reality System for People with Dementia. The Eurographics Association
3. Association A (2017) 2017 Alzheimer's disease facts and figures. Alzheimer's & Dementia 13:325–373
4. Bárrios HSG (2012) Adaptação cultural e linguística e validação do instrumento QOL-AD para Portugal. PhD Thesis
5. Brotons M, Koger SM (2000) The impact of music therapy on language functioning in dementia. Journal of music therapy 37:183–195
6. Bruer RA, Spitznagel E, Cloninger CR (2007) The temporal limits of cognitive change from music therapy in elderly persons with dementia or dementia-like cognitive nmpairment: A randomized controlled trial. Journal of music therapy 44:308–328
7. Cavaco S, Gonçalves A, Pinto C, Almeida E, Gomes F, Moreira I, Fernandes J, Teixeira-Pinto A (2013) Semantic fluency and phonemic fluency: regression-based norms for the Portuguese population. Archives of Clinical Neuropsychology 28:262–271
8. Djaouti D, Alvarez J, Jessel J-P (2011) Classifying serious games: the G/P/S model. In: Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches. IGI Global, pp 118–136
9. El Haj M, Postal V, Allain P (2012) Music enhances autobiographical memory in mild Alzheimer's disease. Educational Gerontology 38:30–41
10. Ferreira L, Spínola M, Câmara J, i Badia SB, Cavaco S (2021) Feasibility of Pitch and Rhythm Musical Distortions as Cueing Method for People with Dementia in AR Cognitive Stimulation Tasks. In: 2021 IEEE 9th International Conference on Serious Games and Applications for Health (SeGAH). IEEE, pp 1–8
11. Ferreira LDA, Cavaco S, i Badia SB (2019) Musiquence: a framework to customize music and reminiscence cognitive stimulation activities for the dementia population. In: 2019 5th Experiment International Conference (exp. at'19). IEEE, pp 359–364
12. Ferreira LDA, Ferreira H, Cavaco S, Cameirão M, i Badia SB (2020) User experience of interactive technologies for people with dementia: comparative observational study. JMIR serious games 8:e17565
13. Fitzgerald M, Ratcliffe G (2020) Serious Games, Gamification, and Serious Mental

Illness: A Scoping Review. Psychiatric Services 71:170–183

14. Freitas S, Simões MR, Alves L, Santana I (2015) Mini Mental State Examination (MMSE): Normative study for the Portuguese population in a community stratified sample. Appl Neuropsych Adults 22:311–9

15. Gerdner LA, McBride MR (2015) Individualized Music Intervention for Agitation in Dementia Care and Disaster Preparedness. J Gerontol Geriatr Med 1

16. Gonzalez J, Mayordomo T, Torres M, Sales A, Meléndez JC (2015) Reminiscence and dementia: a therapeutic intervention. International psychogeriatrics 27:1731–1737

17. Guetin S, Portet F, Picot MC, Pommié C, Messaoudi M, Djabelkir L, Olsen AL, Cano MM, Lecourt E, Touchon J (2009) Effect of music therapy on anxiety and depression in patients with Alzheimer's type dementia: randomised, controlled study. Dementia and geriatric cognitive disorders 28:36–46

18. Karttunen K, Karppi P, Hiltunen A, Vanhanen M, Välimäki T, Martikainen J, Valtonen H, Sivenius J, Soininen H, Hartikainen S (2011) Neuropsychiatric symptoms and quality of life in patients with very mild and mild Alzheimer's disease. International journal of geriatric psychiatry 26:473–482

19. Kettler A, Laurent P, Thireau N (1964) Echelle KLT. Issy-Les-Moulineaux (France): Editions Scientifiques

20. Kola I, Landis J (2004) Can the pharmaceutical industry reduce attrition rates? Nature reviews Drug discovery 3:711–716

21. Kumar AM, Tims F, Cruess DG, Mintzer MJ, others (1999) Music therapy increases serum melatonin levels in patients with Alzheimer's disease. Alternative Therapies in Health and Medicine 5:49

22. Lilly MB, Robinson CA, Holtzman S, Bottorff JL (2012) Can we move beyond burden and burnout to support the health and wellness of family caregivers to persons with dementia? Evidence from British Columbia, Canada. Health & social care in the community 20:103–112

23. Marcinkowska M, Śniecikowska J, Fajkis N, Paśko P, Franczyk W, Ko\laczkowski M (2020) Management of dementia-related psychosis, agitation and aggression: a review of the pharmacology and clinical effects of potential drug candidates. CNS drugs 1–26

24. McCallum S, Boletsis C (2013) Dementia games: A literature review of dementia-related serious games. In: International Conference on Serious Games Development and Applications. Springer, pp 15–27

25. McDermott O, Crellin N, Ridder HM, Orrell M (2013) Music therapy in dementia: a narrative synthesis systematic review. International journal of geriatric psychiatry 28:781–794

26. Regan B, Varanelli L (2013) Adjustment, depression, and anxiety in mild cognitive impairment and early dementia: a systematic review of psychological intervention studies. International psychogeriatrics 25:1963–1984

27. Sachdev PS, Blacker D, Blazer DG, Ganguli M, Jeste DV, Paulsen JS, Petersen RC (2014) Classifying neurocognitive disorders: the DSM-5 approach. Nature Reviews Neurology 10:634–642

28. Santana I, Duro D, Lemos R, Costa V, Pereira M, Simões MR, Freitas S (2016) Mini-Mental State Examination: Avaliação dos Novos Dados Normativos no Rastreio e Diagnóstico do Défice Cognitivo. Acta Médica Portuguesa 29

29. Saposnik G, Teasell R, Mamdani M, Hall J, McIlroy W, Cheung D, Thorpe KE, Cohen LG, Bayley M (2010) Effectiveness of virtual reality using Wii gaming technology in stroke

rehabilitation. Stroke 41:1477–1484

30. Särkämö T, Tervaniemi M, Laitinen S, Numminen A, Kurki M, Johnson JK, Rantanen P (2014) Cognitive, emotional, and social benefits of regular musical activities in early dementia: randomized controlled study. The Gerontologist 54:634–650

31. Spector A, Orrell M, Davies S, Woods B (2001) Can reality orientation be rehabilitated? Development and piloting of an evidence-based programme of cognition-based therapies for people with dementia. Neuropsychological Rehabilitation 11:377–397

32. Starkstein SE, Ingram L, Garau ML, Mizrahi R (2005) On the overlap between apathy and depression in dementia. Journal of Neurology, Neurosurgery & Psychiatry 76:1070–1074

33. van der Steen JT, Smaling HJ, van der Wouden JC, Bruinsma MS, Scholten RJ, Vink AC (2018) Music-based therapeutic interventions for people with dementia. Cochrane Database of Systematic Reviews

34. Tanaka JW, Wolf JM, Klaiman C, Koenig K, Cockburn J, Herlihy L, Brown C, Stahl S, Kaiser MD, Schultz RT (2010) Using computerized games to teach face recognition skills to children with autism spectrum disorder: the Let's Face It! program. Journal of Child Psychology and Psychiatry 51:944–952

35. Tombaugh TN, McIntyre NJ (1992) The mini-mental state examination: a comprehensive review. Journal of the American Geriatrics Society 40:922–935

36. Tong T, Chan JH, Chignell M (2017) Serious games for dementia. In: Proceedings of the 26th international conference on World Wide Web Companion. pp 1111–1115

37. Tsai AY, Lee M-C, Lai C-C, Chou Y-C, Su C-Y (2019) The Outcomes of Cognitive Stimulation Therapy (CST) for Community-Dwelling Older Adults With Cognitive Decline in Taiwan. Topics in Geriatric Rehabilitation 35:306–312

38. Ueda T, Suzukamo Y, Sato M, Izumi S-I (2013) Effects of music therapy on behavioral and psychological symptoms of dementia: a systematic review and meta-analysis. Ageing research reviews 12:628–641

39. Van de Winckel A, Feys H, De Weerdt W, Dom R (2004) Cognitive and behavioural effects of music-based exercises in patients with dementia. Clinical rehabilitation 18:253–260

40. Wattanasoontorn V, Boada I, García R, Sbert M (2013) Serious games for health. Entertainment Computing 4:231–247

41. Wechsler D (2001) WAIS-III: Wechsler adult intelligence scale 3rd ed. Canadian Technical Manual) Harcourt Canada

42. Woods B, Aguirre E, Spector AE, Orrell M (2012) Cognitive stimulation to improve cognitive functioning in people with dementia. Cochrane Database of Systematic Reviews

43. AnTS (Version 2.x) [software]. Retrieved from https://neurorehabilitation.m-iti.org/tools/. Accessed 10 Jun 2020