Enhancing Dementia Care with Social Robot-Guided Music Interventions

Tyler Morris 0000-0001-7800-8940
Department of Mechanical, Aerospace, and Biomedical Engineering
University of Tennessee
Knoxville, TN, USA
tmorri35@vols.utk.edu

Sydney Walker 0000-0003-1153-641X
Department of Mechanical, Aerospace, and Biomedical Engineering
University of Tennessee
Knoxville, TN, USA
swalke9@vols.utk.edu

Laython V. Holder 0009-0005-6902-2018
Department of Mechanical, Aerospace, and Biomedical Engineering
University of Tennessee
Knoxville, TN, USA
layvhold@vols.utk.edu

Eric Vaughan 0009-0001-8450-6476
Min Kao Department of Electrical Engineering & Computer Science
University of Tennessee
Knoxville, TN, USA
evaugha3@vols.utk.edu

Darina V. Petrovsky 0000-0002-3109-1633
School of Nursing
Duke University
Durham, NC USA
darina.petrovsky@duke.edu

Sai Swaminathan 0000-0002-6696-0536
Min H. Kao Department of Electrical Engineering and Computer Science
The University of Tennessee
Knoxville, TN USA
sai@utk.edu

Xiaopeng Zhao 0000-0003-1207-5379
College of Emerging and Collaborative Studies
The University of Tennessee
Knoxville, TN USA
xzhao9@utk.edu

***Abstract*—To address the need for dementia care, we developed a novel social robot-guided music intervention system named the Music intervention Using Socially Engaging robotics (MUSE). Utilizing the state-of-the-art Pepper robot, this system is an innovative fusion of music therapy and advanced human-robot interaction techniques. The system seeks to provide care that provides benefits to the overall well-being of persons with Alzheimer's disease or related dementia (PwADRD) while also providing relief to overburdened caregivers. To assess user acceptance and areas of improvement of the MUSE system, we conducted a series of workshops with PwADRD. Participants were guided through a MUSE session by the social robot and then asked to provide their feedback on the system through a survey and semi-structured interview. Following the workshops, it was found that PwADRD were very accepting of the MUSE system, both in terms of the social robot, the musical activities, and applications. Several areas of possible improvement were also identified, including system volume and visibility. This research not only demonstrates promising user acceptance but also paves the way for a new era in therapeutic interventions, blending technology and music therapy in an unprecedented manner.**

Keywords*—*dementia, social robot, music intervention

I. Introduction

The Alzheimer's Association notes a significant rise in persons with Alzheimer's Disease or related dementia (PwADRD), projecting an increase from 6.7 million in 2023 to 13.8 million by 2060 [1]. However, the surge in demand for PwADRD care surpasses the growth in available caregivers, intensifying caregiver burden [1-2]. Addressing this challenge requires additional care that enhances PwADRD well-being while easing caregiver responsibilities.

Music intervention is an increasingly popular therapeutic approach benefiting cognitive, physical, and emotional well-being in PwADRD [3-8], but its widespread application is hindered by the need for interventionists [3-8]. Social robotics emerges as a solution, offering autonomous interaction to supplement care and alleviate caregiver burden [9, 21-22]. Studies confirm PwADRD's positive response to social robots across various applications [10, 11-15].

To meet the demand for enhanced dementia care, we propose the Music intervention using Socially Engaging robotics (MUSE) system, employing the Pepper robot for a structured music intervention session. The MUSE integrates music activities led by the robot, promoting cognitive, physical, and emotional well-being.

While previous research combined robots and music intervention, most focused on children with autism [16-18], and few addressed PwADRD [19, 23]. The MUSE system addresses these gaps, providing a comprehensive, participant-engaging music intervention guided by the social robot.

This paper outlines MUSE's development and reports preliminary usability results from workshops evaluating PwADRD interaction at assisted living facilities. The goal is to gauge initial end-user acceptance and identify potential areas for improvement.

II. The MUSE System

A. The Pepper Robot

The Pepper robot is a humanoid social robot [24]. As seen in Figure 1, the Pepper robot features a touch-screen tablet embedded in its chest as its main form of user interface [24]. This tablet is used to display buttons, lyrics, and any other visuals for the MUSE program. The robot can also move and gesture for dances, as well as speak to give directions.

B. The MUSE App

Our interdisciplinary team developed the MUSE app using Android Studio and Pepper SDK to control the Pepper robot in the MUSE system. This app features three engaging music activities: the "Keep-With-the-Rhythm" game, a "Sing-Along," and a "Dance-Along," as illustrated in Figure 2.

2832-2975/24/$31.00 ©2024 IEEE
DOI 10.1109/CHASE60773.2024.00024

Upon launching the app, a warm greeting from the robot introduces participants to MUSE. The interface is user-friendly, explaining buttons like 'next,' 'back,' 'repeat,' and 'main menu.' Participants can customize their experience by choosing a session duration of 5 or 10 minutes, with flexibility based on engagement.

The first activity, "Keep-With-the-Rhythm," serves as an introduction to musical engagement. The robot guides participants to tap along with a metronome displayed on the screen. This rhythmic tapping occurs at three different beats per minute (75, 95, and 115 BPM), lasting for one minute each or as desired by the group. After completing this, the app seamlessly transitions to the next activity.

Before diving into the "Sing-Along," participants get to choose a music genre, such as country featuring Dolly Parton or rock n' roll featuring Elvis Presley. Future updates plan to expand the genre options through a cloud-based server. The robot then leads participants in singing along to the displayed lyrics, with the option to tap along to the metronome. The robot remains still during this activity, ensuring participants can comfortably read the lyrics on the screen.

Fig. 1. The Pepper robot displaying the introduction of the MUSE app

The final activity, the "Dance-Along," begins with the robot recommending participants find a comfortable seat to minimize injury risks. Participants are then encouraged to dance while seated, with the option to tap to the metronome. The robot plays music, displaying lyrics and a metronome, and adds a pre-programmed animation to dance to the beat. After the song concludes, the robot expresses gratitude to the participants, encouraging them to return for future MUSE sessions.

We designed the MUSE app after meeting with various experts in the field of ADRD care, music intervention, and human-robot interactions. We met with these experts at various points of the developmental process and asked them about various aspects of the design in an informal setting; their inputs from these meetings were crucial to the development of the MUSE system. The structure of the MUSE session, for example, was designed to reflect traditional music intervention sessions that are commonly held for PwADRD. Consulting with experts on music for PwADRD, we determined that three simple activities were the best for retaining engagement levels and increasing user acceptance. Furthermore, the design of the MUSE app was created with PwADRD in mind. Our

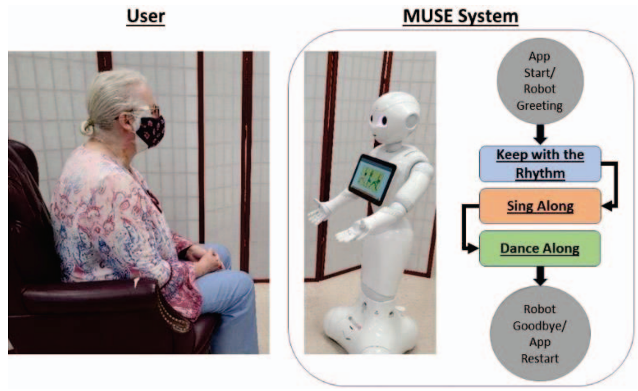

Fig. 2. Breakdown of the MUSE app, with a participant (left) and the MUSE system (right)

collaborators in human-robot interaction as well as those in PwADRD care suggested large, easy-to-read and press buttons and loud speaking volumes. These experts also suggested designs for the workshops we conducted, including questions to be asked during the survey/interview. These details are discussed in the next section. Overall, our interdisciplinary team helped create the MUSE app in a way that accounted for the target audience while also making the most of music intervention and the robot technology.

III. Methods

To evaluate the user acceptance of this initial version of the MUSE system, we hosted two workshops with PwADRD in assisted living facilities. The purpose of the workshops is for PwADRD to engage in a MUSE session, and then share their opinions on the system and its various components. From this, we plan to make improvements to the MUSE system to better appeal to the target audience. The workshop plan and set-up were approved as a part of UTK IRB-23-07526-XP.

The set-up for the workshops is straightforward. First, a group of willing PwADRD participants (no more than 10) are gathered in a designated area at an assisted living facility. Then, a research team member gave a brief introduction to the workshop and explained what exactly would occur. Participants were then assisted in filling out a brief demographic survey. Afterward, they completed a 10-minute MUSE session with the social robot, as described previously. After the session, participants were encouraged to complete a brief post-experimental survey. After the survey, the research assistant hosted a brief, semi-structured interview. This allowed the participants to voice their thoughts and opinions not covered in the survey. During the entire session, audio and video data were recorded via GoPro cameras installed around the room. Throughout the session, a member of the research team operated the robot, just as a caregiver would in a fully deployed system.

The post-experimental survey is a 17-question survey. All but three questions are on the 5-point Likert scale, with 1 representing “strongly disagree” and 5 representing “strongly agree.” The other three questions are open-response questions, where participants can write out their answers to the question. The questions on the survey are based on the Universal Theory of Acceptance and Use of Technology, which examines the acceptance of a novel piece of technology on four points: performance expectancy, effort expectancy, social influence, and facilitating conditions [20]. Using the survey in conjunction with the semi-structured interview, we were able to gauge the user acceptance of the PwADRD that interacted with the MUSE system, as well as identify areas of improvement.

IV. Results

A. Demographics and Participant Background

Across the two workshops that have been held so far, a total of 15 PwADRD participated in a MUSE session and provided their feedback. The demographics of these participants can be seen below in Table 1. Please note that not all questions total 15 responses; this is because the PwADRD often had trouble answering questions and, even with assistance, refused to provide some responses.

The demographic data shows a fairly even spread of ages and education, but there were more females than males and far more Caucasians than other ethnicities. This might have resulted in some biases in the data, but this is minimal. Additionally, this is a known problem when recruiting hard-to-reach vulnerable populations [25].

TABLE I. Demographics of PwADRD participants

Demographic	Responses (#)
Age	
45-54	1
55-64	1
65-74	3
75-84	3
85-94	2
95+	3
Gender	
Male	4
Female	11
Education	
6th grade or less	1
High school graduate or equivalent	4
Some college	4
College Graduate	2
Post-graduate	2
Ethnicity	
Caucasian	12
African American	1
Native American	2

As part of the survey, data on the familiarity and general acceptance of technology by participants and their experience with music were taken. From this, two patterns are observed. First, PwADRD are not familiar with newer forms of technology, including smartphones and tablets. This is especially true for their familiarity with robots, with only a single participant being slightly familiar with them and the rest being unfamiliar. However, many participants believed that a robot would be helpful in their daily lives, and nearly all would like a robot to guide them through a music-based exercise. Additionally, all participants would like to control the robot through speech, although two would also like a tablet control. Second, virtually all forms of music are liked, and 8 of the 15 participants had experience with music in the past. As such, the participants in this workshop come from a variety of backgrounds with a wide variety of experiences and opinions.

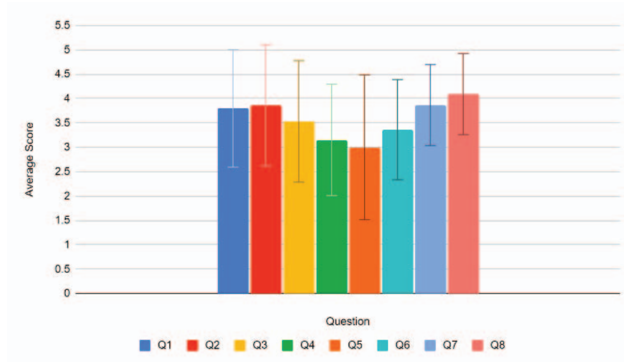

Fig. 3. Survey Results from Section 1: Regarding the Social Robot; Average score and standard deviation

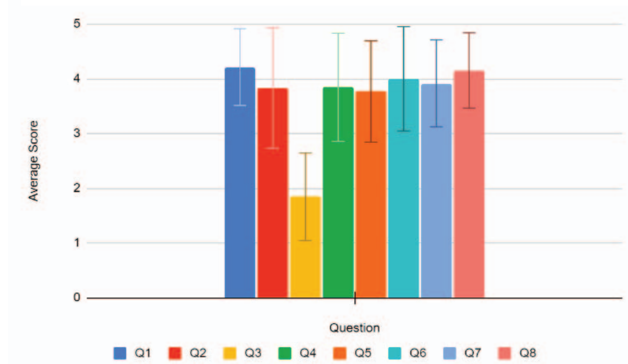

Fig. 4. Survey Results from Section 2: Regarding the MUSE App; Average score and standard deviation

B. Quantitative Results

Following their participation in a MUSE session guided by the social robot, PwADRD participants were invited to complete a post-experimental survey. The survey was broken down into two sections, one on the social robot and the other on the MUSE app. All of these questions were on the Likert scale, with 5 representing 'strongly agree' and 1 representing 'strongly disagree'. Note that Q3 in section 2 regarding the MUSE app has an inversed target, as it is the only question with a negative connotation. It asks participants if they think negatively about the views of others, so the ideal response would be 'strongly disagree'. The average results of these survey questions are displayed in Figures 3 and 4.

TABLE II. Open-Ended Questions and Responses

Do you have any additional comments regarding the robot and its functions/design?
I love how this robot looks and it's amusing and fun.
More personal compared to radio
It would help if it was closer to the people. I had trouble hearing and seeing it.
Do you have any additional comments regarding the MUSE app?
Keep up the good work.
Thank you. I think your “MUSE” is a very good idea and well worth continuing your research.

It’s a more personal approach. Others can participate.
Smaller groups so people can hear and see better. Maybe earphone extensions for people.

C. Qualitative Results

a) Qualitative survey responses: Table 2 displays limited open-ended responses from the post-experimental survey. Participants praised the robot and MUSE app for their engaging design but expressed a major concern about volume, with some older adults struggling to hear. Of the 15 respondents, 10 felt the MUSE system would improve their mental well-being, 12 believed in physical benefits, and 9 anticipated emotional improvement.

b) Audio/video analysis: Real-time data collection during sessions revealed widespread enjoyment, with participants tapping, singing, and mimicking the robot's movements. Some showed less reaction but engaged with the metronome throughout.

c) Semi-structured Interview Results: Participants appreciated the social robot's appearance, particularly its bow and feminine features. Despite complaints about its sound, responses were generally positive. Keep-with-the-Rhythm received mixed feedback, with one finding it confusing, while others enjoyed it. Sing Along was universally praised, although participants wished for better visibility of displayed lyrics. The fewer responses for Dance Along still expressed enjoyment, with one likening it to a daily exercise routine. Overall, the semi-structured interview highlighted positive experiences with the social robot, the MUSE app, and its activities.

V. Discussion

A. Regarding the Social Robot

Workshop results reveal positive responses to the social robot in the MUSE system. Figure 3 displays favorable feedback on the robot's face, eyes, body, and tablet. Some participants found the tablet too small, suggesting possible improvements like projecting onto a larger screen or connecting a speaker for better visibility and volume. Participants were least receptive to the robot's voice (score of 3), with varying opinions reflected in a high standard deviation. This aspect could be enhanced in future iterations, considering past successes in altering robot voices.

Surveyed aspects included participant acceptance of the robot's dances, scoring 3.4 with low variance. The Dance-Along activity received positive feedback in interviews, indicating no immediate need for changes in robot movements. Participants engaged well with the robot, scoring 3.9, as observed in audio/video data where they mimicked the robot's actions and attempted interaction. The participants overwhelmingly believed the robot fit the app (average score of 4.1), emphasizing its compatibility with the MUSE app. While overall positive, areas for improvement are discussed later in the paper.

B. Regarding the MUSE App

Quantitative survey results indicate strong acceptance of the MUSE app by PwADRD, with all questions scoring a point higher than the middle value on a reversed scale. Notable points include positive responses to music choices (Q1), belief in-app benefits for daily living (Q2), and no concerns about judgment (Q3), increasing future participation. Positive scores in Q5-8 indicate enjoyment of all MUSE activities and satisfaction with their order. Overall, PwADRD reacts very positively to all aspects of the MUSE app, signaling high user acceptance of this initial version.

Qualitative findings show participants believe the MUSE app positively impacts mental, physical, and emotional well-being, fostering potential for repeat sessions and increased system effectiveness. Areas for improvement include clearer instructions before activities, potentially linked to cognitive decline, and a need for louder music despite the robot being at max volume. Despite these, participants expressed overall enjoyment with no major complaints, as supported by audio/video data showing high engagement in all activities. Consequently, the MUSE session activities require no major adjustments.

C. Limitations and Future Directions

Given the results of the survey, it is apparent there are a few limitations of the MUSE system. First, many participants agreed that it was difficult to hear the robot speaking and the music playing. This is a physical limitation of the robot since the output volume was maxed out the entire time. It is not possible to increase the volume without outside input. Second, several participants were frustrated with the small size of the tablet, stating it was difficult to see the metronome and the displayed lyrics. Once again, this is a limitation of the robot and cannot be altered without outside influence. Other negative aspects that participants noted about the MSUE system, such as confusing directions and music choices, can be easily altered.

While this workshop was conducted to assess user acceptance of the prototype of the MUSE system, it also allowed us to identify areas of improvement. For example, to address issues of PwADRD not being able to hear the robot or see the tablet, wireless connections to exterior devices could provide a solution. An external speaker for sound and a larger screen for visuals could fix the issues. The Pepper robot is Bluetooth enabled, so these would be the easiest and most effective methods to address participant concerns without replacing the robot. Additionally, the complaints about confusing instructions can be altered easily within Android Studio. The instructions that the robot gives can be altered to be more concise and clearer, and more music genres can be added to the MUSE session. Overall, the areas of improvement identified by the workshop participants can be easily made.

VI. Conclusion

The development and implementation of the MUSE system stand as a noteworthy advancement in dementia care, specifically addressing two critical challenges: enhancing the well-being of individuals with Alzheimer's Disease or related dementia (PwADRD) and alleviating caregiver burden. Our interdisciplinary team has successfully integrated music therapy and advanced robotics, particularly leveraging the capabilities of the Pepper robot. This innovation has given rise to an engaging and innovative social robot-guided music intervention system.

In the realm of therapeutic impact, the MUSE system utilizes music intervention to engage PwADRD in activities designed to promote cognitive, physical, and emotional well-being. The evidence gathered from comprehensive workshops suggests that this approach is effective. Participants not only exhibited increased happiness post-session, but their survey responses also indicated a strong belief in the potential of MUSE to enhance their overall state of being. This positive reception is pivotal, as it lays the groundwork for the therapeutic efficacy of our interventions.

Moreover, the autonomy embedded in the MUSE system, driven by the Pepper robot, plays a crucial role in easing caregiver responsibilities. By independently handling music therapy sessions, the robot allows caregivers to allocate their time to other pressing tasks or take necessary breaks, especially in assisted living settings. Participants in the workshops expressed favorable opinions regarding the robot's interaction, movement, and overall engagement capabilities, further supporting the positive impact on both patients and caregivers.

The broader impact of the MUSE system extends beyond immediate care, representing a paradigm shift in dementia therapy that blends technological innovation with established therapeutic practices. The initial workshop results underscore the potential of MUSE not only in improving the quality of dementia care but also in reshaping perceptions of how technology can be harnessed in healthcare. As we continue to refine and develop the MUSE system, driven by the belief that it can revolutionize dementia care, we envision new perspectives emerging from both therapeutic and technological standpoints.

ACKNOWLEDGMENT

The research was in part supported by NIH under the grant number R01AG077003.

REFERENCES

[1] Alzheimer's Association, “2023 Alzheimer's Disease Facts and Figures,” Alzheimer's Dementia, vol. 18, no. 4, pp. 700–789, 2023.

[2] J. Y. Tu, G. Jin, J.-H. Chen, and Y.-C. Chen, “Caregiver burden and dementia: A systematic review of self-report instruments,” Journal of Alzheimer’s Disease, vol. 86, no. 4, pp. 1527–1543, 2022. doi:10.3233/jad-215082 K. Elissa, “Title of paper if known,” unpublished.

[3] M. Sakamoto, H. Ando, and A. Tsutou, “Comparing the effects of different individualized music interventions for elderly individuals with severe dementia,” International Psychogeriatrics, vol. 25, no. 5, pp. 775–784, 2013.

[4] S. M. Koger, K. Chapin, and M. Brotons, “Is music therapy an effective intervention for dementia? A meta-analytic review of literature,” Journal of Music Therapy, vol. 36, no. 1, pp. 2–15, 1999.

[5] M. Brotons and S. M. Koger, “The impact of music therapy on language functioning in dementia,” Journal of Music Therapy, vol. 37, no. 3, pp. 183–195, 2000.

[6] L. Prieto Álvarez, “Neurologic music therapy with a habilitative approach for older adults with dementia: A feasibility study,” Music Therapy Perspectives, vol. 40, no. 1, pp. 76–83, 2022.

[7] C. Holmes, A. Knights, C. Dean, S. Hodkinson, and V. Hopkins, “Keep music live: Music and the alleviation of apathy in dementia subjects,” International Psychogeriatrics, vol. 18, no. 4, pp. 623–630, 2006.

[8] K. K. F. Tsoi, J. Y. C. Chan, Y.-M. Ng, M. M. Y. Lee, T. C. Y. Kwok, and S. Y. S. Wong, “Receptive music therapy is more effective than interactive music therapy to relieve behavioral and psychological symptoms of dementia: A systematic review and meta-analysis,” Journal of the American Medical Directors Association, vol. 19, no. 7, 2018.

[9] A. K. Ostrowski, C. Breazeal, and H. W. Park, “Mixed-method long-term robot usage: Older adults' lived experience of Social Robots,” 2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2022.

[10] A. Mahmoudi Asl, M. Molinari Ulate, M. Franco Martin, and H. van der Roest, “Methodologies used to study the feasibility, usability, efficacy, and effectiveness of social robots for elderly adults: Scoping review,” Journal of Medical Internet Research, vol. 24, no. 8, 2022.

[11] K. Kühne, M. A. Jeglinski-Mende, M. H. Fischer, and Y. Zhou, “Social Robot – jack of all trades?,” Paladyn, Journal of Behavioral Robotics, vol. 13, no. 1, pp. 1–22, 2022.

[12] R. Khosla, M.-T. Chu, S. M. Khaksar, K. Nguyen, and T. Nishida, “Engagement and experience of older people with socially assistive robots in home care,” Assistive Technology, vol. 33, no. 2, pp. 57–71, 2019

[13] R. Sather, M. Soufineyestani, A. Khan, and N. Imtaiz, “Use of Humanoid Robot in Dementia Care: A Literature Review,” Journal of Aging Science, vol. 9, no. 3, Apr. 2021

[14] F. Yuan, S. Bowland, L. Proctor, J. Blackburn, N. Mukherjee, R. Bray, R. P. Lopez, K. Wick, and X. Zhao, “Robot-assisted Psycho-education to Enhance Alzheimer’s Caregiver Health,” 2022 IEEE/ACM Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE), 2022.

[15] Koh, W.Q., et al.: Barriers and facilitators to the implementation of social robots for older adults and people with dementia: a scoping review. BMC geriatrics 21(1), 1-17 (2021).

[16] H. Feng, M. H. Mahoor, and F. Dino, “A music-therapy robotic platform for children with autism: A pilot study,” Frontiers in Robotics and AI, vol. 9, 2022.

[17] Y. Zhang, C. Zhang, L. Cheng, and M. Qi, “The use of deep learning-based gesture interactive robot in the treatment of autistic children under Music Perception Education,” Frontiers in Psychology, vol. 13, 2022.

[18] Y.-H. Peng, C.-W. Lin, N. M. Mayer, and M.-L. Wang, “Using a humanoid robot for music therapy with autistic children,” 2014 CACS International Automatic Control Conference (CACS 2014), 2014.

[19] R. De Kok, J. Rothweiler, L. Scholten, M. van Zoest, R. Boumans, and M. Neerincx, “Combining social robotics and music as a non-medical treatment for people with dementia,” 2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), 2018.

[20] M. Workman, “Unified theory of acceptance and use of technology measure,” PsycTESTS Dataset, 2014. doi:10.1037/t34374-000

[21] F. Yuan et al., “Assessing the acceptability of a humanoid robot for alzheimer’s disease and related dementia care using an online survey,” International Journal of Social Robotics, vol. 14, no. 5, pp. 1223–1237, 2022. doi:10.1007/s12369-021-00862-x

[22] F. Yuan, E. Klavon, Z. Liu, R. P. Lopez, and X. Zhao, “A systematic review of robotic rehabilitation for cognitive training,” Frontiers in Robotics and AI, vol. 8, 2021. doi:10.3389/frobt.2021.605715

[23] T. Morris, D. V. Petrovsky, S. Swaminathan, and X. Zhao, “POSTER: Design of a Music Intervention System Using Social Robotics for Cognitive Enhancement,” 2023 IEEE/ACM Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE, pp. 185–186, 2021. doi:10.1109/chase52844.2021

[24] “Pepper the humanoid and programmable robot,” Aldebaran, https://www.aldebaran.com/en/pepper (accessed Nov. 29, 2023).

[25] A. Ellard-Gray, N. Jeffrey, M. Choubak, and S. Crann, “Finding the Hidden Participant: Solutions for Recruiting Hidden, Hard-to-Reach, and Vulnerable Populations,” International Journal of Qualitative Methods, vol. 14, no. 5, pp. 1609–4069, Dec. 2015. doi:10.1177/160940691562142