Noise promotes disengagement in dementia patients during non-invasive neurorehabilitation treatment

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Abstract

Introduction: The lack of engagement and the shortage of motivation and drive, also referred to as apathy, negatively impacts the effectiveness and adherence to treatment and the general well-being of people with neurocognitive disorders (NCDs), such as dementia. Methodology: The hypothesis raised states that the engagement of people with dementia during their non-invasive treatments for NCDs is affected by the noisy source levels and negative auditory stimuli present within environmental treatment settings. An online survey was conducted with the study objectives to assess 1) the engagement levels of dementia patients while interacting with others at home versus in therapy facilities, 2) the emotions perceived when interacting with people at home compared to therapy sessions, 3) the perceived loudness of the environment at home versus in therapy facilities, and 4) which source sounds negatively impact the patients at home and during therapy sessions. A purposive sampling (n=62) targeting relatives, friends, and caregivers of dementia patients was conducted via online community forums in the DACH region. Moreover, a recording session was conducted in a psychotherapist's office to verify the answer to the questionnaire on the noise sources perceived in therapy facilities. Results and Discussion: The raised hypothesis that disruptive auditory stimuli and noise levels influence the engagement levels of demented individuals during treatment is confirmed as the engagement is affected by the perceived noise disruptions when comparing perceived noise levels and engagement at home to those in treatment facilities. Significant statistical results were found between the lower engagement of demented individuals when interacting with people during therapy sessions compared to higher engagement in-home interactions. Furthermore, negatively perceived sound sources can be found in both therapy facilities and home settings. The noise sound sources identified, such as human voices, household appliances and household noises, while recording in the psychotherapist's office align with the questionnaire responses received on this topic. The findings indicate that the perceived heightened noise levels in therapy facilities stand in correlation with the lowered engagement rate perceived during the therapy session compared to the lower noise level and higher engagement encountered when demented individuals interact at home. Conclusion: If the identified noise elements are masked or replaced by other auditory stimuli that promote a soothing soundscape, the original disturbances encountered during therapy and the lack of engagement can possibly be minimized. Further studies need to be conducted in the prototyping of a noise intervention tool to analyze the impact on lack of engagement through noise disturbances.

Keywords. Noise, Engagement, Dementia, Therapy, Apathy.

INTRODUCTION

Neurocognitive disorders (NCDs) are a steadily rising global public health concern. In 2020, around 50 million people worldwide lived with major NCDs, specifically dementia, with nearly 10 million new cases per year[1] NCDs can be found in many diseases, including Alzheimer, Parkinson, Huntington, and Creutzfeldt-Jakob (Reith, 2018). The causes of NCDs are typically associated with advanced age. Still, it can occur from incidents such as traumatic brain injuries, infections, thyroid problems, damage to the blood vessels, and other causes (Kane et al., 2017), increasingly affecting a wide range of people and age groups. Successful treatment methods are limited and can be split into two main categories, invasive and non-invasive methods.

Invasive treatment methods are surgical procedures, such as Deep Brain Stimulation (DBS), a neurosurgical procedure in which a neurotransmitter is placed in the brain to send electrical

[1] World Health Organization, *Dementia* [website] https://www.who.int/news-room/fact-sheets/detail/dementia (accessed 12 April 2021)

impulses to specific regions to counteract movement disorders with Parkinson's disease (Kringelbach et al., 2007). Groiss et al. (2009) found that DBS is a highly effective intervention for advanced Parkinson. However, invasive treatments are not suitable for most NCD patients. Only about 10% of Parkinson's patients are eligible for DBS surgery (Lange et al., 2017). Further, patients with pre-existing dementia are at an increased risk of fatal complications, and early death is subject to surgery compared to non-demented patients (Kassahun, 2018). This data visualizes the hindered accessibility of invasive treatment methods for patients with NCDs.

Non-invasive treatment methods focus on tools that do not require incision and damage to the tissue (Cousins et al., 2019). They can be pharmacological or non-pharmacological. The effectiveness of pharmacological treatments for NCDs are reportedly low (Mathys, 2018), and its efficacy can be compromised due to the alteration of the blood-brain barrier (Carvey et al., 2009) and the breakdown of the medication in the blood before it can reach the nervous system (Pardridge, 2012; Tonda-Turo et al., 2019). Non-pharmacological methods have been advocated for the heightened success of the treatment plans. Engagement, i.e., active involvement triggered by meaningful activities promoting more energetic and positive moods (Perugia et al., 2017), has been identified as a critical factor in the effectiveness of treatment methods. Lanctôt et al. (2016) show that apathy, i.e., lack of engagement, has a significant impact on people with NCDs. This leads not only to a decrease in participation, increased disability and frustration but further to a low quality of life for patients and caregivers (Brodaty and Burns, 2017; Onyike et al., 2007).

In this context, the hypothesis is raised that the engagement of non-invasive treatments for NCDs is affected by the noise levels and negative auditory stimuli present within environmental treatment settings. To this end, a survey was conducted that aims to assess the above correlation and additionally capture live audio in a therapy facility to identify further the source and attributes of potential negative impacting sounds.

METHODOLOGY

An anonymous, online, computer-based and structured questionnaire was conducted. It was created using Google Forms and consisted of ten sections which were individually displayed on the screen and navigable by pressing forward or back to access the previous or next section. The questionnaire consisted of seventeen questions and took approximately 3-4 minutes to complete. It had the study objectives to understand 1) the engagement levels of dementia patients while interacting with others at home versus in therapy facilities, 2) the emotions perceived when interacting with people at home in comparison to therapy sessions, 3) the perceived loudness of the environment at home versus therapy facilities, 4) which source sounds perceived that negatively impact the patient. The questionnaire was disseminated in six online support groups for family members, friends, and professional caregivers of dementia patients in the German-speaking DACH region. Dementia patients have been chosen as the primary focus group due to their fast-spreading worldwide condition within NCDs and neuropsychiatric symptoms. The questionnaire included binary (yes or no), multiple-choice, and Likert scale questions. The therapies considered include the most common neurorehabilitation therapies (Aldridge, 2008; Greenwood et al., 2003), namely: exercise and mobility programs, speech therapy, cognitive training, psychotherapy, social skill training, music therapy, and art therapy. Following Cowen and Keltner (2017), the 27 varieties of emotional experiences and the wheel of emotions by Plutchik (1980) to identify emotional states were adopted. Sound sources classification adopts the ontology proposed by Ellis et al. (2017), which distinguishes between seven main sound sources: human sounds, animals, music, the sound of things, environment

and background, natural sounds channel, and source-ambiguous sounds. These are then further divided into multiple subcategories, which include but are not limited to human voices, home sounds, musical instruments, vehicles, and acoustic environment.

The analysis of the collected data was conducted in SPSS software to calculate means, test correlations, frequencies and run a statistical significance using a t-test ($p > .05$ is adopted to test the null hypothesis). To complement the identification of potential negative impacting sound sources and their spectral attributes, additionally, the auditory environment in a psychotherapist's office in the city center of Vienna, Austria was recorded. The building was located on a busy street; however, the room faced the inner courtyard and was therefore distinguishably quieter than other rooms in the area. A Zoom H5n with a X/Y microphone capsule was used for the recording, which consists of two matched unidirectional condenser microphones set at a 90-degree angle, mounted on a tripod. The soundscape was recorded three times for 15 minutes during an hour with the microphone in the middle of the room and the door shut. The connecting room was a kitchen followed by a bathroom and a second therapy room where a session was going on, but the door was closed. Therefore, any sounds recorded would have come from the neighbors, courtyard, or the people present in the session in the other closed-off room.

RESULTS AND DISCUSSION

The participants (n=62) of the questionnaire were family and friends of the person with dementia (77.4%), professional caretakers (21%) — as proxies of dementia patients —, and one person with dementia (1.6%). The participants from the DACH region were geographically distributed as follows: Germany (50%), Austria (32.2%), and Switzerland (14.5%). Two participants did not release the location. The stages of dementia ranged from suspected dementia to stage 7, with the most common selected being stage 6 (22.6%) and stage 5 (19.4%). Slightly more than half of the participants stated the person was not currently in therapy (53.2%). The therapies indicated, of which participants were able to select multiple choices, were mobility and exercise programs (54.5%), cognitive training (72.2%), psychotherapy (40.9%), art therapy (18.2%), social behavior training (9.1%), music therapy (22.7%), speech therapy (9.1%).

Significant statistical results were found between the different engagements during interactions in therapy facilities compared to home environments as perceived by relatives, friends, and caregivers. The engagement during treatment was perceived as much lower with a mean of 1.78 compared to 3.13 in home environments on a 5-point scale, 1 being no engagement; 5 being very high engagement in interactions with others.

The perceived emotions in dementia patients while at home (n=62) versus during therapy in therapy facilities (n=20) showed differences in emotional experience. The perceived emotions at home, of which multiple were selectable at once, were awkwardness (59.7%) followed by joyfulness (53.2%), confusion (53.2%) and apathy (30.6%). In therapy facilities, the most dominant perceived emotion was apathy (60%) followed by awkwardness (40%) confusion (35.5%), and joyfulness (35%), in percentages of selection. There was further significance regarding noise levels at home compared to therapy settings. As visualized in Figure 1, the normal curve is visible as a black line referring to the entered data in regard to frequency and noise level, the data suggests higher levels of experienced noise during therapy in facilities (mean=3.87) compared to at home environments (mean= 2.51) across a 5-point Likert space where one corresponds to very quiet and five to very loud.

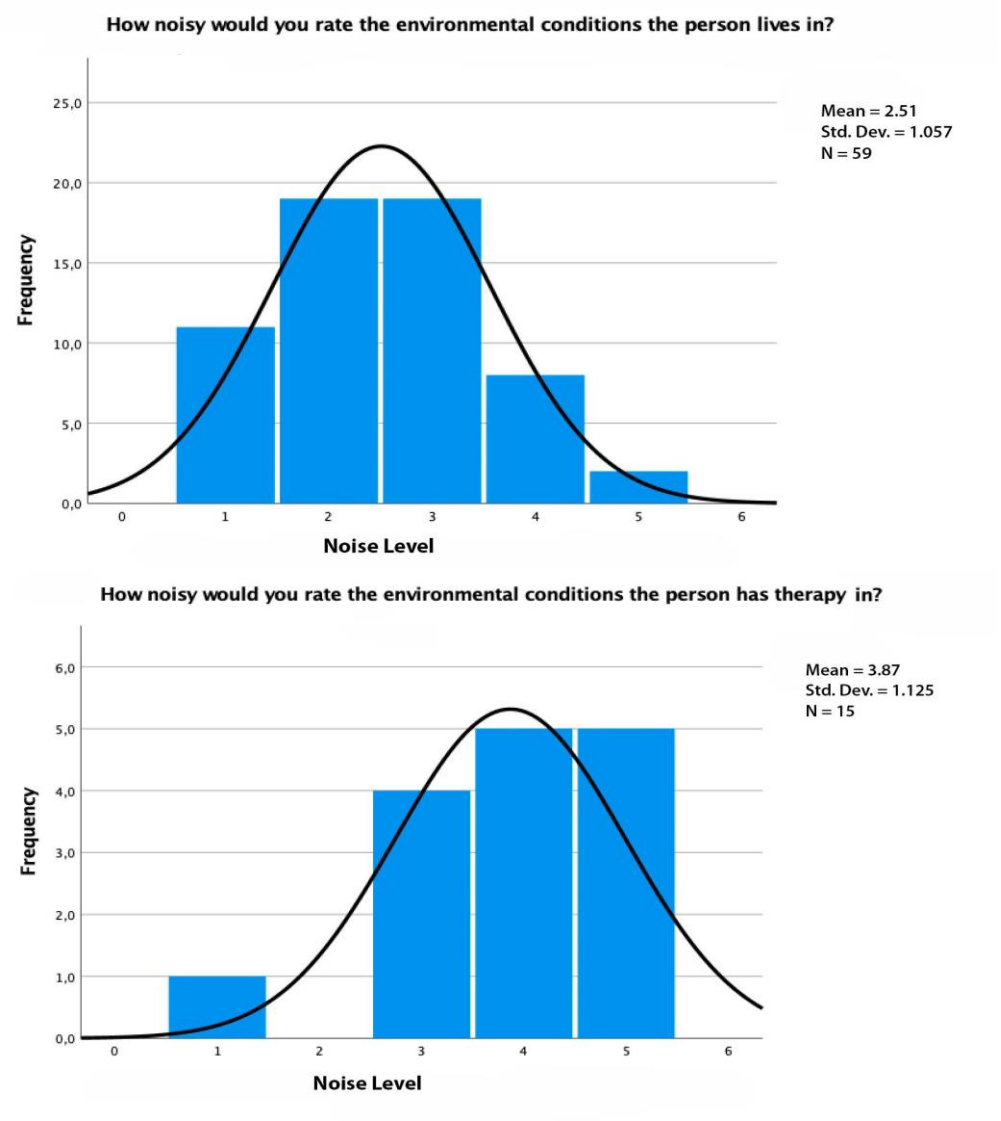

Figure 1. Perceived noise levels at home (upper image) compared to in therapy facilities (bottom image). Solid black lines denote the normal distribution.

However, the smaller number of responses for therapy (n=15) compared to home (n=59) indicates the potential heightened noise levels, and further responses should be collected to draw a cohesive conclusion on noise differences. In both conditions, the most common noisy sound sources identified were: human voices, household noises and devices, instrumental music played by neighbors, and traffic noises. This set of sounds are in line with the recordings taken in the psychotherapist's office, shown in Figure 2.

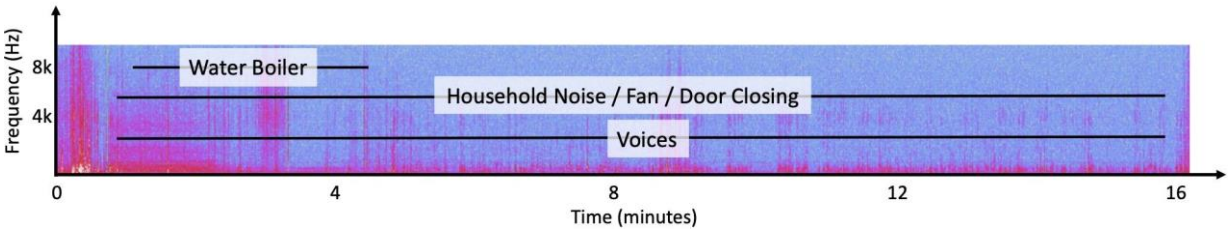

Figure 2. Spectrogram of the collected sound environment in the psychotherapist's office.

From the collected audio recording in the psychotherapist's office, which spectral representation is shown in Figure 2, where cold colors refer to low amplitude and warm colors

to high amplitude, noisy sound sources were identified which include household applications such as water boilers (1-2 minutes) and fans (3-5 minutes); (unintelligible) human voices from adjacent rooms filling the middle of the spectrum most notably between 3 kHz and 5 kHz (1-15 minutes). The identified sound category sources align with the collected categories in the questionnaire.

CONCLUSIONS AND FUTURE IMPLICATIONS

The raised hypothesis regarding that the engagement during non-invasive treatments for demented individuals can be affected by the noise levels and negative auditory stimuli present within environmental treatment facilities was confirmed. It was found that 1) the engagement levels of dementia patients while interacting with others in therapy facilities was higher than at home, 2) the emotions perceived when interacting with people at home were more positive in comparison to during therapy sessions where increased apathy was found, 3) the perceived loudness of the environment in therapy facilities was significantly higher than at home, 4) the source sounds perceived that negatively impact the patient was similar in both environments, at home and in the therapy facility with the most common being human voices and household noises and appliances. The dementia patients' engagement perceived by relatives and caregivers during therapy is lower than at home, which can be due to the unfamiliar environment regarding the associated emotions of apathy, awkwardness, and confusion. There is a correlation between sound levels and engagement, which are lower during therapy compared to a home setting. The most frequent negative impacting sound sources identified are human voices, household devices, and general household-associated noises. One important future implication of the results is the potential application of a soundscape in both home and health care facilities to positively impact the engagement of people with dementia by minimizing and masking the identified disruptive noise sources found in this study to minimize the impact of negatively associated auditory stimuli ultimately. To this end, imposed sound with different spectral attributes seeks to mask negative impacting sound sources based on a dataset researched by Fan et al. (2017) and Andringa and Lanser (2013). To account for the evolving nature of the soundscape based on short soundscape recordings, the model adopted by Bernardes et al. (2016) and Bernardes (2020) can be used in future developments.

References

Aldridge, D. (2008). *Music Therapy and Neurological Rehabilitation: Performing Health* (Illustrated ed.). Jessica Kingsley.

Andringa, T., & Lanser, J. (2013). How Pleasant Sounds Promote and Annoying Sounds Impede Health: A Cognitive Approach. *International Journal of Environmental Research and Public Health*, 10(4), 1439–1461. https://doi.org/10.3390/ijerph10041439

Bernardes, G., Aly, L., Davies, M. (2016). SEED: Resynthesizing Environmental Sounds from Examples. *Proceedings of the Sound and Music Computing Conference*. 55–62.

Bernardes, G. (2020). Interfacing Sounds: Hierarchical Audio-Content Morphologies for Creative Re-purposing in earGram. *Proceedings of the International Conference on New Interfaces for Musical Expression.*, 537–542.

Brodaty, H., & Burns, K. (2017). Non-pharmacological Management of Apathy in Dementia: A Systematic Review. *The American Journal of Geriatric Psychiatry*, 20(7), 549–564. https://doi.org/10.1097/JGP.0b013e31822be242

Cousins, S., Blencowe, N. S., & Blazeby, J. M. (2019). What is an invasive procedure? A definition to inform study design, evidence synthesis and research tracking. *BMJ Open*, 9(7), 1.https://doi.org/10.1136/bmjopen-2018-028576

Cowen, A. S., & Keltner, D. (2017). Self-report captures 27 distinct categories of emotion bridged by continuous gradients. *Proceedings of the National Academy of Sciences*, 114(38). https://doi.org/10.1073/pnas.1702247114

Carvey, P. M., Hendey, B., & Monahan, A. J. (2009). The blood-brain barrier in neurodegenerative disease: a rhetorical perspective. *Journal of Neurochemistry,* 111(2), 291–314. https://doi.org/10.1111/j.1471-4159.2009.06319.x

Ellis, D., Gemmeke, J., Freedman, D., Jansen, A., Lawrence, W., Moore, R., Plakal, M., & Ritter, M. (2017). Audio Set: An ontology and human-labeled dataset for audio events. *Proc. IEEE ICASSP 2017*, 1–5. https://static.googleusercontent.com/media/research.google.com/de//pubs/archive/45857.pdf

Fan, J., Thorogood, M., & Pasquier, P. (2017). Emo-soundscapes: A dataset for soundscape emotion recognition. 2017 *Seventh International Conference on Affective Computing and Intelligent Interaction (ACII)*. https://doi.org/10.1109/acii.2017.8273600

Greenwood, R. J., McMillan, T. M., Barnes, M. P., & Ward, C. D. (2003). *Handbook of Neurological Rehabilitation* (1st ed.). Psychology Press.

Kane, R. L., Butler, M., Fink, H. A., Brasure, M., Davila, H., Desai, P., Jutkowitz, E., McCreedy, E., Nelson, V. A., McCarten, J. R., Calvert, C., Ratner, E., Hemmy, L. S., & Barclay, T. (2017). Interventions To Prevent Age-Related Cognitive Decline, Mild Cognitive Impairment, and Clinical Alzheimer's-Type Dementia. Agency for Healthcare Research and Quality. Published. https://doi.org/10.23970/ahrqepccer188

Kassahun, W. T. (2018). The effects of pre-existing dementia on surgical outcomes in emergent and nonemergent general surgical procedures: assessing differences in surgical risk with dementia. BMC Geriatrics, 18(1), 1–9. https://doi.org/10.1186/s12877-018-0844-x

Kringelbach, M. L., Jenkinson, N., Owen, S. L. F., & Aziz, T. Z. (2007). Translational principles of deep brain stimulation.

Nature Reviews Neuroscience, 8(8), 623–635. https://doi.org/10.1038/nrn2196

Mathys, M. (2018). Pharmacologic management of behavioral and psychological symptoms of major neurocognitive disorder. *Mental Health Clinician*, 8(6), 284–293. https://doi.org/10.9740/mhc.2018.11.284

Lanctôt, Krista L., Luis Agüera-Ortiz, Henry Brodaty, Paul T. Francis, Yonas E. Geda, Zahinoor Ismail, Gad A. Marshall, et al. "Apathy Associated with Neurocognitive Disorders: Recent Progress and Future Directions." *Alzheimer's & Dementia* 13, no. 1 (2016): 84–100. https://doi.org/10.1016/j.jalz.2016.05.008.

Lange, M., Mauerer, J., Schlaier, J., Janzen, A., Zeman, F., Bogdahn, U., Brawanski, A., & Hochreiter, A. (2017). Underutilization of deep brain stimulation for Parkinson's disease? A survey on possible clinical reasons. Acta Neurochirurgica, 159(5), 771–778. https://doi.org/10.1007/s00701-017-3122-3

Onyike, C. U., Sheppard, J. M. E., Tschanz, J. T., Norton, M. C., Green, R. C., Steinberg, M., Welsh-Bohmer, K. A., Breitner,

J. C., & Lyketsos, C. G. (2007). Epidemiology of Apathy in Older Adults: The Cache County Study. *The American*

Journal of Geriatric Psychiatry, 15(5), 365–375. https://doi.org/10.1097/01.jgp.0000235689.42910.0d

Pardridge, W. M. (2012). Drug Transport across the Blood–Brain Barrier. *Journal of Cerebral Blood Flow & Metabolism*,

32(11), 1959–1972. https://doi.org/10.1038/jcbfm.2012.126

Perugia, G., Rodriguez-Martin, D., Diaz Boladeras, M., Mallofre, A. C., Barakova, E., & Rauterberg, M. (2017).

Electrodermal activity: Explorations in the psychophysiology of engagement with social robots in dementia. 2017 *26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 1248–1254. https://doi.org/10.1109/roman.2017.8172464

Plutchik, R. (1980). A general psychoevolutionary theory of emotion. In R. Plutchik & H. Kellerman (Eds.), Emotion: Theory, research, and experience. *Theories of emotion*, 3-33, 1. New York: Academic.

Reith, W. (2018). Neurodegenerative Erkrankungen. Der Radiologe, 58(3), 241–258. https://doi.org/10.1007/s00117-018-0363-y

Tonda-Turo, C., Origlia, N., Mattu, C., Accorroni, A., & Chiono, V. (2019). Current Limitations in the Treatment of Parkinson's and Alzheimer's Diseases: State-of-the-Art and Future Perspective of Polymeric Carriers. *Current Medicinal Chemistry*, 25(41), 5755–5771. https://doi.org/10.2174/0929867325666180221125759