A music therapy experiment based on musical stimuli with artificially implemented physiological complexity in patients with dementia

(scientific paper)

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Abstract: *The aim of this study was to assess the effect of music therapy (MT) with artificially implemented physiological complexity (PHC) in patients in the first and second stages of dementia.*

The research was conducted on 34 seniors divided into three groups: (1) group with MT with PHC; (2) group with MT without PHC; (3) control group with no MT. The participants 'cognitive functions were assessed by the Mini-Mental State Examination (MMSE) and the Addenbrooke's Cognitive Test (ACE).

A high proportion of participants were excluded during the study due to their health condition. No significant difference was found between the compared groups. Nonetheless, the overall results look promising: In the MT group with PHC, the cognitive functions improved in 3 patients; in the MT group without PHC, 1 patient improved; in the control group with no MT, there was no improvement in any of the participants.

Keywords: *dementia, Alzheimer's disease, music therapy, physiological complexity*

1 Introduction

Alzheimer's disease (AD) is a severe neurodegenerative brain disease in which the patient suffers from dementia. According to WHO (2019), AD accounts for 60–70% of dementia cases. According to qualified estimates, the number of people with dementia in the Czech Republic reaches up to 150.000 (ČALS, 2016). The increase in the incidence of this disease is worrying – over the next twenty years, the number of people affected is estimated to double worldwide (ADI, 2019). Although many research teams are trying to find a cure to eliminate harmful beta amyloid plaques, there is no treatment in current medicine that could address this disease effectively

(WHO, 2019). The only option therefore remains slowing the progression of the disease and using a variety of rehabilitation methods that help to train and maintain basic cognitive functions – thinking, memory, judgment. The patient's cognitive abilities, such as memory, attention, logical reasoning, and motor performance, are tested by standardized tests: The Addenbrooke's National State Examination (ACE) (Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006), Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975), or the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005).

Studies of patients with Alzheimer's disease (as well as Parkinson's disease) show that music is an essential therapeutic element for these patients (Herholz, Herholz, & Herholz, 2013; Irish et al., 2006; Lyu et al., 2018; McDermott, Crellin, Ridder, & Orrell, 2013). The acclaimed British neurologist Dr. Oliver Sacks, a recently deceased NYU School of Medicine professor, claimed that the ability of these patients to respond to music is incredible – they often suffer from aphasia, but they can sing and play musical instruments. These fascinating stories are described in the book Musicophilia: Tales of Music and the Brain (Sacks, 2015). He literally says that "music therapy can aid these patients, because musical perception, musical sensibility, musical emotion and musical memory can survive long after other forms of memory have disappeared" (Sacks, 2015). From this point of view, working with musical stimuli becomes one of the few rehabilitation therapies these patients are capable of.

The aim of our research was to verify the effectiveness of the music therapy method, which is based on empirically confirmed effects of musical stimuli in patients with neurological problems and is motivated by the studies of the pioneer of new rehabilitation methods Nicholas Stergiou (Biomechanics Lab, University of Nebraska, Omaha) (Hunt, McGrath, 2014). These are based on signals (sound, visual stimuli, tactile stimuli) that specifically contain artificially implemented physiological complexity (such as pink noise). The point is that the physiological signals (ECG, EEG, gait rhythm) of a healthy organism show some degree of complexity, so the signal is neither too simple (for example periodic), nor too random (as is the case with white noise). The optimal degree of complexity is difficult to quantify, although there are already several new mathematical tools such as Multiscale Entropy (Costa, Goldberger, & Peng, 2005), Detrended Fluctuation Analysis (Schumann & Kantelhardt, 2011). The so-called pink noise is a random signal with such a frequency response that the power spectral density is inversely proportional to the frequency of the signal. This type of noise surprisingly occurs in many biological systems – for example, in the rhythms of heart activity (Ryan, Goldberger, Pincus, Mietus, & Lipsitz, 1994), human brain activity (Natarajan, Acharya, Alias, Tiboleng, & Puthusserypady, 2004) or DNA sequence statistics (Mantegna et al., 1994). With biological aging and disease, physiological complexity decreases, for example, in the dynamics of heart rate,

breathing, or gait (Manor et al., 2010), which is an aspect that strongly corresponds to the intent of the research.

One of the possible approaches is to implement a pink noise disturbance into parts of the musical works that will be used in therapies.

The aim of this research was to work with patients in the first and second stages of dementia, using musical stimuli enriched with physiological complexity and subsequently evaluate (using standardized tests) whether their cognitive functions have improved. We quantified this improvement relative to the control group, which also underwent music stimuli therapy, but without implemented physiological complexity. Both groups were compared with another control group that did not receive music therapy. This design of the study made it possible to evaluate the effect of music therapy as such and to recognize whether physiological complexity is the key component that intensifies the potential effect of music therapy.

The study was approved by the Ethics Committee of the University Hospital Olomouc and the Faculty of Medicine of Palacký University in Olomouc on 11 December 2017, reference number 165/17.

2 Material and Methods

2.1 Sample selection

Three groups of patients were assembled in the POHODA Senior Home in Chválkovice in agreement with the management of the organization. Seniors in the first, at most in the second stage of dementia (n = 34) were selected according to the recommendations of a neurologist and a psychiatrist. The patients were selected by the psychiatrist based on standardized tests.

The participants were divided into three groups: The first group consisted of 12 seniors who did not take part in music therapy; this group is called control group (C) and its purpose was to monitor how the condition of seniors develops without therapeutic interventions. The second group consisted of 11 seniors, with whom we worked using music therapy with implemented physiological complexity; we call it PHC. The third group consisted of 11 seniors, with whom we worked using music therapy without implemented physiological complexity, we call it M.

2.2 Tools

To carry out the experiment, it was necessary to create know-how to enrich the recording of MIDI music with physiological complexity. This algorithm has already been published by the authors, including the results of a pilot study to determine what

degree of physiological complexity implemented in musical stimuli is acceptable to listeners (Dohnalova & Furst, 2017).

The standardized Mini-Mental State Examination (MMSE) and the Addenbrooke's Cognitive Test (ACE) were used to diagnose participants. The Czech version of the MMSE test was validated on the Czech senior population in 1998 (Tosnerova & Bahbouh, 1998). The Czech version of the ACE test was validated on the Czech population in 2009 (Hummel-Fanfrdlova et al., 2009).

2.3 Experiment design

Therapy in both active groups (M and PHC) took place twice a week, on Mondays and Thursdays always for 45 minutes, from 9 November 2017 to 26 April 2018. The sessions were conducted by two music therapists – on Mondays the first therapist always worked with the groups PHC and M, on Thursdays the other one worked with both groups (it was necessary to eliminate the influence of different personalities on patients, therefore we always kept the same algorithm). The beginning and the end of each session were devoted to listening to the first sentence of Mozart's Sonata Facile, in which we implemented physiological complexity for PHC group. We also included activation methods – singing and playing simple instruments in between. Furthermore, we used reminiscence therapy, which is very suitable for patients with dementia (Ashida, 2000; Herholz et al., 2013).

2.4 Statistical analysis of the data

Due to a small number of participants in each group, statistical tests should be used with caution. All tests will only carry very little weight, so it is unlikely that we will find effect unless it is significantly strong. The differences in continuous variables (e. g. age) between the groups were tested by the Kruskal-Wallis test, which is a non-parametric version of the analysis of variance. Due to the small number of patients, we preferred data visualization to formal testing.

3 Results

In all groups we worked with very old and often ill people who also suffer from dementia in the first or second degree of disability. It was therefore not possible to obtain entry and final questionnaires from all participants. In the control group C we received 8 entry questionnaires and 5 final questionnaires, in the music therapy group M 11 entry and 10 final questionnaires, and in the PHC group we obtained 7 entry and 4 final questionnaires.

In the course of the experiment, the age of the patients proved to be one of the most important factors. The age structure of all three groups is shown in Figure 1. There is no difference in median age between groups (Kruskal-Wallis test does not reject the hypothesis of the same medians, $p = 0.54$). However, it can be seen that age dispersion in the music therapy group is smaller. In the other two groups age dispersion was larger, so more seniors in these groups were indeed very old. It has to be counted on more health complications in older patents. For example, in the PHC group one patient died during the experiment and the general health of five others worsened to the extent that they were unable to complete the experiment. There were also four deaths and three hospitalizations in group C.

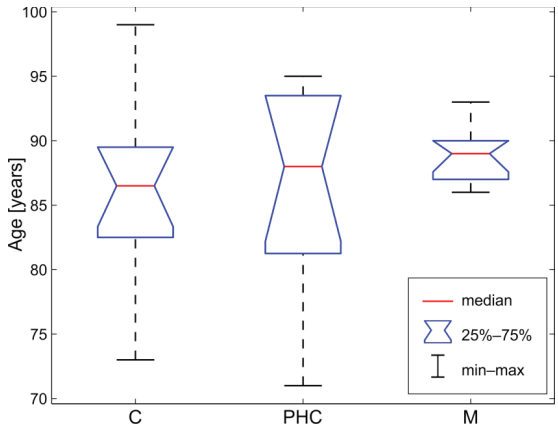

Figure 1: *The age structure of participants in the three treatment groups: the control group (C, n = 12) without music therapy; the music therapy group with implemented physiological complexity (PHC, n = 11); the music therapy group without implemented physiological complexity (M, n = 11).*

There was no significant difference between the results of the entry MMSE test between the groups ($p = 0.23$), although the PHC group achieved slightly better results. The median MMSE score was 18, 25 and 20 in the C, PHC and M groups. There was also no significant difference between the ACE test results between the groups ($p = 0.46$), although the PHC group again achieved slightly better results. The median ACE score was 48, 63 and 40 in groups C, PHC and M.

For further analysis, we subtracted the value of the entry score and the final score. This has eliminated to some extent the problem of entry score imbalance between the groups. The number of seniors who had at least one initial examination was so low that we chose a visual presentation of the data. Figure 2 shows the development of the MMSE scores of individual seniors.

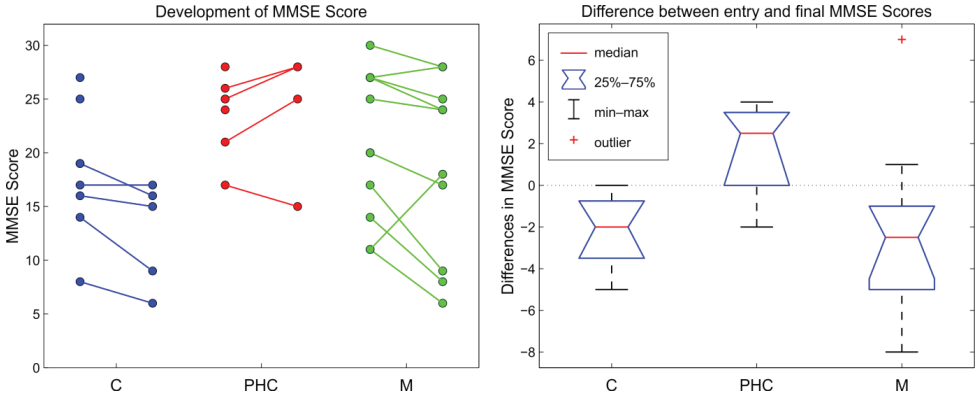

Figure 2: *The development of the MMSE scores of seniors in the individual groups. Left: the line always links the entry and final scores of one patient. Right: the difference between the entry and final score values; a positive value of the difference indicates improvement. The control group (C) without music therapy; the music therapy group with implemented physiological complexity (PHC); the music therapy group without implemented physiological complexity (M).*

It can be seen on the left side of Figure 2 that the condition of all seniors in the control group worsened. In the music therapy group M, all participants except one also got worse. In the PHC group with physiological complexity, the condition of three patients improved and one worsened. On the right side of the figure the differences between the MMSE entry and final scores were used. The participants whose MMSE value improved after therapy had a positive difference. The figure shows that in the PHC group the improvement in the MMSE test predominated, while in the M and C groups the deterioration was rather worse. If we test whether the difference in this change of the score is significant between the groups, the Kruskal-Wallis test does not reject the median compliance ($p = 0.11$).

The same analyses were performed on the ACE test results. The difference between the groups is not significant here either ($p = 0.75$), nor does the data display show any indication of the effect (see Figure 3). Almost all patients in all the groups got worse, except one in the PHC group and one in the M group.

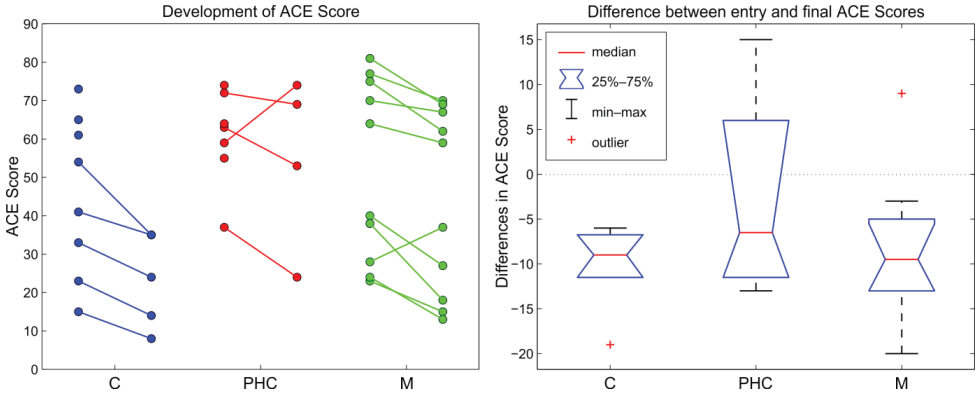

Figure 3: *The development of the ACE scores of seniors in the individual groups. Left: the line always links the entry and exit scores of one patient. Right: the difference between the entry and final score values; a positive value of the difference indicates improvement. The control group (C) without music therapy; the music therapy group with implemented physiological complexity (PHC); the music therapy group without implemented physiological complexity (M).*

Figure 4 shows the percentage change between the entry and final scores in both used tests (MMSE and ACE) simultaneously.

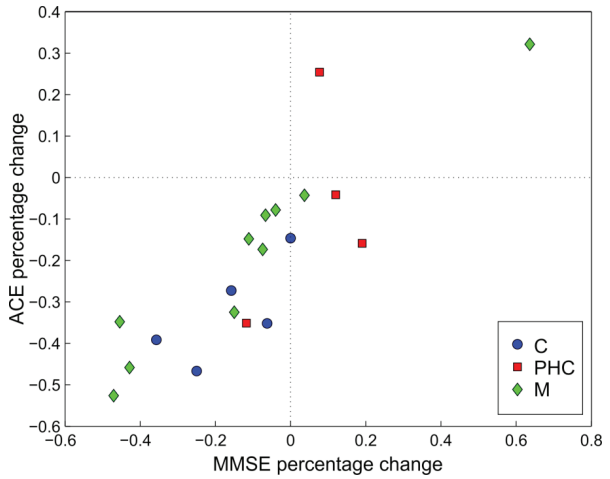

Figure 4: *The percentage change between the entry and final scores in the MMSE and ACE tests in the three groups: The control group (C) without music therapy; the music therapy group with implemented physiological complexity (PHC); the music therapy group without implemented physiological complexity (M).*

4 Discussion

The aim of this study was to work with patients in the first and second stages of dementia, using musical stimuli enriched with physiological complexity and subsequently to evaluate whether their cognitive functions have been improving (using standardized tests). In order to quantify the improvement/deterioration of cognitive functions in the study group, its results were compared with two other groups: a control group that did not receive music therapy and another group that also received music therapy but without implemented physiological complexity. This study design makes it possible to evaluate the effect of music therapy as such and to recognize whether physiological complexity is the key component that enhances the potential effect of music therapy.

The course of the therapy sessions was always the same. The result of this regularity was to induce a sense of familiar and anticipated ritual that led to calming of the seniors. In patients with dementia, the need for basic trust, which results from a loss of self-confidence, comes to the fore (Orti et al., 2018). Therefore it was necessary to ensure such an environment during the experiment and to avoid changes in the routine of activation and therapeutic methods. It is important to note that, according to Maslow's Pyramid of Needs (Maslow, 1943), patients with dementia are at great risk at the basic stages of the pyramid by losing their sense of safety and security, and subsequently their sense of recognition, respect and self-realization.

In the course of music therapy in both M and PHC groups, the emphasis was also placed on working with breath and focusing on the physical body and its manifestations while listening to music. In addition to listening to recorded music, we used activation methods – singing, playing simple instruments, and we also included reminiscence therapy. Using these methods, we achieved good results in stimulating long-term memory pathways. According to several foreign studies (Patel, 2003; Simmons-Stern, Budson, & Ally, 2010), singing songs is more effective in stimulating memory paths than just reading texts or passively listening to music. When singing, folk songs became the most popular genre of our participants, in which they were able to recall a large number of stanzas of individual songs, including variable lyrics. These texts then evoked life situations associated with them in the patients and helped to reduce the uncertainty caused by dementia (van der Roest et al., 2007). Moreover, the results of foreign studies (Istvandity, 2017; Lyu et al., 2018; Orti et al., 2018) suggest that music therapy is effective in enhancing overall well-being in patients with dementia/AD.

The evaluation of the final tests showed that the uneven distribution of the participants' age and their cognitive abilities at the beginning of the study is a problem. The music therapy group M was most balanced in terms of age, with the smallest age variance among the patients. This was due to the fact that the department from

which this group was formed was established all at once, in a very short time, and thus was occupied by the clients not gradually, but within a month. This is probably also the reason why the smallest number of people died during the study period in the M group. The age and general health of the participants in the PHC group probably influenced the findings of this study most significantly: in this group one participant died, and five others experienced a significant deterioration in their health condition so they were no longer able to complete the therapy.

According to the MMSE results, it is, however, an encouraging fact that the condition of three patients in the PHC group improved and one worsened. This is quite interesting, especially considering that the patients with similar baseline scores in the music therapy group all deteriorated. The PHC group already achieved slightly higher results in the entry MMSE and ACE tests. Although the differences in the entry tests between the three groups were not significant, the differences in the values of the entry and final scores were preferred for further analyses. In this way, the problem of the imbalance of the entry score between the groups was eliminated.

Although the results of this study are not statistically significant – either due to the imbalance of the groups or the insufficient number of participants in individual groups, its conclusions are still promising and motivate further research of the methods used.

5 Conclusion

The study has fulfilled the given goal – it brought new knowledge about the effect of music therapy with implemented physiological complexity. Although it was not possible to demonstrate a significant effect of the therapy due to the small number of participants, the results are encouraging. We believe it is meaningful to continue exploring this approach in a larger sample of patients, as dementia and Alzheimer's disease are an important issue in our civilization.

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References

[1] ADI. (2019). The Global Voice on Dementia. Retrieved from https://www.alz.co.uk/
[2] Ashida, S. (2000). The effect of reminiscence music therapy sessions on changes in depressive symptoms in elderly persons with dementia. *J Music Ther, 37*(3), 170–182.
[3] ČALS. (2016). Zpráva o stavu demence 2016. Retrieved from http://www.alzheimer.cz/

[4] Costa, M., Goldberger, A. L., & Peng, C. K. (2005). Multiscale entropy analysis of biological signals. *Phys Rev E Stat Nonlin Soft Matter Phys, 71* (2 Pt 1), 021906. doi: 10.1103/PhysRevE.71.021906
[5] Dohnalova, L., & Furst, T. (2017). The experimental design and technical tools for the research of musical stimuli with artificially implemented complexity used in the rehabilitation of Alzheimer's disease patients. *Musicologica Olomucensia. Acta Universitatis Palackianae Olomucensis, 25*, 22–33.
[6] Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res, 12*(3), 189–198.
[7] Herholz, S. C., Herholz, R. S., & Herholz, K. (2013). Non-pharmacological interventions and neuroplasticity in early stage Alzheimer's disease. *Expert Rev Neurother, 13*(11), 1235–1245. doi: 10.1586/14737175.2013.845086
[8] Hummelova-Fanfrdlova, Z., Rektorova, I., Sheardova, K., Bartos, A., Linek, V., Ressner, P. , … Hort, J. (2009). Czech adaptation of Addenbrooke's Cognitive Examination. *Ceskoslovenska Psychologie, 53*(4), 376–388.
[9] Hunt, N., McGrath, D., & Stergiou, N. (2014). The influence of auditory-motor coupling on fractal dynamics in human gait. *Scientific Reports, 4*. doi: 10.1038/srep05879
[10] Irish, M., Cunningham, C. J., Walsh, J. B., Coakley, D., Lawlor, B. A., Robertson, I. H., & Coen, R. F. (2006). Investigating the enhancing effect of music on autobiographical memory in mild Alzheimer's disease. *Dement Geriatr Cogn Disord, 22*(1), 108–120. doi: 10.1159/000093487
[11] Istvandity, L. (2017). Combining music and reminiscence therapy interventions for wellbeing in elderly populations: A systematic review. *Complementary Therapies in Clinical Practice, 28*, 18–25. doi: 10.1016/j.ctcp.2017.03.003
[12] Lyu, J., Zhang, J., Mu, H., Li, W., Champ, M., Xiong, Q., … Li, M. (2018). The Effects of Music Therapy on Cognition, Psychiatric Symptoms, and Activities of Daily Living in Patients with Alzheimer's Disease. *J Alzheimers Dis, 64*(4), 1347–1358. doi: 10.3233/jad-180183
[13] Manor, B., Costa, M. D., Hu, K., Newton, E., Starobinets, O., Kang, H. G., … Lipsitz, L. A. (2010). Physiological complexity and system adaptability: evidence from postural control dynamics of older adults. *J Appl Physiol (1985), 109*(6), 1786–1791. doi: 10.1152/japplphysiol.00390.2010
[14] Mantegna, R. N., Buldyrev, S. V., Goldberger, A. L., Havlin, S., Peng, C. K., Simons, M., & Stanley, H. E. (1994). Linguistic features of noncoding DNA sequences. *Phys Rev Lett, 73*(23), 3169–3172. doi: 10.1103/PhysRevLett.73.3169
[15] Maslow, A. H. (1943). A theory of human motivation. *Psychological Review, 50*(4), 370–396. doi: 10.1037/h0054346
[16] McDermott, O., Crellin, N., Ridder, H. M., & Orrell, M. (2013). Music therapy in dementia: a narrative synthesis systematic review. *Int J Geriatr Psychiatry, 28*(8), 781–794. doi: 10.1002/gps.3895
[17] Mioshi, E., Dawson, K., Mitchell, J., Arnold, R., & Hodges, J. R. (2006). The Addenbrooke's Cognitive Examination Revised (ACE-R): a brief cognitive test battery for dementia screening. *Int J Geriatr Psychiatry, 21*(11), 1078–1085. doi: 10.1002/gps.1610
[18] Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., … Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc, 53*(4), 695–699. doi: 10.1111/j.1532-5415.2005.53221.x
[19] Natarajan, K., Acharya, U. R., Alias, F., Tiboleng, T., & Puthusserypady, S. K. (2004). Nonlinear analysis of EEG signals at different mental states. *Biomed Eng Online, 3*(1), 7. doi: 10.1186/1475-925x-3-7
[20] Orti, J. E. D., Garcia-Pardo, M. P. , Iranzo, C. C., Madrigal, J. J. C., Castillo, S. S., Rochina, M. J., & Gasco, V. J. P. (2018). Does Music Therapy Improve Anxiety and Depression in Alzheimer's Patients? *Journal of Alternative and Complementary Medicine, 24*(1), 33–36. doi: 10.1089/acm.2016.0346

[21] Patel, A. D. (2003). Language, music, syntax and the brain. *Nat Neurosci, 6*(7), 674–681. doi: 10.1038/nn1082
[22] Ryan, S. M., Goldberger, A. L., Pincus, S. M., Mietus, J., & Lipsitz, L. A. (1994). Gender- and age-related differences in heart rate dynamics: are women more complex than men? *J Am Coll Cardiol, 24*(7), 1700–1707.
[23] Sacks, O. (2015). *Musicophilia: Tales of Music and the Brain.* Praha: Dybbuk.
[24] Schumann, A. Y., & Kantelhardt, J. W. (2011). Multifractal moving average analysis and test of multifractal model with tuned correlations. *Physica a-Statistical Mechanics and Its Applications, 390*(14), 2637–2654. doi: 10.1016/j.physa.2011.03.002
[25] Simmons-Stern, N. R., Budson, A. E., & Ally, B. A. (2010). Music as a memory enhancer in patients with Alzheimer's disease. *Neuropsychologia, 48*(10), 3164–3167. doi: 10.1016/j.neuropsychologia.2010.04.033
[26] Tosnerova, T., & Bahbouh, R. (1998). Mini-mental state examination, a quick cognitive state test. *Ceskoslovenska Psychologie, 42*(4), 328–333.
[27] van der Roest, H. G., Meiland, F. J., Maroccini, R., Comijs, H. C., Jonker, C., & Droes, R. M. (2007). Subjective needs of people with dementia: a review of the literature. *Int Psychogeriatr, 19*(3), 559–592. doi: 10.1017/s1041610206004716
[28] WHO. (2019). World Health Organization: Dementia Fact Sheet. Retrieved from https://www.who.int/news-room/fact-sheets/detail/dementia

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