

## Exercise with Music: An Innovative Approach to Increase Cognition and Reduce Depression in Institutionalized Elderly

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### Abstract:

Concerning dementia and depression prevention, non-pharmacological interventions such as cognitive-training are currently recommended as an alternative for the elderly, for the reason that they produce less side effects.

Based on this perspective, the aim of this study was to identify the effects of movement with music upon cognition and depression in institutionalized elderly.

A longitudinal study was conducted from November 2013 to February 2014 in Vila Real, Portugal. The sample included thirty-nine institutionalized healthy seniors over 60 years of age who were divided into two groups: music plus movement (MMG,  $n=20$ ,  $80.65\pm6.59$  years) and cognitive training group without music (CTG,  $n=19$ ,  $83.68\pm6.54$  years); both groups were submitted to an intervention period (4 months, 3x/week, 90min/session). Before and after the intervention period the following instruments were applied in both groups: Mini Mental State Examination (MMSE), Raven's Coloured Progressive Matrices (MPCR), and Geriatric Depression Scale (GDS-27).

Both interventions proved to improve cognitive function, mental ability and depression. The interaction effect between programs' intervention and time was observed in language, mental ability, and depression indicators. Considering these variables, the magnitude of variation between moments was higher in the MMG in language and depression with a high effect value for depression ( $\eta^2_p=.342$ ). In conclusion, this study emphasises the role of music and movement as a broad intervention in mental health, acting simultaneously as cognitive training and an anti-depressive.

**Keywords:** Exercise; Cognition; Depression; Music; Elderly

### Introduction

The world's population is aging and Portugal shows the same trend. Despite the increase in average life expectancy, the perspective is not encouraging because with increasing age, greater fragility and more diseases arise, such as dementia and depression (WHO, 2012). An active lifestyle is one of the major points and focus areas in disease prevention, maintenance of cognitive functions, and integration in society.

According to the recommendations of the American College of Sports Medicine and the American Heart Association, physical activity (PA) is considered one of the most promising strategies in improving health. PA not only increases strength and physical fitness, but also has implications in cognitive functions, presenting a protective effect against these new epidemics of the twenty-first century by reducing risk for cognitive decline, dementia,

and the incidence of depression (WHO, 2012). PA is associated with an increase of brain oxygenation, which can improve certain brain structures and functions, facilitating neurogenesis, synaptogenesis and angiogenesis, promoting neural plasticity in the adult brain, and maintenance of cognitive performance (Bamidis et al., 2014). Moreover, in addition to the benefits provided by exercise, music seems to increase work out involvement since it allows the rhythm to act as a cue for movement (Nombela, Hughes, Owen and Grahn, 2013). In fact, music rehabilitation programs use the acoustic stimuli to enhance the connection between rhythmical auditory perception and motor behavior (Thaut, 2005).

Music offers a unique opportunity to better understand the organisation and processes of the human brain, being increasingly studied (Kraus, Zatorre and Strait, 2014) highlighting its contribution to the physiological,

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6 Conflict of Interest: All authors declare no conflicts of interest regarding: employment or affiliation, grants/founds, honoraria, speaker forum, consultant, stocks, royalties, expert testimony, board member, patents, personal relationship.

This work is supported by national funding through the Portuguese Foundation for Science and Technology, I.P., under project UID/DTP/04045/2019.

psychological and emotional integration of the individual (Sung, Chang, Lee and Lee, 2006). Music, as a pleasurable stimulus, is often used to affect emotional states and can be a useful tool in improving the quality of life by incorporating it in institutional settings (Sung et al., 2006).

Previous research has shown that music actually reduces depression and anxiety in elderly patients and delays cognitive deterioration (Chu et al., 2014).

The results from a growing body of investigation are consistent with the idea that engaging in cognitive tasks preserves cognitive functioning, evidencing the benefits of cognitive training (Ballesteros et al., 2015; Smith et al., 2009). A meta-analysis study, with thirty-one randomized control trials, concerned with the impact of cognitive training and general mental stimulation on the cognitive and everyday functioning of older adults without known cognitive impairment (Kelly et al., 2014), concluded that intervention is crucial. In fact, a cognitively stimulating environment helps one maintain or increase the cognitive reserve (Alain, Zendel, Hutka and Bidelman, 2014) and

reduce depressive symptoms (Apóstolo, Cardoso, Marta and Amaral, 2011).

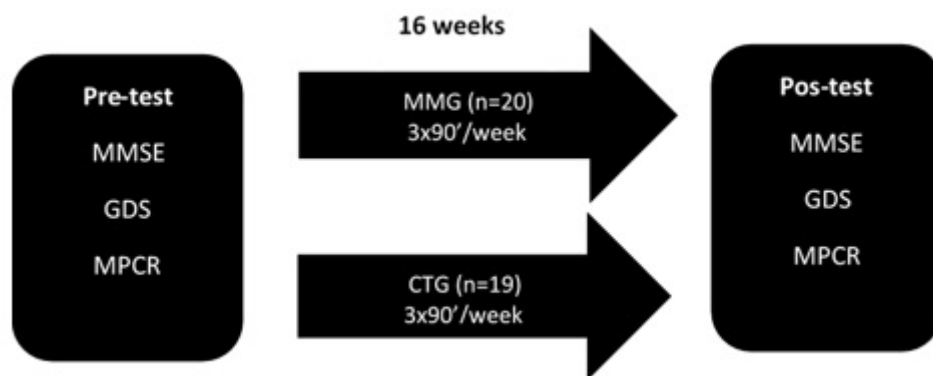
Consequently, it may be expected that intervention programs with the association between movement and music stimulation, with senior citizens could promote cognitive function and positive affections.

In this context, and in order to add a point regarding the disagreement on the efficacy of cognitive-training interventions (Simons et al., 2016), this study aims to examine the effects of two interventions: music plus movement and cognitive training on cognition and depression in the elderly.

## Methods

### Design

This study assumed a longitudinal and a quasi-experimental design (Figure 1). The intervention was carried out for 4 months (16 weeks). Every senior was evaluated at two distinct moments (pre-test and post-test) to compare the programs' effects.



Note. MMSE=Mini Mental State Examination; GDS= Geriatric Depression State; MPCR= Matrix Progressive Colored Raven; MMG= Movement Music Group; CTG= Cognitive Training Group

Figure 1. Experimental design

### Sample

A sample of 42 elderly from two different nursing homes was selected (35 women and 7 men) between 64-96 years of age ( $82.13 \pm 6.66$  years). Three elderly were excluded from the study because they did not comply the three weekly sessions (participation rate: 92.9%). The sample was divided into two different intervention groups: music and movement intervention group (MMG,  $n = 20$ ,  $80.65 \pm 6.59$  years) and a cognitive training group (CTG,  $n = 19$ ,  $83.68 \pm 6.54$  years). The introduction of a cognitive training group aimed to equalize the time spent in activities (though different), and reduces motivational differences between groups.

The inclusion criteria were: subjects aged 60 years old or above, attendance at least two of the three weekly sessions, and absence of any medical contraindication to the practice of physical activity (assessed by a physician) for the MMG; and as to exclusion criteria, presenting any cognitive impairment. All subjects provided a written informed consent to participate in the study and all ethical aspects in the Declaration of Helsinki (UNESCO, 2006) were observed.

### Intervention Programs

The intervention programs were designed and performed in order to stimulate the different cognitive functions (orientation, attention, memory, language, and visual-

constructional ability), and reduce depressive symptoms. A psychomotor therapist, with a specialization in music, implemented these programs at two nursing homes, for 4 months (16 weeks), three times a week, totalling 48 sessions of 90 minutes each, on non-consecutive days.

The MMG program was based on the theory of embodied cognition, which argues that cognition emerges from the interaction between organism and environment, as a result of sensory-motor activity (Smith, 2005). Hence, this program included music plus movement activities, emphasising rhythm as a precursor to movement (Nombela et al., 2013). The musical selection (mostly traditional folk and popular songs) was based on the participants' preferences in order to motivate them. This practice included a combination of group experiences such as: group dynamics, games, rhythmic exercises, rhythmic circuits, choreography, children's songs, folk songs, instrumental accompaniment, body percussion, etc., emphasising social interaction. Additionally, playful stimulating activities were put into practice throughout the program, using a variety of instruments such as: audio systems, musical instruments, balls, hoops, sticks, cones, ropes, parachutes, board games, etc.

The CTG sessions included cognitive activities such as: board games, memory games, puzzles, checkers, bingo, and other sensory, perceptual stimulation activities.

### Instruments

**Cognitive Function.** The cognitive function was assessed by *Mini Mental State Examination* (MMSE) (Folstein, Folstein and McHugh, 1975) validated for the Portuguese population by Guerreiro et al. (1994). MMSE consists of a set of items which evaluate different cognitive abilities: orientation, attention, memory, language, and visual-constructional ability. The maximum score is 30, with higher values indicating a better cognitive performance. The following cut-off values were established to define cognitive impairment: Illiterate  $\leq 15$ ; 1-11 years of schooling  $\leq 22$ ; schooling greater than 11 years  $\leq 27$ ), (Morgado, Rocha, Maruta, Guerreiro and Martins, 2009). The test was individually applied to each elderly person by the researcher. Cronbach's alpha shows a high internal consistency ( $\alpha = .88$ ).

**Depression.** The *Geriatric Depression Scale* (GDS -27) was developed by Yesavage et al. in 1983 and validated for the elderly Portuguese population by Pocinho et al. (2009). The GDS -27 consists of 27 polar questions (yes/no) which measure depressive symptoms, particularly covering the previous week. The occurrence of 11 or more symptoms is used as the cut-off value to define the absence or presence of depression (Pocinho et al., 2009). This instrument was applied individually and the Cronbach's alpha shows a high internal consistency ( $\alpha = .88$ ).

**Mental Ability.** *Raven's Coloured Progressive Matrices* (MPCR) was developed by Raven (1947) to evaluate the mental ability from a non-verbal perspective. The

Portuguese version was validated by Simões (2000), and it is composed of 36 items divided into three series of 12 problems, arranged in order of ascending difficulty. The test consists of presenting an incomplete picture, to which the individual has to choose one out of six possible alternatives to complete the design; the final score varies between 0-36. The test was applied individually, according to standard instructions and the internal consistency was calculated based on Cronbach's alpha statistic and revealed poor internal consistency ( $\alpha = .55$ ).

### Statistical Analysis

Statistical analysis was performed with the SPSS 19.0 (*Statistical Package for the Social Sciences*). Normal distributions were obtained as all skewness and kurtosis values arranged from -1 to 1. The *t*-test and the chi-squared test were used to compare baseline data between groups. The repeated measures Analysis of Variance (MANOVA) was applied to observe changes in the two groups after the two intervention programs. The effect size was evaluated by the partial square test ( $\eta^2 p$ ) adopting values smaller than 0.05 as small effect, between 0.06 and 0.25 as a moderate effect, between 0.26 and 0.50 as high and greater than 0.50 as a very high effect (Cohen, 1988; Marôco, 2014).

The level of significance was set at 5%.

### Results

As shown in table 1, no significant differences were found between age groups, in formal education.

**Table 1.**

*Comparison between MMG and CTG group at baseline*

Characteristics	MMG (n= 20)	CTG (n= 19)	p
Age (years)	80.65±6.59	83.68±6.54	.158 <sup>a</sup>
Education level			.421 <sup>b</sup>
- illiterate	11 (55%)	8 (42.1%)	
- elementary school	9 (45 %)	11 (57.9%)	
Cognitive Funtion	13.15±5.07	13.84±6.48	.712 <sup>a</sup>
Mental Ability	12.30±2.00	11.47±3.69	.395 <sup>a</sup>
Depression	16.15±6.22	13.42±5.51	.156 <sup>a</sup>

*Note.* MMG = music plus movement; CTG = cognitive training group; Depression score: ranges from 0 to 27; the higher the score, the more depressed the subject

\* $p \leq 0.05$ ; <sup>a</sup> *t*-test ;<sup>b</sup> *chi-square*<sup>2</sup>

The differential analysis between pre and post-test moments in Cognitive Function, Mental Ability, and Depression in both groups are described in table 2.

**Table 2.**

Baseline and Post-test Data for Cognitive Function, Mental Ability, Depression Data for MMG and CTG groups

	MMG (n= 20)		CTG (n= 19)	
	Pre-test	Post-test	Pre-test	Post-test
Cognitive Function	13.15±5.07	18.55±4.93	13.84±6.48	18.11±6.18
- Orientation	4.55±2.65	6.55±2.52	5.00±3.32	6.74±2.47
- Retention	2.15±.98	2.80±.41	1.79±1.27	2.52±.84
- Attention & calculation	.80±1.28	1.20±1.82	1.21±1.36	1.52±1.95
- Evocation	.40±.68	.90±.96	.42±.84	1.00±1.00
- Language	5.25±1.37	7.00±.56	5.42±1.54	6.26±1.24
- Constructive ability	.00±.00	.10±.31	.00±.00	.10±.32
Mental Ability	12.30±2.00	13.10±2.69	11.47±3.69	14.47±4.40
Depression	16.15±6.22	7.45±4.43	13.42±5.51	12.21±5.90

Note. MMG = music plus movement; CTG = cognitive training group

## Cognitive Function

There is a significant change in the MMSE total score across time (baseline and pos-test) [ $F(1, 39) = 59.59, p < .000, \eta_p^2 = .60$ ], but for the interaction between time and group no significant changes were found [ $F(1, 39) = 0.89, p < .351, \eta_p^2 = .022$ ].

Significant changes across time were also found for the items: orientation [ $F(1, 39) = 25.97, p < .000, \eta_p^2 = .40$ ], retention [ $F(1, 39) = 14.9, p < .000, \eta_p^2 = .27$ ], evocation [ $F(1, 39) = 18.96, p < .000, \eta_p^2 = .33$ ], language [ $F(1, 39) = 45.99, p < .000, \eta_p^2 = .541$ ] and constructive ability [ $F(1, 39) = 4.22, p < .047, \eta_p^2 = .09$ ], but for the item attention & calculation no significant change were found [ $F(1, 39) = 2.17, p < .15, \eta_p^2 = .05$ ].

For the interaction between time and group no significant changes were found for all the items of the MMSE: orientation [ $F(1, 39) = 0.13, p < .717, \eta_p^2 = .003$ ], retention [ $F(1, 39) = 0.152, p < .698, \eta_p^2 = .004$ ], attention & calculation

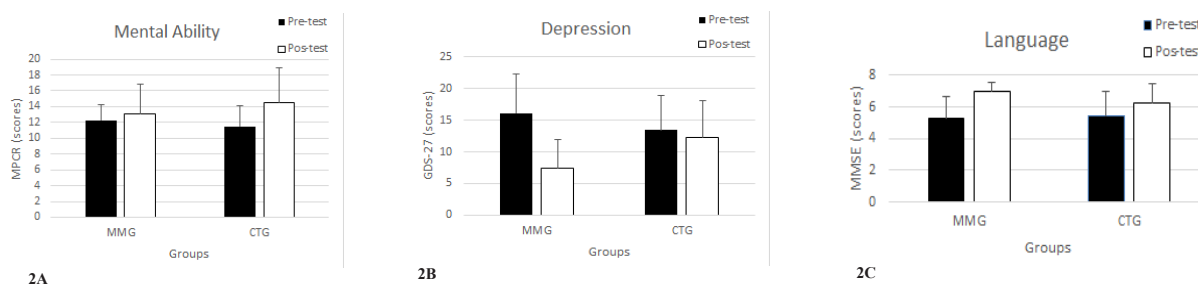
[ $F(1, 39) = 0.031, p < .862, \eta_p^2 = .001$ ], evocation [ $F(1, 39) = 0.098, p < .756, \eta_p^2 = .003$ ] and constructive ability [ $F(1, 39) = 0.003, p < .960, \eta_p^2 = .000$ ], except for the item language [ $F(1, 39) = 6.48, p < .015, \eta_p^2 = .143$ ] (Fig. 2A).

## Mental Ability

There is a significant change in the mental ability across time (baseline and pos-test) [ $F(1, 39) = 13.173, p < .001, \eta_p^2 = .263$ ], as well as for the interaction between time and group [ $F(1, 39) = 4.415, p < .042, \eta_p^2 = .107$ ] (Fig. 2B).

## Depression

There is a significant change in the depression across time (baseline and pos-test) [ $F(1, 39) = 34.765, p < .000, \eta_p^2 = .484$ ], as well as for the interaction between time and group [ $F(1, 39) = 19.26, p < .000, \eta_p^2 = .342$ ] (Fig. 2C).



Note. MMG = music plus movement; CTG = cognitive training group

**Figure 2.** Interaction between time and MMG and CTG on language (MMSE), mental ability and depression



## Discussion

The results of this study revealed that in general both groups showed significant improvements in cognitive function, mental ability and depression. These results are in congruence with the existing literature, which states that intervention programs (either cognitive-training or physical activity, or a combination of both) are effective and lead to the maintenance and/or improvement in the performance of cognitive skills, and in reducing depression levels (Oliveira et al., 2014; Verrusio et al., 2014).

The MMG results support the hypothesis that an intervention that uses only music associated with movement allows, similarly to CTG (cognitive training), positive effects on cognitive function. These results were also documented in literature (Chu et al., 2014; Eggermont, 2014). In fact, music mobilizes almost all cognitive functions and musical processing involves different regions, including all the lobes, cortical and subcortical structures (Levitin and Tirovolas, 2009). In this study, an improvement in all the items (orientation, retention, evocation and language) was also observed, except in the item “attention & calculation”. Chu et al. (2014), underlie the contribution of rhythm, which is positively reflected in the issues of temporal/spatial orientation, retention, recall, language, and attention and calculation, items that showed an increase from baseline to post-intervention. Moreover, a significant interaction effect was only observed in the item language. In fact, although the effect size was moderate ( $\eta^2_p = .143$ ), the intervention with movement and music proved to be more effective in improving language of elderly people compared with the cognitive intervention. A possible explanation could be related to the use of traditional folk music and popular songs that stimulated singing and conversation related to the songs in the group during the exercises. The effect of music in speech and fluency was also demonstrated by Brotons and Koger (2000) with patients suffering from Alzheimer’s disease.

Because previous studies (Simmons-Stern, Budson and Ally, 2010) have found that attention is the basic cognitive function most affected by an intervention to improve cognitive performance, more significant results had been expected. Moreover, as music enhances individuals’ activity, allowing for an improvement in attentional processes and memory (Simmons-Stern et al., 2010), its association with movement and sequences of movements should have elicited an improvement in attention & calculation in this study.

With regard to the results of mental ability, significant differences between baseline and post-intervention moments were found in both groups. A significant interaction effect was also observed with a moderate effect size ( $\eta^2_p = .107$ ), revealing that cognitive-training was more effective in developing mental ability than music plus movement. The approach used by CTG was restricted to cognitive-training activities (board games, spatial reasoning puzzles, puzzles, etc.) which entail a greater degree of ability

of reasoning and problem solving evaluated by the MPCR. This promotes a greater degree of transfer between tasks due to the shared elements and can explain the results.

Our results showed a significant interaction effect of group x time in depression symptoms ( $\eta^2_p = .342$ ), revealing a higher reduction in the MMG compared to CTG. One possible explanation for the displayed discrepancy may be related to the type of intervention performed, since the MMG focused on the experience of music using movement. There is, on its own, a strong relationship between physical activity and depression, and more active individuals have a lower incidence, especially when associated with a musical component (Verrusio et al., 2014). Several authors add that music is considered a facilitator of movement, making the physical effort minor and more enjoyable (Satoh et al., 2014). Another possible interpretation may focus on the effects of music based on preferences/familiar music on the regulation of psychological mood, evoking more positive responses which will be reflected upon depression (Chu et al., 2014). According to Chu et al. (2014) auditory stimulation may “distract” the elderly from unpleasant feelings, providing them with a more pleasant stimulus in detriment of depressive thoughts. It also plays an important role in social interactions (Herholz and Zatorre, 2012), thus promoting a sense of belonging, companionship, and psychological well-being by activating circuits associated with pleasure and reward (Herholz and Zatorre, 2012). The use of musical instruments also allowed an opportunity for an enriching expression of emotions, leading to an emotional balance (Chu et al., 2014). Moreover, music acts as a catalyst in promoting motor activity as a powerful phenomenon to which most people respond spontaneously and intuitively to by clapping, foot-tapping, finger snapping, etc. (Sung et al., 2006).

Over recent years, a close and natural connection has been explored between the auditory and motor systems (Chen, Penhune and Zatorre, 2008; Nombela et al., 2013) suggesting the existence of brain areas involved in processing rhythm which are interrelated with movement. These areas are mostly the premotor cortex, supplementary motor area, basal ganglia, and cerebellum (Chen et al., 2008; Chen, Penhune and Zatorre, 2009). The latter is also involved in sensory-motor associations, monitoring rhythmic patterns and adapting changes in behaviour (Bijsterbosch et al., 2010). Several studies using functional magnetic resonance imaging have shown that cognition, emotion, perception, and motor functions are interconnected (Goldshtröm, Korman, Goldshtröm and Bendavid, 2011; Kraus et al., 2014).

The positive results of the MMG in cognition and depression suggest a new approach to promote the mental health of institutionalized elderly, by means of motor-musical activities. The communication provided by “music and movement” (Sung et al., 2006), based on the association of physical, cognitive and social activities, is indispensable for harmony between body and mind. Our brain is sculpted and shaped by life experiences. It is, therefore, fundamental to create an enriching environment to capitalize brain plasticity.

Finally, it should also be highlighted that this study has some limitations associated with the size and representativeness of its sample. Additionally, the inclusion of a control randomized group with a double blinded intervention could have allowed for more accurate and relevant results. Future research could combine different cognitive training protocols with physical or exercise activities in an effort to enhance cognitive and brain health (Gajewski and Falkenstein, 2016). Furthermore, the usage of more precise instruments in order to assess the impact upon brain structure and function would be recommended.

In conclusion, the application of both programmes was beneficial to our sample, but the MMG program was more effective in emphasising the role of music and movement as an innovative approach with potential in the emergent field of mental health, acting simultaneously as cognitive training and an anti-depressive.

## Aknowledgements

The authors thank the older men and women for their participation in the study.

### **Ejercicio con musica: Un enfoque innovador para aumentar la cognición y reducir la depresión en ancianos institucionalizados**

#### **Resumen:**

Actualmente las intervenciones no farmacológicas se recomiendan como alternativas en la prevención de la demencia y la depresión en los ancianos, porque tienen menos efectos secundarios.

En esta perspectiva, este estudio tiene como objetivo identificar los efectos de una intervención que combina música y ejercicio en la cognición y la depresión en ancianos institucionalizados.

Se realizó un estudio longitudinal de noviembre de 2013 a febrero de 2014 en dos instituciones de ancianos, en la ciudad de Vila Real, Portugal. La muestra incluyó a 39 individuos ancianos sanos institucionalizados mayores de 60 años que se dividieron en dos grupos: “grupo de música y ejercicios” (MMG,  $n = 20$ ,  $80.65 \pm 6.59$  años) y “grupo de entrenamiento cognitivo” (CTG,  $n = 19$ ;  $83.68 \pm 6.54$  años). Ambos fueron sometidos a un período de intervención (4 meses, 3 veces por semana, 90 minutos por sesión). Antes y después de la intervención, se utilizaron los siguientes instrumentos en ambos grupos: *Mini Mental State Examination* (MMSE), Test de Matrices Coloridas de Raven (MPCR) y Escala de Depresión Geriátrica (GDS-27).

Ambas intervenciones mostraron mejoras en la función cognitiva, la capacidad mental y la depresión. El efecto de interacción entre los programas de intervención y el tiempo se observó en el lenguaje, la capacidad mental y la depresión. Teniendo en cuenta estas variables, la amplitud de la variación entre los momentos fue mayor en el lenguaje y la depresión en el grupo MMG, y se encontró un alto valor de efecto para la depresión ( $\eta^2 p = 0.342$ ). En conclusión, este estudio enfatiza el papel de la música y del movimiento como una intervención más completa en la salud mental, actuando simultáneamente en el entrenamiento cognitivo y en la depresión.

**Palabras clave:** ejercicio; cognición; depresión; música; anciano

### **Exercício com música: uma proposta inovadora para otimização da cognição e da redução da depressão em idosos institucionalizados**

#### **Resumo:**

Hoje em dia, as intervenções não farmacológicas são recomendadas como alternativas na prevenção da demência e depressão em idosos, porque apresentam menos efeitos secundários.

No âmbito desta perspectiva, o presente estudo tem como objetivo identificar os efeitos de uma intervenção combinando a música e o exercício na cognição e depressão em idosos institucionalizados.

Foi realizado um estudo longitudinal de Novembro de 2013 a Fevereiro de 2014 em duas instituições de idosos, na cidade de Vila Real, Portugal. A amostra incluiu 39 idosos saudáveis institucionalizados, com idade superior a 60 anos, que foram divididos em dois grupos: “grupo música e exercício” (MMG,  $n = 20$ ;  $80.65 \pm 6.59$  anos) e “grupo de treino cognitivo” (CTG,  $n = 19$ ;  $83.68 \pm 6.54$  anos). Ambos foram sujeitos a um período de intervenção (4 meses, 3x/semana, 90min/sessão). Antes e depois da intervenção foram utilizados os seguintes instrumentos em ambos os grupos: *Mini Mental State Examination* (MMSE), Matrices Coloridas de Raven (MPCR), e a Escala de Depressão Geriátrica (GDS-27).

Ambas as intervenções evidenciaram melhorias na função cognitiva, capacidade mental e na depressão. O efeito de interação entre os programas de intervenção e o tempo foi observado na linguagem, capacidade mental e depressão. Considerando estas variáveis, a amplitude da variação entre os momentos foi maior na linguagem e na depressão no grupo MMG, sendo o tamanho do efeito grande na depressão ( $\eta^2 p = 0.342$ ). Em conclusão, este estudo enfatiza o papel da música e do movimento como uma intervenção mais completa na saúde mental, atuando simultaneamente no treino cognitivo e na depressão.

**Palavras Chave:** exercício físico; cognição; depressão; música; idosos

## References

- Alain, C., Zendel, B. R., Hutka, S. and Bidelman, G. M. (2014). Turning down the noise: The benefit of musical training on the aging auditory brain. *Hearing Research*, 308, 162-173.
- Apóstolo, J. L. A., Cardoso, D. F. B., Marta, L. M. G. and Amaral, T. I. O. (2011). Efeito da estimulação cognitiva em Idosos. *Revista de Enfermagem Referência*, 3(5), 193-201. doi:http://dx.doi.org/10.12707/RIII11104
- Ballesteros, S., Mayas, J., Prieto, A., Toril, P., Pita, C., Poncede de León, L., . . . Waterworth, J. A. (2015). A randomized controlled trial of brain training with non-action video games in older adults: results of the 3-month follow-up. *Front Aging Neurosci.*, 7(45). doi:10.3389/fnagi.2015.00045
- Bamidis, P. D., Vivas, A. B., Styliadis, C., Frantzidis, C., Klados, M., Schlee, W., . . . Papageorgiou, S. G. (2014). A review of physical and cognitive interventions in aging. *Neuroscience & Biobehavioral Reviews*(0). doi:http://dx.doi.org/10.1016/j.neubiorev.2014.03.019
- Bijsterbosch, J. D., Lee, K. H., Hunter, M. D., Tsoi, D. T., Lankappa, S., Wilkinson, I. D., . . . Woodruff, P. W. R. (2010). The Role of the Cerebellum in Sub- and Supraliminal Error Correction during Sensorimotor Synchronization: Evidence from fMRI and TMS. *Journal of Cognitive Neuroscience*, 23(5), 1100-1112. doi:10.1162/jocn.2010.21506
- Brotons, M. and Koger, S. (2000). The impact of music therapy on language functioning in dementia. *J Music Ther*, 37(3), 183-195.
- Chen, J. L., Penhune, V. B. and Zatorre, R. J. (2008). Listening to Musical Rhythms Recruits Motor Regions of the Brain. *Cerebral Cortex*, 18(12), 2844-2854. doi:10.1093/cercor/bhn042
- Chen, J. L., Penhune, V. B. and Zatorre, R. J. (2009). The Role of Auditory and Premotor Cortex in Sensorimotor Transformations. *Annals of the New York Academy of Sciences*, 1169(1), 15-34. doi:10.1111/j.1749-6632.2009.04556.x
- Chu, H., Yang, C. Y., Lin, Y., Ou, K. L., Lee, T. Y., O'Brien, A. P. and Chou, K. R. (2014). The Impact of Group Music Therapy on Depression and Cognition in Elderly Persons With Dementia: A Randomized Controlled Study. *Biological Research For Nursing*, 16(2), 209-217. doi:10.1177/1099800413485410
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (L. E. Associates Ed. Second ed.).
- Eggermont, J. J. (2014). Music and the Brain. In J. J. Eggermont (Ed.), *Noise and the Brain* (pp. 240-265). San Diego: Academic Press.
- Folstein, M. F., Folstein, S. E. and McHugh, P. R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, 12(3), 189-198. doi:http://dx.doi.org/10.1016/0022-3956(75)90026-f6
- Gajewski, P. D. and Falkenstein, M. (2016). Physical activity and neural cognitive functioning in aging - a condensed updated review. *European Review of Aging and Physical Activity*, 13(1). doi:10.1186/s11556-016-0161-3
- Goldstroom, Y., Korman, D., Goldstroom, I. and Bendavid, J. (2011). The effect of rhythmic exercises on cognition and behaviour of maltreated children: A pilot study. *Journal of Bodywork and Movement Therapies*, 15(3), 326-334. doi:http://dx.doi.org/10.1016/j.jbmt.2010.06.006
- Guerreiro, M., Silva, A. P., Botelho, M. A., Leitão, O., Castro-Caldas, A. and Garcia, C. (1994). Adaptação à população portuguesa da tradução do "Mini Mental State Examination" (MMSE). *Revista Portuguesa de Neurologia*, 1, 9-10.
- Herholz, S. C. and Zatorre, R. J. (2012). Musical Training as a Framework for Brain Plasticity: Behavior, Function and Structure. *Neuron*, 76(3), 486-502. doi:http://dx.doi.org/10.1016/j.neuron.2012.10.011
- Kelly, M. E., Loughrey, D., Lawlor, B. A., Robertson, I. H., Walsh, C. and Brennan, S. (2014). The impact of cognitive training and mental stimulation on cognitive and everyday functioning of healthy older adults: A systematic review and meta-analysis. *Ageing Research Reviews*, 15, 28-43.
- Kraus, N., Zatorre, R. J. and Strait, D. L. (2014). Editors' introduction to Hearing Research special issue: Music: A window into the hearing brain. *Hearing Research*, 308(0), 1. doi:http://dx.doi.org/10.1016/j.heares.2013.09.013
- Levitin, D. J. and Tirovolas, A. K. (2009). Current Advances in the Cognitive Neuroscience of Music. *Annals of the New York Academy of Sciences*, 1156(1), 211-231. doi:10.1111/j.1749-6632.2009.04417.x
- Marôco, J. (2014). *Análise Estatística com o SPSS Statistics* (ReportNumber Ed. 6ª ed.). Pero Pinheiro.
- Morgado, J., Rocha, C. S., Maruta, C., Guerreiro, M. and Martins, I. P. (2009). Novos Valores Normativos do Mini-Mental State Examination. *Sinapse: Sociedade Portuguesa de Neurologia*, 9(2), 164.
- Nombela, C., Hughes, L. E., Owen, A. M. and Grahn, J. A. (2013). Into the groove: Can rhythm influence Parkinson's disease? *Neuroscience & Biobehavioral Reviews*, 37(10, Part 2), 2564-2570. doi:http://dx.doi.org/10.1016/j.neubiorev.2013.08.003
- Oliveira, T. C. G., Soares, F. C., Macedo, L. D. D., Diniz, D. L. W. P., Bento-Torres, N. V. O. and Picanço-Diniz, C. W. (2014). Beneficial effects of multisensory and cognitive stimulation on age-related cognitive decline in long-term-care institutions. *Clin Interv Aging*, 9, 309-321. doi:10.2147/CIA.S54383
- Pocinho, M. T. S., Farate, C., Dias, C. A., Lee, T. T. and Yesavage, J. A. (2009). Clinical and Psychometric Validation of the Geriatric Depression Scale (GDS) for Portuguese Elders. *Clinical Gerontologist*, 32(2), 223-236.
- Raven, J. C. (1947). *Coloured Progressive Matrices Sets A, Ab, B*. Oxford: Oxford Psychologists Press Ltd.
- Satoh, M., Ogawa, J., Tokita, Y., Nakaguchi, N., Nakao, K., Kida, H. and Tomimoto, H. (2014). The Effects of Physical Exercise with Music on Cognitive Function of Elderly People: Mihama-Kiho Project. *PLoS One*, 9(4), e95230. doi:10.1371/journal.pone.0095230

- Simmons-Stern, N. R., Budson, A. E. and 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
- Simões, M. M. R. (2000). Investigações no Âmbito da Aferição Nacional do Teste das Matrizes Progressivas Coloridas de Raven (M.P.C.R.). Dissertação de Doutoramento, Universidade de Coimbra, Coimbra.
- Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z. and Stine-Morrow, E. A. L. (2016). Do “Brain-Training” Programs Work? *Psychological Science in the Public Interest*, 17(3), 103-186.
- Smith, G. E., Housen, P., Yaffe, K., Ruff, R. M., Kennison, R. F. and al., e. (2009). A cognitive training program based on principles of brain plasticity: results from the Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) study. *J Am Geriatr Soc*, 57, 594–603.
- Sung, H. C., Chang, S. M., Lee, W. L. and Lee, M. S. (2006). The effects of group music with movement intervention on agitated behaviours of institutionalized elders with dementia in Taiwan. *Complementary Therapies in Medicine*, 14(2), 113-119. doi:http://dx.doi.org/10.1016/j.ctim.2006.03.002
- Thaut, M. H. (2005). The future of music in therapy and medicine. *Annals of the New York Academy of Sciences*, 1060, 303-308.
- Verrusio, W., Andreozzi, P., Marigliano, B., Renzi, A., Gianturco, V., Pecci, M. T., . . . Gueli, N. (2014). Exercise training and music therapy in elderly with depressive syndrome: A pilot study. *Complementary Therapies in Medicine*, 22(4), 614-620. doi:http://dx.doi.org/10.1016/j.ctim.2014.05.012
- WHO. (2012). *Dementia: a Public Health Priority* (Genebra: World Health Organization ed.).