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THE MOTOR AND COGNITIVE EFFECTS ASSOCIATED WITH MUSICAL TRAINING: A NARRATIVE REVIEW

EFEITOS MOTORES E COGNITIVOS ASSOCIADOS AO TREINAMENTO MUSICAL: UMA REVISÃO NARRATIVA

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ABSTRACT

Music is an element constantly present in our society, regardless of time or location. Archaeological evidence reveals the possible existence of musical instruments in prehistoric times, showing a long-lasting relationship with music. Currently, studies have grown that indicate that musical practice (musical instrument training and singing) could generate effects that would benefit musicians. Such data gave rise to the hypothesis that musical training could be an interesting stimulus for cognitive and motor development. The aim of this study was to synthesize current evidence (last 10 years) on the influence of musical practice on motor and cognitive developments. A critical narrative review of the literature was carried out. Discuss the effects of musical training exposure in different age groups and the possible implications for neuropsychomotor development and motor rehabilitation.

Keywords: Music training. Music practice. Effects. Brain. Motor.

RESUMO

Music is an element constantly present in our society, regardless of time or location. Archaeological evidence reveals the possible existence of musical instruments in prehistoric times, showing a long-lasting relationship with music. Currently, an increasing number of studies indicate that musical practice (such as musical instrument training and singing) can generate effects that benefit musicians. These data have given rise to the hypothesis that musical training could be an effective stimulus for cognitive and motor development. The aim of this study was to synthesize current evidence (from the last 10 years) on the influence of musical practice on motor and cognitive development. A critical narrative review of the literature was carried out, discussing the effects of musical training exposure in different age groups and the possible implications for neuropsychomotor development and motor rehabilitation.

Palavras-chave: Treinamento musical. Prática musical. Efeitos. Cérebro. Motor.

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INTRODUCTION

The relationship between music and humanity dates back to prehistory (around 36,000 years), archaeological evidence suggests that *homo sapiens sapiens* already produced rudimentary bone wind instruments in the Paleolithic period (Killin, 2018; Zhang et al., 2004). If the long-lasting origin of music dates back to prehistory, its diversity of characteristics is so vast that it lacks a precise consensus regarding its definition (Mithen, 2009).

Considering that its permanence and presence are independent of time and place, its emergence could be linked to the evolution of human communication (Mithen, 2009). Therefore, music is one of the oldest arts and still intensely present in contemporary society.

In addition to entertainment and pleasure, music has been explored as an effective resource to induce specific behaviors. In the commercial sector, companies use music to create a bond with customers, which favors the consumption of goods and/or services. In cinema, music is an indispensable resource to enhance immersion in the narrative and enhance the emotional effects of the plot (Esfidani et al., 2022; Hoeckner et al., 2011).

The effects of music are linked to its ability to stimulate different brain areas with the same stimulus. In a recent meta-analysis it was found that only by listening to music it is possible to produce activations bilaterally in the frontal, temporal, striatal and cerebellar regions (Chan & Han, 2022). Going beyond passive appreciation, when comparing the brains of music practitioners and non-music practitioners, significant differences in gray matter volume were seen in the motor, auditory and visuospatial regions in favor of the musical group (Gaser & Schlaug, 2003).

Furthermore, the effect of music and its practice is not limited to changes in behavior and brain activation, as this can positively influence motor learning and motor performance. In the study of Bonassi et al. (2023) it was demonstrated that pleasant melodies can improve motor components involved in learning a specific test sequence, complementing this finding, the study of Taheri et al. (2022) proved that ambient music accelerates the performance of skills and working memory of students.

Given the context, several studies have proposed to investigate the effects of music on motor and cerebral effects, this interest particularly comes from the possibility of implications in the rehabilitation and cognitive development sector.

Therefore, the objective of this review was to synthesize the current evidence on the influence of musical practice on motor and cognitive outcomes.

METHOD

The articles selected to integrate the general analysis of this review should be published in the 2013-2023 time frame. The choice of articles was made according to their theme. The searches were completed on 12/10/2023, using the PubMed, SciELO and Google Scholar databases. The data was extracted and interpreted by the authors according to their expertise on the subject.

Musical training in children

Exposing children to music has always seemed like a very productive hobby and happens quite frequently, but beyond that, several recent studies have investigated the effects of musical training on children. It is hypothesized that early exposure could improve/facilitate neural processes involved in hearing, motor coordination, brain functions and structures involved in cognition, speed of reasoning and working memory (Bergman et al., 2014; Carpentier et al., 2016; Gleichmann et al., 2022; Loui et al., 2019; Martins et al., 2018; Tervaniemi et al., 2021).

There were significant results with the musical interventions in this audience. In the study by Loui et al. (2019) it was found that children who had musical practice for at least 30 minutes per week had better verbal and intellectual skills than the group that did not have such experience. Corroborating this data, in the study by Bergman et al. (2014), it also concluded that the training was associated with an improvement in reasoning, working memory and mathematics.

However, the question arises, when does the child have a condition or pathology? Could musical training be positive too or a fruitless attempt? The study by Gleichmann et al. (2022) answered this question when it evaluated the neuropsychological effects of musical training in children with fetal alcohol spectrum disorders. Exposure to musical training has been shown to improve neural levels of attention. This is important information to illustrate that musical training is not restricted to a population of asymptomatic children, and that it can be beneficial in conditions that compromise attention levels.

In addition, going beyond cognitive factors in the study (Martins et al., 2018), motor skills related to motor coordination were measured in three groups: control, basketball and music. It was found that dexterity and bimanual motor coordination had a robust superiority in favor of the musical training group compared to the other groups.

What would be the ideal starting age for musical training to produce effects on children's neuropsychomotor development? None of the studies that made up this review set out to answer this question, however it is something considerable when we think about a strategy that, in addition to well-being, can possibly affect their cognitive and motor development (regardless of an asymptomatic state or not). Although specific studies are needed to elucidate this issue, the age range chosen for interventions can give us guidance on this issue.

Ages ranged from 4-25 years (Bergman et al., 2014; Carpentier et al., 2016) (this data is explained by a long-term study that carried out multiple collections over the years), but the most prevalent ages were around 8 years of age (Gleichmann et al., 2022; Martins et al., 2018; Tervaniemi et al., 2021). The relevant fact is that everyone obtained positive results regarding the variables analyzed, so that there was no superior effect in one age group. The study by Bergman et al. (2014) carried out multiple collections over the years and also found that there was no development window where the results were more expressive.

Consideration needs to be made regarding the type of musical training, intensity and content. Tasks given to children must also consider the child's age and stage of development and their particular evolution with a musical instrument. Although it is an important element for development, the playful and pleasurable context of the experience cannot be removed to the detriment of an exhaustive performance, which can actually reduce the child's adherence and liking to the training. Moderation and fun are the guidelines for musical training with children.

Musical Training in Adults and Elderly

There are some recent studies that have investigated the effects of musical training with the adult population (Amengual et al., 2013; Cheung et al., 2017; Ullén et al., 2015; Wirth et al., 2021). However, the samples were different, two studies used an asymptomatic adult population, one study evaluated the effects of musical training

in the elderly (over 60 years old) and another study evaluated the intervention with post-stroke patients.

When evaluating the effects of musical training in asymptomatic adults, we had divergent results. In the study conducted by Gaser and Schlaug (2003) who carried out a co-hort study with a pair of twins who were exposed to musical training, it was found that musical practice may be associated with a more stable motor performance, however the effect is less significant when external variables are controlled (environment). On the other hand, in the study by Cheung et al. (2017), which compared two groups, one with musical training and the other without musical training, it was found that the group that had the training showed a significant increase in the coherence of the right and left intrahemispheric EEG throughout the theta range during the encoding phase of verbal memory.

In the study by Wirth et al. (2021), the association between music production throughout life and the maintenance of cognition was evaluated, comparing a group with musical training and another without training. It was found that the musical training group achieved better results in global cognition, working memory and executive function. This work had asymptomatic elderly people in the early stages of cognitive decline and Alzheimer's disease. This study gives us long-term insight into the effects of musical training, which is protective of the maintenance of cognitive functions. And in turn, this data is important as it opens up a range of possibilities for implementing musical training during senescence.

Would musical training be effective when considering a population affected by neurological pathology? According to the study by Amengual et al. (2013), significant motor gains are also accompanied by neuroplastic changes in patients with chronic stroke after just 20 music sessions. This study found an increase in the excitability of the affected hemisphere after training.

Such studies offer an interesting panorama for motor rehabilitation, patients with neurological pathologies could benefit from strategies based on musical training for recovery and maintenance of function. One of the classic guiding principles of neuroplasticity is that of Use and Disuse and Repetition, so one of the problems in the physiotherapy process is how to make a therapy motivating, even though it requires frequent intensity and a high degree of repetition. Perhaps adhering to a complementary protocol with musical training could provide a great motivator for this challenge.

Frequency for musical training

What is the minimum time to produce beneficial motor and cognitive effects with musical training? The protocol with the minimum time that was covered by this review carried out musical training for 4 weeks and the protocol with the longest duration lasted 2 semesters (Amengual et al., 2013; Tervaniemi et al., 2021). Interestingly, the studies that used a more limited time of approximately one month (Amengual et al., 2013; Carpentier et al., 2016) had a more intense frequency with daily sessions. So there does not seem to be an exact determination of how much time is needed for the effects of musical training to reverberate in motor and cognitive conditions, as the studies used different “dosages”. However, it can be inferred that we have a certain degree of evidence that a month of daily musical practice can have positive effects, mainly on levels of brain reorganization (Amengual et al., 2013; Carpentier et al., 2016).

Musical training and cognition

Some studies have more directly assessed the effects of musical training on cognitive variables. In the study by Cheung et al. (2017), a group with musical training and one without was compared, it was found that the musical training group had a significant improvement in verbal memory. This corroborates the data from Bergman et al. (2014) who found that practicing music is associated with better performance in reasoning, working memory and mathematics tests. And finally, as previously mentioned, the study by Wirth et al. (2021) verified that this superiority can be maintained in senility, because, when comparing a group of music practitioners and another group of non-practitioners at an advanced age, there is an advantage in global cognition, memory work and executive functions. This fact suggests a tendency for effects to be maintained in the medium and long term.

Musical Training versus Second Language Learning

Recently, two studies evaluated the comparison between musical training and non-native language learning (Carpentier et al., 2016; Tervaniemi et al., 2021). The results differed. In the study of Tervaniemi et al. (2021) the learning of a new language seemed to cause more effects on auditory processes early predictive auditory

processes than musical training. On the other hand, in the research by Carpentier et al. (2016), which compared a musical practice group and another French learning group regarding the complexity of the EEG signal, it was found that the music group had an increase in the complexity of the EEG, a fact that occurred minimally in the French group. Therefore, it is not possible to say which model is more effective. Especially because the learning processes are distinct and their transfer effects are probably particular even though they have similarities in some variables.

DISCUSSION

The present review provided an updated overview of the last 10 years regarding the effects of musical training specifically. In the literature there is a growing production involving music therapy and music-based interventions for motor (Braun Janzen et al., 2022; Fan et al., 2023; Lee & Ko, 2023; Rusowicz et al., 2022; Xiong et al., 2022), cognitive (Bian et al., 2021; Ito et al., 2022; Lyu et al., 2018) and emotional (Chu et al., 2014; Moreno-Morales et al., 2020; Zhang et al., 2017) treatment. Such procedures have evidence of producing benefits in communication, cognition and well-being in populations with pathologies according to systematic reviews (Bleibel et al., 2023; Geretsegger et al., 2022; Liu et al., 2022; Witte et al., 2022).

In this review we set out to elucidate concrete evidence about musical training itself. Music therapy and music-based interventions have their own developments and techniques that are sometimes relatively difficult to normalize. On the other hand, systematic musical training is an accessible and replicable procedure.

One of the possible effects of musical training is its correlation and possible influence on the cognitive development of children, so that early exposure to this intervention could optimize their general reasoning. Some studies set out to evaluate this relationship between musical education and indicators of intelligence and cognition and, like the studies already mentioned above, they found a positive correlation between such interactions (Hille et al., 2011; Lima et al., 2022; Schellenberg, 2011).

From the point of view of motor benefits, the study by (Silva et al., 2022) demonstrated that the motor capacity of children who had musical training was significantly better than that of children who did not have it. Having superior results in balance, temporal orientation and general motor quotient, which corroborates the

study by mentioned previously. Although the movements required in musical training are specific to the instrument and require a certain amplitude and limited movement, coordination, rhythm and body perception of space are essential for performing melodies assertively. This requirement is possibly reflected in non-musical motor skills with similar demands, leading to improved motor performance as a whole (Moumdjian et al., 2017; Silva et al., 2022; Prinz et al., 2023).

There are a number of studies that attempt to identify and reflect genetic influences on music aptitude (Centanni et al., 2019; Tan et al., 2014; Wesseldijk et al., 2023; Wang, 2022), such studies correlate some innate conditions that can influence and even determine involvement with music. However, even with these genetic factors to be considered, even if, in hypothesis, maximum fitness is interfered by other factors, exposure to musical training can induce neuroplastic processes, thinking about the development and recovery/maintenance of cognitive and motor performance, this already is of great value (Moniz et al., 2020; Neves et al., 2022).

The evidence that musical training produces beneficial effects is still fairly sparse and unstandardized. More studies are needed, which in addition to an evaluation with a control group and intervention group, carry out collections prior to the interventions to define a baseline with the musical training group. It is also necessary to describe musical protocols in detail to ensure greater replicability.

FINAL CONSIDERATIONS

Current literature demonstrates a trend toward significant benefits from musical training, whether in cognitive factors such as general executive functions, working memory, verbal and mathematical memory. As well as changes at brain levels, such as greater excitability, gray matter volume and intra-hemispheric coherence. From this perspective, musical training becomes an option to complement physiotherapeutic treatment in patients after brain damage, being particularly interesting in those who have never had such an experience. In a context where common actions are no longer done in the usual way, learning a new skill can be particularly motivating. Although there have been a fair number of studies evaluating musical training recently, standardized studies that determine causality between musical training and neurobehavioral changes are needed. Conflict of interests the authors declare that there are no conflicts of interest.

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