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The learning of music as a means to improve mathematical skills

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Music improves the development of our brains and helps to improve our abilities in other subjects such as reading and mathematics. From simple sums to complex functions, mathematical concepts form part of the world of music. Because of this connection, it is possible to establish a positive correlation between participation/performance in music and cognitive development in mathematics. Gardner's theory of multiple intelligences incited several researchers to re-examine the relationships between musical experiences, music learning, and academic achievement. The majority of studies have found that the most significant relationships are between music and mathematics, or to be more specific, between music and spatial-temporal reasoning (important in mathematical concepts), and music and performance in reading. With regard to the former relationship, the assumption is based on a group of studies which explore the effects of learning to play the keyboard on spatial-temporal reasoning, suggesting that mastering a musical instrument helps one to develop an understanding of mathematics. Furthermore, neuroscientific research has been carried out which associates certain types of musical practice to the cognitive development of humans.

Keywords: music; mathematics; spatial-temporal reasoning; brain; mathematical achievement

The present work aims to contribute to a better understanding of the connection between music and mathematics. More specifically, it intends to examine whether musical experiences and learning may enhance mathematical performance. In order to achieve that purpose a revision of related literature was carried out, which was divided into three themes: music and mathematics; music, spatial-temporal reasoning, and mathematical achievement; and music and the brain.

MAIN CONTRIBUTION

Music and mathematics

The present work refers to the way in which the basic elements of music are related to mathematics. Firstly, notes, intervals, scales, harmony (consonance and dissonance), tuning, and temperaments are related to proportions and numerical relations, integers, and logarithms (Beer 1998). Secondly, mathematical concepts are present in melody and rhythm; musical notation includes concepts of time (length of notes, bar lines, and time signatures), rhythm (beat and the grouping of notes in tempos), pitch (clefs, staff, and frequency of the sound), and dynamics (signs of graduation of intensity), all in the circle of musical space (geometry of music). These elements are related to certain arithmetical operations (division, multiplication, addition, and logarithmic function), trigonometry, and geometry (Beer 1998, Fauvel *et al.* 2006). Third, mathematical patterns, "friezes", and motifs (types of symmetries) have been employed in musical compositions by a number of composers within geometrical ideas. Some examples are the motet *Non vos relinquam orphanos* by Byrd, fugues by J. S. Bach, and *Le courlis cendré* from the *Catalogue d'oiseaux* by Messiaen, among many others (Fauvel *et al.* 2006). Lastly, the mathematical concepts of the "Fibonacci sequence" and the "Golden Section" theory may be found in musical compositions, such as piano sonatas by Mozart (Garland and Kahn 1995, May 1996). We may thus conclude that music is connected to several different areas of mathematics: arithmetic, geometry, and trigonometry.

Music, spatial-temporal reasoning, and mathematical achievement

Gardner (1993) suggests that each individual possesses a portfolio of distinct forms of intelligence. In this context, the musical ability is seen as its own discreet domain of intelligence. Gardner (1997, p. 9) states that "music may be a privileged organizer of cognitive processes, especially among young people." There appear to be connections between musical capabilities and certain spatial capabilities. In addition to encompassing the concept of autonomous forms of intelligence, these interpretations allow for the possibility of an experience in a given area having an influence on performance in another area (Rauscher and Zupan 2000). Some of the effects measured in musical research have strong links with the capability of spatial reasoning, notably mathematics and reading. Musical experiences or musical learning are particularly related with music audition (Rauscher *et al.* 1995, Hetland 2000) and instrumental and/or vocal learning (Rauscher *et al.* 1997, Costa-Giomi 1999, Graziano *et al.* 1999, Rauscher and Zupan 2000, Martinez *et al.* 2005). Moreover, regarding the relationship between music and spatial intelligence, it should be mentioned that "playing a melody involves reconstructing a spatial-temporal pattern in which the elements are not puzzle pieces but notes of high and low pitches of long and short duration" (Rauscher 1997, p. 31). An analysis of these studies enables us to say that music facilitates cognitive learning, particularly in the field of logical reasoning, spatial reasoning, and abstract reasoning. It is thus possible to affirm that musical teaching improves proportional reasoning related to certain mathematical concepts, such as the understanding of fractions and ratios (Rauscher and Zupan 2000), and confirms the role of spatial-temporal reasoning in a number of mathematical operations. These inferences are important because the understanding of proportional mathematics and fractions is a pre-requisite for the grasping of mathematics at higher levels (Vaughn 2000). Along different lines of research, there are a number of studies which explore the positive effects of musical learning on academic performance, notably in terms of mathematical achievement (Graziano *et al.* 1999, Vaughn 2000, Gouzouasis *et al.* 2007). Considering the literature referred to here, we may say that the effects of music on academic performance stand at a medium level. However, it is possible to conclude that certain musical experiences have a positive impact on academic achievement under given circumstances (Hodges and O'Connell 2005).

Music and the brain

What has been said so far suggests the existence of an interaction between music and the brain, and demonstrates that music and the teaching of music to children and youths results in an optimization of their spatial-temporal and mathematical performances. The structured neuronal model of the cerebral cortex developed by Leng and Shaw (1991), named the "trion model," provides the neuroscientific context for the relationship between music and spatial cognition. Behavioral studies motivated by this model have found a causal relationship between music and spatial-temporal reasoning (Rauscher *et al.* 1995). The tasks of reading music and instrumental performance involve a variety of capabilities, and that provides plausible explanations for the teaching of music leading to transfer effects in other areas, such as the fact of musical practice having the capacity to improve spatial reasoning, as notation in music is itself spatial. On the other hand, mathematical capabilities may also be improved by musical learning (Schlaug *et al.* 2005). Stewart (2005) suggests that, as a result of learning how to read and play keyboard music, pianists acquire vertical/horizontal visual-motor mapping which becomes generalized beyond the musical context. The neural correlatives of the link previously assumed between the formal teaching of music and mathematical achievement were researched by Schmithorst and Holland (2004) through the use of fMRI. Musical practice has been associated with enhanced activation in the left fusiform gyrus and prefrontal cortex and decreased activation in visual association areas and the left inferior parietal lobule during mathematical tasks. Schmithorst and Holland (2004) believe that the correlation between musical teaching and mathematical achievement may be associated with the improved performance of short-term memory and an increase in the abstract representation of numerical quantities. Experimental projects show that formal musical training and informal experience in diverse environmental situations lead to measurable changes in the neurochemistry and even in the neuroanatomy of the brain (Black and Greenough 1998). Certain parts of the brains of adult musicians which are related to musical tasks and musical processing are larger (Schlaug *et al.* 1995, Hutchinson *et al.* 2003) and more energetically activated (Schmithorst and Holland 2004, Koelsch *et al.* 2005, Schlaug *et al.* 2005).

IMPLICATIONS

What has been said demonstrates the existence of a correlation between musical experiences and learning with cognitive performance, notably in mathematics. This fact has important educational implications, especially in regards to the inclusion or maintenance of the teaching of music in the national school curriculum of both children and adolescents.

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