Journal of the Indian Institute of Science
A Multidisciplinary Reviews Journal
ISSN: 0970-4140 Coden-JIISAD

REVIEWS

Effect of Music Instruction on Cognitive Development: A Review

Arkoprovo Paul, Megha Sharda and Nandini C. Singh

Abstract | There has been a dramatic increase in investigations of the effect of musical training on cognitive development in recent years. Basic musical competence, acquired through everyday exposure to music during development, enables listeners to tap to musical beat, memorize, recollect and reproduce familiar tunes and rhythms, and experience the emotions expressed in music, regardless of formal training. Research over the past decade has highlighted that formal musical training also has remarkable non-musical cognitive benefits. We review recent literature for effects of formal musical training on cognitive development and also discuss recent work in our laboratory. While our review suggests that music instruction has a number of positive effects, further work is required to establish the role of early musical instruction when part of a school curriculum.

1 Introduction

The effect of training in one field which gives rise to dexterity in some other domain is commonly called **'transfer'** phenomenon. The study of transfer mechanisms has a long and illustrious history.[3–5] When the 'training domain' and the 'transfer domain' are similar it is commonly called 'near transfer', whereas if they are distinct it is called 'far transfer'. An example of near transfer can be demonstrated by a person who knows how to drive a car and can transfer these existing skills to learn how to drive a bus. Far transfer is said to happen if a person who has learned the principles of wind flow to design a windmill can transfer that knowledge to direct the sail on a sailboat.

Training to sing or to play a musical instrument is a complex task involving a large number of cognitive and technical skills. As discussed by Corrigall and Trainor,[6] children undergoing musical training must learn to identify and discriminate subtle differences in pitch, rhythm, loudness and timbre, while learning to differentiate between and memorize complex auditory patterns. In the motor domain, they must learn how to control their vocal chords, hands, and/or fingers. A critical and more sophisticated feature is the integration between auditory and motor domains that will allow them to monitor how different motor responses produce different auditory outcomes. A higher cognitive ability, namely reading musical notation requires learning to map visual symbols onto specific motor responses with specific sounds in real time to ensure steady and stable music tempo.[6]

Since music instruction involves such an extensive range of skills, it is not surprising that it has been associated with widespread perceptual, cognitive, and educational benefits.[7,8] It has been proposed that music training might benefit skills in various domains through either a near transfer or a far transfer mechanism.

Figure 1 highlights some of the domains wherein both near and far transfer has been demonstrated due to music training. In the following sections, we will review and discuss both near and far transfer domain effects as a result of music training. In particular, we will discuss studies related to cognitive development and attempt to understand how music instruction during development can impact a child's cognitive abilities.

2 Near Domain Transfer

Near transfer training usually involves tasks that are procedural in nature, that is, tasks which are

National Brain Research Centre, Manesar, India.

nandini@nbrc.ac.in
meghasharda@nbrc.ac.in
arkoprovopaul@gmail.com

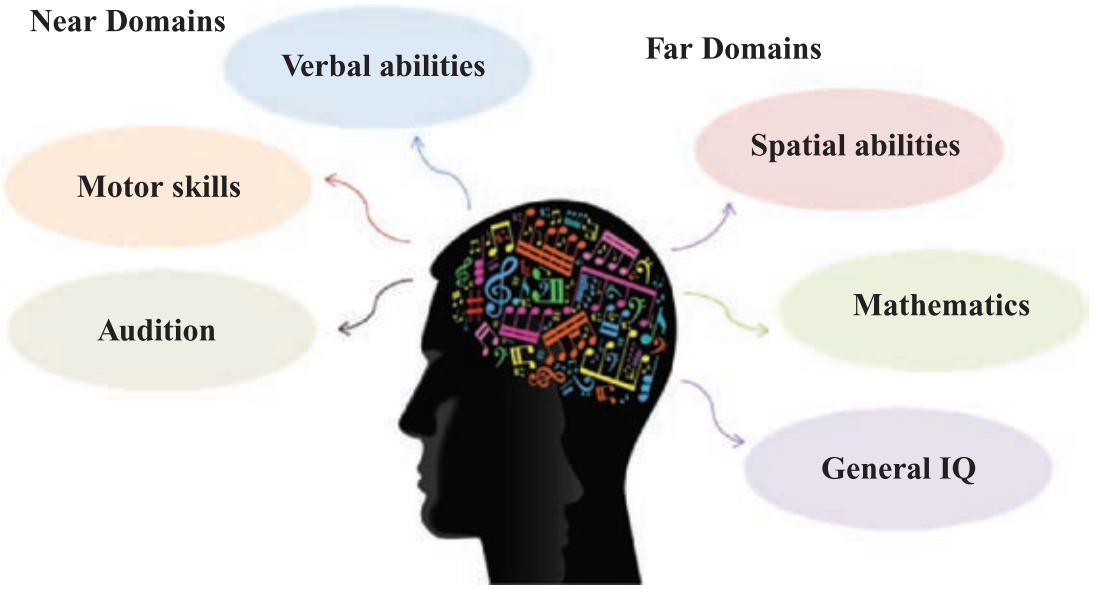

Figure 1: Effect of music instruction on cognitive development.

always applied in the same order in that there is a high degree of similarity between the training and the transfer domain. We discuss below a few results from near domain transfer below.

2.1 *Music and verbal abilities*

The analogy between music and language is quite obvious, as reading music requires understanding of progression of several symbols in the temporal domain that meaningfully stand for pitch, melody, harmony, rhythm/time signature, accents, phrasing etc. Moreover, listening to speech and music requires attention to temporal order of quickly changing acoustic events.[9,10] Literature shows that musicians demonstrate greater verbal memory span than non-musicians.[11] There is also evidence to show that extensive musical training influences the perception of pitch contour in spoken language.[12]

2.2 *Music and auditory abilities*

Auditory processing encompasses a wide array of perceptual skills to extract meaningful information from sound stimuli. It is debated that not only are most stages of auditory processing susceptible to changes due to experience, many are influenced by higher cognitive functions like attention, memory and context, and this dynamic processing is achieved by the anatomical and functional connections between auditory and other brain regions.[13] Past studies have shown that musically trained children score higher on tonal/melodic and rhythm discrimination task and hence demonstrate better auditory perception skills.[14–16]

2.3 *Music and motor abilities*

Children who are musically trained for three years or more, outperformed control groups in tests of fine motor skills, which is a domain closely related to music.[14] This was consistent with previous reports showing that music training is closely associated with enhanced fine motor skills in children[17,18] and adults.[19] For instance, the effect of Kodaly music instruction was shown to improve performance on a motor sequencing task. The Kodaly method of music instruction uses child developmental approaches to introduce musical concepts through experiences such as listening, singing, movement and hand gestures. The effect of Kodaly music training on primary grade children was shown to improve performance on a task where the participants tapped the keys synchronously with a metronome and were asked to continue tapping even after the metronome was turned off.[18] Participants trained using Kodaly instruction were shown to tap for significantly longer even after the metronome was turned off.

Another correlational study with adult participants showed that those with training tap faster to beats of rhythm than non-musicians and the rate of tapping of the non-dominant finger increases with duration of music training.[19] This suggests that tasks to assess, refine and time the motor responses to music stimuli, and the constant evaluative feedback of sound produced during a

prolonged period of practice, result in more accurate and instantaneous motor responses in children with music training.[17]

2.4 *Far domain transfer*

While near transfer is a common transfer mechanism, far transfer is hard to demonstrate[3,4] as the resemblance between the training domain and the transfer domain is less obvious. With far transfer tasks, instructional designers need to design instruction where learners are trained to adapt guidelines to changing situations or environments. Recent research has shown that music training also has a positive impact on other far domains like spatial, mathematical skills and general intelligence, as well as near domains such as verbal, auditory and motor skills.

2.5 *Music and general IQ*

A correlational study in children showed positive correlation between music training and IQ and reported that taking music lessons predicts academic achievement and IQ in early adulthood.[20] Another experimental study by the same researchers showed that a group of six-year-olds receiving vocal/keyboard training had significantly larger full-scale IQ and standardised academic achievement than an age-matched group with either drama or no lessons.[21] Since it is well established that schooling increases IQ,[22] they argued that music training acts as additional schooling, requiring memorisation, focussed attention and sight-reading comprehension.

2.6 *Music and spatial abilities*

Western music notation is inherently spatial as the notes of different pitches are differentially arranged on the stave consisting of a series of lines and spaces. Hence, western music training, which essentially involves sight reading of notation and comprehending any given piece of music, is argued to enhance spatial reasoning.[23] A study on the effect of piano training on kindergarten children in a public school setting showed improvement in spatio-temporal tasks only after four months of training and the effect was greater in magnitude after eight months of lessons.[24] An earlier investigation on preschool children had shown significant improvement in spatio-temporal reasoning with keyboard training that lasted at least one day, a duration classically termed long-term, and suggested that music training might produce long term modifications in neural circuitry in regions not primarily associated with music perception,[25] though this is a subject for further investigation. Some have pointed out that the proximity of brain regions responsible for music and spatial processing might be the reason behind these 'transfer effects'.[13,26]

2.7 *Music and mathematical abilities*

Many explanations could be given for potential transfer between music and mathematical skills, as understanding of rhythm/time signature requires expertise of arithmetic, typically fractions. However, little evidence has been reported so far. In a study by Vaughn et al., three meta-analyses were done considering a total of twenty five studies included from 1950 to 1990. Eight correlational studies examined whether students who chose to study music have higher mathematical outcomes. Five experimental studies assessed if music instruction causes mathematical improvement. Twelve experimental studies tested if performance on math tests improves when music is played in the background during test-taking. For each of the meta-analyses, the researchers calculated effect sizes, along with the associated Z level and the significance level associated with the Z. These meta-analyses showed positive correlation between voluntary study of music and mathematical achievement, effectiveness of music training in mathematics performance but an insignificant effect of playing music in the background on mathematics performance.[27] Behavioural experiments to delineate the effect of music instruction on developing cognitive systems at the foundations of mathematics and science, have shown a close association between music and geometry only when music education is extensive and prolonged.[28] Although this type of training is easier to impart and the transfer of learning is usually a success, the learner is unlikely to be able to adapt their skills and knowledge to changes.

On the contrary, far transfer tasks involve skills and knowledge being applied in situations that change. Far transfer tasks require instruction where learners are trained to adapt guidelines to changing situations or environments. Although this type of training is more difficult to instruct (transfer of learning is less likely), it does allow the learner to adapt to new situations.

2.8 *Near transfer explorations in autism—exploring the effects of sung speech in children with autism spectrum disorder*

In light of the above described theories about the beneficial effects of music, a new project was set up in our laboratory to explore near transfer effects in children with autism. Recently, there

has been much interest in exploring musical stimuli for improving communication and social behaviour in individuals with autism. Ever since the earliest reports on Autism by Leo Kanner,[29] enhanced musical function has been associated with autism, with more than 1 in 20 individuals possessing absolute pitch.[30] It has also been shown that individuals with autism perform better than typical controls on pitch discrimination tasks.[31] At the same time, functional speech, another vital skill in the auditory domain, is significantly impaired in a large percentage of individuals with autism. This suggests that auditory processing mechanisms in autism are a combination of enhancements and deficits, and it might be possible to use one to entrain the other. Past research as well as anecdotal evidence has shown that the use of music as a tool can be beneficial for a child with autism not only for social behaviour modification and emotional-cue processing but also for development of improved communication. However, the kind of music that is beneficial and the mechanisms of structural and functional changes in the brain associated with it, still elude us. Drawing from past research, it seems possible that two hypotheses may be proposed for music-associated improvement in speech and communication. In light of near domain transfer, it might be possible to entrain speech like functions via bottom-up processes such as low-level processing of repetitive elements in music like rhythm and pitch drones. This could be beneficial for improving both perceptual as well as fine motor skills. On the other hand, more top down influences could be used to induce an overall positive effect on function across multiple domains using music a stimulus. However, there are not many studies, which have looked at the neural correlates of music processing in autism and how it might affect language and speech functions. Much work in this area is needed to further understand the nature of auditory processing in autism, and how and whether the enhanced function might be best used to compensate for impairments.

In our laboratory, we have been working with children with autism spectrum disorder (ASD) for the last 3 years in order to understand both production and perception mechanisms of speech and music. In our earlier study, we looked at vocalizations of children with autism as compared to neurotypical controls and found that the ASD group who did develop language exhibited exaggerated pitch, pitch range, pitch excursion and pitch contours in their speech, distinct from typical age-matched controls (Fig. 2) These exaggerated features, which are distinctive characteristics of motherese, were also seen in interactions of an independent group of 8 mothers of typical infants using child-directed speech (Fig. 3).[32]

Thirty-three subjects were recruited for this study: 15 children (14M, 1F) with autism spectrum disorder (AUT), 10 (9M, 1F) age-matched typically developing (TD) control

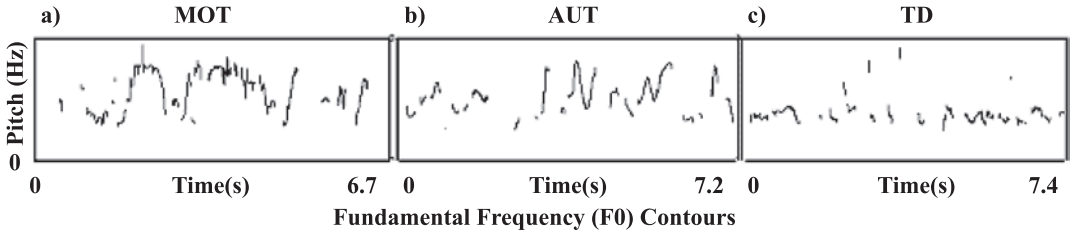

Figure 2: (a–c) Fundamental frequency contours.

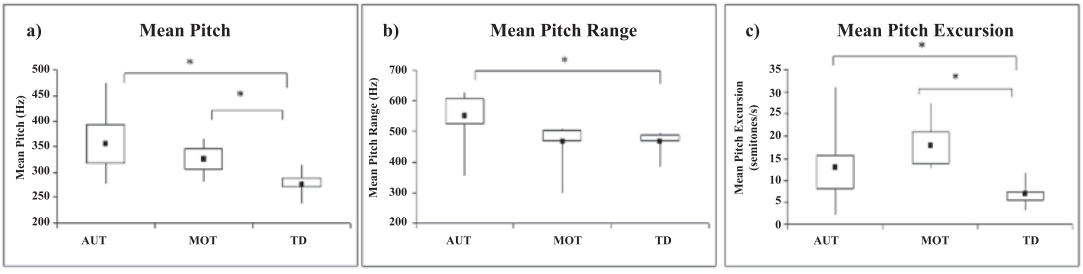

Figure 3: (a–c) Box plots of mean pitch, pitch range and pitch excursion.

children and 8 mothers (MOT) of typically developing infants aged 6–18 months.[32]

These findings may lend support to the use of sung/exaggerated speech from a signal processing angle. Our current project is aimed at understanding the nature of auditory processing in children with autism with a focus on perception of speech versus music using structural and functional MRI in order to tease apart the mechanisms discussed above. We used a combination of spoken words, sung words and musical tone stimuli as part of our experimental paradigm and tested children from both an ASD group as well as age-matched controls to understand if the there is biological evidence for sung speech eliciting improved verbal communication in children with ASD. Findings from this research will have significant implications for implementation of music-based interventions for communication difficulties in the ASD population.

3 Discussion

Past research provides strong evidence for transfer mechanisms between music and cognitive development, and different explanations have been put forward by researchers to account for such 'transfer'. Forgeard et al. have explained such phenomenon in the light of 'domain-specific effect', also called 'near transfer', which states that transfer effect occurs from the domain of music training to some closely related domains. For instance, learning to read or write music notation might enhance reading skills or learning to discriminate pitch/melody/rhythm might increase phonological awareness in non-musical setting.[14] On the other hand, Schellenberg has proposed 'domain-general effect' also called far transfer which suggests that music training may enhance overall intellectual ability in general rather than any specific domain of cognitive development. Hence, children undertaking music lessons should experience improvement in all domains.[20,21] Whether the effect of music instruction on cognitive development is domain-specific or domain-general that remains subject to further investigation. At the same time, this wealth of data strongly suggests that music might to be an important component in cognitive development and it seems to be a suitable time to initiate a serious investigation to establish its impact when introduced as an active and important component of our educational curricula. In particular, it would be exciting to explore its possibilities in helping children with developmental disabilities.

Received 20 November 2012.

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Nandini Chatterjee Singh is an Associate Professor at the National Brain Research Centre. Her research interests include understanding the cortical networks underlying reading development and music processing in typical and atypical populations using techniques of structural and functional MRI.

Megha is currently a doctoral student at the Cognitive Neuroscience and Neuroimaging laboratory at the National Brain Research Centre, Manesar. Her undergraduate training was in Biotechnology from the Vellore Institute of Technology University, Vellore. Her research interests include understanding of structural and functional networks underlying auditory processing in children with autism, with a specific focus on a basis for using music-based interventions for improving communication. She is also interested in studying the experience-dependent plasticity in the brains of professional singers using neuroimaging techniques.

Arkoprovo obtained B.Sc.(Hons) and M.Sc. in Biochemistry from University of Calcutta in 2011. Presently he is pursuing M.A. in Psychology from IGNOU. He is currently, a Junior Research Fellow at the Cognitive Neuroscience and Neuroimaging Laboratory and is exploring the effect of music on cognitive development in children. His research interests include perception in visual art, music (Neuroaesthetics); social cognition and autism using neuroimaging, genetics and behavioural studies. He is also passionate about western music theory and blues, art appreciation, poetry and theatre direction.