Effect of Cross-Motor Activities on Auditory Integration

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This Dissertation is submitted as part fulfillment

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CERTIFICATE

This is to certify that this dissertation entitled **'Effect of Cross-Motor Activities on Auditory Integration'** is bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD028. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **'Effect of Cross-Motor Activities on Auditory Integration'** is result of my own study under the guidance of Dr. Asha Yathiraj, Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Registration No: 17AUD028**

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ABSTRACT

Aim: The study aimed to establish the efficacy of cross-motor exercises of Brain Gym®, a commercially available physical training program, on auditory integration abilities in typically developing children and children with auditory integration problems. The study also aimed to compare auditory integration scores obtained by the participants on two different dichotic tests.

Methods: Twenty participants in the age range of 7 to 11 years were studied, with 10 of them being typically developing children and 10 having auditory integration problems. The effect of training was determined by comparing the scores obtained by the participants before and after the training. Two baseline evaluations were measured two days apart and a post-training evaluation was assessed after 10 sessions of training. On all three evaluations the participants were evaluated using a Dichotic Digit test (Shivashankar & Herlekar, 1991) and a Dichotic CV test (Yathiraj, 1999). The training was given for 10 consecutive days, with each session lasting 10 to 15 minutes.

Results: No significant difference was observed between the scores obtained on the two pre-training evaluations. However, the post-training scores were significantly better than the pre-training evaluation in both groups of participants. Further, the participants were found to score significantly higher scores on the Dichotic Digit test than the Dichotic CV test. It was also observed that the typically developing children secured significantly higher scores than those with auditory integration problems in the pre as well as the post-training evaluations. However, there was no significant difference in the quantum of improvement obtained by the two groups.

Conclusions: The study confirmed the utility of cross-motor exercises in improving auditory integration. This was construed from the absence of improvement in the two baseline evaluations but the presence of improvement following the training. The children with auditory integration problems continued to get significantly poorer scores than the typically developing children subsequent to the training. Hence, it is recommended that those with auditory integration problems undergo longer durations of training than what was provided in the study to enhance the amount of improvement.

Keywords: Brain Gym®, cross crawl, puppet crawl, Dichotic CV, and Dichotic digit.

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Chapter 1

Introduction

Bimanual skills have been reported to facilitate co-ordinated functioning of both the hemispheres (Andres et al., 1999). It has been established that exercising regularly improves the functioning of the cardiovascular system, facilitates greater bone mineral density and triggers the production of neurotrophins (Cotman & Cesar, 2002; Knaepen, Goekint, Heyman, & Meeusen, 2010). Physical tasks have also been reported to positively influence hearing abilities. It has been found that bilateral motor tasks, performed while playing music or while following verbal commands, had a positive effect on auditory abilities (Hyde et al., 2009; Janet & Yathiraj, 2003; Yathiraj & Priyadarshini, 2009).

There are various physical training programs that claim to bring about improvement in mental, cognitive, and auditory processes. These include ‘Touch for health’, proposed by Thie (1979); Brain Gym®, put forth by Dennison (1986); ‘Activate™’, designed by Wexler (2013); ‘Dore program’ developed by Dore (2013); and ‘Brain Training and Exercise (BRiTE)’, developed by Becker, Lopez, and Skidmore (2016).

Brain Gym®, developed by Dennison (1986) is a commercially available physical training program recommended for individuals of all ages. It was reported by Dennison and Dennison (2007) to activate the brain through motion and connect the whole brain synergistically. It was considered to be a part of education kinesiology or Edu-K. A manual describing Brain Gym® by Dennison and Dennison (2007) has divided the exercises into three dimensions based on the movement. The dimensions were communication, organization, and comprehension.

In the Brain Gym® manual, ‘communication’ has been described as a ‘V’ shaped field that defines the extent of motion of the eyes, hands, and arms when the eye gaze was fixated on the ground. This dimension was reported to be accessed by the supraspinatus muscle, which lies superior to the shoulder blade. Further, communication was reported to comprise of skills like seeing, listening, crossing the laterality and writing. The second dimension, ‘organization’, was reported to be an ‘A’ shaped field defined by the range of motion of hands, eyes, and arms when the center point of the motion is at eye level. The hands were required to move apart from the center point towards the sides making a conical field. It was described to incorporate the skill of keeping a positive attitude. The third dimension, ‘comprehension’ has been described to involve higher cognitive skills.

Using the dynamic model of brain functioning, Dennison and Dennison (2007) proposed that sensory skills, physical movements, brain organization, and the process of learning are interconnected. They also suggested that all forms of learning require the experience of association of physical movement. They reported that the holistic functioning of the brain is based on this interconnection between senses, physical movement, learning, and brain organization. This was called the ‘Dynamic Brain’ model. Based on this model it was speculated by Dennison and Dennison (2007) that in stress-free conditions the brainstem, limbic mid-brain and the cerebral cortex work in harmony. This synchronous working was reported to get affected when an individual was under stress.

The developers of Brain Gym® profess that in certain situations even normal individuals lose balance in the three dimensions (communication, organization, & comprehension). This lost balance was reported to result in a reduced ability to learn. To regain this lost balance, it was suggested that the 26 movements of Brain Gym® should be practiced**.** Dennison and Dennison (2007) claimed that these 26 activities brought about ‘dramatic improvements’ in concentration and focus; memory; academics that include reading, writing, math, and test taking; physical coordination; relationships; self-responsibility; organization skills; and attitude. Additionally, it has been reported by

Cosgrove (2009) that regular practice of the exercises in Brain Gym® facilitates increased nerve connections and myelination in the corpus callosum resulting in better interhemispheric communication.

Twomey (2009) reported that many of the schools in the United States of America have incorporated Brain Gym®. Improved attention skills and sitting compliance was observed in children performing Brain Gym® exercises by Cosgrove (2009). However, the direct effect of these exercises on auditory processing abilities was not studied.

1.1 Need for the study

The developers of Brain Gym® claim that the exercises used in the programme help connect the whole brain synergistically. Such connections included the inter-hemispheric transfer of information, improving cortical processing and maintaining holistic balance. The manual describing the program reports that it helps in improving the processing of information through all modalities including audition. However, proof of these claims of Brain Gym® is sparse. Hence, there is a need to study the effectiveness of Brain Gym® on interhemispheric transfer function through audition, in typically developing children and those with auditory processing problems.

A few of the exercises in the Brain Gym® programme focuses on cross-motor training, which is suggested to improve interhemispheric transfer. It is possible that this could have a positive impact on auditory integration tasks such as dichotic measures that involve an interhemispheric transfer. It was observed that children with auditory integration problems face tremendous difficulty in processing degraded auditory inputs such as in the presence of noise and reverberation (Keith, 1999). Hence, there is a need to study the impact of bimanual training using specific exercises of Brain Gym® on children with auditory integration problems. This will provide evidence whether the Brain Gym® exercises does facilitate auditory integration.

1.2 Aim of the study

The current study aimed to compare auditory integration using dichotic tasks before and after training using specific Brain Gym® exercises in typically developing children and those with auditory integration problems.

1.3 Objectives of the study

The objectives of the current study are as follows:

- Comparison of dichotic test scores across evaluations without any cross-motor training.
- Evaluate the effect of cross-motor exercises of Brain Gym® on dichotic listening tasks in typically developing children as well as children with auditory integration problems.
- Compare the scores between the two dichotic tests in typically developing children and in children with auditory integration problems in before and after cross-motor training.
- Determine the significance of the difference between the scores obtained by typically developing children and those with auditory integration problems prior to and following cross-motor training.
- Compare the amount of improvement in scores obtained by typically developing children with that of children with auditory integration problems following cross-motor training on dichotic tests.

In order to determine the variables that could affect the objectives of the study, a review of the literature was carried out. Studies regarding the effect of physical training on an individual's health, cognitive and auditory processing abilities were reviewed. This was done to have a better insight into designing the method of the study.

Chapter 2

Review of literature

Motor-related tasks such as physical exercises are reported to improve the functioning of physiological processes and help in maintaining physical wellbeing (Baranowski et al., 1992; Beniamini, Rubenstein, Faigenbaum, Lichtenstein, & Crim, 1999; Colcombe et al., 2004). Physical exercises were also reported to be a key factor to improve cognition, attention, and mental health (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Norris, Carroll, & Cochrane, 1992). Details of the effect of physical exercises are provided below.

2.1 Effect of physical exercises on overall health

It has been well established that physical exercises have a positive impact on the wellbeing of individuals. It is known to influence physiological processes such as metabolism (Cauza et al., 2005), cardiovascular function (Beniamini et al., 1999), reduce post-pregnancy complications (Sternfeld, Quesenberry, Eskenazi, & Newman, 1995), building muscle strength and coordination in treating Achilles tendon (Fahlström, Jonsson, Lorentzon, & Alfredson, 2003), and reduce low back pain (Hurwitz, Morgenstern, & Chiao, 2005). Besides these positive effects, exercises are also reported to bring about anatomical and physiological changes in the brain.

2.2 Effect of motor activities on anatomical and physiological changes of the brain

Researches have demonstrated that physical exercises have an influence on the sensory and motor areas of the brain (Sadato, Yonekura, Waki, Yamada, & Ishii, 1997), resulting in the plasticity of the brain (Kleim, Jones, & Schallert, 2003). Exercises have also been observed to be beneficial for the development of cognition and higher cortical processing (Colcombe et al., 2004). The researches done to study the effect of exercises on anatomical and physiological changes have been done on animals as well as humans.

2.2.1 Effect of motor activities on anatomical and physiological changes in animals. Physical training was found to be beneficial for animals too (Carro, Trejo, Busiguina, & Torres-Aleman, 2001; Ploughman et al., 2007). The studies reviewed in this section have administered training mostly on rats/mice.

Carro et al. (2001) reported that physical exercises helped to limit neuronal loss in 6 adult mice that they induced injury to the hippocampus. This limited neuronal loss was found to be mediated by insulin-related growth factor 1 (IGF-1), produced during physical activities. Their research attempted to study the effect of exercising before and after the damage and the effect of administration of blocking anti- insulin-related growth factor 1 on exercising animals to reduce the uptake of insulin-related growth factor 1. They measured cognition on a spatial memory task and balancing skill was measured on a motor acquisition task throughout the experiment. It was observed that those mice who were trained on a treadmill running task for 15 days before or after induction of hippocampal damage demonstrated better spatial memory retention than the sedentary mice. The reduction in insulin-related growth factor 1 up-take induced by anti- insulin-related growth factor 1 resulted in negligible benefits from physical training in those mice. The authors concluded that exercising ameliorates the insulin-related growth factor 1 uptake and thereby prevents higher neuronal damage.

Ploughman et al. (2007) reported that brain-derived neurotrophic factor (BDNF) is an important component as it ameliorates the neuro-plasticity post stroke and also prevents neuronal damage. They evaluated 66 male Sprague–Dawley rats with induced stroke. All the animals were randomly divided into two experimental and control/sedentary groups. The animals in experimental group 1 received 60 minutes of a motorized treadmill running task and those in experimental group 2 underwent 12 hours of voluntary wheel running exercises. They found increased levels of brain-derived neurotrophic factor 2 weeks post-focal ischemia. The heart rate monitoring technique was used to classify treadmill running as high-intensity exercise and voluntary wheel running was labeled as low-intensity exercise. The physical training given to experimental group 2 was found to increase brain-derived neurotrophic factor levels in the hippocampal region. They concluded that chronic voluntary exercises which are of low-intensity played an important role in stroke recovery through neuroplasticity than acute high-intensity exercises.

From the above studies done on animals, it can be inferred that physical exercise brings about positive effects on the neuro-plasticity related changes in the brain. The studies have also shown that regular low-intensity exercises are better than acute high-intensity exercises.

2.2.2 Effect of motor activities on anatomical and physiological changes in humans. Physical training was also considered as a treatment option to improve executive functioning (Ferris, Williams, & Shen, 2007), attention and concentration (Budde et al., 2008), cognition (Coe, Pivarnik, Womack, Reeves, & Malina, 2006), and memory (Stroth, Hille, Spitzer, & Reinhardt, 2009) in humans. It was also claimed to induce neuro-plasticity via bilateral cortical excitation, generated by learning a bimanual task (Sadato et al., 1997).

The influence of a bimanual task on cortical activity was studied by Sadato et al. (1997) using positron emission tomography (PET) scans and measuring regional cerebral blood flow. They reported of larger areas on the right dorsal premotor area extending to the posterior supplementary motor area for bimanual activity compared to a unimotor or a mirror bimanual task. This was observed in all their 12 right-handed participants who were in the age range of 19 to 25 years. This increased activity seen for the bimanual task was absent while performing unimotor or mirror bimanual task.

A similar study was done by Andres et al. (1999) using electroencephalography (EEG). They too reported that during the process of learning, a bimanual task generated larger activities in both the sensory and motor areas as compared to unimanual performance. They conducted an EEG analysis of unimanual and bimanual learned tasks on 18 subjects aged 34 to 46 years. The participants were divided into two groups, with only those in the experimental group receiving trained on a bimanual task for 30 minutes. Unlike the earlier studies, they found that activation of the cortex remained the same for training with unimanual and bimanual tasks, with the activation being present throughout the cortices. The authors reported that this discrepancy in the findings could be because of the lesser sensitivity of EEG compared to PET scans for detecting subcortical activities.

The effect of physical training on the higher cognitive function in older adults (age range = 58 to 77 years) was studied by Colcombe et al. (2004). They measured reaction time and recorded fMRI for a cognitive task involving finding out an arrow that was placed in the opposite direction in an array of flanking arrows. Twenty-nine individuals in the experiment group received aerobic training for 40 to 45 minutes, thrice a week for 6 months, whereas 41 older adults in the control group were enrolled for stretching and toning training. They found a significant reduction in reaction time and larger task-related activation of cortical areas on fMRI in individuals in the experiment group as compared to the control group.

Improvement in executive functioning was observed with moderate physical activity in 43 individuals with mild cognitive impairment by Scherder et al. (2005). The participants, who had a mean age of 46 years, were divided into 3 groups. Two groups received training and one control group did not. Group 1 and Group 2 received hand/face exercises and walking, respectively. The training was given for 30 minutes, thrice a week for 6 weeks. The difference in performance post-training was measured using an executive functioning task involving reaction time and word retrieval time. Additionally, memory was evaluated using a digit-span test. A significant improvement in executive functioning was reported in both the experimental groups as compared to the control group. However, no significant improvement was observed in the memory-related task.

The effect of physical training on academical achievements was shown by Coe et al. (2006). Based on their study of 214 sixth graders they reported that those attending physical exercise classes in schools managed to achieve higher grades. The physical training classes were conducted for 6 months with 55 minutes of training every day. They analyzed the activity done by the children during these sessions on a scale depending upon their physical strength. It was observed that children who managed to perform more strenuous activity secured higher grades in school. Hence, they concluded that physical training sessions helped children have a longer span of attention and concentration by increasing arousal levels and reducing boredom.

Ferris et al. (2007) found that brain-derived neurotrophic factor was an important component for maintaining good health of neurons. They subjected 15 individuals in the age range of 24 to 26 years to two bouts of 30 minutes of endurance training. The effect of motor activities was measured on executive functioning and blood serum brain-derived neurotrophic factor levels. A significant improvement in the performance of participants on a Stroop color and word test was noted after the endurance training. However, the brain-derived neurotrophic factor levels were not significantly different across the two conditions.

Attention and concentration skills were evaluated by Budde et al. (2008) to study the efficacy of physical training. They randomly recruited 115 students, aged 13 to 16 years, into an experimental and control group. The children in the experimental group were trained on bilateral coordinative exercises and those in the control group performed normal sport lesson for a single session of 10 minutes. The authors observed that attention and concentration skills improved following bilateral coordinated exercises and no significant improvement was observed with regular sports done by the control group. They reported that co-ordinated exercises were more effective than normal sports. They also propose that this improvement could be because of neuronal coupling between the cerebellum and frontal cortex which led to better performance on an attention and concentration task after bilateral coordinated physical activity.

The effect of exercise on memory was studied by Stroth et al. (2009) on 28 students who performed 30 minutes of running sessions, thrice a day for six weeks. The control group of the study was asked to follow their daily routine activities without any change. It was reported that physical exercise improved visuospatial memory but had no significant effect on verbal memory and concentration.

Similarly, Gapin and Etnier (2010) also observed improvement in executive functioning of 20 children (age range = 8 to 12 years) with attention-deficit hyperactivity disorder after 45 minutes of physical activities done for 7 days. The level of physical activity of the participants was measured using an accelerometer, based on which they were classified as having undergone moderate or vigorous intensity of exercises. The authors measured executive functioning on inhibition, working memory, planning, and speed of processing. They found that children with higher levels of structured physical activities, done for 7 days, had better executive functioning than those with lower levels.

According to Erickson et al. (2011), physical training brings about a significant improvement in spatial memory abilities. They randomly assigned 120 elderly individuals to experiment and control groups. The individuals in the experiment group performed aerobic exercises thrice a week for 1 year and those in the control group performed stretching and toning exercises for the same period. MRI was performed after 6 months and 1 year of training in both the groups. A significant increase in hippocampal volume was observed in the experimental group, but a significant reduction in the hippocampal volume was seen in the control group. They also observed a non-significant increase in blood serum brain-derived neurotrophic factor levels. Further, they reported that physical training led to an increase in spatial memory scores only for those in the experiment group.

Thus, studies have brought to light that specific manual activities/exercises result in anatomical and physiological changes in the brain. These changes were seen more when PET scans were used rather than when EEG was measured. Hence, it can be summarised that the physiological changes that are seen due to exercises can be measured only with certain techniques. Overall, it can be concluded that physical training has a positive effect on the executive functioning task but the role of the brain-derived neurotrophic factor as mediator is still inconclusive. It can also be inferred that physical training helps in building concentration, attention and also improvising an academical performance.

Some studies reported in literature have also shown that physical training helps to improve neuronal plasticity. It was also shown to be helpful in improving cognitive skills like executive functioning, visuospatial memory, and attention. The studies provide information about an increase in the volume of the hippocampus post physical training. From the above-reviewed studies, it can be inferred that physical training has positive effects on higher cognitive skills not only in typically developing individuals but was also found to be helpful in children with attention-deficit hyperactivity disorder.

2.3 Effect of exercise on mental health

It has been reported in the literature that exercises help in maintaining mental wellbeing and reducing stress. Such studies have been conducted on adolescents (Norris et al., 1992), and adults (Tiggemann & Williamson, 2000), including those with major illnesses (Segar et al., 1998). Details of studies that have evaluated the effect of exercise on mental health are reviewed below.

The effect of exercise on self-reported information of stressful life was conducted by Brown and Lawton (1986). They measured the level of physical exercise in 220 females from secondary school, aged 11 to 17 years. They reported an increased negative effect of stress on emotional and physical health in individuals with infrequent exercising patterns. Reduction in stress through regular exercises, noted on a checklist, led to an improved emotional and physical state of the individuals.

A positive effect of high-intensity aerobics was shown on physical wellbeing by Norris et al. (1992). The exercises involved were a high or moderate level of flexibility and aerobic training. They analyzed a self-report on exercise, wellbeing and psychological stress of 147 adolescents. The participants were randomly assigned to high, moderate intensity aerobic training, flexibility training, and a control group. All participants, other than the control group, received training for 10 weeks. The duration of each session was 25 to 30 minutes that was conducted twice a day. They evaluated the outcome on a self-reported scale before and after 10 weeks. The individuals who had undergone high-intensity aerobic training reported significantly lesser stress than the other three groups.

While Segar et al. (1998) reported no significant effect of exercises on the self-esteem in women who had undergone breast cancer surgery, they noted a positive effect on depression and anxiety. The participants were 24 women who had undergone breast cancer surgery. The participants were provided aerobic trained for 40 to 45 minutes, four times a week for 10 weeks. The training was given by dividing the participants into three groups. The first group received only aerobics training, the second group underwent aerobic and behavioral modification training and the third group was a control group. They reported a significant reduction in depression and anxiety only in the groups receiving aerobic training but no improvement in self-esteem.

Tiggemann and Williamson (2000) found that the effect of intensity of physical exercises varied depending on the gender and age of the participants. They recruited 252 subjects, grouped based on their gender and their ages. The two age groups comprised of young individuals aged between 16 to 40 years and matured individuals aged between 41 to 60 years. They reported that in young females there was an inverse relation between the intensity of exercise and self-esteem. The remaining groups showed a positive correlation between the intensity of exercises and self-esteem. The reason given by authors for the negative relation found in young women was increased importance given by them to weight control and toning of their body.

Acil, Dogan, and Dogan (2008) conducted a study on 30 individuals with schizophrenia to study the effect of aerobic training on psychiatric symptoms and quality of life. They divided the participants equally and randomly into an experiment and a control group. They reported a significant reduction in psychological symptoms and improvement in the quality of life in the experimental group after 10 weeks of training provided thrice a week.

A similar study done by Maggouritsa et al. (2014) separated 30 individuals diagnosed with schizophrenia into two experimental groups (groups A & B) and one control group. Individuals in group A received only physical training, those in group B received behavioral modification therapy along with physical training and the control group did not get any training. The authors observed that behavioral therapy along with physical exercises provided better intervention for individuals with schizophrenia as compared to only physical training, after 24 training sessions.

From the above-reviewed studies, it can be inferred that physical training brings about improvement not only in physical but in the mental state too. In some studies, it can be seen that physical training combined with behavioral therapy gives better results than physical exercises alone.

2.4. Effect of exercises on audition

The researches have shown a positive impact of physical training that involved playing musical instruments on hearing skills (Hyde et al., 2009; Janet & Yathiraj, 2003; Wong, Skoe, Russo, Dees, & Kraus, 2007). The improvement was demonstrated using electrophysiological measures (Magnié et al., 2000; Polich & Lardon, 1997), and behavioral measures (Janet & Yathiraj, 2003; Yathiraj & Priyadarshini, 2009).

Polich and Lardon (1997) segregated individuals based on the high or low level of physical exercise into two groups. Each group contained 11 participants, matched in terms of age, educational level, and gender. The group with high intensity of exercise comprised of athletes with a life-long commitment to sports and was involved in tedious exercising for at least 3 years, with physical activity levels greater than 5 hours a week. However, individuals in the low-intensity physical exercise had total activity levels lesser than 5 hours per week. Both visual, auditory evoked resting potentials and EEG were measured on the participants. The auditory evoked potential used was P300, recorded in the oddball paradigm using a standard tone of 1 kHz and the target tone of 2 kHz. They found larger amplitudes of evoked potentials in those with higher-intensity exercise as compared to those with lower-intensity exercise.

Magnié et al. (2000) reported reduced latencies and increased amplitudes in P300 and N400 potentials after physical activity that involved cycling. The participants were 20 French speakers aged 18 to 30 years, equally divided into two groups based on their level of activity in day-to-day life. P300 potential was measured using 2,000 Hz as the target and 1000 Hz as the standard stimuli. No significant difference was observed between those who exercise daily versus those with a sedentary lifestyle before cycling. Both the groups had significant difference before and after the training session of cycling. The effect was seen even when the heart rate returned to the baseline that existed before exercising. Hence, authors inferred that not all those who exercise will have better ERPs than individuals with a sedentary lifestyle. The only thing that brings a change is the level of physical training done at just before testing.

Janet and Yathiraj (2003) evaluated frequency discrimination, recognition of speech-in-noise, and auditory recall and sequencing abilities in children who had undergone musical training. They assessed fifteen children in the age range of 6 to12 years who had undergone keyboard playing as well as vocal music training for 3 to 9 years. The children with musical training scored significantly better than the age and gender-matched control group, in all the auditory tasks.

Similarly, Wong et al. (2007) examined the effect of instrumental musical training on the accuracy of pitch coding in frequency following responses. The stimuli used was lexical pitch contours of a tonal language. Three different pitch contours were used from the Mandarin language. The participants were segregated into the experimental and control group. The adults in the experiment group had at least 6 years of experience in instrumental music. However, the participants in the control group had no, or a maximum of 3 years, of musical exposure in their whole life. The fundamental frequency tracking was more accurate for the individuals in the experimental group than those in the control group. This was attributed to instrumental training that improved attention.

The performance of children enrolled in abacus training on a Dichotic CV and a Dichotic Digit test was studied by Yathiraj and Priyadarshini (2009). They enrolled sixteen children between the age of 7 to 12 years who attended two different abacus training and eight age-matched control group. A part of the abacus training required the children to manipulate beads bimanually to diotic auditory commands. Those who underwent the abacus training were found to have higher scores on the Dichotic CV test but not on the Dichotic Digit test. They concluded that no significant difference was obtained between experiment group and control group on the Dichotic Digit test due to higher redundancy present in digits. The significant difference on the Dichotic CV was considered to have occurred due to intensive training using diotic listening task and lesser redundancy Dichotic CV test that led to better identification of training related changes.

The effect of keyboard music training on structural changes in the brain was evaluated by Hyde et al. (2009). They evaluated 15 children aged 5 to 7 years who had undergone the training for 15 months and 16 children aged 5 to 6 years who had not undergone training. They participants were evaluated using MRI and two sets of behavioural tests (3 musical tasks & 5 non-musical tasks). They observed significant improvement in the music-related behavioural tasks like finger-motor coordination and the melody-rhythm discrimination post training. However, no significant difference was observed for non-musical tasks. From the MRI findings they observed the presence of larger volume functional areas involved in efficient processing sound stimuli after 15 months of training. They suggested that instrumental training required efficient bimanual co-ordination which was the foundation stone for brain plasticity.

The effect of reduced lower limb movement on the hearing abilities of elderly individuals was studied by Mikkola et al. (2015). They conducted a self-reported study on 848 individuals in the age range of 75 to 90 years. They found increased complaints of hearing impairment in adverse conditions in individuals having difficulty with mobility and activities of daily living. The authors suggested that hearing seems to be associated with the motor task, as reduced hearing makes the movement more uncertain and cognitive decline led by hearing problems paved way for the motor decline.

The review of studies that have evaluated the effect of physical activities on auditory performance has demonstrated positive results. This was seen in the studies that measured behavioral responses as well as those that measured electrophysiological measures. Further, a positive correlation was observed with the intensity of exercise. This link between physical activity and audition was suggested to be a bi-product of some indirect neuronal connections between the motor and auditory areas in the cortex.

Overall, the review of the literature indicates that physical exercises bring about changes in the holistic functioning of the system. It ameliorates neuronal plasticity that considered essential for any learning-related or recovery-related task. However, there is limited research done on the effect of physical training on central auditory processing deficits. Hence, more research in this area needs to be undertaken.

Chapter 3

Methods

To investigate the effectiveness of cross-motor activities on auditory integration skills, typically developing children and children with auditory integration problems (AIP) were evaluated. This was done using a pre-post design as well as a standard comparison design. The scores of two different tests of auditory integration (Dichotic CV & Dichotic Digit test) were compared before and after a training program. The effect of training on a group of children with AIP was compared with that of typically developing children. The study was carried out in three stages, Stage 1 consisted of two baseline evaluations; Stage 2 involved a training period; and Stage 3 comprising of a post-training evaluation.

3.1 Participants

A purposive sampling technique was used to enroll the children in two the groups that consisted of 10 typically developing children aged 8 to 10 years (mean age = 8years 6 months; SD = 1.26 years) and 10 children with AIP aged 9 to 11 years (mean age = 9 years; SD = 1.15 years). There were 6 males and 4 females among the typically developing children and 5 males and 5 females in the group with AIP.

All the participants had normal air conduction and bone conduction thresholds from 250 Hz to 8 kHz and 250 Hz to 4 kHz, respectively; had 'A' type tympanogram with reflexes present between 90 to 100 dB HL; speech identification scores in quiet that were at least 80%; no reports of speech and language problems; no history of developmental delay; and no associated problems. All children had age appropriate Intelligence Quotient on Raven's colored progressive matrices Raven (2000). The participants enrolled in the study were right-handed, as per the Eidenburg's handedness inventory (Oldfield, 1971). All the children had undergone at least two years of schooling in an English medium school.

The typically developing children were included in the study only if they had passed the 'Screening checklist for auditory processing' (SCAP) developed by Yathiraj and Mascarenhas (2002, 2004). On the other hand, the children were categorized as having AIP if they were referred on SCAP and had failed either the Dichotic CV test (Yathiraj, 1999) or the Dichotic Digit test (Shivashankar & Herlekar, 1991). To diagnose that they had AIP the norms of Yathiraj and Vanaja (2015) were used for the former test and scores given by Regishia (2003) for the latter test. The pass/fail criterion was based on the double correct scores obtained by the participants.

Informed consent was obtained from the parents of the participants before they were subjected to any evaluation. It was ensured that the 'Ethical guidelines for Bio-Behavioural Research Involving Human Subjets (2009) of the institute were followed.

3.2. Equipment

A calibrated dual channel diagnostic audiometer (GSI Audiostar pro) coupled with TDH-39 headphones housed in MX-41/AR ear cushion was utilized to obtain air conduction thresholds. Bone conduction thresholds were obtained using a B-71 Radioear bone vibrator. GSI-Tymstar immittance meter was used to rule out the presence of any middle ear problem. A Lenovo G50 laptop with 4^{th} Generation Intel® Core™ Processor was utilized to present the CD version of the tests.

3.3. Material

To screen for the presence or absence of APD, SCAP, developed by Yathiraj and Mascarenhas (2002, 2004) was used. Those with a score of ≥ 6 were labeled as being at-risk for APD while those with a score of < 6 were considered to have passed the screening test. Additionally, to rule out the presence of any mental challenge, Raven's colored progressive matrices was administered (Raven, 2000). To check their speech identification scores in quiet, the ‘Phonetically balanced word test in Kannada’ (Yathiraj & Vijayalakshmi, 2005) was utilized.

‘Dichotic CV-Revised test’ developed by Yathiraj (1999) as well as the ‘Dichotic Digit Test’ developed by Shivashankar and Herlekar (1991) were used to assess auditory integration. The Dichotic CV list having a 0 ms lag was chosen for the study. Cross-motor training exercises were provided to the participants, employing Brain Gym®, a movement-based program founded by Dennison and Dennison in 1987.

3.4. Test environment

All testing was done in a sound-treated two-room setup with talk forward and talk-back facilities. The noise level in the room was maintained as per ANSI S3.1-1999 (R2013). The training exercises were performed in a quiet distraction-free environment.

3.5. Procedure

Those participants who meet the subject selection criteria were further evaluated. All participants were subjected to the 3 stages of the study.

Stage 1 (Baseline evaluations 1 & 2): Initially, 2 baseline evaluations were carried out 2 days apart. The two baselines were measured to ensure that no covariables influenced the scores obtained by the participants. During each evaluation session, all participants were evaluated using the Dichotic CV and Dichotic Digit tests. The order in which the tests were administered was counterbalanced to avoid a test order effect. The stimuli, presented through a computer via a diagnostic audiometer (Audiostar pro), were heard by the participants through TDH-39 headphones. The 1 kHz calibration tone, recorded in each diagnostic test, was used to set the VU meter deflection of the audiometer to zero. The stimuli of both dichotic tests were presented at 70 dB HL. The participants were informed that they will hear two different speech sounds/digits at the same time in their two ears and that they should repeat both stimuli in any order. They were told that they could guess the stimuli in case of uncertainty.

The Dichotic CV test scores were compared with the normative data reported by Yathiraj and Vanaja (2015). The scores obtained by participants on the Dichotic Digit test were compared with the age-matched scores obtained on typically developing children by Regishia (2003). The maximum possible score for the two tests was 30.

Stage 2 (Training phase): During this phase, the typically developing children and the children with AIP were provided training on the communication dimension of Brain Gym®. The training was provided by an individual certified for Brain Gym® 101 level. The participants underwent training for 10 consecutive days, with each of the 10 sessions lasting 10 to 15 minutes. This approximated the schedule used in studies that have provided physical motor or auditory training and reported of improvements in skills such as executive functioning, dichotic and temporal processing (Gapin & Etnier, 2010; Priya & Yathiraj, 2007; Ramya & Yathiraj, 2015). This criterion was followed as the Brain Gym® module by Dennison and Dennison (2007) did not provide specific details regarding the schedule of therapy.

Initially, the participants were provided training using the E.C.A.P. sequence, as given in the Brain Gym® module. The sequence involved 'Energy', 'Clear', 'Active' and 'Positive' activities. In the 'Energy' activity, the participants were asked to take a mouth-full of water and hold it for 5 seconds after which they gulped it in five small sections; they were instructed to massage the area over the collar bone with two fingers in clockwise and anti-clockwise direction along with eye continuously moving laterally in the 'Clear' activity; this was followed by performing a cross crawl, touching their knee with their elbow of the opposite side, in the 'Active' activity; for the 'Positive' phase, the participants were required to maintain balance in hook-up position, where they had to cross their arms and legs, tongue stuck to the palate and eyes closed. Each step in E.C.A.P was proposed to restore hydration, cross the midline, activate the whole brain and maintain balance, respectively.

After E.C.A.P., specific exercises of Brain Gym® (Dennison & Dennison, 2007) were taught to the participants, as listed under the dimension 'Communication' in the category of Dennison Laterality Repatterning. They were taught only the two exercises that crossed the laterality midline. The two exercises were the Cross Crawl and Puppet Crawl. The Cross Crawl exercise was performed by asking the participants to fix their gaze up-left and then move their eyes in all directions; for the Puppet Crawl exercise, the participants had to simultaneously move their hands and legs of the same side, first with their gaze fixed down-right and later by moving their eyes in all directions. Each of these exercises was repeated 20 times with the participants instructed to count them. According to Dennison and Dennison (2007) these exercises "---- re-establish an efficient and integrated pattern of cross-lateral movements which helps in strengthening the inter-hemispheric pathways responsible for balancing the system" (Pp. 76).

The training was given to the children individually or in groups of not more than 3 children. The children were given individual training only if an adequate number of children were not available to form a group. The trainer first demonstrated all the exercises to the participants on the first day and later performed all the exercises along with them, throughout the training sessions in the subsequent days. The trainer also gave verbal instructions to the participants before the exercises were carried out and counted the moves along with the children while the exercises were performed. This was done for all six exercises, 4 related to E.C.A.P and 2 related to laterality, daily for 10 sessions.

Stage 3 (Post-training evaluation): To determine the influence of the training, all the participants were revaluated using the two dichotic tests (i.e., Dichotic CV and Dichotic Digit test) soon after the cessation of the 10 sessions of training. The procedure to administer the tests was the same as that used in Stage 1 of the study. The order of the two tests was altered such that half the participants were tested with the Dichotic CV test first and the other half were tested with the Dichotic Digit test first. It was ensured that no participant was tested with the same order of tests in all three evaluation sessions.

3.5.1 Scoring. For both dichotic tests, single correct and double correct scores were calculated. The single correct scores were calculated for each ear separately with every correct response being given a score of one. While calculating the double correct scores, a score of one was given only if a child correctly repeated the stimuli presented to both ears simultaneously. The scores were tabulated in a scoring sheet which was later subjected to statistical analyses.

3.6. Analyses

The data were subjected to statistical analyses using SPSS (Version 21). Shapiro Wilks test indicated that the data were normally distributed. Hence, parametric statistics were used. Both the descriptive and inferential statistics were performed.

Chapter 4

Results

The results are provided regarding the pre and post cross-motor Brain Gym® training given to 10 typically developing children (TDC) and 10 children with auditory integration problem (AIP). The data of the two pre-training evaluations and the post-training evaluation are reported for the two auditory integration tests that were administered (Dichotic CV & Dichotic Digit). The results are given under the following sub-headings:

4.1 Comparison of scores within each participant group (TDC & AIP)

4.1.1 Comparison of the dichotic scores obtained in the two baselines in each group.

4.1.2 Comparison of pre and post training dichotic scores in each group.

4.1.3 Comparison of the scores obtained in the two dichotic tests in each group.

4.2 Comparison of scores between the participant groups (TDC & AIP)

4.2.1 Comparison of the pre-training evaluation scores between the two groups.

4.2.3 Comparison of post training scores between the two groups.

4.2.3 Comparison of the difference in the pre and post training scores obtained by two groups.

Prior to the analyses, a Shapiro-Wilk test of normality was done using SPSS (version 21). It was found that the data were normally distributed ($p > 0.05$), hence parametric statistics were done. To study if a main effect of the group existed on the training program on the two dichotic test scores, a mixed ANOVA was conducted (3 evaluations x 2 groups x 2 tests x 3 score-types). As a significant main effect of groups [$F(1, 18) = 16.02$, $p < 0.01$]

was obtained, the remaining analyses were done separately for the two participant groups.

Table 4.1

Pre and post-training Mean and Standard Deviation (SD) of the Dichotic CV and Dichotic Digit scores obtained by typically developing children (TDC) and children with auditory integration problems (AIP).

Group	Score Types	Statistical Test	Pre-training Evaluation 1		Pre-training Evaluation 2		Post-training	
			Dichotic CV	Dichotic Digit	Dichotic CV	Dichotic Digit	Dichotic CV	Dichotic Digit
TDC	Right SCS	Mean	20.3	22	21.2	21.8	25.9	27.8
		SD	3.9	4.2	2.2	3.5	3.4	2.3
	Left SCS	Mean	18.1	20.9	18.1	19.2	23	26.5
		SD	4.4	4.7	4.0	4.2	3.8	2.2
	Double correct scores	Mean	10.4	15.5	11.3	15.1	19.8	24.6
		SD	6	5.8	4.9	5.2	5.4	3.9
Children with AIP	Right SCS	Mean	14.9	17.9	15.4	17.6	19.5	23.9
		SD	3.6	5.9	1.8	6.7	3.7	4.7
	Left SCS	Mean	14.3	14.3	13.7	14.2	16.4	20.4
		SD	3.8	4.9	2.2	5.8	4.7	6.9
	Double correct scores	Mean	4	9.7	4.5	9.2	10	17.6
		SD	2	5.7	2.3	5.9	4.8	8.1

Note. Maximum possible score = 30; SCS = Single correct scores.

4.1 Comparison of scores within each participant group (TDC & AIP)

Initially, a comparison of the two pre-training evaluation scores (evaluations 1 & 2) was done to rule out the effect of any covariable that could have influenced the responses of the participants in the absence of any training. This was done separately for each participant group, as a significant main effect of groups was present.

4.1.1 Comparison of the dichotic scores obtained in the two baselines in each group. From the mean and standard deviation (SD) of the two pre-training evaluations provided in Table 4.1, it is can be seen that the scores varied only marginally. This is evident for both participant groups and for both the dichotic tests that were administered. Paired t-tests were carried out to confirm whether a significant difference was present between the two pre-training evaluations. The t-tests indicated that there was no significant difference between the two evaluations in the *typically developing children* for the Dichotic CV test for right single correct scores [$t(9) = -0.69$, $p = 0.50$, $d = 0.22$], left single correct scores [$t(9) = 1$, $p = 0.34$, $d = 0.108$], and double correct scores [$t(9) = -1.86$, $p = 0.09$, $d = 0.588$]. Similarly, for the Dichotic Digit test there existed no significant difference for the right single correct scores [$t(9) = 0.46$, $p = 0.65$, $d = 0.14$], left single correct scores [$t(9) = 0.08$, $p = 0.93$, $d = 0.02$], and double correct scores [$t(9) = 1.46$, $p = 0.17$, $d = 0.46$].

Likewise, in the *children with AIP* there was no significant difference between the two pre evaluations for the Dichotic CV test for right single correct scores [$t(9) = -0.75$, $p = 0.46$, $d = 0.23$], left single correct scores [$t(9) = 0.00$, $p = 1$, $d = 0$], and double correct scores [$t(9) = -0.91$, $p = 0.38$, $d = 0.28$]. A similar finding was observed for the Dichotic Digit test where no significant differences were observed for the right single correct scores [$t(9) = 0.22$, $p = 0.82$, $d = 0.07$], left single correct scores [$t(9) = 1.75$, $p = 0.11$, $d = 0.55$], and double correct scores [$t(9) = 0.45$, $p = 0.65$, $d = 0.14$]. As no significant difference was seen between the two baseline evaluations for the tests and score-types, the scores of pre-training evaluation 2 was utilised as the baseline for further comparisons.

4.1.2 Comparison of pre and post training dichotic scores in each group. The mean and SD of the scores obtained by the two groups (Table 4.1) indicate that the post-training scores were better than the pre-training scores. This improvement was also evident in the individual scores of the typically developing children (Figure 4.1) and children with AIP (Figure 4.2) on both the tests. To determine whether these differences were significant, ANOVAs were calculated separately for each group (2 evaluations x 2 tests x 3 score-types).

The ANOVA results revealed a significantly main effect of evaluation in the typically developing children [$F(1, 9) = 107.16$, $p < 0.001$, $\eta p^2 = 0.92$] as well as in the children with AIP [$F(1, 9) = 69$, $p < 0.001$, $\eta p^2 = 0.88$]. Further, a significant interaction was observed between types of scores and evaluations in the typically developing children [$F(2, 18) = 11.27$, $p < 0.01$, $\eta p^2 = 0.55$] and the children with AIP [$F(2, 18) = 4.87$, $p < 0.01$, $\eta p^2 = 0.35$].

As there was an interaction between the types of scores and evaluations, when the scores of the two dichotic tests were combined, repeated measure ANOVAs were done for each type of score. It was observed that the performance in the post-training evaluation was significantly better than the pre-training evaluation in the *typically developing children* for the right single correct scores [$F(1, 9) = 100.92$, $p < 0.001$, $\eta p^2 = 0.98$], left single correct scores [$F(1, 9) = 55.90$, $p < 0.001$, $\eta p^2 = 0.86$], and double correct scores [$F(1, 9) = 80.11$, $p < 0.01$, $\eta p^2 = 0.89$]. A similar findings were obtained for the scores secured by *children with AIP* for the right single correct scores [$F(1, 9) = 55.18$, $p < 0.001$, $\eta p^2 = 0.86$], left single correct scores [$F(1, 9) = 29.84$, $p < 0.001$, $\eta p^2 = 0.76$], and double correct scores [$F(1, 9) = 56.66$, $p < 0.001$, $\eta p^2 = 0.86$].

Further, a paired t-test with the α-correction incorporated was done to know the test-specific pre and post evaluation findings for all the three score-types. In the *typically developing children*, the scores obtained in the Dichotic CV test post training were significantly better than the pre-training evaluation for the right single correct [$t(9) = -4.21$, $p < 0.001$, $d = -1.33$], left single correct [$t(9) = -5.04$, $p < 0.001$, $d = -1.59$], and double correct scores [$t(9) = -5.31$, $p < 0.001$, $d = -1.68$]. Similarly, for the Dichotic Digit test the post training scores were found to be significantly better than the pre training scores for right single correct [$t(9) = -9.00$, $p < 0.001$, $d = -2.84$], left single correct [$t(9) = -5.81$, $p < 0.001$, $d = -1.83$], and double correct scores [$t(9) = -6.39$, $p < 0.001$, $d = -2.02$].

Also, in the *children with AIP* the right single correct [$t(9) = -2.81$, $p < 0.01$, $d = -0.90$], left single correct [$t(9) = -1.73$, $p = 0.019$, $d = -0.54$], and double correct scores [$t(9) = -3.72$, $p < 0.01$, $d = -1.17$] were significantly better following training than in the *pre-training evaluation* for the Dichotic CV test. The results obtained for Dichotic Digit demonstrated a similar trend with significantly better scores in post-training evaluation being obtained than the pre-training evaluation for the right single correct [$t(9) = -8.12$, $p < 0.01$, $d = -2.57$], left single correct [$t(9) = -6.43$, $p < 0.01$, $d = -2.03$], and double correct scores [$t(9) = -5.62$, $p < 0.01$, $d = -1.78$].

TYPICALLY DEVELOPING CHILDREN

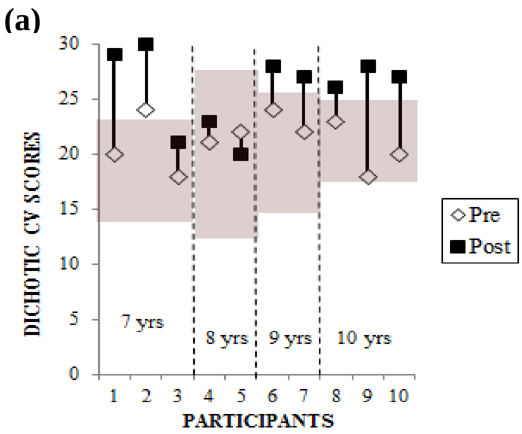
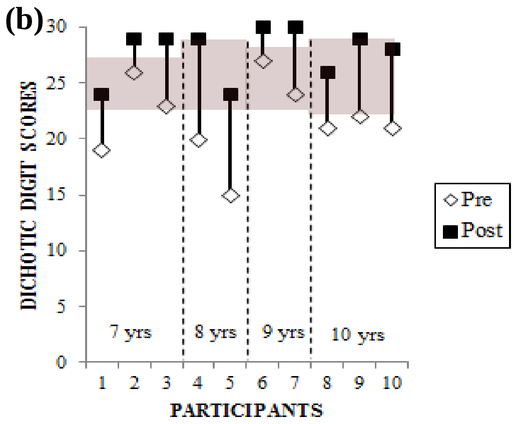
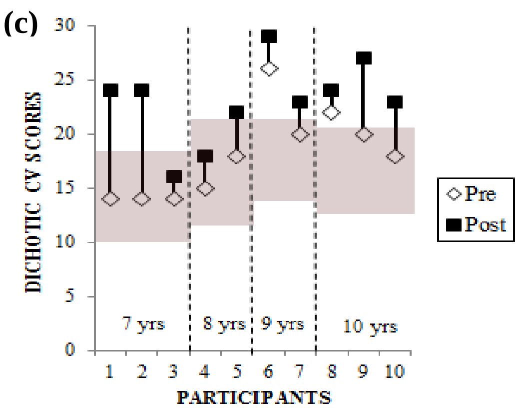
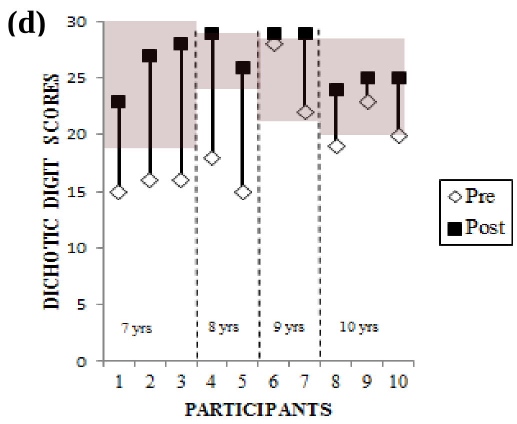
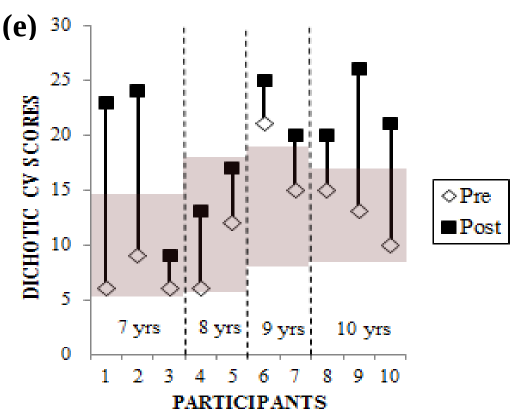
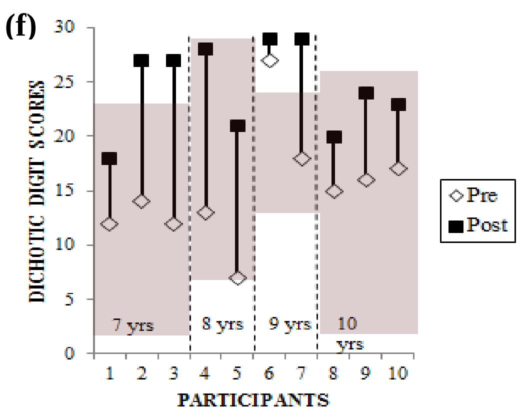
Score-type	Dichotic CV	Dichotic Digit
Right SCS		
Left SCS		
Double correct scores		

Figure 4.1 Scores of typically developing children for Dichotic CV test (Left panel) and Dichotic Digit test (Right panel) for right ear single correct scores (a & b); left ear single correct scores (c & d); and Double correct scores (e & f) for pre-training and post-training evaluations.

Note. SCS = Single correct scores; Shaded region depicts the normative for Dichotic CV (Yathiraj & Vanaja, 2015) and age appropriate scores for Dichotic Digit test (Regishia, 2003).

CHILDREN WITH AUDITORY INTEGRATION PROBLEM

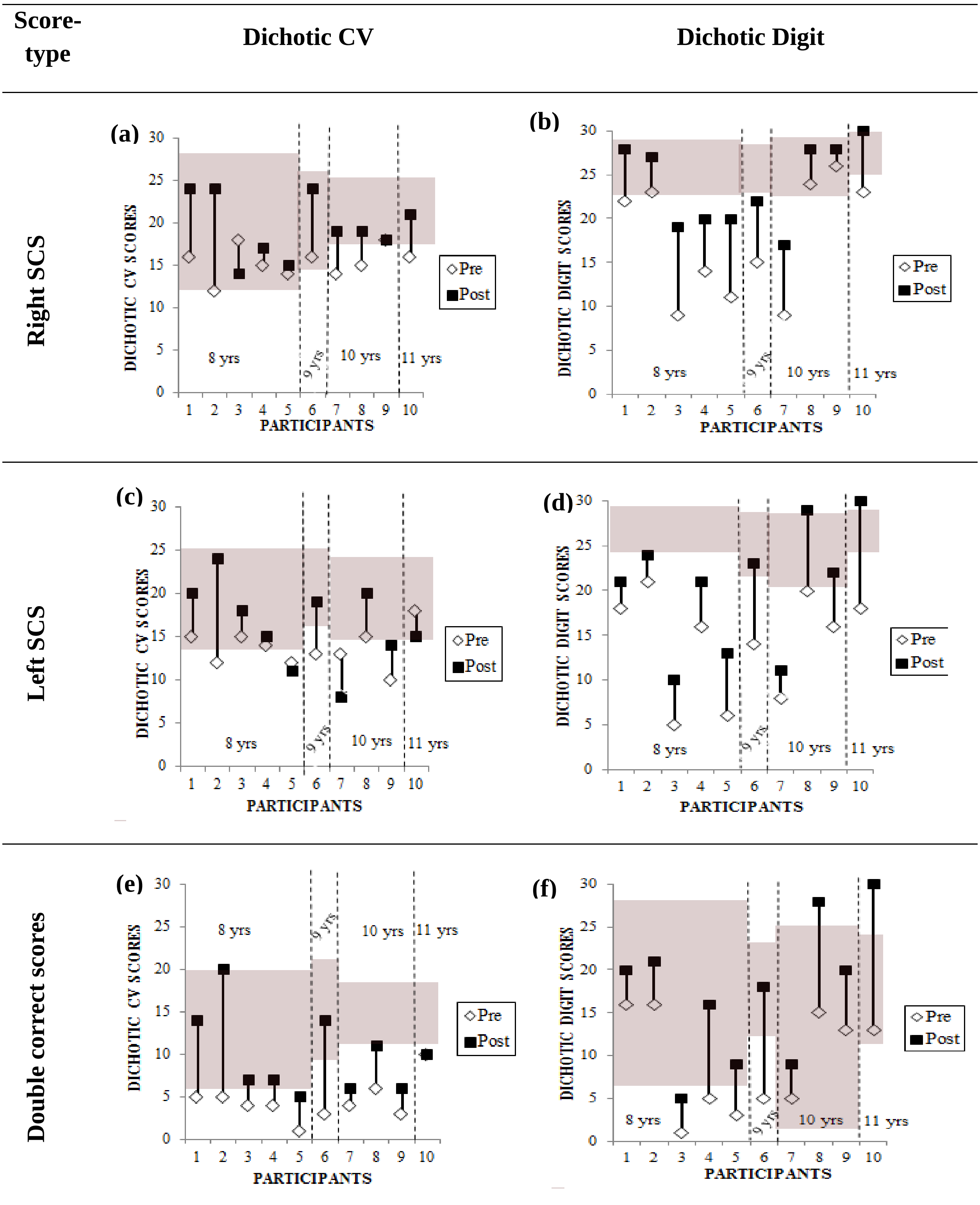


Figure 4.2 Scores of children with auditory integration problem (AIP) for Dichotic CV test (Left panel) and Dichotic Digit test (Right panel) for right ear single correct scores (a & b); left ear single correct scores (c & d); and Double correct scores (e & f) for pre-training and post-training evaluations.

Note. SCS = Single correct scores; Shaded region depicts the normative for Dichotic CV (Yathiraj & Vanaja, 2015) and age appropriate scores for Dichotic Digit test (Regishia, 2003).

4.1.3 Comparison of the scores obtained in the two dichotic tasks in each group. The mean scores obtained on the Dichotic Digit test were better than Dichotic CV test, as can be seen in Table 4.1. Thus, an ANOVA was administered to check if the scores of the two tests differed significantly. A significant main effect of test was observed for the typically developing children [$F(1, 9) = 6.81$, $p = 0.03$, $\eta p^2 = 0.43$] and the children with AIP [$F(1, 9) = 6.70$, $p = 0.03$, $\eta p^2 = 0.43$], when the scores of the two evaluations were combined. Hence, to get evaluation-specific data, separate ANOVAs were obtained for each of the evaluations.

It was found that no significant difference exist between the tests for *pre-training evaluation in the typically developing children* [$F(1, 9) = 3.97$, $p = 0.07$, $\eta p^2 = 0.30$]. However, a significant interaction was observed between the test and score-type [$F(2, 18) = 9.40$, $p = 0.002$, $\eta p^2 = 0.51$]. Thus, paired t-tests were done to evaluate the significance between the two tests for each score-type, with Bonferroni correction being applied. It was observed that no significant difference exist between the tests in the right single correct scores [$t(9) = -0.54$, $p = 0.1$, $d = 0.17$], but for the left single correct scores [$t(9) = -1.55$, $p = 0.025$, $d = 0.49$], and double correct scores [$t(9) = -3.16$, $p < 0.01$, $d = 1$].

A similar trend was observed for the *children with AIP*, with there being no significant difference between the tests *for the pre-training evaluation* [$F(1, 9) = 1.86$, $p = 0.20$, $\eta p^2 = 0.17$], but a significant interaction between the tests and score-type [$F(2, 18) = 9.55$, $p = 0.001$, $\eta p^2 = 0.51$]. Paired-t test with Bonferroni correction indicated that there was no significant difference between the two tests for the right single correct scores [$t(9) = -1.01$, $p = 0.05$, $d = 0.32$], and left single correct scores [$t(9) = -0.26$, $p = 0.13$, $d = 0.08$]. However, a significant difference was present for the double correct scores [$t(9) = -2.93$, $p < 0.01$, $d = 0.93$] .

Although there was no significant difference between the two tests in the *post-training evaluation for the typically developing children* [$F(1, 9) = 4.43$, $p = 0.06$, $\eta p^2 = 0.33$], there was a significant interaction between the test and score-type [$F(2, 18) = 4.43$, $p = 0.06$, $\eta p^2 = 0.33$]. Using a paired t-test with Bonferroni correction, a significant difference was found between the right single correct scores [$t(9) = -1.63$, $p = 0.04$, $d = 0.51$], left single correct scores [$t(9) = -2.27$, $p < 0.01$, $d = 0.72$], and double correct scores [$t(9) = -2.09$, $p = 0.01$, $d = 0.66$].

On the other hand, a significant difference was observed between the two tests during *post-training evaluation for children with AIP* [$F(1, 9) = 11.65$, $p < 0.01$, $\eta p^2 = 0.56$]. Additionally, a significant interaction existed between the tests and the score-type [$F(2, 18) = 11.65$, $p < 0.01$, $\eta p^2 = 0.56$]. Therefore, to evaluate the effect of the score-type between the tests in the post-training evaluation scores obtained by children with AIP paired t-tests were administered with Bonferroni correction. There was a significant difference between the right single correct scores [$t(9) = -3.29$, $p < 0.01$, $d = 0.54$], left single correct scores [$t(9) = -2.05$, $p = 0.01$, $d = 0.65$], and double correct scores [$t(9) = -3.32$, $p < 0.01$, $d = 1.05$].

4.2 Comparison of scores between the participant groups (TDC & AIP)

To see if the impact of cross-motor Brain Gym® training had an impact on two participant groups who were evaluated, MANOVA. This statistical test was performed to avoid a type-1 error due to multiple comparisons. A comparison of the type of scores for each of the tests and evaluations was done to compare the two groups (2 tests x 3 score-types x 2 evaluations).

4.2.1 Comparison of the pre-training evaluation scores between the two groups.

The typically developing children were observed to have higher mean scores than the children with AIP (Table 4.1). The better performance of the typically developing children than the children with AIP was also reflected in the individual scores depicted in Figures 4.1 and 4.2. Further, from the figures, it can also be seen that the double correct scores obtained by children with AIP were poorer than the age appropriate norms/scores for the Dichotic CV test (Yathiraj & Vanaja, 2015) and the Dichotic Digit test (Regishia, 2003).

The MANOVA results indicated that the difference in scores between the two groups were statistically significant for most parameters. A significant difference in the baseline scores existed between two groups for the Dichotic CV test for the right single correct scores [$F(1, 18) = 40.91$, $p < 0.01$, $\eta p^2 = 0.69$], left single correct scores [$F(1, 18) = 9.21$, $p < 0.01$, $\eta p^2 = 0.33$], and double correct scores [$F(1, 18) = 15.61$, $p < 0.01$, $\eta p^2 = 0.46$]. Similarly, for the Dichotic Digit test a significant difference was found for the left single correct scores [$F(1, 18) = 4.85$, $p = 0.04$, $\eta p^2 = 0.21$] and double correct scores [$F(1, 18) = 5.60$, $p = 0.02$, $\eta p^2 = 0.23$]. However, no significant difference was obtained for the right single correct score [$F(1, 18) = 3.11$, $p = 0.09$, $\eta p^2 = 0.14$].

4.2.2 Comparison of post training scores between the two groups. The mean scores given in Table 4.1 indicated that the typically developing children had better post training scores than the children with AIP in both the dichotic tests. For the Dichotic CV test this difference was found to be statistically significant for the right single correct [$F(1, 18) = 16.21$, $p < 0.01$, $\eta p^2 = 0.47$], left single correct [$F(1, 18) = 11.79$, $p < 0.01$, $\eta p^2 = 0.39$], and double correct scores [$F(1, 18) = 18.25$, $p < 0.01$, $\eta p^2 = 0.50$]. Further, it was found that a significant difference also existed between the groups for the Dichotic Digit test for the right single correct [$F(1, 18) = 5.46$, $p = 0.03$, $\eta p^2 = 0.23$], left single correct [$F(1, 18) = 6.90$, $p = 0.01$, $\eta p^2 = 0.27$] and double correct scores [$F(1, 18) = 5.98$, $p = 0.02$, $\eta p^2 = 0.25$].

4.2.3 Comparison of difference in the pre and post training scores obtained by two groups. The mean and standard deviation of the difference in scores obtained by the typically developing children and those with AIP are given in Table 4.2. The mean improvement in scores obtained by the participants of the two groups varied marginally. The lack of difference in the improvement seen in the two groups was confirmed by a MANOVA test. No significant difference existed between the two groups for the Dichotic CV test for the right single correct [$F(1, 18) = 0.10$, $p = 0.74$, $\eta p^2 = 0.006$], left single correct [$F(1, 18) = 1.43$, $p = 0.24$, $\eta p^2 = 0.07$], and double correct scores [$F(1, 18) = 1.89$, $p = 0.18$, $\eta p^2 = 0.09$]. A similar trend was observed in the Dichotic Digit test for the right single correct [$F(1, 18) = 0.009$, $p = 0.92$, $\eta p^2 = 0.001$], left single correct [$F(1, 18) = 0.48$, $p = 0.49$, $\eta p^2 = 0.02$], and double correct scores [$F(1, 18) = 0.27$, $p = 0.60$, $\eta p^2 = 0.01$].

Table 4.2

Mean and Standard Deviation (SD)of difference in pre and post-training scores in Dichotic CV and Dichotic Digit scores obtained by typically developing children and children with AIP.

Group	Score Types	Statistical test	Difference in pre and post-training scores	
			Dichotic CV	**Dichotic Digit**
TDC	Right SCS	Mean	4.70	6.00
		SD	3.52	2.10
	Left SCS	Mean	4.90	7.30
		SD	7.30	3.97
	Double correct scores	Mean	8.50	9.5
		SD	5.06	4.69
Children with AIP	Right SCS	Mean	4.10	6.10
		SD	4.60	2.55
	Left SCS	Mean	2.70	6.20
		SD	4.92	3.04
	Double correct scores	Mean	5.5	8.40
		SD	4.6	4.71

Note. Maximum possible score = 30; TDC = Typically Developing Children; AIP = Auditory Integration Problem; SCS = Single correct scores.

The summary of the findings of the study is given in Table 4.3. The effects of within-subject variables as well as between subject variables were provided.

Table 4.3

Summary of the within-group findings.

Evaluation/ Test	Test/Evaluation	Score-type	Groups	
			TDC	Children with AIP
Pre-training evaluation 1 Vs. Pre-training evaluation 2	Dichotic CV	Right SCS	NS	NS
		Left SCS	NS	NS
		Double correct scores	NS	NS
	Dichotic Digit	Right SCS	NS	NS
		Left SCS	NS	NS
		Double correct scores	NS	NS
Pre-training evaluation 2 Vs. Post-training evaluation	Dichotic CV	Right SCS	***↑	**↑
		Left SCS	***↑	*↑
		Double correct scores	***↑	**↑
	Dichotic Digit	Right SCS	***↑	**↑
		Left SCS	***↑	**↑
		Double correct scores	***↑	**↑
Dichotic CV Vs. Dichotic Digit	Pre-training evaluation	Right SCS	NS	NS
		Left SCS	*↑	NS
		Double correct scores	**↑	**↑
	Post-training evaluation	Right SCS	*↑	**↑
		Left SCS	**↑	*↑
		Double correct scores	*↑	**↑

Note. * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; Upward arrow (↑) indicates significantly higher scores in the second parameter over the first; TDC = Typically Developing Children; AIP = Auditory Integration Problem; NS = Not significant; SCS = Single correct scores.

Table 4.4
Summary of the between group findings.

Evaluations	Tests	Score-type	TDC Vs. Children with AIP
Pre-training 2	Dichotic CV	Right SCS	**↑
		Left SCS	**↑
		Double correct scores	**↑
	Dichotic Digit	Right SCS	NS
		Left SCS	*↑
		Double correct scores	*↑
Post-training	Dichotic CV	Right SCS	**↑
		Left SCS	**↑
		Double correct scores	**↑
	Dichotic Digit	Right SCS	*↑
		Left SCS	*↑
		Double correct scores	*↑
Difference between Post & Pre evaluations (Post - Pre)	Dichotic CV	Right SCS	NS
		Left SCS	NS
		Double correct scores	NS
	Dichotic Digit	Right SCS	NS
		Left SCS	NS
		Double correct scores	NS

Note. * = $p < 0.05$; ** = $p < 0.01$; Upward arrow (↑) indicates significantly better scores obtained by typically developing children over those with AIP; TDC = Typically Developing Children; AIP = Auditory Integration Problem; NS = Not Significant; SCS = Single correct scores.

Chapter 5

Discussion

The results of the current study that aimed to find the effect of cross-motor activities of Brain Gym® on auditory integration are discussed. The results are discussed in terms of the comparison of the two baseline scores; comparison of the pre- and post-training scores; and the scores obtained between the two dichotic tests. Additionally, the comparisons of scores between the two groups of participants have discussed for each of the evaluations as well as the improvement in scores following training.

5.1 Comparison of scores within each participant group (TDC & AIP)

The findings regarding the significance of the difference between the two baselines; the efficacy of cross-motor training; and the difference between the two dichotic tests are discussed. Each of these aspects is discussed separately.

The comparison of the dichotic scores obtained in the two baselines in each group was done to establish whether any covariables influenced the responses of the participants. The scores obtained by the participants on the two pre-training evaluations (pre-training evaluation-1 & pre-training evaluation-2) were not found to be significantly different. This indicated that in the absence of any intervention, no changes occurred in the dichotic test scores, substantiating that no external variables influenced the responses of the participants. These findings were true for both participant groups and both tests that were administered. The absence of any difference between the two pre evaluations also confirmed the high test-retest reliability of the tests (Dichotic CV & Dichotic Digit test) that were administered.

A comparison of the pre and post training dichotic scores in each group indicated that the post-training scores were significantly better than the pre-training scores. This was observed in the typically developing children and those with AIP. The improvement was found across all the score-types (right single correct, left single correct, & double correct scores).

Cortical reorganization could have occurred in the participants of the current study subsequent to them performing bimanual activities of Brain Gym® to continuous oral commands. Earlier studies have also demonstrated that bimanual activities to oral commands resulted in enhanced Dichotic CV test scores. This was reported by Yathiraj and Priyadarshini (2009) who noted that children who underwent abacus training, which required carrying out bimanual activities to verbal commands, had better Dichotic CV test scores compared to a control group who did not receive the training. They attributed this improvement in dichotic scores following bimanual activities to inter-hemispheric interaction. They concluded, based on the findings of Sperry (1968) and Riza (2002), who had noted that the left hemisphere is the primary center for processing verbal commands and the right hemisphere for performing motor commands.

It was also observed by Nagel (1971) that the transfer of information between the cortices is affected by sectioning the corpus callosum. This was concluded from a case who had naming difficulties for tactile inputs given to the right hand, after sectioning of the corpus callosum. From this the author inferred that the left hemisphere was responsible for naming or language related skills and the right for the motor task. Further, it was reported that the activities involving both the hemispheres resulted in better integration through interhemispheric transfer.

The physical training-related cortical re-organization has also been demonstrated with the help of imaging techniques like EEG, PET scans and MRIs (Andres et al., 1999; Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Sadato et al., 1997). Thus, in the present study also, it is possible that better integration via interhemispheric transfer led to cortical reorganization due to the cross-motor exercises performed on verbal commands / verbal count.

The improvement seen in the participants of the present study following bimanual training using Brain Gym® could have also occurred due to increased attention following training. The developers of Brain Gym® have claimed that the cross-motor exercises of the programme, that include E.C.A.P followed by cross crawl and puppet crawl improve attention. This improvement in attention could have also included auditory attention. Therefore, the observed improvement could be due to a combined effect of increased auditory vigilance and effective auditory integration through cortical re-organization that may have occurred following the training.

The comparison of scores across the two dichotic tests in each group indicated that in general, the scores of Dichotic Digit test were higher than that of the Dichotic CV test. This was observed for most of the score-types in the per- and post-therapy evaluations in both groups (Table 4.1). This difference was statistically significant for the double correct scores and left single correct scores in the pre-training evaluations for typically developing children. However, in the pre-training evaluation, no significant difference was found for the right single correct scores in both groups and the left single correct scores in the children with AIP.

Unlike the pre-training scores, all the score-types obtained following training were found to be statistically higher for the Dichotic Digit test compared to the Dichotic CV test (Table 4.3). From Table 4.1 it can be noted that the average quantum of improvement was considerably more for the Dichotic Digit test when compared to the Dichotic CV test. This probably occurred due to digits being used more frequently than the isolated stimuli used in the Dichotic CV test. This familiarity of the material probably enabled the participants to identify the numerical stimuli more easily than the less redundant CVs. This would have resulted in there being a significant difference between the two tests for all score-types in both the participant groups, following the training.

These findings are congruence with what is reported in literature where it has been reported that scores for the Dichotic Digit test to be better than the Dichotic CV test (Hällgren, Johansson, Larsby, & Arlinger, 1998; Priya & Yathiraj, 2007; Yathiraj & Priyadarshini, 2009). It was reported to be the effect of higher linguistic redundancy present in digits.

5.2 Comparison of scores between the participant groups (TDC & AIP)

The comparison of the two participant groups are discussed in term of the difference between their baseline scores on the two tests; their post-training scores; and the quantum of improvement in scores following the cross-motor training. Details of the individual responses are also provided.

Comparison of the pre and post-training evaluation scores between the two groups revealed that the typically developing children scored significantly higher than the children with AIP on both the dichotic tests. This significant difference was noted in the pre- and post-training evaluations, for all the score-types (right single correct, left single correct, & double correct scores) on the Dichotic CV test. A similar trend was observed for the Dichotic Digit test, except for the right single correct scores in pre-training evaluation. This could be attributed to the relatively high right ear scores obtained by one of the participants with AIP that skewed the mean scores positively. While this child (subject 8) obtained a score of 26 in the pre-training Dichotic Digit test, but obtained poor scores on the more difficult Dichotic CV test. Eliminating the scores of this child resulted in the right single correct scores also being significantly different between the two groups.

The better performance of the typically developing children as compared to those with AIP in the pre-training evaluation stems from the inclusion criteria utilised. The participants in the latter group were selected only if they performed below the available norms. This difference between the two groups continued to persist following the cross-motor training. This difference occurred as the training had a positive impact on both the groups. It was observed that the improvement in scores following training were not significantly different between the two groups. Although the quantum of improvement was similar across the two groups, the scores obtained by the typically developing children following the training were higher than those with AIP. Several of those in the former group obtaining scores close to the maximum possible score, as can be seen in Figure 4.1. On the other hand, many of those in the latter group had post training scores that were considerably lower than the maximum possible score. Thus, it is possible that with further training the scores of the children with AIP could have improved further.

Further, from the individual data of those with AIP it was observed that the double correct scores of 5 of them on the Dichotic CV moved from being out of the normative values to being within the normative value of Yathiraj and Vanaja (2015). However, for 4 of the remaining participants with AIP, although the double correct scores of the Dichotic CV test did improve, their scores continued to be below the normative value. For one participant, the training brought about no change. Likewise, on the Dichotic Digit test, all 4 children with AIP who had double correct scores below the age appropriate values given by Regishia (2003) prior to training, showed improvement. However, only in 3 of the 4 did the double correct scores improve to be considered as age appropriate and one continued to have scores below the age appropriate scores. Hence, it is recommended that for the children who did not demonstrate adequate improvement in the double correct scores, the duration of training should be extended beyond the 10 days for which it was provided.

In light of findings of the current study, the claim made by the developers of Brain Gym® that the exercises improve inter-hemispheric information transfer and attention (Dennison & Dennison, 2007) is supported. However, the individual data reveals that the quantum of improvement varied across the participants. While most of the participants in both groups showed an improvement in scores, a small percentage showed a limited improvement. In general, although the extent of improvement was similar in the two groups, the scores obtained by the children with AIP continued to be significantly poorer than that obtained by the typically developing children. It is speculated that with more extensive training, those with AIP are likely to demonstrate further improvement. This needs to be explored along with studying the maintenance of the improvement following therapy.

Chapter 6

Summary and Conclusions

Physical training is reported to be important to improve physical health (Ades, Waldmann, & Gillespie, 1995; Beniamini et al., 1999; Fahlström et al., 2003). Researchers have also found that physical exercises also have a positive impact on mental, physiological and higher cognitive skills like executive functioning and attention (Acil et al., 2008; Carro et al., 2001; Erickson et al., 2011; Scherder et al., 2005; Wexler, 2013). Further, it has been reported that motor activities led to an improvement in auditory processing skills like auditory integration, memory, sequencing, speech perception in noise, and, melody discrimination (Hyde et al., 2009; Janet & Yathiraj, 2003; Yathiraj & Priyadarshini, 2009). These studies have evaluated participants who were trained to carry out bimanual activities that involved the hands/fingers. However, the effects of cross-motor training activities on auditory processing have not been studied in the literature.

It was reported that most of the children with central auditory processing disorders demonstrate poor reading, writing, spelling, articulatory skills, poor attention and also have lower self-esteem (Keith, 2000). They were also found to have larger vocal reaction time than typically developing peer group (Dagenais, Cox, Southwood, & Smith, 1997). The inability to differentiate between and remember phonemes, to process prosody, to understand a foreign accent and reduced attention to auditory inputs are some of the major difficulties reported to be present in children with auditory processing disorders (Keith, 2000). To help such children, it needed to be studied whether specific cross-motor exercises of a commercial program would reduce their difficulties.

The physical training-based program, Brain Gym®, developed by Dennison (1986), was reported to activate the brain thorough motion. It was also claimed to connect the whole brain synergistically (Dennison & Dennison, 2007). Hence, the current study was undertaken to study the effect of specific exercises provided in Brain Gym® on auditory integration in typically developing children and children with auditory integration problems. The study also aimed to compare the improvement in scores after training between typically developing children and children with auditory integration problems on two tests of auditory integration (Dichotic CV test & Dichotic Digit test). The difference in scores across the two dichotic tests before and after training in typically developing children and in children with auditory integration problems were also studied.

Ten typically developing children and 10 children with auditory integration problems were evaluated on the Dichotic CV test (Yathiraj, 1999) and the Dichotic Digit test (Shivashankar & Herlekar, 1991). Each child was evaluated thrice, that included two baseline evaluations measured prior to the training one to two days apart and one evaluation administered after 10 sessions of cross-motor training of Brain Gym®.

The data were found to be normally distributed on Shapiro-Wilk's test of normality and hence, parametric inferential statistics were used after performing descriptive statistics. An ANOVA done for within-group analyses revealed that the two baselines were not significantly different. However, a significant difference was seen between the pre and post evaluations for both groups on both the dichotic tests. Additionally, it was found that the scores obtained on the Dichotic Digit test were higher than the Dichotic CV test for all the participants. MANOVA done to compare the scores across the two participant groups, revealed the presence of significantly better pre and post-training scores by the typically developing children as compared to those with auditory integration problems. Although the typically developing children attained significantly higher scores, the quantum of improvement in the two groups was not significantly different.

From the findings of the study, it was concluded that the cross-motor exercises of Brain Gym® resulted in an improvement in auditory integration skills in typically developing children as well as in children with auditory integration problem. This improvement was attributed solely to the training activities that were administered on the children as the scores on the two evaluations prior to the training were not significantly different. In contrast, significant improvement was seen following the training.

Implications of the study

1. The study indicates that the cross-motor exercises in Brain Gym® are effective in improving interhemispheric transfer of information in typically developing children and children with auditory integration problem.
2. The study provides information regarding the utility of Brain Gym® as a fun-based treatment procedure for children having auditory integration problems.

Future directions

1. It is recommended that the study should be carried out on a larger number of participants, both children, and adults.
2. The impact of the training on other auditory processes could be studied.
3. It needs to be studied whether the improvement seen in the performance is maintained over a period of time.
4. It needs to be seen if providing the training for a longer period of time would increase the quantum of improvement in those with auditory integration problems.

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