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Interactive Metronome: Research Review Related to Treating Auditory Processing Disorders in Children

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Abstract

Introduction

Interactive Metronome (IM) is a computer-based neurological assessment and treatment tool to improve processing abilities (McGrew, 2013).

Methods

A search of electronic databases, peer reviewed journals, and various clinical reports between 1995 and 2017 was conducted to review research literature and analyze the evidence available for using IM to treat auditory processing disorders (APD) in children.

Results

The literature suggests that IM improves auditory temporal processing, language comprehension, reading, and attention skills that are deficient in children with APD.

Conclusions

Further assessments of IM training is needed to support its use, as an effective rehabilitative treatment.

Introduction

Interactive Metronome® (IM) is a patented computer-based interactive version of a traditional music metronome (Cassily, 1996). Jim Cassily, an acoustics engineer, developed IM in the early 1990s. In 1994, he created a remote-control headset that presented metronome beats to help a child walk with a new prosthetic leg. Success led Cassily to apply IM to help children with learning and developmental disorders (McGrew, 2013). IM is a brain-training assessment and treatment tool used for pediatric and adult individuals to improve processing abilities that affect attention, motor planning, and sequencing.

The Interactive Metronome program consists of a software, a master control unit, a hand trigger, insole triggers, a tap mat, and headphones. The software includes a reference tone, guide sounds transmitted through headphones, visual guidance through the computer screen, graded sequential interactive neuro motor exercises, and the ability to record the speed of the patient's response. IM provides rhythm and timing training by presenting an auditory tone in the form of metronome beats through the headphones. The listener matches the timing of the beats with handclaps or foot taps, and obtains feedback from a computerized hand and foot sensor as shown in Figure 1. The listener learns to match the rhythm of the beat in a synchronous manner, which requires an integration of auditory perception of rhythm with the motor task (such as clapping hands). The training provides the listener with auditory and visual feedback that indicates the extent to which the beat of the metronome was matching to the rhythm of the motor task. The motor responses are classified as either too quick (before the tone

Fig. 1. The IM equipment consists of a software, a master control unit, a hand trigger, insole triggers, a tap mat, and headphones (Reproduced with permission from Interactive Metronome®)

was heard), too slow (longer than expected after hearing the tone), or on target (within a specified millisecond time limit after hearing the tone). It has been hypothesized that this feedback improves temporal processing and neural efficiency, leading to improvements in auditory, sensory, motor, and cognitive functions (McGrew, 2013). Because the improvements are based on auditory processing of the rhythmic beats, it is believed that IM training improves auditory processing abilities, especially auditory temporal processing.

Audiologists, occupational therapists, physical therapists, speech-language pathologists, psychologists, and educators have described IM as a potentially successful training technique (Alpiner, 2006; Etra, 2004; Shaffer et al., 2001). Researchers claim that IM improves rhythm, temporal processing, and motor coordination, as well as auditory processing and language comprehension abilities. The purpose of this article is to review the evidence available regarding IM, and to determine whether it is an efficacious and effective treatment for children with auditory processing deficits referred to audiologists, speech language pathologists, and occupational therapists.

Method of Research Review

The literature search included research and non-research based articles published between 1995 and 2017. The resources included electronic databases such as Education Resources Information Center (ERIC), MEDLINE, Cumulative Index to Nursing, and Allied Health Literature (CINAHL), Cochrane Database of Systematic Reviews, and eBook Clinical Collection (EBSCOhost). Key words used to search the literature included the following terms: “Occupational Therapy”, “Audiology”, “Auditory Processing”, “Speech Language Pathology”, and “Interactive Metronome”. Recently published articles in peer-reviewed journals, including the Journal of Neurological Sciences, Neuropsychologia, American Journal of Occupational Therapy, Journal of Speech Language and Hearing Research, Psychology in Schools, Trends in Cognitive Sciences, Journal of Music Therapy, American Journal of Psychiatry, Annual Review of Neuroscience, International Journal on Disability and Human Development, and various other national and international journals were reviewed. Reported case studies, and clinician reports from various institutes around the United States were gathered and evaluated. Also examined were materials presented at professional conferences by one of the co-authors of this paper. A graduate assistant conducted the searches, and generated 118 relevant citations based on the title and/or abstract. The first two authors independently reviewed the abstracts of these articles and excluded those that were irrelevant. They also reviewed the reference lists of the published articles to identify additional sources, the IM training manual, and recently written papers posted on the research tab of the Interactive Metronome website (www.interactivemetronome.com). This search resulted in 10 relevant publications related to IM. Table 1 presents an overview of effectiveness of IM and similar Auditory-Motor Integration training.

Table 1. Overview of Effectiveness of Interactive Metronome (IM) training

Author (s)	Study Focus	Sample Size	Quality Measures	Summary of Results
Shaffer et al. (2001)	The IM training on children with ADHD	56 children all males, ages 6-12 years	Conners' rating Scale-R, Achenbach Child Behavior Checklist, The sensory Profile, Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), Wide range Achievement Test, Language Processing Test	53 of 58 measures including areas of attention, motor control, language processing, reading, regulation of aggressive behavior improved following the IM treatment.
Jacokes (2003)	The IM training on motor, language and cognition in children	13 children (ages and gender not available)	Clinical Evaluation of Language Fundamentals (CLEF-3), The Sensory Profile, Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), Self-Perception Profile, Evaluation Tool of Children's Handwriting (ETCH), The Listening Test	Significant gain for auditory processing related to concept and reasoning on Listening Test (p=.003 & .001). Other areas of gain included balance, bilateral coordination, sensory processing, and handwriting. Some areas with no significant change were Self Perception Profile, and ability to transition between tasks.
Alpiner (2004)	The IM training could increase existing auditory-motor processing networks.	Seven adults with experience in training IM and one control adult	Participants were placed in an MRI scanner and were asked to simulate IM cues using the scanners internal cycling noise. Images were taken while this was being done	Increased neural activity in– cingulate gyrus, temporal gyrus, and superior frontal gyrus.
Bartscherer & Dole (2005)	The IM training for improving timing, attention and motor coordination difficulties	Case report nine year old male	Timing and accuracy of various subtests were measured using BOTMP	Changes in timing, fine and gross motor skills, and behaviors as reported by parents.
Etra (2006)	The IM training on children	Eight children {six males}, ages 8-14 years	The IM Long Form Assessment (LFA) Scores, SCAN-C Scores	Significant increase (19%-34%) in LFA and SCAN-C Scores.

Table I cont.

Taub et al. (2007)	Effect of Synchronized Metronome Tapping (SMT) intervention on reading achievement in children	86 children (37 males) ages 7-10 years	Woodcock-Johnson III, Comprehensive Test of Phonological Processing, Test of Word Reading Efficiency, and Test of Silent Word Reading Fluency	Scores on selected measures of reading were significantly higher (p<.001) in the experimental group.
Ritter et al. (2012)	The IM training in children with language and reading impairment	49 children (34 males), ages 7-10 years	CLEF-4, Core Language Scores, Expressive Vocabulary Test (EVT-2), Gray Oral Reading Test (GORT -4)	The treatment group made larger gains than the control group in areas of reading rate/fluency and comprehension.
Taub et al. (2015)	Effect of improvements in timing/ rhythmicity on mathematics achievement using synchronized metronome beat	86 children, ages 7-10 years	Woodcock-Johnson III Tests of Achievement	Scores on the measures of mathematics were significantly higher (p<.015) in the experimental group.
Shank & Harron (2015)	The IM training on timing skills, hand function, and self-regulatory behaviors in children.	48 children (41 males), ages 6-17 years	Jebsen Taylor Test of Hand Function (JTTHF) and the IM Long Form Assessment (LFA)	Improved on timing scores (LFA): 64% (p<0.0001), dominant and non-dominant hand (JTTHF): (p<0.0001), Parent Questionnaire: 26% (p<0.0001).
Reeves & Lucker (2017)	Effectiveness of therapy (Integrated Listening and earphone training, IM, and Phonemic Synthesis training) in Auditory Processing	125 children, ages 5-16 years	Outcome measures included Speech in Noise (SIN), Phonemic Synthesis Test (PST), NU-6 Filtered Words (FW), Pitch Pattern Sequence Test (PPST)	Comparisons of related samples t-tests revealed highly significant (p= 0.0009) improvements in all areas of auditory processing and IM timing post-therapy.

Review of Research on Interactive Metronome and Auditory-Motor Integration

When considering any therapy for children with auditory processing problems, it is important to examine the theoretic basis of the treatment believed to be effective. Four of the articles reviewed addressed the underlying theory behind IM training (Jacokes, 2003; Etra, 2006; Ritter et al, 2012; Shank and Harron, 2015). Alpiner (2004) suggested that IM training works by augmenting internal processing speed due to its effect on key regions of the cerebellum, prefrontal cortex, cingulate gyrus and basal ganglia. He argued that the inherent neurosensory and neuromotor exercises that are part of IM training helps to improve the brain's inherent ability to repair or remodel itself through neuroplasticity processes. The level of a person's performance on IM that involves planning, timing, and rhythmicity of motor regulation correlates with the severity of developmental, learning, and attentional problems, improvements in academic performance, and age-expected performance changes during the school years (Kuhlman & Schweinhart, 1999). The underlying mechanisms for the gains made through IM training, however, were not well understood. Additionally, recent research (Peterson, 2016; Peterson, Simpson, & Lucker, 2016; Reeves & Lucker, 2017) has demonstrated positive outcomes from IM training on auditory temporal processing and language comprehension, as well as on overall auditory processing including speech understanding in noise, understanding distorted (filtered) speech, and auditory integrative processing.

Mauk and Buonomano (2004) described how temporal processing is inextricably related to sensory processing, auditory processing, motor coordination and control, language development, visual tracking (saccadic eye movements) and behavior. The most sophisticated temporal processing occurs at a 10-100 milliseconds, which is fundamental for auditory and speech processing as well as motor coordination. Thaut et al. (2002) identified research supporting the interaction between rhythm and motor control. These researchers investigated the effect of rhythm on control of paretic arm movements. They found that individuals with a paretic arm showed improvements in timing and trajectory control during structured auditory rhythmic conditions, but not during non-rhythmic conditions. Their data suggested that the use of IM with its structured auditory rhythm could be an effective training tool to enhance sensorimotor control. The IM training improves temporal processing at the 10-100 milliseconds providing better auditory-motor integration and control due to the auditory training (Thaut et al., 2002)

Interactive Metronome has been used as a treatment to improve processing abilities in a variety of disorders. For example, it has been used in individuals with Attention Deficit Hyperactivity Disorder (ADHD), speech and language disorders, balance and gait disorders, traumatic brain injuries, sport and motor disorders, and auditory processing issues (McGrew, 2013; Peterson, 2016; Peterson et al., 2016; Reeves and Lucker, 2017). Research demonstrated that because of IM training, individuals respond more in synch with the rhythmic beat of the metronome improved significantly when compared to baseline results in many areas (McGrew, 2013; Peterson, 2016; Peterson et al., 2016; Reeves and Lucker, 2017). Gorman (2003) and McGrew (2013) also reported improvements in cognitive function and motor skills following IM training. Theoretically the gains observed may have resulted from taking advantage of the neuroplasticity potential of the brain. The IM training works by changing neurocognitive mechanisms within the brain allowing for more efficient processing. This success through improved communication between brain structures within neural networks that are responsible for the cognitive and motor functions necessary during IM training (McGrew, 2013). These brain structures including cerebellum, anterior cingulate, basal ganglia, dorsolateral prefrontal cortex, right parietal cortex, motor cortex, and the frontal-striatal loop are thought to be involved in intellectual and cognitive functioning, working memory, and controlled attention (Lewis & Miall, 2006; Taub, McGrew, Keith, 2007; McGrew, 2013).

Research on IM Training and Other Non-Motor Areas

In addition to looking at changes in motor control and coordination after IM training, Taub, McGrew and Keith (2007) studied the impact of IM training on factors that can affect attention and academic achievement. The researchers looked at sustained attention, ability to tune out distractions (an auditory processing skill), multi-tasking, working memory, impulse-control and self-monitoring, mental processing speed, executive functions (meta-cognition), and academic achievement. Taub et al.'s research demonstrated cognitive improvements after 12 sessions of IM. They believed that IM had an impact on the timing structures of the brain, mostly, in the cerebellum and basal ganglia (Mauk & Buonomano, 2004) known for temporal processing, and that IM is one of the only intervention that works on timing at a level of a 10-100 milliseconds. Therefore, it was believed that IM could benefit children with temporal processing deficits, such as those found in children diagnosed with ADHD and Autism Spectrum Disorder (ASD).

Several other researchers examined the effects of IM on ADHD behavior. Leisman and Melillo (2010) examined the effects of IM training on male, school-aged children with ADHD. Using a signal detection task in which children were asked to detect the presence of a signal and the letter U on a computer screen (an auditory-visual integration attention measure) by pressing the appropriate key on the keyboard; the researchers evaluated the change in attention in children who underwent IM training. The children were awarded points for correct responses and lost points for incorrect responses. They included four groups of children: children with ADHD treated with IM, children with ADHD receiving no IM treatment, children with typical functioning who received IM treatment, and a control group of children with typical development who received no IM treatment. Comparison of pre-treatment and post-treatment signal detection scores revealed little change for children without ADHD. However, significant changes in performance were observed in the ADHD group receiving IM treatment. Their ability to correctly identify the signal improved while the number of false alarms and misidentification of signals being present decreased following IM training.

Shaffer et al. (2001) found improvements in several areas following IM training with children who had ADHD. The researchers examined three groups of male students, aged 6 to 12, with ADHD; one group who received IM treatment, one group assigned to play a computer-based video game, and a control group who did not receive any intervention. Multiple measures were used to examine attention and concentration, clinical functioning, and academic and cognitive skills pre- and post-intervention. The results revealed that those students with ADHD who received IM training showed significant improvements in the areas of attention, motor control, language processing, reading ability, and ability to control aggression when compared to participants in the video game or control group. Thus, research has demonstrated significant improvements in motor control and coordination using IM, an auditory-based training tool.

Research Findings Related to Interactive Metronome and Auditory Processing Disorders

In view of the improvements in motor coordination and control, academic achievement, and attention factors found with IM training, a question arises as to changes that may be seen in auditory processing abilities. Can IM be used effectively as a treatment for auditory processing disorders, especially in children?

There is limited published data on using IM for the treatment of auditory processing disorders. Etra's (2006) research focused on whether IM training would change auditory processing abilities in children. Six male and two female students between the ages of 8-14 who demonstrated deficits in attention, but had not been diagnosed with ADHD or auditory processing disorders, were recruited into the study. Etra (2006) used IM training and then examined the children's performance on the SCAN-C Test for Auditory Processing Disorders in Children Revised (Keith, 2000), a test that evaluates auditory processing abilities. SCAN-C performance was assessed prior to and following 15 to 17, one hour IM training sessions. The SCAN-C includes four measures of auditory processing: two of which are monaural tests of low redundancy using filtered word (distorted speech), a measure of speech understanding in noise (auditory-figure ground) and two dichotic listening tests using competing words (auditory integration) and competing sentences (auditory separation).

In a recent unpublished doctoral dissertation Peterson (2016) and Peterson et al. (2016), looked specifically at auditory processing and auditory/language comprehension in young adults with traumatic brain injury (TBI). The participants underwent IM training and completed a variety of auditory processing and language tests, including the SCAN-3: A (Adult level version of the updated SCAN test; Keith, 2009). The subtests used included Filtered Speech, Auditory Figure-Ground 0, Competing Words, Competing Words – Directed Ear, Competing Sentences and Time Compressed Sentences (TCS). The TCS is a measure of auditory temporal processing that measures a person's abilities to repeat rapidly presented sentences. The results of post-treatment vs. pre-treatment findings on the SCAN-3: A revealed a highly significant (p=0.0009) improvement in this measure of auditory temporal processing after the IM training supporting the theory that the IM training improves temporal processing in the brain. Additionally, significant improvement was found in auditory/language comprehension based on results from the Computer Revised Token Test – Listening Version (McNeil et al., 2015) and The Discourse Comprehension Test – Second Edition (Brookshire & Nicholas, 1997).

Recently, Reeves and Lucker (2017) looked at a combination of listening therapy (Integrated Listening Systems or iLS www.integratedlistening.com) along with IM training in a large group (N=125) of students (aged 5 to 17 years). All students were evaluated and found to have auditory processing disorders. A variety of auditory processing measures were administered prior to the treatments and included filtered words (NU6 Filtered Words Test), auditory figure-ground (W-22 Speech-In-Noise with a signal-to-noise ratio (SN) of +5), dichotic listening (SSW Test), and auditory temporal processing (Pitch Pattern Sequence Test and IM timing measure). The students underwent iLS and IM treatments and were re-evaluated on each of the same measures. Comparisons of related samples t-tests revealed highly significant (p= 0.0009) improvements in all areas of auditory processing and IM timing post-therapy. Thus, iLS and IM treatments were found to contribute to significant improvements in auditory processing abilities, especially temporal processing/timing, in young adults (Peterson, 2016) and in children and adolescents (Reeves & Lucker, 2017).

Summary of Findings for Interactive Metronome Training

The potential use and efficacy of IM treatment is documented in literature across various disciplines with participant having disorders, including auditory processing and auditory/language comprehension problems. The underlying skill that appears to be most consistently responsive to IM training is temporal processing, although it should be noted that other improvements in auditory processing and motor planning and timing were also observed. Kuhlmann and Schweinhart (1999) discussed that motor planning and timing activities are important for children to improve their social interactions as well as their performance levels in sports, music, dance, speech, and general life functioning. The IM training requires participants to match an auditory based rhythm with other modalities and processes, such as motor activities, language comprehension, correctly repeating what they hear which can help children develop motor and timing skills and improve perception of temporal and spatial cues as well as understanding of linguistic information. Shaffer et al. (2001) provided important evidence that IM training programs, may be helpful in improving timing and rhythmicity related to motor planning and sequencing, as well as improving higher cognitive skills that are important for performance in many areas of education, communication, sensorimotor functioning, and for daily living skills. Etra (2006) found that children with auditory processing disorders showed significant improvement in dichotic listening following 15-hours of IM training. Additionally, Peterson (2016) and Peterson et al. (2016) showed improvements in auditory temporal processing and auditory/language comprehension. Reeves and Lucker (2017) revealed that IM training (along with a listening therapy) significantly improved auditory processing and timing skills in a large sample of students.

Current evidence indicates that IM may be beneficial in improving multiple domains associated with motor planning, attention, auditory processing, language processing, and cognitive functioning. Though more research is required to establish IM training as a valid and reliable treatment method for use in children with auditory processing issues, some of the studies supports its use, especially to improve auditory temporal processing in such children.

Limitations

There are some limitations to the present investigation. This review of previously published material was limited to those publications available through a literature search, as well as some known publications, doctoral dissertations, and presentations at professional meetings. There may be other studies that were not identified.

Another limitation relates to the research methods. Many studies used convenience sampling so if reviewed studies that the participants were not randomly chosen. However, much of the published research focusing on clinical therapies uses convenience sampling or children who are available to the investigators. Using convenience sampling introduces potential biases but likely did not confound the conclusions drawn from the sources examined. Additionally, most of the research compared findings after IM treatment, but did not compare findings with a control group not receiving any IM training. This lack of control makes it difficult to interpret the treatment results.

Because of these identified limitations, future research should consider completing more randomized subject selection and studies using control groups. Such research would add to what is known about the positive outcomes from IM training.

Conclusion

Every child, adolescent, and adult has a unique way of processing information, especially auditory information, and using information for motor planning and sequencing. It is evident that listeners with auditory processing deficits have difficulties understanding auditory-verbal stimuli, which leads to problems comprehending information presented to them in social, work and academic environments. The present review of the literature indicates that the use of a technology (i.e., IM Training) aimed at strengthening motor planning, sequencing, timing, and rhythmicity may have an important role in improving abilities to attend and learn as well as comprehend what is heard (Etra, 2006 ; Peterson, 2016; Peterson et al., 2016; Reeves & Lucker, 2017). However, the present review of the literature indicates that little research has been done investigating the effects of IM specifically on auditory processing issues in children seen by audiologists and speech-language pathologists for evaluations and by speech-language pathologists and occupational therapists for treatment. Thus, there is a need for researchers to further investigate whether IM training is effective for improving auditory processing skills as well as auditory-motor integration, and improving cognitive and executive functions. It is evident from the available data reviewed that IM can help clients accomplish outcomes that improve a wide variety of listening and functional skills.

In conclusion, the literature on IM training suggests that it may have potential usefulness in a wide range of clinical conditions to address attention, motor planning and sequencing, as well as improve auditory processing abilities. As we continue to understand auditory processing issues in children, we will be able to find effective ways to help these children. Auditory-motor integration therapies, like IM, seem to be very useful treatment strategies to address auditory processing problems in children seen in rehabilitative clinical practices.

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