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A Preliminary Study of the Effects of Interactive Metronome Training on the Language Skills of an Adolescent Female With a Language Learning Disorder

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The interactive metronome (IM) is an innovative, patented, microcomputer-based version of the traditional music metronome (Jacokes, 2003, 2004). IM hardware includes a computer, headphones, and two contact sensing triggers (one for the hand and one for the foot). IM software generates a steady beat through the headphones, and the user produces continuous rhythmic movements of the hands and/or feet in response to the auditory stimuli. Sensors register these movements and the software analyzes them according to their speed and accuracy. Interactive visual and auditory feedback are then provided to the user to allow for adjustments in rhythm and timing until movements are synchronized with the auditory stimuli. Rhythmic movements may include clapping of both hands, clapping one hand at a time against the side of the body, alternating toe and heel tapping of a

ABSTRACT: The interactive metronome (IM) uses innovative technology to provide a movement-based repetition program that may improve a person's cognitive and motor performance. Essentially, the IM is a patented, microcomputer-based version of the traditional music metronome in which the user listens to a steady beat through headphones and makes synchronized rhythmic movements in response to the beat. The assumption is that IM training provides drill in rhythm and timing, which in turn may influence neural pathways. To date, IM training has been found to have beneficial effects on motor, cognitive, and academic performance (P. Bartscherer & R. Dole, 2005; T. M. Libkuman, H. Otanim, & N. Steger, 2002; R. J. Shaffer et al., 2001). However, there are no studies reported in the literature of the application of IM training to the field of speech-language pathology. As delayed response time is one characteristic of many learning disabilities (S. J. Diamond, 2003), IM training may facilitate improvement of underlying motor and cognitive processing capacities that are foundational in an individual's ability to attend and learn.

The present study investigated the effects of IM training on an adolescent female with a language learning disorder (LLD). Results showed that the participant demonstrated improvement in all language areas assessed on the Expressive One-Word Picture Vocabulary Test (R. Brownell, 2000) and the Oral and Written Language Scales (E. Carrow-Woolfolk, 2006) from pre- to posttest. These preliminary results suggest that IM training may have potential application to a wide range of clinical conditions in the field of speech-language pathology.

KEY WORDS: interactive metronome, intervention strategies, language learning disorder

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foot, and alternating toe tapping and hand clapping. The IM training program consists of 15 sessions. Each session has predetermined objectives and specific instructions on how to perform the required movements. Variations of movements can be developed to accommodate the user. IM treatment requires administration by a certified trainer. Certification can be accomplished through the Internet within a day's time.

According to Koomar et al. (2001), the underlying theory behind IM training is that motor planning processes of organizing and sequencing are based on an internal sense of rhythm. Rhythm provides the foundation of timing upon which one organizes and sequences the thoughts and movements of daily life. An individual may have the ability to organize and sequence, but without an accurate internal sense of timing, there is no foundation on which to functionally organize and sequence. Drill in rhythm and timing provides for more efficient neuronal organization that in turn facilitates improvement for underlying central nervous system motor and cognitive processing capacities such as motor planning, motor sequencing, concentration, thinking, and interacting. These capacities are foundational in an individual's ability to attend and learn. As such, IM training may have implications for motor skill development, cognitive and language abilities, and academic achievement.

IM training has been found to be beneficial with motor, cognitive, and academic performance. Libkuman, Otanim, and Steger (2002) studied the effects of IM treatment on the motor performance of golfers. This study involved 6 women and 34 men, 25–61 years of age, with basic level golf skills. Due to the wide range in age among participants, age was used as a covariate. The 40 participants were randomly assigned to either a control group or an experimental group. The experimental group received approximately 10 hr of IM training in twelve 50-min sessions over the course of 5 weeks. The control group read golf instruction literature. Participants were asked not to practice swings with golf clubs outside the experiment setting. The dependent variable was the accuracy of golf swings as defined by the number of feet that each ball landed from a target. Pretest measures were taken of each participant's accuracy. Upon completion of the 5-week period, both groups were posttested. A full-swing golf simulator was used in an indoor booth to estimate the distance and direction of each shot from the hole for pre- and posttesting. Participants played the same hole using the same balls, driving mats, rubber tees, and their drivers along with their five, seven, and nine irons. Fifteen shots were taken with each iron for a total of 60 shots for both pre- and postmeasures. Statistical analyses indicated that there was no significant difference in accuracy between groups at pretest. However, the experimental group demonstrated statistically significant improvement from pretest to posttest in accuracy of golf shots. By comparison, no significant improvement in accuracy of golf shots was found for the control group. Therefore, the IM training program was found to have a positive effect on golf swing accuracy.

In addition to motor performance, IM training appears to enhance cognitive abilities. Shaffer et al. (2001) found IM training to have positive effects on the motor and cognitive skills of boys with attention deficit hyperactivity disorder (ADHD). Fifty-six boys between 6 and 12 years of age with a diagnosis of ADHD were randomly selected as study participants. Three groups were formed based on age, medication dosage, and severity of ADHD. Group 1 received fifteen 1-hr sessions of IM training; Group 2 received no treatment; and Group 3 received training on selected nonviolent video games requiring eye–hand coordination, advanced mental planning, and multiple task sequencing. All groups were pre- and posttested using several assessment instruments. The Test of Variables of Attention (TOVA; Greenberg & Dupuy, 1993), Conners' Rating Scales—Revised (CRS–R; Conners, 1990), Wechsler Intelligence Test for Children—3rd Edition (Wechsler, 1992), and Achenbach Child Behavior Checklist (ACBC; Achenbach & Edelbrock, 1991) were used to assess the participants' attention and concentration. The CRS–R, the ACBC, and Bruininks-Oseretsky Test of Motor Proficiency (B-O; Bruininks, 1978) were used to assess each participant's senses, movement, and socioemotional functioning. Finally, the Wide Range Achievement Test—3rd Edition (WRAT–3; Stone, Jastak, & Wilkinson, 1995) and Language Processing Test—3rd Edition (LPT–3; Wilkinson, 1993) were used to assess the participants' academic and cognitive skills. Results revealed significant improvement between pre- and posttest scores for Groups 1 and 3, but no significant improvement from pre- to posttest for Group 2. In addition, Group 1, which received IM treatment, scored significantly better than Group 3, which received video game treatment. Results of this study suggest that IM treatment improves the motor control and cognitive abilities of boys with ADHD.

Bartscherer and Dole (2005) investigated IM training through a case study on a boy with attention and motor coordination difficulties. The participant was a 9-year-old African American male with difficulties in attention and a developmental delay of unspecified origin. He attended a private school that focused on experiential learning; he had not received any special education or therapeutic services. In addition, due to the parents' fear of labeling their son, the boy had not been officially evaluated for learning difficulties, attention problems, or other developmental delays. However, according to the *Diagnostic and Statistical Manual of Mental Disorders—4th Edition* (American Psychiatric Association, 1994), he exhibited several behavioral characteristics that are consistent with a diagnosis of ADHD and developmental coordination disorder.

After seeing reports in the news media, the boy's mother had him undergo a 7-week IM training program. Accuracy in timing on IM tasks was assessed before, during, and after treatment. The B-O Test (Bruininks, 1978) was used to assess the boy's gross and fine motor skills before and after treatment. The boy's pretest motor skills revealed a performance that was markedly below that of his same-age peers. The boy demonstrated significant improvement on timing accuracy on the B-O posttest (Bruininks, 1978). In addition, before treatment, the boy's mother expressed that the boy had trouble with concentration, coordination, organization, and fine motor movements (e.g., cutting out shapes with scissors). After IM treatment, his mother provided anecdotal reports of positive changes in these behaviors at home. In addition, the boy's mother reported improvements in his math and handwriting skills.

Lazarus (2006) investigated the effects of timing and rhythm as a result of IM treatment on various components of reading in high school students. A total of 280 physical education/health students were recruited from Florida's largest, most multicultural high school. All participants were pretested using various reading subtests (i.e., Letter Word Identification, Reading Fluency, Passage Comprehension, and an overall Broad Score of all subtests) of the Woodcock-Johnson III Tests of Achievement (WJ III; Woodcock, McGrew, & Mather, 2001), then randomly placed in a control group receiving no treatment or an experimental group receiving twelve 45–60-min IM treatment sessions. Both groups were then posttested with the WJ III. Statistical analyses revealed that scores for all three subtests improved from pre- to posttreatment for both groups. However, the IM treatment group had a statistically significant higher Reading Fluency score and overall Broad Score. In addition, students in the IM group reported in posttreatment interviews that they felt more attentive and focused on tasks following IM training in timing and rhythm. Improvements were hypothesized to be due to more efficient cognitive processing strictly from the IM training because treatment was not academically oriented, did not require new learning, and only lasted 3 weeks in duration.

From the small body of research that currently exists, preliminary data appear to indicate that IM training is an effective tool for improving a person's motor, cognitive, and academic performance (Bartscherer & Dole, 2005; Lazarus, 2006; Libkuman et al., 2002; Shaffer et al., 2001). Current evidence suggests that IM training provides beneficial improvements in timing and rhythm related to motor planning and sequencing and cognitive processing. There is a well-established relationship between the processes underlying cognition and language processing and use. As such, one might expect to see gains in language skills for some persons who undergo IM training. To date, however, no studies involving IM training in the field of speech-language pathology have been reported in the literature. The purpose of the present study was to conduct a preliminary investigation into the effects of IM training on an adolescent female with a language learning disorder (LLD). It is anticipated that the present study will establish a starting point for future investigation of the IM's use with persons exhibiting various communication deficits.

METHOD

Participant

Developmental and communication history. Renee[1] is a 13-year-old female of Bulgarian descent. A complete case history is lacking due to the fact that she was born outside the United States and spent her first 4 years of life in orphanages. Renee was adopted by American parents at the age of 4½ and as a result emigrated to the United States. Details concerning her early developmental history are unknown. Her adoptive parents reported that the orphanage was clean, but all of the children slept in the same room in individual twin-size beds. Renee's birth mother was 23 when she gave birth to Renee. Renee's birthweight was 3 lbs., 5 oz. A videotape of Renee at 3 years of age revealed that she did not know her own name or age. She weighed 32 lbs. upon adoption, could not run or skip, and demonstrated poor gross motor development. She spoke only two to three Bulgarian words upon adoption but was speaking in simple English sentences by 5½ years of age. Despite the fact that Renee had virtually no expressive Bulgarian language, it is still considered her native language due to her exposure to it for the first 4½ years of her life.

Renee's language deficits were originally thought to be due to her immersion in a new culture and language. Once in kindergarten, Renee's deficits were more apparent and she began receiving speech-language services until the sixth grade, when services were discontinued in 2005. In November 2005, Renee's parents had an outside evaluation conducted by a neuropsychologist due to the fact that Renee still displayed major language issues despite the fact that she had been immersed in English for more than 7 years. The Clinical Evaluation of Language Fundamentals—4th Edition (CELF–4; Wiig, 2004), LPT–3 (Wilkinson, 1993), and Test of Narrative Language (TNL; Gilliam & Pearson, 2004) were used to assess Renee's language abilities. Renee received a receptive language standard score of 79 (8th percentile), an expressive language standard score of 59 (<1st percentile), and an overall standard score of 62 (1st percentile) on the CELF–4. In addition, Renee received a standard score of 87 (20th percentile) on the LPT3 and a standard score of 12 (5th percentile) on the TNL. Results suggested that Renee's expressive language skills were much weaker than her receptive language skills, although her receptive skills were also suspect. As a result of the assessment, Renee was diagnosed with an LLD and was referred to speech-language pathology services. Renee received language intervention from a speech-language pathologist (SLP) in private practice. It was at this clinic that Renee received IM training.

Educational history. At the time of the study, Renee was a seventh grader at a middle school in the Pacific Northwest. Her adoptive parents reported that Renee still had problems with oral and written expressive language. Her parents also reported Renee's extreme frustration with her language difficulties. Academically, Renee received several special accommodations (e.g., additional time for tests and assignments, altered or shortened assignments, modified grading scale, open book exams, shortened verbal instruction) in the regular classroom and also received special education services in the areas of reading, writing, and math. Her individual education plan (IEP) targeted word retrieval, syntax (with pronouns specifically), reading, writing, and math.

[1]For the purpose of confidentiality, the participant will be referred to as Renee throughout the remainder of the article.

Social history. Renee's American parents also adopted another girl from the same orphanage in Bulgaria. Although Renee's nonbiological sister is of the same age and descent and came from the same environment at the Bulgarian orphanage, she is not delayed in her English language development.

Renee has difficulty establishing friendships because she is often teased by peers. Her parents reported that her immaturity and receptive and expressive language difficulties have caused social isolation. Renee enjoys playing the piano, running, listening to music, engaging in church activities, and being with the few friends she has. Renee resides with her adoptive parents and her nonbiological sister. Her adoptive family speaks English only.

Procedure

Research design. This study used a single-subject pretest–posttest design. Measures of language ability were taken before the introduction of IM training. Once the pretest measures were taken, the treatment was introduced. Upon completion of the treatment, the same measures that were taken before treatment were administered as a posttest. Comparisons were then made between the pretreatment and posttreatment measures. This design is relatively weak but was used as a starting point of inquiry that hopefully will lead to more well-controlled studies.

Pretest and posttest. In order to determine the possible effects of IM training on Renee's language abilities, the Expressive One-Word Picture Vocabulary Test (EOWPVT; Brownell, 2000) and the Oral and Written Language Scales (OWLS; Carrow-Woolfolk, 2006) were administered both before and after the IM treatment. The EOWPVT and OWLS were chosen as basic measures of Renee's receptive and expressive language abilities, and each instrument was administered twice. The first administration of these instruments provided a baseline of Renee's language skills before commencement of IM training. The second administration occurred after IM training and served as comparison data to the pretreatment measures. This comparison allowed the researchers to determine to some degree the effects of treatment in timing and rhythm on Renee's language skills. Both the pretest and posttest measures were administered in a quiet room that was free of distractions by the first author, who was a speech-language pathology graduate student at the time of the experiment.

Treatment

Renee's speech-language services were temporarily suspended during the experiment in order to prevent confounding of the results by ongoing language intervention. IM treatment was administered by a certified IM trainer. Renee participated in the 15-session plan provided by the IM software. Renee received treatment four times a week for nearly a month until all 15 sessions were completed. Each session took approximately 50 min to complete.

The IM software maps out each session in duration in minutes and total repetitions of body movements per session. Each session is then analyzed further according to the specific exercises and their individual durations, total repetitions, and levels of difficulty. The broad goal of Renee's IM treatment was to improve her receptive and expressive language abilities through exercises in motor and cognitive rhythm and timing. The IM software guides the certified trainer to the appropriate settings for each session (e.g., difficulty level and beat tempo).

Depending on the specific exercise, Renee was asked to engage in various motor activities (e.g., clapping her hands, jumping, etc.) in synchrony with the audible beeps that she was hearing through headphones. The beeps were presented using various rhythmic patterns that Renee had to emulate through her motor responses. As Renee engaged in the training, the IM software kept measurements of her timing accuracy. Although these measurements could be used clinically to gauge Renee's improvement in timing accuracy, the data were not used because the language pretest and posttest data were the measurements of interest. Throughout the IM training program, Renee received positive reinforcement by the certified trainer in the form of verbal praise.

RESULTS

Renee's standard scores on the EOWPVT and OWLS revealed dramatic improvement from pretest to posttest.[2] Before initiation of the IM treatment protocol, Renee received a raw score on the EOWPVT of 106, which converted to a standard score of 93 and a percentile rank of 66 (age equivalent = 11;4 [years;months]). One month later, after completion of the IM treatment, Renee's raw score on the EOWPVT was 138, which converted to a standard score of 124 and a percentile rank of 95 (age equivalent >19). Renee received a pretest raw score of 70 on the OWLS, which converted to a standard score of 86 and a percentile rank of 18 (age equivalent = 9;6). The posttest raw score 1 month later was 81 (standard score = 99; percentile rank = 47; age equivalent = 12;9). Renee's performance on the EOWPVT and the OWLS revealed an increase of 29 percentile points on each test. Renee demonstrated improvement in all language areas assessed.

Upon termination of the month-long experiment, it was noted that Renee had completed more tasks on the posttest than she had on the pretest. Anecdotally, Renee reported that her mind felt "cleaner" and "lighter." Renee's mother also reported a decrease in the amount of time that Renee needed to process language, as well as an increase in her ability to cope with frustrating situations on a day-to-day basis.

[2] Although Renee produced few Bulgarian words upon adoption, her exposure to the Bulgarian language for 4½ years indicates that English is her second language. Consequently, results of these language measures must be interpreted with caution as they were not normed on children of foreign birth who speak English as a second language. Therefore, test results may be an underestimate of Renee's true scores. It is important to focus on the comparison and improvement from pre- to posttest rather than on the scores per se.

DISCUSSION

The present study investigated the effects of IM training on an adolescent female with an LLD. Results revealed dramatic gains in language skills as noted by pre- to posttest comparisons of standard scores on the EOWPVT (Brownell, 2000) and the OWLS (Carrow-Woolfolk, 2006). The positive effect of IM training on language skills appears to lend further credence to its facilitative effect on motor, cognitive, and academic performance (Bartscherer & Dole, 2005; Lazarus, 2006; Libkuman et al., 2002; Shaffer et al., 2001). According to Koomar et al. (2001), drill in rhythm and timing provides for more efficient neuronal organization, which in turn facilitates improvement for underlying central nervous system motor and cognitive processing capacities. Further study into whether IM training actually facilitates neuronal organization and/or reorganization is warranted.

The facilitative effect of IM training on language performance is not surprising in light of the body of research that exists on similar intervention techniques that also exploit timing and/or rhythm. Perhaps the oldest of these techniques is delayed auditory feedback. Its disruptive effect on the timing of normal speech production (Stuart, Kalinowski, Rastatter, & Lynch, 2002; Van Borsel, Sunaert, & Engelen, 2005; Zanini, Clarici, Fabbro, & Bava, 1999) and facilitative effect on disfluent speech (Harrington, 1988; Kalinowski, Armson, Roland-Mieszkowski, Stuart, & Gracco, 1993; Kalinowski & Stuart, 1996; Macleod, Kalinowski, Stuart, & Armson, 1995; Martin & Haroldson, 1979; Novak, 1978; Radford, Tanguma, Gonzalez, Nericcio, & Newman, 2005; Soderberg, 1968; Stager, Denman, & Ludlow, 1997; Stark & Pierce, 1970; Stuart, Kalinowski, & Rastatter, 1997; Timmons, 1983; Van Borsel, Reunes, & Van den Bergh, 2003; Webster, Schumacher, & Lubker, 1970) have been well established. Delayed auditory feedback has also been demonstrated to slow the rate of speech and thereby improve intelligibility for persons who exhibit accelerated speech as a characteristic of some forms of dysarthria (Adams, 1994; Downie, Low, & Lindsay, 1981; Hanson & Metter, 1981, 1983; Yorkston, Beukelman, & Bell, 1988).

An intervention technique that is somewhat similar to IM is melodic intonation therapy (MIT; Helm-Estabrooks & Albert, 2004; Helm-Estabrooks, Nicholas, & Morgan, 1989). MIT uses the rhythmic intoning of propositional utterances for the purpose of improving expressive speech and language. It has been found to have a facilitative effect on the speech skills of persons with aphasia (Albert, Sparks, & Helm, 1973; Belin et al., 1996; Naeser & Helm-Estabrooks, 1985; Popovici, 1995; Popovici & Mihailescu, 1992; Sparks, Helm, & Albert, 1974; Sparks & Holland, 1976) and apraxia of speech (Helfrich-Miller, 1994). IM training may have similar effects on neural organization as MIT.

The music metronome (as an informal tool) has been used effectively in the past as a technique for improving speech abilities in persons with fluency disorders (Hanna & Morris, 1977; Silverman, 1971) and in persons with dysarthria or apraxia of speech (Dworkin, 1991; Dworkin, Abkarian, & Johns, 1988; Pilon, McIntosh, & Thaut, 1998). In these cases, the metronome was typically used to reduce the rate of speech, thereby improving fluency and/or intelligibility. Whether the use of a metronome in these cases facilitated speech production by tapping into underlying neural organization is unclear.

Although it is not fully understood what neural underpinnings are involved in the use of the IM, it does appear at least tentatively that training in rhythm and timing has positive effects on language skills. Results of the present study suggest that it is possible that motor planning and cognitive processing difficulties found in those with deficits in learning disabilities, ADHD, central auditory processing disorders, autism, Down syndrome, cerebral palsy, traumatic brain injury, and apraxia of speech (to name a few) may be ameliorated to some degree by training in timing and rhythm. IM treatment may be an effective complement to existing interventions that are currently being used by therapists to address these disorders.

Limitations and Future Research

As the current study was a preliminary investigation into IM treatment in speech-language pathology, a simple case study format with a pretest, treatment, and posttest was used. This research design is relatively weak and has its limitations. As a single-subject study without controls, both internal and external validity may be compromised. Variables such as maturation and history may have accounted for some of the gains seen between pre- and posttesting. Similarly, with the relatively short duration of the experiment (approximately 1 month), there may have been a practice effect of the pretest on performance on the posttest. Finally, no attempt was made to see if the gains in language performance that were seen between pre- and posttesting carried over for any extended period of time. With these limitations in mind, one should be cautious in interpreting the results. However, due to the dramatic improvement in posttest scores over pretest scores seen in this experiment, one may reasonably assume that IM training had some influence on the outcome. Further study into the effect of IM training on language performance using stronger research designs with controls is warranted. Additional systematic studies are needed to explore the IM's potential usefulness across age groups and types of disorders involving difficulties in timing, rhythm, and motor planning and sequencing. Continued scientific inquiry into the effects of IM training may make it possible to determine its efficacy as an intervention approach.

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