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Interactive Metronome® training for a 9-year-old boy with attention and motor coordination difficulties

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The purpose of this case report is to describe a new intervention, the Interactive Metronome,®[1] for improving timing and coordination. A nine-year-old boy, with difficulties in attention and developmental delay of unspecified origin underwent a seven-week training program with the Interactive Metronome.® Before, during, and after training timing, accuracy was assessed with testing procedures consistent with the Interactive Metronome® training protocol. Before and after training, his gross and fine motor skills were examined with the Bruininiks-Oseretsky Test of Motor Proficiency (BOTMP). The child exhibited marked change in scores on both timing accuracy and several BOTMP subtests. Additionally his mother relayed anecdotal reports of changes in behavior at home. This child's participation in a new intervention for improving timing and coordination was associated with changes in timing accuracy, gross and fine motor abilities, and parent reported behaviors. These findings warrant further study.

Introduction

This case report discusses the use of a new computerized intervention that is aimed at improving attention, timing, sequencing, and coordination. Initial reports indicate that this technology, the Interactive Metronome® (IM)[1], may be a useful tool in increasing attention, promoting academic skills, and decreasing aggression in young boys with attention deficit hyperactivity disorder (Shaffer et al, 2001). The intervention is gaining popularity in the media and parents of children with attention and motor coordination difficulties are seeking out individuals who are trained in the approach. Physical therapists need to be aware of the intervention and the relevant science to support it, in order to provide effective consultation and recommendations to their patients and families.

Improving timing, sequencing, and coordination is often a goal of physical therapy but can be quite difficult to accomplish. Overall, therapists have little at their disposal to draw on for guidance other than "common sense" interventions, which appear to have little more than face validity. The purpose of this case report was to describe the application of the IM Intervention on timing for one child and

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present the ways in which this child changed over the course of seven weeks.

Evaluating this intervention for scientific merit is important for evidence-based physical therapy practice. This report will also discuss what is currently known regarding the scientific validity of this new intervention and use this information to provide possible explanations for the outcomes reported in this case.

Case description

"John" was a nine-year-old, right-handed, African-American male, whose mother was interested in reports in the news media about a training program that claimed to help improve attention and organization. She described her son as having "difficulty concentrating" and not being "very coordinated." She related that it took him "a long time to get anything done," and that his teachers were concerned over his lack of ability to complete tests within the required timeframe. Additionally he "never liked to color, draw, play with playdough, or do cutting," but has "always been good at figuring things out that interested him." She also commented that he made loose knots in his shoes and it was difficult for him to button his pants.

During the year prior, he attended a private school that focused on experiential learning and therefore did not receive any special education or therapeutic services. At his parents' request, he had not been officially evaluated for learning difficulties, attention problems, or other developmental delays to avoid having him "labeled." He also was not taking medications during the time of this intervention. His mother reported a normal birth and a medical history negative for trauma or illnesses.

Examination

The child was a quiet, thin boy who appeared slightly small for his age. He was polite and followed directions well. During the initial session, it was apparent that he had difficulties with speech articulation that made it difficult to understand him the majority of the time. Additionally, he had difficulty coordinating the movements that comprise the initial metronome testing sequence and got easily tangled in the wires for the headphones and hand trigger that are used in both testing and training sessions. During the initial session, the Interactive Metronome® long-form test (IM LFT) and the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks, 1978) were administered.

Interactive metronome® program

The Interactive Metronome® is a PC-based version of a traditional music metronome and was originally developed for improving timing accuracy in musicians. The equipment utilized for this program included a laptop computer with 200 MHz Pentium Processor, Windows 98 and IMPro 5.0 software. Additional hardware included a hand trigger, foot trigger, and two stereo headphones. The hand trigger is a small circular pressure sensitive trigger approximately 1″ in diameter. It connects by Velcro to a cuff strap that attaches around the individual's hand. The foot trigger consists of two $1'' \times 10''$ trigger strips aligned in parallel and placed inside a vinyl pad. Both hand and foot triggers are connected to the computer by cables. The stereo headphones are connected to a splitter and then to the computer, thus allowing both the trainer and participant to hear the metronome beat and feedback sounds.

The IMPro 5.0 software generates a computer-based metronome at a set frequency of 54 beats per minute and, through guide sounds, provides bandwidth feedback to the learner following each practice trial (beat of the metronome). The learner performs 1 of 13 tasks and tries to activate the trigger in time with the reference beat of the metronome. The program calculates timing error (absolute error in milliseconds) for each task performed in the session. Additionally recorded for each task are: number of trials considered very early, early, late, and very late, number of trials completed, percentage of trials in which the timing error is 15 milliseconds (ms) or less, and the greatest number of trials in a row in which the timing error is 15 milliseconds or less.

Feedback on timing error, via "guide sounds," is given during training at a relative frequency of 100%. Feedback is auditory only and heard by the learner as high and low tones through stereo headphones. If the learner activates the trigger prior to the metronome beat, the guide sounds are heard in the left ear.

If trigger activation occurs following the metronome beat the guide sounds are heard in the right ear. If trigger activation is within 15 milliseconds of the metronome beat the guide sounds are heard in both ears.

Interactive metronome® testing

The IM LFT is comprised of 14 tasks. The first 13 tasks (see Table 1) are performed with the metronome reference beat only, and the last task (task number 14) is a repeat of the first task and is performed with the metronome beat and guide sounds. When the guide sounds are turned on, the child will hear a second sound that is separate from the reference beat and occurs at the time the trigger is hit. This timing of this sound indicates how close the child's trigger activation is to the metronome reference beat. The guide sounds appear in the left or right ear (indicating either being before or after the metronome beat) and with lower and higher tones (indicating how far off the beat). As the child tries to hit the trigger in time with the metronome beat, timing is measured as the number of milliseconds before or after the beat. Average milliseconds are

Table 1. Descriptions of the 13 IM tasks.

IM task	Description
Both hands	Both hands are moved in circles such that the trigger is hit in midline followed by the hands moving up, out, and around. Circles are approximately 10″ in diameter.
Right hand	The right hand makes a horizontal circle making contact with the thigh then moving forward, out, and back.
Left hand	The left hand makes a horizontal circle making contact with the thigh then moving forward, out, and back.
Both toes	One foot moves forward to tap the toes on the trigger pad while weight is supported on the other foot. Feet are alternated.
Right toe	Weight is supported on the left foot while the right foot toe taps on the trigger pad. The heel of the tapping foot remains on the floor.
Left toe	Weight is supported on the right foot while the left foot toe taps on the trigger pad. The heel of the tapping foot remains on the floor.
Both heels	The trigger pad is placed behind the individual. The individual alternately taps heels on the trigger pad.
Right heel	Weight is supported on the left foot while the right heel taps on the trigger pad. The toe of the tapping foot remains on the floor.
Left heel	Weight is supported on the right foot while the left heel taps on the trigger pad. The toe of the tapping foot remains on the floor.
Right hand/left toe	This is a combination of right hand alternated with left toe. Thus, the hand movement is slowed to occur over two beats (every other beat) as is the left toe.
Left hand/right toe	This is a combination of left hand alternated with right toe. Thus, the hand movement is slowed to occur over two beats (every other beat), as is the left toe.
Balance right foot/tap left	The individual balances on the right foot while keeping the left foot in the air and tapping the left toe on the trigger pad.
Balance left foot/tap right	The individual balances on the left foot while keeping the right foot in the air and tapping the right toe on the trigger pad.

calculated for each of the tasks. Upper limb average is calculated with those activities involving the arms and lower limb average with those activities involving the legs, including tasks that combine upper and lower limbs. Sufficient test-retest reliability ($r = .85$ to $.97$) for the IM LFT has been reported (Cassily and Jacokes, 2001).

The results of the initial IM LFT revealed that the child had significant timing and movement coordination difficulties. Table 2 describes his timing accuracy for each of the IM LFT items and the calculated upper limb, lower limb, and combined averages. The average time off of the beat at the initial LFT was 159.44 ms. According to the Interactive Metronome Indicator Chart (2003), the average pre-test performance on the long-form test for children between 9 and 10 years of age is in the range of 55–79 ms. Upon closer examination, it was noted that he was less accurate with his feet than with his hands. Additionally, those tasks requiring opposite upper and lower limb coordination were much less accurate than those relying on just one limb or alternating bilateral upper or lower limbs.

Qualitatively, the child exhibited timing deficiency patterns of the disassociative and hyperballistic types. A disassociative pattern is one in which there is no clear association between the child's response of hitting the target and the beat of the metronome. Rather, the responses appear chaotic and random without a discernable pattern. At times the responses are very early, sometimes late, sometimes the individual will respond several times in between beats, other times a beat will be totally missed. In this situation, the individual has difficulty interpreting the metronome beat in order to synchronize his or her movements to it. This difficulty led to the inability to calculate a millisecond average for the first task during his initial long form test (LFT; see Table 2). Additionally, he exhibited movements, which were hyperballistic; rather than being of uniform and smooth speed throughout the movement pattern, his movements were first slow and then very fast, forceful, and ballistic as he moved to hit the trigger. These two patterns are among the six deficiency pattern's that can be identified with the IM testing and training protocol (Burpee et al, 2001; Shaffer

Table 2. Timing accuracy (milliseconds off of the beat) on IM LFT–initial, midterm, and final sessions.

IM task	IM LFT initial (ms)	IM LFT midterm (ms)	IM LFT final (ms)
Both hands	No score obtained*	47.06	23.32
Right hand	53.37	27.38	34.50
Left hand	140.00	33.92	24.86
Both toes	76.11	75.11	26.19
Right toe	337.67	55.47	25.30
Left toe	129.93	51.04	28.07
Both heels	49.48	63.70	26.08
Right heel	69.11	85.10	61.19
Left heel	135.03	75.63	34.97
Right hand/left toe	275.00	78.37	43.88
Left hand/right toe	229.22	24.47	25.93
Balance right foot	193.79	105.35	40.90
Balance left foot	311.56	61.93	21.87
Both hands with guide sounds	110.61	39.13	24.40
Hands average	138.19	36.87	26.77
Feet average	180.69	67.62	33.44
LFT average	159.44	52.25	30.11
Normal for age	55–79		

*Child did not perform enough repetitions in the allotted time to determine a score for this task.

et al, 2001). These represent various timing difficulties that can be exhibited qualitatively and quantitatively with the program, and have been termed dissociative, contraphasic, hyper-ballistic, hyper-anticipatory, hypo-anticipatory, and auditory hypersensitivity.

The child also exhibited motor planning difficulties, which were worse with his legs than his arms. When doing the tasks of alternating toe taps, unilateral toe taps, or alternating heel taps, he had difficulty organizing the movement without hand over foot assistance. His foot would drift out of the target field or he would spontaneously shift to a different task. He was unable to continue the task pattern for more than 3 to 5 repetitions without assistance.

Motor skill testing

The child's motor skills were assessed via administration of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP). The BOTMP is a standardized, norm referenced test used to assess gross and fine motor skills in children between the ages of 4.5 and 14.5 years of age. The purported uses of the test include making decisions about educational placement, assessing gross and fine motor skills, developing and evaluating motor training programs, and assisting researchers and clinicians. Psychometric properties have been reported with established face validity, content validity, internal consistency, test-retest ($r = .88$), and inter-rater reliability ($r = .98$; Bruininks, 1978). The test is divided into gross motor, upper-limb coordination, and fine motor subtests. Gross and fine motor as well as total battery composites are calculated by converting the raw scores to standard scores based on the child's age. Percentile ranks and stanines can then be determined.

The results of the BOTMP revealed that John exhibited significant delays in both gross and fine motor skills, with the greater deficiencies noted in fine motor skills. The Battery Composite revealed that he scored below the 1st percentile rank and in the first stanine when compared to children of similar age (see Table 3).

Evaluation

According to the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition

Table 3. Results of Bruininiks-Oseretsky test of motor proficiency - initial and final sessions.

BOTMP complete battery	Point score		Standard score		Composite score		Percentile rank		Stanine	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Gross motor subtests										
Running speed and agility	8/15	8/15	10	10						
Balance	8/32	17/32	1	3						
Bilateral coordination	10/20	11/20	13	14						
Strength	16/42	17/42	10	11						
Gross motor composite			34	38	31	34	3	6	1	2
Upper limb coordination	15/21	12/21	8	2						
Fine motor subtests										
Response speed	9/17	13/17	15	23						
Visual-motor control	12/24	13/24	2	3						
Upper limb speed and dexterity	26/72	32/72	2	7						
Fine motor composite			19	33	25	39	1	14	1	3
Battery composite			61	73	24	30	<1	2	1	1

(American Psychological Association, 1994), the child exhibited many of the behavioral characteristics consistent with two specific diagnoses; attention deficit hyperactivity disorder—inattentive type and developmental coordination disorder. Though he had not been formally diagnosed with either of these conditions, the result of motor skill testing revealed that his performance was markedly below that of his same aged peers and his parents confirmed that his inattentiveness, poor motor coordination, and impaired motor skills were negatively impacting his participation at school and home.

Diagnosis and prognosis

According to the Guide to Physical Therapist Practice, the child's difficulties are consistent with the preferred practice pattern 5B: Impaired Neuromotor Development (American Physical Therapy Association, 2001). Given that his motor skills were so far below his peers and acknowledging what is known from the literature on children with developmental coordination disorder (Barnhart, Davenport, Ebbs, and Nordquist, 2003), his difficulties are not likely to improve without intervention and can be expected to contribute to problems of low self-esteem and poor social interactions. The child would be a candidate for traditional physical therapy intervention aimed at improving his overall motor coordination and specific skills needed for active participation with his family and peers. The Guide provides an estimate of number of visits between 6 and 90 in order to achieve the expected and desired outcomes of intervention. Based on the examination findings and the information found in the literature (e.g. Pless, Carlsson, Sundelin, and Persson, 2001; Polatajko et al, 1995), it would be reasonable to expect an initial program of intervention to cover at least 10 to 20 sessions.

Intervention

The Interactive Metronome® intervention took place over a 7-week period during the summer when the child was off from school. During this time, he did not receive other therapy services nor did he participate in any school, academic or sports related activities, other than what he did at home with his family.

The Interactive Metronome® intervention consists of approximately 15 to 20 sessions of practice using a variety of upper and lower limb tasks as are found in the IM LFT. Sessions were scheduled for three times weekly, with at least one day of no training in between sessions. During the first half of the program, the primary goals were to learn the tasks and the meaning of the guide sounds that were used to provide feedback on performance. The focus of the last half of the program was on increasing accuracy and consistency. Within the program, the child optimally works up from being able to do 100 to 200 repetitions of a single task without rest to a maximum of 2,000 repetitions of a single task without rest. Repetitions are set at a frequency of 54 beats per minute; therefore a 2,000 repetition task takes approximately 40 minutes to complete.

Each session began with a retention test, the short form test (IM SFT), which consists of 2 trials of 54 repetitions (1 minute) each of the "both hands" task. For the both hands task, John moved both hands in a circular fashion in front of his body and activated the hand trigger when his hands came together. For the first trial in the IM SFT, the child heard only the metronome reference beat. In the second trial, he heard the metronome reference beat and the guide sounds. After the IM SFT, he engaged in several tasks with the total number of repetitions in a single session ranging from 1,500 to 2,500. Each session lasted approximately 1 to 1.5 hours.

In order to help decrease the dissociative timing pattern and improve his ability to perform the tasks required of the IM program, the child participated in four recommended pre-sessions prior to starting the typical 15 session IM protocol. The pre-session training was to aid in understanding the meaning of the metronome beats and guide sounds and developing basic skill at hitting the trigger in time with the metronome beat. The number of pre-sessions was not predetermined, rather pre-sessions were continued until his dissociative pattern had decreased and his understanding of the connection of his movements to hit the trigger and the metronome beat had improved. Tasks practiced during the pre-sessions included providing hand-over-hand

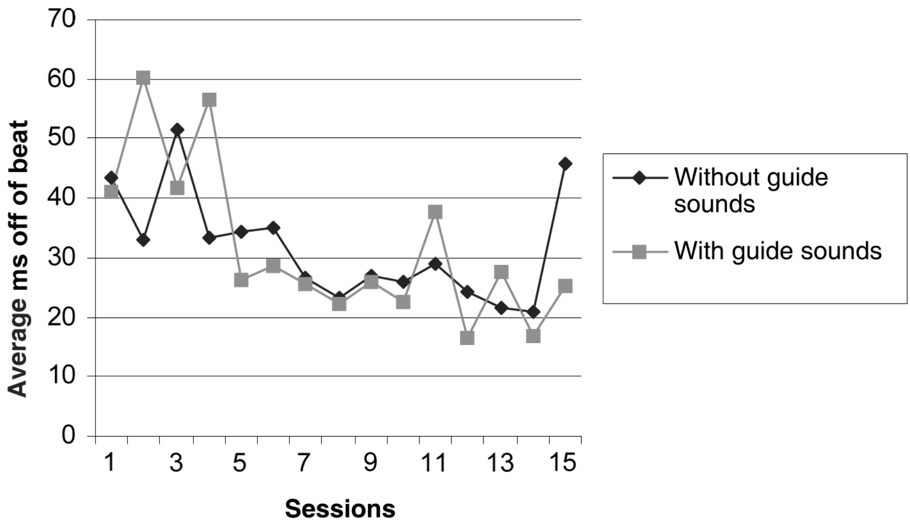

Figure 1. Short Form Test scores over time.

assistance, playing "patty cake," tapping knees then clapping hands, "high fives," and using verbalizations on the beat, in addition to the regular tasks of "both hands" and "both toes." On the fourth pre-session, the child had decreased his short form test score to 43.43 seconds without feedback sounds and 40.98 seconds with feedback sounds and it was determined that he was ready to complete the 15 session program (see Figure 1).

As the child progressed through his sessions, several items were recorded for each task practiced including the number of "right on" repetitions in a row (IAR) and the number of "bursts." Being "right on" the beat is defined as being within 15 milliseconds of the beat, with four "right ons" in a row considered a burst. These are determined by the IM software and tracked on a spreadsheet through each session. He was encouraged to do his best with the present goals relating to the number of IARs and bursts he was working toward. In general, the goals were based on what was achieved in previous sessions and his motivation. Personal best scores for bursts and IARs were recorded (see Table 4).

Example training session

All sessions were conducted in a closed and quiet room. The selection of tasks and repetitions to perform per task in a given session is prescribed in the standard IM protocol. The computer was set up on a table and both John and the therapist wore headphones. The therapist could hear the same sounds and feedback that the child heard while he practiced each task.

Table 4. Personal best records during training.

Session number	Burst record	IAR record	Task	Number of repetitions in task
2	5		Right hand	300
4	13	11	Both hands	1,000
5	19		Both hands	1,200
7	41		Both hands	1,000
9	65		Both hands	2,000
10	72	12	Both hands	1,500

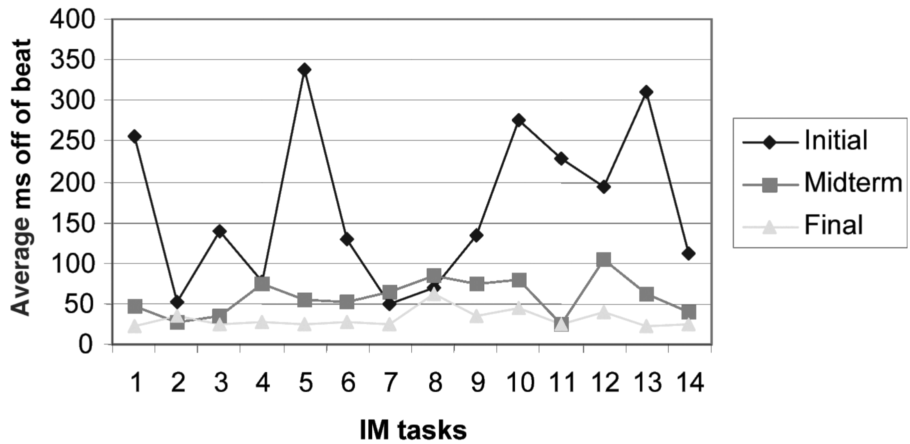

Figure 2. Performance on each task of the Long Form Test—initial, midterm, and final.

He stood for all tasks and was allowed to sit in between tasks to rest. The child had difficulty managing the cables for the hand trigger and headphones coming from the computer. He frequently became entangled such that he had difficulty doing the tasks. To improve this, he faced away from the computer so that all cables went away from his back going to the computer. Because of his difficulty with his foot movement, the floor trigger tended to move. This problem was solved by placing Velcro on the bottom of the trigger, keeping it firmly in place on the carpeted floor.

All training sessions began with the IM SFT. A verbal description and visual demonstration of the task to be performed was given prior to beginning each task. Each session followed the protocol for use with the Interactive Metronome® and contained many of the same tasks that were included in the IM LFT. Initially, physical assistance was given to his feet. This was diminished over time such that by the 6th session he no longer needed physical guidance. For a description of how the program increases the amount of time spent on a single task over the course of several sessions and the number of repetitions per session, see Table 5.

Outcomes

IM goals

Following four pre-sessions and 15 regular sessions of IM, the child had achieved many of the goals related to successfully completing the IM training protocol. He was able to perform a 2000 repetition task that required him to stay focused and moving to the metronome beat for 40 minutes. He achieved a high of 72 bursts and a high of 12 IARs ("right on" hits of the trigger in a row), each within a single 1000 or more repetition task. He was able to pay attention to the task such that he consistently corrected his pattern within one to three beats of the metronome. The child no longer required physical guidance to perform any of the movements. Qualitatively, his movements appeared much more coordinated and he had developed a new smoothness to his movements reflective of his less ballistic tendencies.

Short form tests

The child had consistent decreases in average milliseconds off the beat as seen by his short form test results (see Figure 1). This figure represents his averages during the 15-session protocol. He began at session one with SFT results in the 40-millisecond range and was able to steadily decrease these to the 20-millisecond range over the 15 sessions.

He was able to achieve many personal bests with regard to number of IARs and bursts throughout the training sessions. Table 4 represents each new record. He made quick and consistent gains in the first ten sessions. Though he continued to do well in the last 5 sessions he was

Table 5. Session descriptions to illustrate how time and repetitions on task was increased.

Session number	Number of repetitions	Description of session
Session 2	Approx. 2,400	• IM SFT (108 repetitions) • 500 repetitions of correcting faulty timing (purposefully going before or after the beat) • 300 repetitions each of correcting faulty timing in both toes, right hand, left hand, both toes, right toe, and left toe (total – 1,800)
Session 6	Approx. 2,400	• IM SFT (108 repetitions) • 500 repetitions of staying before or after the beat • 1000 repetitions of the child's choice • 100 repetitions each of balance on one foot, tap with the other (total – 200) • 300 repetitions each of right and left heel (total – 600)
Session 10	Approx. 2,500	• IM SFT (108 repetitions) • 1500 repetitions of non-leg choice • 300 repetitions each of improving the worst task from the midterm long form test, both heels, and both toes (total – 900)
Session 13	Approx. 2,500	• IM SFT (108 repetitions) • 2000 repetitions of the child's choice • 200 repetitions each of the two worst tasks from the midterm long form tests (total – 400)

not able to top the records set on session ten. As can be seen, all of his records were set with upper extremity tasks performed over relatively large numbers of repetitions (1000+ repetitions).

Long form tests

As noted in Table 2, the child made notable gains in his timing accuracy over the course of training. He began IM training with an overall timing accuracy of 159.44 ms off of the beat. By the midterm IM LFT (session 7 in the 15 session protocol) he had decreased this to 52.5 ms and by the final IM LFT had decreased this to 30.11 milliseconds. Based on the Interactive Metronome Indicator Chart (2003), for individuals of his age these scores represent a change from approximating a severe timing deficiency (160–259 ms) to being above average for his age (below 37 ms). The areas of his largest improvements included tasks with his left hand, right toe, combining hand on one side with foot on other, and balancing on one foot while tapping with the opposite toe. As seen in Figure 2, the child showed a trend toward decreased variability across the 14 tasks when comparing the initial, midterm, and final long form tests.

Motor skills testing

With regard to his performance on the BOTMP, the child again made appreciable changes over the course of seven weeks. As can be seen in Table 3, he made gains on standard scores in every subtest except for running speed and agility, and upper limb coordination. Most notably, however, are the improvements in response speed, visual motor control, and upper limb speed and dexterity. Of clinical significance is the change in percentile rank (a measure of how his skills compare to his same age peers) seen in the fine and gross motor composites as well as the battery composite. The child improved in the gross motor composite from performance in the 3rd percentile to the 6th percentile. In the fine motor composite, he improved from the 1st percentile to the 14th percentile. Lastly, he improved in the battery composite from the below the 1st percentile to the 2nd percentile. This is important clinically when considering he did not engage in any specific therapeutic interventions or recreational activities geared at improving the skills tested in the BOTMP.

Also worthy of note is the change seen in point scores on the BOTMP. In their study of the use of the BOTMP, Wilson, Polatajko, Kaplan, and Farris (1995) recommend that if this test is being used to evaluate change over time, an assessment of changes in point scores may be more reflective of change than standard and test composite scores. This provides an evaluation of the child's current performance with previous performance rather than the child's current performance relative to children from the normative sample, which would require that the child show improvements that obtained quicker than what is obtained through time and maturation. A review of the child's performance in point scores on the BOTMP (see Table 3) shows that he made the largest improvements in balance, response speed, visual-motor control, and upper limb speed and dexterity. Smaller changes were noted in bilateral coordination and strength. No change was noted in running speed and agility, and a decline in performance was noted with upper limb coordination.

Parent observations

During the second half of the training sessions, the child's parents reported changes they had noticed in his behavior. His father noted that he was more cooperative with his sister evidenced by decreased resistance to sharing TV time and in choosing sides in the car. His mother described a rule in their house that requires him to read to his younger sister everyday. Usually this turned into an argument or a fight very quickly. During the latter part of the IM training his mother noticed that the fighting had stopped and that he was now reading to his sister for 15 to 20 minutes without difficulty.

She also reported that he appeared more willing to take risks. This was evidenced to her when he asked her if he could try riding his father's bicycle and then asked for a similar "big bike" for his upcoming birthday. This was surprising to her because he had many previous, unsuccessful attempts at trying to learn to ride, and she thought he had given up. She was also surprised because his father's bike had thumb gears, which he was now able to manage.

He had been practicing math problems, as this was an area identified by his teacher as being problematic in school as he was unable to complete a series of math problems in a timely manner. His mother felt that his speed had picked up significantly during the course of IM training. She also noted that his handwriting was age-appropriate after the intervention training. She described that it had been difficult to distinguish lower from upper case letters and that he typically made all of his letters the same size. His mother reported that there was now greater distinction between the lower and uppercase letters.

Discussion

This case report discussed the outcomes related to timing and motor coordination in a 9-year-old boy after participation in a 7-week program of training with a specialized computer program using a metronome beat and guided feedback. Several notable changes occurred that might be attributable to the intervention, including the changes observed on the IM LFT, IM SFT and the BOTMP. Also of interest, however, are the anecdotal changes reported by the child's parents, some of which were related to motor function but most of which were related to affective or organizational behavior.

The literature related to the phenomenon of timing itself, specifically related to finger tapping (Ivry, 1996), and the neuroanatomical correlates related to timing (Rao et al, 1997) may be helpful in explaining the potential effect of the Interactive Metronome® training. Irvy (1996) and others (Ivry and Hazelton, 1995; Ivry and Keele, 1986) have studied the phenomenon of timing for several decades. In a frequently cited study, the results led to the hypothesis that there may be a common and central timing mechanism that governs all movements (Ivry and Hazelton, 1995). This "central clock" may be responsible for the breadth of timing issues ranging from perception of time, such as having a sense for how long a minute is or being able to distinguish between music that has a fast tempo versus a slow tempo, to being able to precisely time one's movements to an external source such as an orchestra conductor or precisely time one's agonists to antagonists in order to reach out for a glass of water. A main tenet of the theory of a central clock is that if one could find a means for training the central clock then the timing and coordination of all movements may improve. There is evidence that children considered to be "clumsy" may have altered time perception (Williams, Woollacott, and Ivry, 1992). While the child was not officially diagnosed as being clumsy or having developmental coordination disorder, he presented with many of the typical motor behaviors of children with this diagnosis. He also exhibited initial scores on the BOTMP that indicated significant delays in gross and fine motor skills.

Similar to the IM training process, experimental studies of timing of movement at the functional level using a metronome have been done to train gait in adults with central nervous system dysfunction such as stroke (Prassas, Thaut, McIntosh, and Rice, 1997) and Parkinson's Disease (McIntosh, Brown, Rice, and Thaut, 1997; McIntosh, Rice, Hurt, and Thaut, 1998). This work has shown a positive training and carryover effect with metronome training. In a training protocol that lasted three weeks, changes in temporal and kinematic components of gait were noted immediately after the training and continued through a one-month follow up (McIntosh, Rice, Hurt, and Thaut, 1998; Thaut, Kenyon, Schauer, and McIntosh, 1999).

This child was able to synchronize his movements to the beat of the metronome during the training protocol. Unlike the studies by Thaut and colleagues (Thaut, Kenyon, Schauer, and McIntosh, 1999; Thaut, McIntosh, Rice, and Prassas, 1993), however, the synchronization was not immediate. In the present case, the child required significant physical assistance and guidance to entrain his movements to the beat. One difference may lie in the presence or absence of a timing deficiency pattern and if one is present, the type of pattern. In this case report, the child exhibited a disassociative pattern that may have represented a lack of an accurate internal time precept.

The studies that used metronome training for gait were done without guide sounds or feedback and the training was task-specific. In this case, the child received guide sounds that provided feedback on accuracy. In addition the movements practiced during training were the same as those on the long and short form tests, but they were not the same as those tested on the BOTMP. It is logical to assume that practicing thousands of repetitions of a task would lead to improved performance on those tasks when a retention test without feedback is given. Evidence in the motor learning literature supports this notion (Schmidt and Lee, 1999; Shumway-Cook and Woollacott, 2001). Findings less explainable are the improvements observed in the BOTMP. The child did not practice the BOTMP test items, was not engaged in therapy interventions for motor skills, and was not involved in additional recreational activities during the weeks of IM training. If it were true that the IM training was associated with the change in BOTMP scores, this may lend support for the central clock theory. The IM training may in some way impact the function of a central time keeper such that when it is called into action for even a small set of movements and functions, overall movement and function are improved.

The child presented here exhibited some behavioral changes that where not strictly related to motor skills. His parents reported changes in his risk taking, ability to get along with his sister, ability to put his own desires aside for the sake of his sister, and his ability to stay focused to read and complete timed math problems. The connection of these behaviors to IM training appears, at the surface to be more remote. An experimental study examining the effects of IM on academic, affective, and motor performance in children with ADHD showed significant changes in the area of affective control. The children who received IM training were also significantly less aggressive (Shaffer et al, 2001) following 15 sessions of IM.

Alternative explanations

This case report was not a controlled study and as such, cannot assert that IM training contributed to the observed changes in this specific child. It is possible that other factors played a role. This child had the opportunity to work on isolated motor skills with feedback for approximately 20, one to one, 30 minute sessions. This could have accounted for some improvement in movement performance. Additionally, he received one to one instruction and attention by an adult. This may have been highly motivating to this child and contributed to the observed changes.

The child's parents were highly vested in seeing positive change in their son. Though the training was provided free of charge, they were making significant efforts to bring their son to the training and had sought out the training specifically for the types of changes noted. Their vested interest in observing change may have contributed not only to their positive interpretation of his actions but their interest may also have impacted John's behaviors.

Lastly, IM training itself is complex and multifaceted. The training program includes approximately 35,000 repetitions. Instantaneous feedback is provided on 100% of the practice trials, and there are 13 specific tasks practiced. One could hypothesize that any one of these variables may have led to the behavioral outcomes; for example, the shear number of repetitions of a task could lead to a practice effect. Further investigation is needed to understand how each of the IM components may contribute, individually and collectively, to improved timing, coordination and attention.

Conclusion

This case report provides clinical evidence that this intervention can be applied safely, and was well tolerated by the child. It also appeared to be associated with positive changes in behaviors as reported by parents and as evidenced in clinical measures. The results of this case report also raise intriguing questions that warrant future research that is well designed and controlled. Such research would help to clarify the relationship between IM training and behavioral changes including those that are motoric, affective, and organizational. If a relationship can be established, the next step may be to identify whether there are key components at play or whether the combination of IM factors is the critical aspect. In addition to forging an improved understanding of the effects of IM in children such as the child presented in this case, it will also be important to determine if a training effect occurs in other populations.

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