Interactive Metronome training in children with attention deficit and developmental coordination disorders

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The objective of this study was to examine the efficacy of Interactive Metronome (Interactive Metronome, Sunrise, Florida, USA) training in a group of children with mixed attentional and motor coordination disorders to further explore which subcomponents of attentional control and motor functioning the training influences. Twelve children who had been diagnosed with attention deficit hyperactivity disorder, in conjunction with either developmental coordination disorder ($n=10$) or pervasive developmental disorder ($n=2$), underwent 15 1-h sessions of Interactive Metronome training over a 15-week period. Each child was assessed before and after the treatment using measures of attention, coordination, and motor control to determine the efficacy of training on these cognitive and behavioral realms. As a group, the children made significant improvements in complex visual choice reaction time and visuomotor control after the training. There were, however, no significant changes in sustained attention or inhibitory control over inappropriate motor responses after treatment. These results suggest Interactive Metronome training may address deficits in visuomotor control and speed, but appears to have little effect on sustained attention or motor inhibition.

Die vorliegende Studie soll die Wirksamkeit des interaktiven Metronomtrainings in einer Gruppe mit Kindern mit unterschiedlichen Aufmerksamkeitsstörungen und motorischen Koordinationsstörungen untersuchen, um weiter zu erforschen, welche Teilkomponenten der Aufmerksamkeitskontrolle und der motorischen Funktionsfähigkeit das Training beeinflusst. Zwölf Kinder, deren Diagnose hyperkinetisches Syndrom in Verbindung mit einer anderen entwicklungsbedingten Koordinationsstörung ($n=10$) oder tiefgreifenden Entwicklungsstörung ($n=2$) lautete, unterzogen sich über einen 15-wöchigen Zeitraum hinweg 15 Sitzungen mit interaktivem Metronomtraining von jeweils einer Stunde. Jedes Kind wurde vor und nach der Behandlung anhand von Aufmerksamkeit, Koordination und der motorischen Kontrolle bewertet, um die Wirksamkeit des Trainings auf diese kognitiven und verhaltensbedingten Bereiche zu ermitteln. Als Gruppe machten die Kinder signifikante Fortschritte bei der komplexen visuellen Reaktionszeit und der visomotorischen Kontrolle nach dem Training. Es gab jedoch keine signifikanten Veränderungen bei der anhaltenden Aufmerksamkeit oder der inhibitorischen Kontrolle über unangemessene motorische Reaktionen nach der Behandlung. Diese Ergebnisse legen nahe, dass das interaktive Metronomtraining sich zwar der Defizite in der visomotorischen Kontrolle und der Geschwindigkeit annimmt, ansonsten aber kaum eine Wirkung auf die anhaltende Aufmerksamkeit oder die motorische Inhibition zu haben scheint.

Cette étude avait pour objet d'examiner l'efficacité de la thérapie par métronome interactif dans un groupe d'enfants souffrant de divers troubles de l'attention et désordres de coordination moteurs en vue d'explorer de manière plus approfondie les sous-éléments de contrôle de l'attention et du fonctionnement moteur qui sont influencés par la thérapie. Douze enfants ayant reçu un diagnostic d'hyperactivité avec déficit d'attention, associé soit à des troubles de coordination développementaux ($n=10$) soit des troubles développementaux envahissants ($n=2$), ont suivi 15 séances d'1h de thérapie par métronome interactif sur 15 semaines. Chaque enfant a été évalué avant et après le traitement par des mesures de l'attention, de la coordination et du contrôle moteur afin de déterminer l'efficacité de la thérapie sur ces domaines cognitifs et comportementaux. Dans le contexte du groupe, les enfants ont témoigné d'améliorations significatives en termes de temps de réaction face à des choix visuels complexes et de contrôle visuo-moteur après la thérapie. Toutefois, aucun changement important n'a été constaté dans l'attention soutenue ni le contrôle inhibiteur des réponses motrices inappropriées après le traitement. Ces résultats suggèrent que la thérapie par métronome interactif peut permettre de traiter les déficits de contrôle visuo-moteur et de vitesse, mais semble avoir peu d'effet sur l'attention soutenue ou l'inhibition motrice.

El objetivo de este estudio fue evaluar la eficacia del entrenamiento Metrónomo Interactivo en un grupo de niños con una combinación de trastornos motores y trastornos de la atención, a fin de investigar con mayor detalles cuáles son los subcomponentes del control de la atención y del funcionamiento motor que este entrenamiento modifica. Doce niños con diagnóstico de trastorno de hiperactividad con déficit de atención, acompañado de trastorno del desarrollo de la coordinación ($n=10$) o de trastornos generalizados del desarrollo ($n=2$), recibieron sesiones de entrenamiento Metrónomo Interactivo, de 1 hora de duración durante 15 semanas. Se valoró a cada niño antes y después del tratamiento, utilizando para ello medidas de la atención, la coordinación y el control motor, con el fin de determinar

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la eficacia del entrenamiento en estas esferas cognitivas y conductuales. Como grupo, los niños presentaron mejoras importantes en el tiempo de reacción en la selección visual compleja y en el control visual motor después del entrenamiento. Sin embargo, no se hallaron cambios importantes, después del tratamiento, en la atención mantenida ni en el control inhibitorio de respuestas motoras inadecuadas. Estos resultados indican que el entrenamiento Metrónomo Interactivo pudiera mejorar las dificultades del control visual motor y la velocidad, pero parece tener escaso efecto sobre la atención mantenida o la inhibición motora. ***International Journal of Rehabilitation Research*** **32:331–336 © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Movement and motor planning are complex processes of the brain. In children with neurodevelopmental disorders, the timing between planning and acting may be disrupted or disorganized across neural centers. A study of Rao *et al.* (2001) suggested that the basal ganglia and right parietal cortex are activated during tests involved in the timing of motor actions. Reduced neural activity in these cerebral regions resulted in dysfunction in the timing of motor actions as well as in the timing of attentional focus. The association between motor action and attentional functions suggests that techniques focused on strengthening motor planning, sequencing, timing, and rhythmicity could play a critical role in increasing children's capacity to attend and learn (Shaffer *et al.*, 2001).

Kendall *et al.* (2003) conducted a study describing children's accounts of their attention deficit hyperactivity disorder (ADHD). The children had complaints that 'it's harder for me to think … I always feel distracted', or 'I get bored very easily and I have a hard time sitting …', voicing their problems with attention and inhibitory motor control. With the knowledge that these higher cognitive processes may be impaired in disorders of attention and motor control, a technique targeted toward correcting them could result in improved performance in these routine tasks.

The Interactive Metronome (Interactive Metronome, Sunrise, Florida, USA) was initially developed as a therapeutic tool in the early 1990s to improve fine motor and visuomotor coordination in children with developmental conditions. Since that time, it has gained wide and uncritical acceptance within the allied health professions as a seemingly useful tool to improve attention, academic skills, language, behavioral difficulties, and motor functions in patients of all ages who suffer from many different disorders including ADHD, autism, nonverbal learning disorders, balance disorders, amputees, traumatic brain injury, stroke, multiple sclerosis, and Parkinson's disease. The Interactive Metronome is a PC-based, noninvasive technique that requires participants to practice timing and rhythmicity of varied movements of the hands and feet in synchrony with auditory cues. It includes headphones to hear the beats and also motion-sensory trigger buttons. These are attached either to the hand or foot, appropriate to whichever exercise is being performed. Changes in sound the user hears inform him of variance from the to-be-followed beat, whether his reaction is too fast or too slow. This allows the user to correct rhythmicity and timing errors immediately, so that he can break from an incorrect motor pattern and restart with correct timing. The objective is for the user to synchronize his or her extremities with the timing of the metronome. Application of the Interactive Metronome is based on the original music metronome and is intended to improve timing, sequencing, and inhibition of motor responses and to improve the ability for sustained attention (Shaffer *et al.*, 2001).

Despite early anecdotal reports of positive therapeutic effects of the technique, there continue to be only a handful of studies examining Interactive Metronome efficacy. This sparse literature includes individual case studies (Koomar *et al.*, 2001; Bartscherer and Dole, 2005; Sabado and Fuller, 2008), unpublished studies (Diamond SJ, 2003, unpublished observation; Gorman, 2003, unpublished observation), and unpublished meeting abstracts (Stemmer, 1997; Jones, 2004). There are only two peer-reviewed studies comparing pretreatment and posttreatment effects that include a control group, and one of these found that the Interactive Metronome improved golf swings in healthy normal individuals (Libkuman and Otanie, 2002). Shaffer *et al.* (2001) investigated the efficacy of Interactive Metronome training in 19 boys (between the ages of 6 and 12 years) with ADHD and compared them with equivalent participants in either a no-treatment or a video game control group across a variety of tests measuring sustained attention,

intelligence, academic achievement, motor efficiency, and two rating scales for behavior disorders. The authors concluded that there were significant improvements in attention, motor control, language processing, and reading and a reduction in aggressive behavior in the Interactive Metronome training group relative to controls.

It has been suggested that some of the main difficulties (i.e. staying seated, maintaining postural control, staying attentive, and impulsivity) for children with neurodevelopmental disorders, such as incoordination disorders, pervasive developmental disorders (PDDs), developmental learning disabilities, and ADHD, are primarily the result of a dysfunction in motor planning, coordination of timing, sequencing, sensory integration, and attentional abilities (Koomar *et al.*, 2001). Training with the Interactive Metronome was specifically designed to address such problems by enhancing an individual's timing, sequencing, and inhibition of motor responses, whereas simultaneously improving sustained attention. The purpose of this study was to test the Interactive Metronome as an effective therapy method that would enable children to overcome the deficits in attentional focus and motor control caused by several common neurodevelopmental disorders.

The specific hypotheses for this study were as follows: children with neurodevelopmental disorders who complete treatment with the Interactive Metronome will display pretreatment to posttreatment improvement in motor coordination (as assessed by the Bruininks–Oseretsky Test of Motor Proficiency-Short Form) and sustained attention [as assessed by the Gordon Diagnostic System's (GDS) continuous performance test].

Methods

Participants

The sample consisted of 12 children, age ranging from 6 years 5 months to 13 years 5 months, who had a variety of neurodevelopmental disorders. All children had been diagnosed with an ADHD ($n=12$); two of these children were also diagnosed with PDD (ADHD + PDD, $n=2$), and 10 carried comorbid diagnoses of developmental coordination disorder (DCD) (ADHD + DCD, $n=10$). Diagnoses were made by referring physicians, including pediatricians, child psychiatrists, pediatric neurologists, and family practitioners, using the appropriate criteria from the *Diagnostic and Statistical Manual of Mental Disorders,* IV edition (American Psychiatric Association, 1994).

There were 10 boys and two girls in the sample, which is as expected because the neurodevelopmental conditions included in the study are more prevalent among boys than girls. Racial/ethnic composition included 10 Caucasians, one African–American, and one Latino. Of the 12 children included in this study, six of them were not prescribed medication. Of the six children taking medication, two were on Strattera, three on Adderall, one on Provigil, one on Zoloft, and one participant was taking an asthma medicine. No medication changes occurred over the course of the study.

Children who were referred to the Medical College of Georgia's Rehabilitation Center for outpatient treatment of a neurodevelopmental disorder that involved motor regulation or attentional deficits were invited to participate in the study. Permission to conduct the study was granted by the institution's Human Assurance Committee, and written informed consent was obtained from both the child and the parent/guardian.

Materials/instrumentation

The Interactive Metronome is a noninvasive, PC-based technique developed in 1992, that requires children to practice the timing and rhythmicity of various movement combinations of the hands and feet in response to auditory cues (Shaffer *et al.*, 2001). It was the instrumentation used for the treatment in this research study.

The Bruininks–Oseretsky Test of Motor Proficiency-Short Form provides an index of motor proficiency and was used to measure motor control and coordination for both the pretesting and posttesting (Bruininks, 1978). Specific aspects of motor function measured on the Bruininks Short Form included running speed and agility, balance, bilateral coordination, strength, upper limb coordination, response speed, and visuomotor control. The average reliability for the Bruininks–Oseretsky Test of Motor Proficiency-Short Form is 0.85 for grades 2–6. The Short Form average validity is 0.78.

Both pretreatment and posttreatment attention was assessed with the GDS (Model III-R; Gordon, 1979). The test used on this system was the "Vigilance Task '1/9' mode", which takes 9 min to complete and requires participants to press a button every time they see a number '9' on the screen directly after a '1'. The target number is 45 correct answers. The Vigilance Task assesses how well a child maintains self-control in situations requiring sustained attention. Standardization was based on the performance of over 1250 nonhyperactive, normal children. Reliability was measured with test–retest correlations on the Vigilance Task. This included at 2–22 days, with 0.72 total correct and 0.84 total commissions, and then at 1 year with 0.68 total correct and 0.94 total commissions. The validity was tested against criteria. There was high agreement between the Total Commission Score and ADHD classification criteria using rating scales by parents and teachers (63%).

Research design

To test the research hypotheses that Interactive Metronome training will improve both attention and coordination

in individuals with neurodevelopmental disorders, the research was conducted using a pretest–posttest design. The independent variable in this design was the Interactive Metronome treatment received, whereas the dependent variables were attention and coordination. The goal of the research was to see a positive impact on the dependent variable, in that the participants' attention and coordination would improve.

Procedure

After acceptance into the study, all participants were initially evaluated before treatment. The children then underwent Interactive Metronome training. Treatment consisted of 15 1-h sessions using the Interactive Metronome over a 15-week period. The treatment was provided by Elizabeth Bishop, occupational therapist, registered/licensed, a registered Interactive Metronome trainer.

Individual treatment sessions included the use of headphones to hear the beats and also motion-sensory trigger buttons, which attach either to the hand or foot for use in performing various repetitive patterned activities, which are standardized parameters described in the Interactive Metronome manual. The protocols within this manual were used to guide the participants for the treatment. After the completion of the Interactive Metronome training, posttreatment data were collected once again using the Bruininks–Oseretsky Test of Motor Proficiency-Short Form to assess motor coordination and the GDS Continuous Performance Test to assess the sustained attention.

Data analysis

Pairwise *t*-tests were used to compare baseline scores of attention and motor coordination with their post-Interactive Metronome training scores on the same measures within participants. Three scores from the GDS Continuous Performance Test were analyzed and compared with both pretreatment and posttreatment. The three component mean scores used included vigilance (total number of targets correctly identified), errors of commission (total number button presses to nontargets), and reaction time (time to respond to targets). Similar analyses were conducted on each of the Bruininks–Oseretsky Test of Motor Proficiency subtests, as well as the Battery Composite, using mean raw scores.

Results

With regard to performance on the GDS, children with mixed attentional and motor coordination neurodevelopmental disorders made significant improvements in complex visual choice reaction time on the Continuous Performance Test ($t = 2.37$, d.f. = 11, $P < 0.05$). There were, however, no significant improvements on measures of the sustained attention (vigilance) ($t = -1.39$, d.f. = 11, $P > 0.05$) or inhibitory control over inappropriate motor responses ($t = -0.44$, d.f. = 11, $P > 0.05$) after 15 weeks of the Interactive Metronome treatment. The pretraining and posttraining scores for each of three GDS variables are presented in Table 1.

Some support for the hypothesis that Interactive Metronome training would result in increased motor control for participants was obtained. Paired *t*-test analyses showed that participants made significant improvements in visuomotor control after the training ($t = -2.167$, d.f. = 11, $P = 0.02$) on the Bruininks–Oseretsky Test of Motor Proficiency. The only other score on the Bruininks that reached statistical significance was the Battery Composite score ($P = 0.049$). This was most likely because of trends toward improvements in balance ($P = 0.06$), upper limb coordination ($P = 0.06$), and upper limb speed ($P = 0.07$). Pretraining and posttraining means, standard deviations, and *t*-test results on the Bruininks–Oseretsky Test of Motor Proficiency are provided in Table 2.

As there were several statistical trends toward improvement on the Bruininks Motor Proficiency Test, and as group means may obscure the effects of Interactive Metronome training in individual cases, results were also examined by looking at pretraining to posttraining changes in individual patients. Individual participants were classified as to whether they improved or did not improve (either scored worse or stayed the same) after Interactive Metronome training. These results are presented in Table 3.

As may be seen in Table 3, most participants' (nine of 12) reaction times improved on the GDS's continuous performance task, whereas roughly equal numbers either

Table 1 Pre-IM and post-IM training scores (means and SDs) for each of three Gordon diagnostic system variables

GDS variable	Pretraining	Posttraining	*P*
Vigilance (number of hits)	36.46 (2.19)	38.91 (4.53)	0.19
Errors of commission	9.10 (5.24)	12.50 (8.35)	0.67
Reaction time (ms)	450.0 (73.5)	397.27 (85.6)	0.04

GDS, Gordon diagnostic system; IM, Interactive Metronome.

Table 2 Pre-IM and post-IM training scores (means and SDs) for each subtest on the Bruininks–Oseretsky test of motor proficiency

Subtest	Pretraining	Posttraining	*t* value	*P*
Running speed	6.83 (3.13)	7.92 (1.68)	−1.06	0.15
Balance	4.75 (3.41)	6.67 (2.35)	−1.60	0.06
Bilateral coordination	6.67 (2.35)	2.17 (1.34)	−1.18	0.13
Strength	5.92 (2.31)	7.08 (1.98)	−1.32	0.10
Upper limb coordination	3.67 (1.37)	4.42 (0.79)	−1.64	0.06
Response speed	4.50 (2.91)	5.67 (3.20)	−0.94	0.18
Visual motor	5.58 (1.16)	6.67 (1.30)	−2.17	0.02
Upper limb speed	7.92 (2.75)	9.67 (2.90)	−1.52	0.07
Battery composite	42.00 (13.86)	50.58 (10.03)	−1.74	0.049

IM, Interactive Metronome.

Table 3 Number (and percentage) of cases ($n=12$) who showed improvement or no improvement on the GDS continuous performance task and Bruininks–Oseretsky Test of Motor Proficiency

Test/subtest	Improvement (%)	No improvement (%)
GDS		
Vigilance	5 (42)	7 (58)
Errors of commission	6 (50)	6 (50)
Reaction time	9 (75)	3 (25)
Bruininks–Oseretsky test		
Running speed	6 (50)	6 (50)
Balance	9 (75)	3 (25)
Bilateral coordination	7 (58)	5 (42)
Strength	8 (67)	4 (33)
Upper limb coordination	7 (58)	5 (42)
Response speed	10 (83)	2 (17)
Visual motor	9 (75)	3 (25)
Upper limb speed	10 (83)	2 (17)
Totals	66 (69)	30 (31)

GDS, Gordon diagnostic system.

improved or did not improve on the other two GDS measures (i.e. vigilance and errors of commission). Nonetheless, there were no statistically significant differences between the improved versus not improved groups on the GDS measures ($\chi^2 = 2.92$, d.f. = 2, $P = 0.23$).

Similar results were obtained on the Bruininks' motor measures. Consistent with the parametric statistical analyses, a majority of participants showed improvements in balance (nine of 12), response speed (10 of 12), visuomotor coordination (nine of 12), and upper limb speed and dexterity (10 of 12). Nevertheless, there also were no statistically significant differences between the improved versus not improved groups across the Bruininks' measures ($\chi^2 = 6.01$, d.f. = 7, $P = 0.54$).

Discussion

Results of this study suggest the Interactive Metronome seems to be a reasonably effective treatment technique to increase some aspects of motor control and reaction time in children with mixed attentional and motor coordination neurodevelopmental disorders. In contrast, the Interactive Metronome was neither shown to be effective for improving sustained, focused attention nor for reducing inhibition of inappropriate motor responses (impulsivity) in these children who had significant attentional deficits. These negative results are in conflict with the Interactive Metronome's claims that Interactive Metronome training will help children to focus and attend for longer periods, monitor actions as they are occurring, and filter out internal and external stimuli (Interactive Metronome, 2008).

These results are consistent with the few earlier studies showing the Interactive Metronome can improve certain aspects of motor control, but inconsistent with the only investigation that reported Interactive Metronome training improved attention (Shaffer *et al.*, 2001). In this sole study, which found attentional improvements, there were no significant pretraining to posttraining improvements in any aspect of a continuous performance task in the Interactive Metronome treatment group. The positive results found in this study were due to an interaction effect; where the control groups declined on posttesting and the treatment group improved somewhat (although not to a statistically significant degree) on posttesting. Although the magnitude of these score changes is unknown, as no raw data were reported in the study, it is clear in light of the interaction effect that a conclusion that Interactive Metronome training improved attention on the continuous performance task cannot be made.

This study was a within-subjects design, where each individual patient acted as his or her own control, and thus, if a no-treatment control group would have been included, perhaps our results would have been different. The other major limitations of this study are the small number of participants and the comorbid diagnoses, which complicated the interpretation. Thus, these results must be considered preliminary, and future research needs to be conducted using a sample of ADHD children with demographically matched controls to further explore the relationship between Interactive Metronome training and various aspects of attention.

Summarizing, the Interactive Metronome's potential to increase motor control and reaction speed seems to be evident, whereas its usefulness for increasing other skills (e.g. sustained attention and increased inhibitory control over inappropriate motor responses) has not been demonstrated. The apparent uncritical acceptance of the Interactive Metronome within the allied health professions to treat symptoms of ADHD seems to be unjustifiable at this time. There is very little peer-reviewed, empirical research to back up many of the claims of Interactive Metronome training, and clearly, a great deal of future research is necessary to examine the nature and potential range of applications of this treatment device. As the prevalence of neurodevelopmental disorders continues to rise, it is imperative that adjunctive therapies beyond medication be proposed, investigated, and validated to address the needs of these children.

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