

Effect of Interactive Metronome® Training on Children With ADHD

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Key Words: attention deficit disorder with hyperactivity • coordination training • motor control

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This article was accepted for publication March 16, 2000.

Objective. *The purpose of this study was to determine the effects of a specific intervention, the Interactive Metronome®, on selected aspects of motor and cognitive skills in a group of children with attention deficit hyperactivity disorder (ADHD).*

Method. *The study included 56 boys who were 6 years to 12 years of age and diagnosed before they entered the study as having ADHD. The participants were pretested and randomly assigned to one of three matched groups. A group of 19 participants receiving 15 hr of Interactive Metronome training exercises were compared with a group receiving no intervention and a group receiving training on selected computer video games.*

Results. *A significant pattern of improvement across 53 of 58 variables favoring the Interactive Metronome treatment was found. Additionally, several significant differences were found among the treatment groups and between pretreatment and posttreatment factors on performance in areas of attention, motor control, language processing, reading, and parental reports of improvements in regulation of aggressive behavior.*

Conclusion. *The Interactive Metronome training appears to facilitate a number of capacities, including attention, motor control, and selected academic skills, in boys with ADHD.*

Shaffer, R. J., Jacokes, L. E., Cassily, J. F., Greenspan, S. I., Tuchman, R. F., & Stemmer, P. J., Jr. (2001). Effect of Interactive Metronome® training on children with ADHD. *American Journal of Occupational Therapy, 55*, 155-162.

The ability to attend, which begins early in life, is a vital part of the capacity to learn, concentrate, think, interact with others, and master basic academic skills (Greenspan, 1997; Greenspan & Lourie, 1981; Mundy & Crowson, 1997). Relative deficits in sustaining attention, inhibiting competing impulses, and engaging in joint attention can be found in attentional, learning, and developmental disorders. These deficits are part of several clinical disorders, including attention deficit disorder (ADD), pervasive developmental disorder (autistic spectrum disorders), language disorders, motor disorders, and specific learning disorders involving reading, math, and writing (Barkley, 1997a; Mundy, 1995).

Increasing evidence suggests that broad constructs such as motor planning and sequencing, rhythmicity, and timing are relevant to attentional problems. Barkley (1997b) postulated that deficits in inhibition and executive functions, which involve the regulation and sequencing of motor patterns and behavior, are important in understanding attention deficit hyperactivity disorder (ADHD). Additionally, several investigators have postulated important relationships between attention and aspects of motor

when one hand was tapped on the thigh. The other trigger, a flat plastic pad placed on the floor, sensed when a toe or heel was tapped on it.

When the participant tapped a limb in time with the steady metronome reference beat sound heard in the headphones, the trigger sent a signal via a cable to the program. The Interactive Metronome analyzed exactly when in time the tap occurred in relation to the reference beat and instantaneously transposed the timing information into guidance sounds that the participant heard in the headphones as each tap occurred. The pitch and left-to-right headphone location of the guidance sounds precisely changed according to each tap's accuracy. The program-generated rhythmicity accuracy scores (Interactive Metronome scores), displayed in milliseconds on the screen, indicated to administrators how close in time the participant's responses were to the reference beat as they occurred. After each exercise, the participants were shown their scores. This feedback appeared to motivate them to do better.

The object of the Interactive Metronome treatment was to help participants improve their ability to selectively attend, without interruption by internal thoughts or external distractions, for extended periods. Simple limb motion exercises were used as systematic external catalysts to an underlying mental focus-improvement process. Each participant underwent 15, 1-hr Interactive Metronome treatment sessions, one session per day, spread out over a 3-week to 5-week period. Each session included 4 to 8 exercises that were repeated a specific number of times as prescribed in the daily treatment regimen guide. Exercises were done at a preset tempo of 54 repetitions/min, and the number of repetitions per exercise increased from 200 during the first session to a maximum of 2,000 during the ninth session.

The 13 Interactive Metronome treatment exercises were designed to help the participants put their efforts toward improving mental concentration rather than toward developing new physical motion techniques. The exercises included clapping both hands together, tapping one hand alone against the upper thigh, alternating toe taps on the floor, alternating heel taps on the floor, tapping one toe or heel alone on the floor, alternating between tapping one hand on the thigh and the toe on the floor, and balancing on one foot while tapping the other toe.

Before beginning their first Interactive Metronome treatment session, participants were given an automated Interactive Metronome pretest to quantify their ability to recognize timing patterns, selectively attend to a task, and make simple motion corrections. The pretest also indicated whether each participant had one or more rhythmicity deficiency patterns that needed to be addressed during their initial stage of treatment. Interactive Metronome treatment regimens were designed and accomplished in stages according to instructions in the daily treatment regimen guide.

During the first stage, the administrators helped the participants break the existing rhythmicity deficiency pat-

terns that were identified during the pretest. The six rhythmicity deficiency patterns most frequently identified were the following

1. *Disassociative*: Three participants' responses were chaotic and random and not related to the beat in any way.
2. *Contraphasic*: Within a few beats, six participants' responses consistently moved to in between the beat rather than on the beat.
3. *Hyperballistic*: Sixteen participants used inappropriate snappy ballistic-type motions.
4. *Hyperanticipatory*: Eighteen participants' responses continually occurred much before the reference beat.
5. *Hypoanticipatory*: One participant's responses continually occurred much after the reference beat.
6. *Auditory hypersensitivity*: Seven participants were exceptionally distracted by the computer-generated guide sounds that were added to the headphone mix during the last test task, as indicated by their Interactive Metronome scores on that task, which were two to three times less accurate than those of the previous 13 tasks done without the guide sounds.

The initial Interactive Metronome treatment sessions were devoted to helping the participants learn how to discriminate between the sounds triggered by their own actions and the steady metronome beat. They were instructed to make smooth, controlled hand and foot motions that continuously cycled through a repeating pattern without stopping at any time between beats. Participants were repeatedly instructed to focus on the metronome beat and to try not to be interrupted by their own thoughts or things happening around them. When the participants had broken their existing rhythmicity patterns and were able to achieve the Interactive Metronome score average prescribed in the daily treatment regimen guide, they were considered to have achieved the adequate control and accuracy necessary to begin a second distinct phase of the Interactive Metronome treatment.

During the second treatment phase, participants were instructed to focus their attention only on the steady reference beat and ignore the computer-generated guide sounds, internal thoughts, and unrelated stimuli around them. They were also instructed to keep repeating their motion patterns without making any deliberate adjustments whatsoever. Doing so usually resulted in obvious improvements in the participant's Interactive Metronome score, and the entrainment experience of staying on beat without trying seemed to have a positive motivating effect. From session to session, participants increased the length of time they could selectively focus on the metronome beat without interruption, and their Interactive Metronome

scores improved correspondingly. Most participants appeared to be highly motivated to achieve the best score possible during their Interactive Metronome training regimen. According to the Interactive Metronome scores, each participant improved his rhythmicity and was able to stay on task without being interrupted for significantly longer periods by the end of the training.

Video game group. Five commonly available PC-based, nonviolent video games were used as a treatment placebo for the video game group. Each game involved eye-hand coordination, advanced mental planning, and multiple task sequencing. In each game, the participant played against the computer, and at each new level achieved, the game became increasingly more difficult to play.

The test administrators followed a daily treatment regimen guide in the same manner as they did for the Interactive Metronome group. The prescribed video game exercises provided the participants with the same type of supervision, attention, and support as was received by the Interactive Metronome group. Each participant underwent 15, 1-hr video game training sessions, one session per day, spread out over a 3-week to 5-week period. Each training session involved a number of video game exercises, and the length of time they spent on each video game exercise typically increased from the first session to the last session.

Results

Sampling Design

After completion of pretesting of all 56 participants, a matched random assignment process was used to form the three treatment groups (i.e., Interactive Metronome, video game, control). Three factors were used in the matching process: medication dosage (mg/body weight), age, and severity of ADHD as measured by the TOVA. An analysis of variance (ANOVA) of these matching variables revealed no significant differences at the $p \leq .05$ level among the treatment groups. Chi-square analysis of three demographic variables—race, parental education, and parental household income—revealed no significant differences at the $p \leq .05$ level, suggesting that the treatment groups were equal for these socioeconomic factors.

An ANOVA of the 58 pretest factors revealed only one significant difference among the treatment groups. Sakoda, Cohen, and Beall's (1974) table for tests of significant difference revealed the probability of this one significant difference in 58 significance tests occurring by chance to be $p > .50$, establishing this single occurrence to be likely a chance difference. The other 57 factors produced values in excess of $p > .05$, establishing the treatment groups' statistical equality.

Pattern Analysis

Pattern analysis of the 58 pretest factors examined the overall direction of mean differences between pretest and

posttest phases for each group. In performing the analysis, the means for each test were computed, and the mean differences between the tests were determined. Each mean difference was dichotomized by whether the change represented an improvement or a decline in the desired direction for that test. For example, the posttest–pretest mean differences for the Wechsler Digit Span subtest for each treatment group were the following: Interactive Metronome = .473, control = $-.278$, and video game = $-.054$. The mean differences revealed improved performance in the Interactive Metronome group, whereas the control and video game groups showed decreased performance. Similar analyses were completed for all 58 test scores.

To statistically test the pattern, a binomial test was used to determine whether the proportion of dichotomous pairs (improvement vs. decline) was likely a chance occurrence (where the probability of either an improvement or decline = .50) or whether the directional proportion was so unusual as to reflect a non-chance event. The rationale for using a binomial test rests on the assumption that if a large number of variables collectively showed an unusual directional propensity (e.g., improved performance), this represented an overall pattern of change worthy of notice. The binomial test allows detection of a combined directional pattern that individual variables, taken one at a time, do not detect.

The pattern analysis revealed that the control group had 28 scores improve and 30 decline. Such a result has a high probable chance occurrence of $p = .8955$ and suggests that no significant combined directional pattern is present (Norusis, 1993). Analysis of the Interactive Metronome and video game groups produced significant improvement–decline patterns. For the Interactive Metronome group, 53 of the 58 variables showed improvement ($p \leq .0001$). For the video game group, 40 of 58 variables showed improvement ($p \leq .0058$). Both groups showed significant pattern increases in performance over the control group. The Interactive Metronome group experienced significantly better improvement than the video game group, suggesting that the Interactive Metronome treatment produced significant additional benefits above and beyond the experience of the video game and control group participants.

Significant Difference Analysis

The pattern analysis identified the overall improvement–decline characteristics of the test mean differences but did not address the magnitude of these differences. Because a pretest–posttest repeated measures design was used, an ANOVA for repeated measures (SPSS, 1988) was performed separately on each of the 58 variables. This approach was chosen to view the effects of the three treatment groups on each test score individually. However, one possible disadvantage of the approach is its potential of increasing Type 1 error.

Of the 58 test scores analyzed, 12 either had significant

interaction effects ($p = .0001-.047$), suggesting that some combination of treatments and subgroup means were different, or there were significant pretest–posttest differences. Twelve significant differences out of 58 significance tests had a $p \leq .001$ at the .05 level of confidence (Sakoda et al., 1974), suggesting that these are not chance differences. Additionally, Keppel's (1973) calculation for the potential number of Type 1 errors over 58 separate experiments is 2.9. Thus, these 12 significant differences far exceed the calculated potential of 2.9 Type 1 errors, suggesting that these differences are real, significant differences.

Among the significant effects, seven significant differences between-phase effects were found ($p = .0001-.023$). This analysis finds the Interactive Metronome participants significantly improving their performance in identifying similarities and differences between concepts and in experiencing declines in aggressive behavior, as reported by their parents. Both the Interactive Metronome and video game treatments produced significant improvements on three Sensory Profile subtests, suggesting that both groups benefited from the attention and activities provided in these treatments. Parental reports on the Child Behavior Checklist also revealed significant declines in aggressive behavior for the Interactive Metronome group, a nonsignificant improvement for the video game group, and no improvement for the control group.

The remaining five tests had significantly different interaction effects ($p = .0001-.047$). These five tests were the WRAT 3 Reading subtest and four tests of the TOVA, including Omissions, RT (Response Time) Variability, Response Time Variability Total STD (Standard) Deviation, and ADHD Total Score. The significant interaction effects suggest that the posttest Interactive Metronome performances, though not significantly improved over the pretest performances, were significantly higher than the control and video game posttest performances. For all five tests, the patterns of differences were identical: Interactive Metronome performances improved, whereas both control and video game performances declined.

In summary, the pattern analysis revealed that both the Interactive Metronome and the video game groups experienced significant improvement patterns across the 58 test scores. Additionally, the Interactive Metronome group had a significantly stronger improvement pattern than the video game group, showing improvements over 53 test scores compared with 40 for the video game group. This finding supports the hypothesis that Interactive Metronome training produced a stronger improvement pattern than the video game group for boys with ADHD.

Analysis of test means found 12 factors with significant quantitative changes among the various group and treatment combinations. The Interactive Metronome group showed significant pretest–posttest improvement in identifying similarities and differences and reduction of aggres-

sion problems compared with the other two treatment groups. Both the Interactive Metronome and the video game groups showed significant improvements in three sensory processing tasks and in parental reports of impulsiveness and hyperactivity. Only parents of the Interactive Metronome participants, however, rated their children as significantly less aggressive ($p \leq .001$) after the treatment period. Additionally, five tests measuring reading and four characteristics of attention revealed that the Interactive Metronome group had significantly higher posttest performances than the other two groups.

Discussion

The results indicated that boys with ADHD who received the Interactive Metronome intervention improved significantly more in areas of attention, motor control, language processing, reading, and ability to regulate aggression than boys receiving either the video game treatment or no treatment. Participants who received video game treatment improved more than the participants in the control group on a number of measures as well, demonstrating that focused perceptual activities and support alone may be helpful for selected areas of functioning. The video game group, however, showed decreased performance in selected areas involving modulation and control, such as consistency of concentration, reaction time, and overall attention.

Interactive Metronome treatment, on the other hand, only showed improved performance, including significant positive gains, over the video game treatment on a series of TOVA attentional tasks measuring lack of errors and distractibility, consistency of reaction time, and overall attention; selected language (i.e., similarities and differences); academic tasks (reading); and control of aggression. In addition, pattern analysis was used to control for the effect of using a large number of assessments and demonstrated that the differences between the group patterns were significant. The National Institutes of Health (NIH, 1997) asserted that studies on ADHD interventions must properly control for the positive overall effect of attentive adult interaction, alone. Consistent with NIH guidelines, two of the three groups in this study received adult attention during the treatment period.

Limitations

Only male participants in a defined age range were included to minimize age and gender variation, thereby limiting generalizability to the other gender and age groups. The variables measured by the assessments are limited to selected aspects of attention, motor control, language, cognition, and learning.

In this study, Interactive Metronome training influenced a number of performance capacities. A possible explanation for the positive changes is the central role of motor planning and sequencing in each performance area.

accuracy in golf. Unpublished manuscript, Central Michigan University, Mt. Pleasant, MI.

Mundy, P. (1995). Joint attention and social-emotional approach behavior in children with autism. *Development and Psychopathology*, 7, 63-82.

Mundy, P., & Crowson, M. (1997). Joint attention and early social communication: Implications for research on intervention with autism. *Journal of Autism and Developmental Disorders*, 27, 653-676.

NIH consensus statement. (1997). *Archives of General Psychiatry*, 54, 865-870.

Norusis, M. (1993). *SPSS for Windows base system user manual* (Release 6.0). Chicago: Statistical Package for the Social Sciences.

Piek, J. P., Pitcher, T., & Hay, D. A. (1999). Motor coordination and kinaesthesia in boys with attention deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology*, 41, 159-165.

Rubia, K., Overmeyer, S., Taylor, E., Brammer, M., Williams, S., Simmons, A., & Bullmore, E. (1999). Hypofrontality in attention deficit hyperactivity disorder during higher-order motor control: A

study with functional MRI. *American Journal of Psychiatry*, 156, 891-896.

Sakoda, J. M., Cohen, B. H., & Beall, G. (1974). Test of significance for a series of statistical tests. *Psychological Bulletin*, 51, 172-175.

Schonfeld, I., Shaffer, D., & Barmack, J. (1989). Neurological soft signs and school achievement: The mediating effects of sustained attention. *Journal of Abnormal Child Psychology*, 17, 575-596.

Smith, L. B., & Thelen, E. (Eds.). (1993). *A dynamic systems approach to development: Applications*. Cambridge, MA: MIT Press.

Statistical Package for the Social Sciences. (1988). *SPSS-X users guide* (3rd ed.). Chicago: Author.

Stemmer, P. M. (1996). *Improving student motor integration by use of an Interactive Metronome*. Paper presented at the 1996 Annual Meeting of the American Educational Association, Chicago.

Wechsler, D. (1992). *Wechsler Intelligence Scale for Children manual* (3rd ed.). San Antonio, TX: Psychological Corporation.

Wilkinson, G. S. (1993). *Wide Range Achievement Test administration manual*. Wilmington, DE: Wide Range.