IM Research & White Papers

Profound Effects of Interactive Metronome and Brain Balance Exercises on a Subset of Children with Attention Deficit Hyperactivity Disorder

YEAR: 2019 **PUBLICATION:** WHITE PAPER: DEVELOPMENTAL BIOPSYCHIATRY RESEARCH PROGRAM, MCCLEAN HOSPITAL, HARVARD MEDICAL SCHOOL **AUTHOR:** Martin H Teicher, PhD, MD

RESULTS:

Simply Preliminary results from this ongoing study showed that 5 of 14 children (36%) diagnosed with ADHD demonstrated 40% or greater improvement on standardized neuropsychological measures of hyperactivity and spatial working memory (the executive function most notably impaired in ADHD) following completion of a combined Interactive Metronome (IM) and Brain Balance (BB) training protocol. According to Dr Teicher, "this is a degree of improvement that we have not previously observed in children with ADHD unless they were receiving medications, and then only if they were receiving the correct medication at optimal dose."

Neuroimaging of brain regions strongly implicated in the neurobiology of ADHD helped to parse out the influence of each training program and the effect of combining them. Specifically, scans showed that BB training was associated with increased connectivity between prefrontal cortex and the frontal pole, temporal pole, cerebellum, precentral gyrus and supramarginal gyrus with extensive effects on connectivity of the amygdala and hippocampus, which are involved in implicit and explicit memory as well as stress response.

Increased connectivity of the amygdala with supramarginal gyrus, cingulate gyrus, anterior cingulate, angular gyrus, frontal pole and precuneus were associated with combined IM and BB training. Greater connectivity between the amygdala and cingulate allows for better emotional self-regulation and impulse-control.

IM training was associated with increased connectivity between the hippocampus and the angular gyrus, precuneus, middle temporal gyrus, lateral occipital cortex, supramarginal gyrus, cingulate gyrus and frontal pole, areas responsible for language processing, memory retrieval, handwriting, mathematical calculations, and L/R discrimination. A closer examination of the impact on the cerebellum revealed that IM training was associated with increased resting state functional connectivity between: cerebellum I and middle frontal gyrus; cerebellum II and inferior temporal gyrus/fusiform gyrus; cerebellum IV-V and parahippocampal gyrus and inferior temporal gyrus/fusiform gyrus; cerebellum VII and lateral occipital cortex; cerebellum VIII and superior frontal gyrus and cerebellum IX and lingual gyrus and postcentral gyrus. IM training was also associated with decreased resting state functional connectivity between cerebellum III and anterior cingulate gyrus and cerebellum VI and lateral occipital gyrus.

CONTINUED FROM FRONT...

"These appear to be potent changes. Our findings of symptomatic improvement and enhanced connectivity of the supramarginal gyri with the amygdala, hippocampus, and prefrontal cortex is consistent with a recent report showing that reduced connectivity of the left and right supramarginal gyri was associated with increased symptom severity in ADHD24. Given the role these regions appear to play in timing makes these observations particularly compelling." Research is ongoing and will continue to investigate and further define the host of neurobiological changes associated with IM and BB training as well as their relationship to clinical outcome for individuals with ADHD.

DETAILS:

- n=14 (8-14 years of age) confirmed to have ADHD through structured diagnostic interview (K-SADS-PL)
- intervention: 15 weeks of combined Interactive Metronome and Brain Balance training (up to 75 sessions) were completed remotely via online access
    - standardized exercises with no individualization
    - not directly supervised by an experienced administrator (carried out by families at home)
- clinical outcome measures:
    - ADHD Quotient System. "This test is highly responsive to the effects of medication, correlates with blood levels of methylphenidate but is not responsive to placebo. Indeed, we reported in N=30 children receiving placebo that only 7% showed a greater than 25% improvement and none had a 40% or greater improvement in Quotient scaled scores."
    - Cambridge Neuropsychological Test Automated Battery (CANTAB) to evaluate spatial working memory
    - Neuroimaging with diffusion MRI optimized to evaluate the brain's structural connections (part of the Human Connectome Project)

How Rhythmic Skills Relate and Develop in School-Age Children

YEAR: 2019 **PUBLICATION:** GLOBAL PEDIATRIC HEALTH **AUTHOR:** Silvia Bonacina, Jennifer Krizman, Travis White-Schwoch, Trent Nicol, and Nina Kraus

RESULTS:

Simply drumming to a isochronous beat had no impact on recall of rhythmic patterns. Children who performed better at drumming to the beat of music were better at both drumming to a beat and remembering rhythmic patterns. However, children who were able to clap in time with a steady beat with the least amount of variability in their synchronization (due to real time millisecond feedback from Interactive Metronome) demonstrated better ability to drum to a beat, recall rhythmic patterns & drum to the beat of music. According to Dr Nina Kraus, rhythm is complicated, there are several rhythm intelligences, & Interactive Metronome, by itself, impacts all of these vital rhythms that are so important to the development of language and literacy. "Several clinical populations exhibit timing deficits that co-occur with to language deficits; for example, individuals with reading impairment often struggle to tap along to an isochronous beat. It is conceivable that clapping in time to feedback could be a viable intervention for populations with distinct rhythmic deficits (such as one group who struggles to synchronize to a beat and another who struggles to remember rhythmic patterns)." The authors hypothesize that the perception & production of rhythm begins as a global skill early and becomes more specialized later in life. This is in line with previous IM research and the IM Indicator Table data.

DETAILS:

- n=68 typically developing children between 5 - 8 years of age
- n=46 children were re-assessed 1 year after conclusion of the study to monitor development of rhythmic skills
- first study of its kind to provide evidence of the interconnections among rhythmic skills in school-age children
- assessed via 4 different rhythmic tasks:
    - 3 tasks used a conga drum, with a trigger to register drum hits:
        1. Drumming to an Isochronous Beat: listen and drum to an isochronous pacing beat presented through in-ear headphones
        2. Remembering and Repeating Rhythmic Patterns: listen to 3 repetitions of a rhythmic sequence without drumming and then drum out the sequence during a pause, producing the sequence exactly when it would have occurred had it repeated a fourth time
        3. Drumming to the Beat of Music: listen to a musical excerpt through speakers and tap to the perceived beat
    - 1 task involved clapping in time and was completed using Interactive Metronome (IM)

PEDIATRIC

Interactive Metronome (IM): A Modality for Executive Function and Motor Coordination

YEAR: 2018 **PUBLICATION:** Poster presented at THE AMERICAN OCCUPATIONAL THERAPY ASSOCIATION CONFERENCE, April 19 – 22, 2018, Salt Lake City, UT **AUTHOR:** Kaitlyn Caspero and Blythe Westendorf

RESULTS:

Children who completed Interactive Metronome (IM) training demonstrated statistically significant improvement in fine motor & bilateral coordination on standardized measures. Parents also observed better performance on multi-step task completion, time management and organizational skills indicating perceived improvement in executive functioning.

DETAILS:

- n=30 children from outpatient pediatric therapy clinic at The Children's Institute of Pittsburgh
- intervention consisted of 18 sessions of IM training
- pre-post measures included:
  - Canadian Occupational Performance Measure (COPM)
    - Performance – improvement of 87%
    - Satisfaction – improvement of 78%
  - Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition (BOT-2)
  - IM measurements of timing & rhythm
  - parent interview

PEDIATRIC

Influences of Synchronized Metronome Training on Soccer Players' Timing Ability, Performance Accuracy, and Lower-Limb Kinematics

YEAR: 2018 **PUBLICATION:** FRONTIERS IN PSYCHOLOGY **AUTHOR:** Louise Rönnqvist, Rachel McDonald & Marius Sommer

RESULTS:

The experimental Interactive Metronome (IM) group demonstrated significant improvement in millisecond timing, compared to the control group, as a result of IM training. Additionally, the group that received IM training demonstrated greater speed and accuracy on a high cognitive-load, complex stepping task. IM training appeared to positively impact executive-controlled attention and working memory in the experimental group leading to improved performance in motor coordination, precision and speed when compared to the control group. Of interest, those athletes who demonstrated the MOST improvement in timing scores on Interactive Metronome also demonstrated the GREATEST gains in speed and accuracy on the complex stepping task. Correlations were found between the participants' performance on the stepping task and kinematic parameters, likely associated with inter-individual variations in higher-order cognitive processing ability. Recent studies have confirmed that executive functions are imperative for high performance in soccer and hockey. The more elite the player, the higher they tend to perform on tests of executive functioning. "To conclude, even if physical strength and mental ability are of high importance in all sport performance, sensorimotor timing ability may be the key factor. The present study emphasizes the importance of improving the cognitive-motor planning ability and sensorimotor timing skills, especially in team sport such as soccer where the players have to rely on accurately timed actions on milliseconds level. It is clear from the results that synchronized sensorimotor timing abilities should be acknowledged as a critical factor for soccer player's performance. Additionally, that SMT [Interactive Metronome training] also may be beneficial for both general motor planning and in other sports performance and situations of complex, high cognitive-motor demanded tasks, and dynamic contexts."

DETAILS:

- n=24 female elite & sub-elite soccer players ages 16.2 to 25.8 were randomly assigned to:
  - experimental group: 12 participants completed 12 IM training sessions (45-50 min each) over 4 weeks in addition to regular pre-season soccer practices
  - control group: 12 participants completed the same regular pre-season soccer practices
- pre & post sensorimotor timing skills were measured via Interactive Metronome
- pre & post performance on a complex, high cognitive-load stepping task was recorded in 2D and 3D for each participant via an optoelectronic motion capture system for kinematic analysis.

ATHLETE

Timing Training in Female Soccer Players: Effects on Skilled Movement Performance and Brain Responses

YEAR: 2018 **PUBLICATION:** FRONTIERS IN HUMAN NEUROSCIENCE **AUTHOR:** Jin Hyun Kim, Joung Kyue Han, & Doug Hyun Han

RESULTS:

Elite women soccer players who participated in Interactive Metronome (IM) training to improve timing, rhythm and synchronization demonstrated statistically greater accuracy and consistency of cross-pass performance than players in a control group who participated in regular soccer practice. Additionally, the IM group demonstrated remarkable changes in brain function on fMRI such as improved neural recruitment & efficiency, corresponding to greater automaticity during cross-pass execution. Automaticity of action in sports performance is considered the "holy grail."

DETAILS:

- n=25 high ranking elite and sub-elite female soccer players from highest and second highest divisions in Sweden were randomly assigned to two groups:
    - experimental group: 12 participants received 12 sessions of IM training for 27,000 total repetitions (13 pre-set IM exercises and 10 additional custom exercises - none of which including any motions related to kicking the ball or cross-pass)
    - control group: 13 participants engaged in 4 sessions of regular team practice (6 hours each) over a period of 4 weeks
- objective pre and post measures were conducted for accuracy and variability of cross-pass
- fMRI captured associated brain responses as participants viewed videos of soccer-specific actions, capitalizing on mirror neurons

ATHLETE

Training effects of Interactive Metronome® on golf performance and brain activity in professional woman golf players

YEAR: 2018 **PUBLICATION:** HUMAN MOVEMENT SCIENCE **AUTHOR:** Jin Hyun Kim, Joung Kyue Han, & Doug Hyun Han

RESULTS:

Professional female golfers demonstrated improved consistency of timing and rhythm for putting and associated changes in brain function following Interactive Metronome (IM) training, including increased brain connectivity from the cerebellum to the frontal cortex when compared to the control group. A comparison of brain activity under fMRI between the IM group and the control showed increased functional connectivity from the superior cerebellar vermis to the right medial frontal gyrus, left superior temporal gyrus, right middle occipital gyrus, right middle temporal gyrus, right cingulate gyrus, and right supramarginal gyrus (uncorrected $p < 0.001$, voxels > 40).

DETAILS:

- n=20 professional female golfers from the KLPGA were randomly assigned to two groups:
  - experimental group: 10 participants completed 35-40 minutes of IM training twice weekly for 6 weeks
  - control group: 10 participants spent 35-40 additional minutes of time playing golf twice weekly for 6 weeks
- golf putting movements and brain activity were analyzed using Kinovea Software and resting state functional MRI (fMRI)
- performance variability (or consistency) was measured as the standard deviation of mean swing speed (SSD) during 3 sections of the swing: backswing, backswing-impact, and impact-finish

ATHLETE

Clapping in time parallels literacy and calls upon overlapping neural mechanisms in early readers

YEAR: 2018 **PUBLICATION:** ANNALS OF THE NEW YORK ACADEMY OF SCIENCES **AUTHOR:** Silvia Bonacina, Jennifer Krizman, Travis White-Schwoch, & Nina Kraus

RESULTS:

The Children who were able to clap in sync with an auditory beat during Interactive Metronome (IM) assessment with the least variability in timing & rhythm demonstrated more advanced neurophysiological responses associated with language skills. Further, those children that demonstrated greater rhythmic ability (or the least variability in timing) while receiving visual feedback for millisecond timing feedback demonstrated superior literacy skills in the areas of processing speed, phonological processing, word reading, spelling, morphology, and syntax. "These results suggest that rhythm skills and literacy call on overlapping neural mechanisms, supporting the idea that rhythm training may boost literacy in part by engaging sensory-motor systems."

DETAILS:

- n=64 typically developing children ages 5-7
- beat synchronization was assessed using IM:
  - without feedback (just the metronome beat)
  - with feedback (the metronome + visual guidance for millisecond timing)
  - participants did not practice prior to the assessment
- 4,000 artifact-free FFRs (frequency-following responses) were elicited from each child – this measures the microsecond precision of auditory processing and is used a measure to explore the connection between motor & auditory systems
  - other assessments included: intertrial phase-locking consistency, intertrial stability, verbal intelligence, phonological awareness, morphology & syntax, basic reading, processing speed

PEDIATRIC

The Effectiveness of Interactive Metronome® as a Restorative Modality to Improve Cognition and Motor Performance in Healthy Older Adults In Eastern North Carolina

YEAR: 2017 **PUBLICATION:** JOURNAL OF NEUROLOGY AND NEUROSCIENCE **AUTHOR:** Leonard G. Trujillo

RESULTS:

Healthy older adults performed better on measures of cognitive and motor function following Interactive Metronome (IM) training (p=0.001). Participants reported feeling more organized, balancing their check book seemed easier, they were able to sign their name more legibly; they enjoyed water aerobics classes with more confidence, and gains were maintained with little statistical change 6-8 weeks following the completion of IM training.

DETAILS:

- n=30 healthy older adults (each participant established a baseline for their individual performance)
- pre-post assessments included:
  - IM Long Form Assessment
  - d2 Test of Attention
  - Nine Hole Peg Test
- IM training was completed twice weekly for 12 sessions
  - initially 15 minutes per session, progressing to 35 minutes
  - 9 exercises, including come custom exercises to address bilateral skills
  - auditory and visual millisecond feedback for timing

ADULT

Effects of Interactive Metronome training on upper extremity function, ADL and QOL in stroke patients

YEAR: 2017 **PUBLICATION:** NEUROREHABILITATION **AUTHOR:** Ga-Hui Yu, Jae-Shin Lee, Su-Kyoung Kim, & Tae-Hyun Cha

RESULTS:

Stroke patients who received Interactive Metronome (IM) training demonstrated greater improvement in finger control, ability to perform self-care ADLs & overall motor function compared to a control group. Significant ADL improvements were noted in the areas of feeding, toileting, dressing & transfers with most notable difference in dressing. Quality of life measures indicated greater performance & satisfaction for those that received IM training, particularly in the domain of Self-Help, which is in line with the outcome of previous IM research on stroke patients with hemiplegia.

DETAILS:

- n=30 adults, 6 months post-CVA were randomly assigned to:
  - experimental group: 15 patients completed IM training 3x/week for 12 sessions
  - control group: 15 patients completed bilateral arm self-exercises for the same period of time

Incorporation of Feedback during Beat Synchronization is an Index of Neural Maturation and Reading Skills

YEAR: 2016 **PUBLICATION:** BRAIN & LANGUAGE

AUTHOR: Kali Woodruff Carr, Ahren B. Fitzroy, Adam Tierney, Travis White-Schwoch, & Nina Kraus

RESULTS:

Adolescents who were able to clap in sync with an auditory beat during Interactive Metronome (IM) assessment scored higher on reading-related tests. Those who demonstrated better rhythm (greater consistency) while receiving feedback for millisecond timing performed better on tests of phonological memory and reading sub-skills and demonstrated greater cortical maturation for auditory processing. "Synchronization employing feedback [via IM] may prove useful as a remedial strategy for individuals who struggle with timing-based language learning impairments."

DETAILS:

- n=74 four adolescents participated in the following IM assessments to measure beat synchronization:
  - clapping in sync with the beat for 1 minute without any feedback for timing accuracy
  - clapping in sync with the beat for 1 minute while receiving visual feedback for millisecond timing accuracy (participants were provided with 2 minutes of feedback training prior)
- precision and variability of beat synchronization with and without feedback were then correlated with performance on various other measures, including:
  - Verbal intelligence via Wechsler Abbreviated Scale of Intelligence (WASI)
  - Working memory via Woodcock Johnson III Test of Cognitive Abilities (WJ – III)
  - Phonological Awareness & Phonological Memory via Comprehensive Test of Phonological Processing (CTOPP)
  - Reading via Woodcock Johnson Test of Achievement (WJ – III)
  - Reading Fluency via Test of Word Reading Efficiency – 2nd Edition (TOWRE-2)
  - Cortical Speech Processing via amplitude & latency of cortical auditory evoked potential (CAEP) components elicited by speech sounds
  - Spectral power of intrinsic neural oscillatory power in the gamma frequency band (31-50 Hz) at rest via continuous EEG.

The Effects of Interactive Metronome on, Cognitive and Upper Extremity function, balance for Parkinson's disease

YEAR: 2016 **PUBLICATION:** WHITE PAPER **AUTHOR:** A-Reum Kim

RESULTS:

Patients with Parkinson's Disease demonstrated significant improvements in cognition, upper extremity function and balance following Interactive Metronome (IM) training.

DETAILS:

- n=2 patients with diagnosis of Parkinson's Disease participated in single-subject research with ABA design
  - both patients were evaluated for cognition, upper extremity function and balance during pre-intervention baseline phase (A)
  - both patients then participated in 30-40 minutes of IM training for 15 sessions during the intervention phase (B) – upper extremity function and balance were assessed at the conclusion of each IM training session
  - both patients were then evaluated again for cognition, upper extremity function and balance during the post-intervention phase (A)

ADULT

Effects of interactive metronome on balance and stability indexes of a 77-year –old female

YEAR: 2016 **POSTER PRESENTED AT:** FRONTIERS INTERNATIONAL SYMPOSIUM ON CLINICAL NEUROSCIENCE: CLINICAL NEUROSCIENCE FOR OPTIMIZATION OF HUMAN FUNCTION, ORLANDO OCTOBER 7-9, 2016 **AUTHOR:** Michael Bagnell, Hannah Irons and Susan E. Esposito

RESULTS:

A 77 year old female demonstrated substantial improvement on neurological assessments of balance following 5 weeks of Interactive Metronome (IM) training, demonstrating that IM may be an effective tool to reduce fall risk in the aging population.

DETAILS:

- n=1 female (77 years of age with complaints of imbalance, instability, chronic obsessive-compulsive disorder (OCD), anxiety, and rheumatoid arthritis
- pre-post assessments included:
  - Four Step Square Test
  - Biodex Biosway Clinical Test of Sensory Integration & Balance (CTSIB) on perturbed and non-perturbed surfaces
- intervention:
  - IM training for 10 sessions, twice weekly for 12-18 minutes each over a 5-week period
  - IM exercises included clapping hands and stepping at default tempo of 54 bpm
  - subject performed the exercises over increased time intervals beginning at 2.6 minutes per session and reaching a maximum of 18 minutes
  - repetitions performed began with 138 for the initial session and reached a maximum of 972
- outcomes:
  - Four Step Test improved by 12%
  - CTSIB on perturbed surface, with eyes closed, headphones on, showed an average improvement of 16.5%
  - CTSIB on perturbed surface with eyes opened improved 21.7%
  - CTSIB on non-perturbed surface with eyes improved 51.4%
  - CTSIB on non-perturbed surface with eyes closed improved 0.6%

ADULT

Effects of Interactive Metronome (IM) training on motor timing, EEG, and putting performance in golf: A neuropsychological approach

YEAR: 2016 **PUBLICATION:** WHITE PAPER **AUTHOR:** Pil Jung Kim

RESULTS:

Interactive Metronome (IM) training facilitated decreased theta activity in the brain and increased right brain activity. Attention, processing, motor timing & golf putting performance were all improved. Of note, improvements measured in the laboratory setting carried over to the real world environment with positive effect on golf putting in the field. "...as a single training protocol, IM training is expected to improve kinematic, neurological, and psychological functions all together among the elite golfers."

DETAILS:

- n=34 elite golfers were randomly assigned to:
  - experimental group: 18 participated in 12 IM training sessions
  - control group: 16 participated in golf practice sessions for the same duration
- pre, mid, and post measures of motor timing were gathered via the IM Long Form Assessment(LFA)
- EEG of prefrontal lobe was measured and attentiveness (RSMT) was identified by analyzing EEG
- putting analyzer (SAMPUTTLAB) and 50-ball test were used to examine putting performance

Effect of Interactive Metronome Training on Timing, Attention and Motor Function of Children With ADHD: Case Report

YEAR: 2015 **PUBLICATION:** WHITE PAPER **AUTHOR:** Young Namgung, Da-In Son, & Kyeong-Mi Kim

RESULTS:

A 7 year old boy demonstrated improvement in visual attention & response Inhibition & improved from 42nd to 96th percentile in motor coordination, and a 14 year old boy demonstrated improvement in sustained attention & improved from 21st to 66th percentile in motor skills following IM training.

DETAILS:

- two boys ages 7 & 14 participated in IM training for a period of 3 weeks
- pre and post assessments:
    - IM Long Form Assessment to measure timing
    - RehaCom screening module to assess attention
    - Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2) to evaluate motor skills

PEDIATRIC

The Effects of Interactive Metronome on Timing, Attention, Bilateral Coordination and Balance for Adult with Intellectual Disabilities: Single Subject Design

YEAR: 2015 **PUBLICATION:** JOURNAL OF SPECIAL EDUCATION & REHABILITATION SCIENCE **AUTHOR:** Kyeong Mi Kim, Mi Su Kim & Soo Min Lee

RESULTS:

A young woman with intellectual disabilities demonstrated improvements in timing skills, attention, bilateral coordination, and balance following Interactive Metronome (IM) training.

DETAILS:

- single subject design case study AB design with 26 year old female
- pre and post assessments included:
    - IM Long Form Assessment to measure timing skills,
    - IM Short Form Test Super Right-On (SRO) Percentage for attention,
    - and Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2) to evaluate bilateral coordination and balance

Validity of Long Form Assessment in Interactive Metronome® As a Measure of Children's Praxis

YEAR: 2015 **PUBLICATION:** THE JOURNAL KOREAN ACADEMY OF SENSORY INTEGRATION **AUTHOR:** Kyeong-Mi Kim, Seo-Yoon Heo, Mi-Su Kim, Soo-Min Lee

RESULTS:

The This study validated use of the Interactive Metronome (IM) Long Form Assessment as a measure of praxis in children. There were significant differences in the IM LFA scores between children with and without ADHD (p<. 05). Additionally, a high correlation between IM LFA scores and BOT-2 for the area of hand control (rs=-.532) (p<.05) and high negative correlation for the area of fine-motor accuracy (rs=-.447), hand dexterity (rs=-.532), and balance control (rs=-.623) (p<. 05) were discovered.

DETAILS:

- n=25 children ages 6-11 with and without ADHD Attention Deficit Hyperactivity Disorder (ADHD)
- to evaluate discriminative ability of IM LFA for the assessment of praxis, children completed the LFA and scores were correlated with performance on the Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2)

PEDIATRIC

Effects of the Interactive Metronome® on Memory Process and Balance with Aging Adults 60+ population

YEAR: 2015 **PUBLICATION:** WHITE PAPER PRESENTED AT ISNR 2015 **AUTHOR:** Leonard G. Trujillo

RESULTS:

Aging adults demonstrated improvement in timing, cognitive function, ADLs (dressing & bathing), fine motor dexterity, speed and balance following Interactive Metronome (IM) training. Improvements and increased confidence resulted in decreased fall risk. Despite performing all of the upper extremity exercises in a seated position, there was a notable transfer effect to speed, balance and coordination in standing and during ambulation leading to decreased fall risk.

DETAILS:

- n=9 adults ages 60-80 participated in 12 sessions of IM training over a period of 2 months with a 6 week break period followed by 6 additional sessions of IM training (total of 18 IM training sessions)
- IM sessions were 30-45 minutes, never exceeding 275 repetitions per exercise
- all IM exercises focused on upper extremities and were completed while seated
- improvements were measured on all pre-post assessments including:
    - IM Long Form Assessment
    - IM Short Form Assessment
    - 4 Step Square Test of Balance
    - D2 Test of Attention
    - Woodcock Johnson
        - Decision Speed
        - Visual Matching
        - Math Fluency
        - Reading Fluency

ADULT

The Validation of the Interactive Metronome: A Pilot Study Prior to Implementation for Post Deployment Service Members

YEAR: 2015 **PUBLICATION:** JOURNAL OF NEUROLOGY AND NEUROSCIENCE **AUTHOR:** Leonard G. Trujillo & Jane Painter-Patton

RESULTS:

The In this proof of concept pilot study a training protocol that combined Interactive Metronome (IM) and Total Body Resistance Exercise (TRX®) produced meaningful changes in attention, fine motor control (hand dexterity), & life satisfaction in a group of normal college subjects of similar age and physical status as active duty military. It is hypothesized that the same regimen may be helpful for post-deployed military personnel & individuals with Mild Traumatic Brain Injury (mTBI) and/or Posttraumatic Stress Disorder (PTSD) symptoms.

DETAILS:

- n=4 (2 males, 2 females)
- 12-session intervention plan 3x/week with sessions lasting a maximum of one hour and a half, consisting of:
    - first and last session: pre/post evaluations
    - remaining ten sessions: 1,350-1,512 repetitions of IM paired with similar TRX® exercises
    - TRX® performed in 30 second increments with 30 seconds of break between each interval
    - 2 participants treated simultaneously to encourage motivation and competition – as 1 participant completed an IM exercise, the other participant completed a paired TRX® exercise
- pre/post assessments included:
    - Canadian Occupational Performance Measure (COPM)
    - Test of Everyday Attention (TEA)
    - Interactive Metronome (IM) Long Form Assessment
    - Nine-Hole Peg Test (NHPT)

ADULT

Effects of Improvements in Interval Timing on the Mathematics Achievement of Elementary School Students

YEAR: 2015 **PUBLICATION:** JOURNAL OF RESEARCH IN CHILDHOOD EDUCATION **AUTHOR:** Gordon E. Taub, Kevin S. McGrew & Timothy Z. Keith

RESULTS:

Elementary school-age children who received Interactive Metronome (IM) training demonstrated significantly higher scores on tests of math achievement compared to the control group who participated in recess. Those that completed IM training demonstrated greater accuracy in their math problem solving and completed mathematics problems faster than the control group. The growth in math achievement in the experimental (IM training) group was above and beyond the expected growth for that age group in that same time period.

DETAILS:

- n=86 children ages 7-9 (1st – 4th grades) were randomly assigned to:
  - experimental group: 49 children participated in IM training in groups of 12 for 18 daily sessions, lasting 50 min each, over a 4 week period
  - control group: 37 children participated in recess
- math achievement was measured pre & post via Woodcock-Johnson III (WJ III) Calculation & Math Fluency subtests
- neither group received academic instruction during the study

A Retrospective Outcomes Study Examining the Effect of Interactive Metronome on Hand Function

YEAR: 2015 **PUBLICATION:** JOURNAL OF HAND THERAPY **AUTHOR:** Tracy M. Shank & Wendy Harron

RESULTS:

Children who participated in Interactive Metronome (IM) training demonstrated statistically significant improvements in timing skills, behavior, & hand function in both the dominant and non-dominant hand.

DETAILS:

- n=48 children, 41 boys and 7 girls ages 6-17 (average 9 years) with mixed motor and cognitive impairments, completed an average of 14 1-hour long IM training sessions over a period of 8.5 weeks in an outpatient therapy setting. Diagnoses included:
  - 14 - ADHD
  - 5 – CP/Hemiplegia
  - 9 – Coordination Disorder
  - 10 – PDD/Autism
  - 5 – rare neuromuscular disorders
  - 5 – neurologic conditions such as seizures/concussion
- retrospective analysis of pre/post assessments, including:
  - Interactive Metronome (IM) Long Form Assessment for timing skills
  - Jebsen Taylor Test of Hand Function
  - Parent questionnaire for behavior

PEDIATRIC

Effect of timing training in golf and soccer players: skill, movement organisation, and brain activity

YEAR: 2014 **DOCTORAL THESIS** (4 papers were published from this body of work) **AUTHOR:** Marius Sommer

RESULTS:

Interactive Metronome (IM) training produced statistically significant improvements in athletic performance of golfers and elite soccer players as measured by timing skills, shot/kick accuracy, variability in execution during sport (automaticity), kinematic analysis & functional MRI.

SEE PUBLISHED STUDIES FOR DETAILS:

- Sommer, M. & Rönnqvist, L. (2009). Journal of Sports Science and Medicine, 8, 648-656. This study investigated the impact of IM training on golf shot accuracy and variability.
- Sommer, M., Häger, C. & Rönnqvist, L. (2014). Sports Biomechanics, 13, 1-16. This study further investigated the impact of sensorimotor synchronization training (via IM training) on the kinematic properties of the golf swing, specifically spatiotemporal movement organization and dynamics.
- Sommer, M., Häger, C., Olsson, C. J., & Rönnqvist, L. (2018). This study investigated the effect of IM training on cross-pass soccer kick accuracy in elite and sub-elite female soccer players. Underlying brain activity was studied via fMRI.
- Rönnqvist, L., McDonald, R., & Sommer, M. (2018). This study explored the impact of IM training on soccer players timing ability, performance accuracy & lower limb kinematics.

The Evaluation of the Effectiveness of Interactive Metronome® Training in Older Adults, as a Potential Modality for Enhancing Skills Necessary for Driving

YEAR: 2014 **PUBLICATION:** WHITE PAPER **AUTHOR:** Leonard G. Trujillo, Lindsay Alspaugh, Sandy Gant & Amanda Garner

RESULTS:

Normally aging adults demonstrated improved fine motor coordination (finger dexterity) following Interactive Metronome (IM) training. It is typical to notice a decline in motor function around age 65, impacting several activities of daily living like driving and grooming. IM training may improve and preserve motor function as we age.

DETAILS:

- n=12 aging adults (4 males, 8 females) ages 55-68 completed 8 sessions of IM training
- IM training was completed in a seated position with only hand exercises
- pre-post testing included:
    - Interactive Metronome (IM) Long Form Assessment for timing skills
    - Nine Hole Peg Test (NHPT) for fine motor skills

ADULT

Efficacy of the Interactive Metronome® for Improving Attention in Veterans Returning to School Settings: A Pilot Study

YEAR: 2014 **PUBLICATION:** WHITE PAPER PRESENTED AT NATIONAL AMERICAN OCCUPATIONAL THERAPY ASSOCIATION (AOTA) CONFERENCE 2014 **AUTHOR:** Karla Baker & Leonard Trujillo

RESULTS:

Veterans enrolled in studies at East Carolina University demonstrated improved attention skills on objective pre-post assessment (3/3) and reported functional increase in attention & concentration in school (2/3) after participating in Interactive Metronome (IM) training.

DETAILS:

- n=3 veteran students at East Carolina University completed 15 IM training sessions at home using IM-Home over a period of 4-6 weeks
- Before IM training:
  - Participant 1: 55 year old female struggling with memory for new information and focusing attention
  - Participant 2: 29 year old male, also struggling with retaining new information and with maintaining concentration during studies
  - Participant 3: 38 year old male, wishes to improve ability to focus and tune out distractions, is less able to multitask and feels more scattered
- pre-post assessments included:
  - Interactive Metronome (IM) Long Form Assessment to measure timing skills
  - D2 Test of Attention for attention & concentration
  - Canadian Occupational Performance Measure (COPM)

ADULT

Synchronized metronome training induces changes in kinematic properties of the golf swing

YEAR: 2014 **PUBLICATION:** SPORTS BIOMECHANICS **AUTHOR:** Marius Sommer, Charlotte Hager & Louise Rönnqvist

RESULTS:

Golfers who participated in Interactive Metronome (IM) training demonstrated improved timing, coordination & degree and consistency of synchronization between joint couplings of the arms and individual joints and golf club motions during the golf swing.

DETAILS:

- n=13 male golfers with 20- 34 years of experience and 5.0 to 19.5 handicap, who participated in 12 45-50 minute IM training sessions over a period of 4 weeks in the previously published study by Sommer, M. & Rönnqvist, L. (2009), participated in further investigation to measure the impact of Interactive Metronome (IM) on the kinematic properties of the golf swing
- pre-post assessments included:
    - 3D motion capture of club velocity at 3 different swing phases (backswing, downswing, and follow-through) with 3 different clubs (4-iron, 7-iron, and pitching wedge)
    - cross-correlation analysis of time-series signals were made on joint couplings (wrist–elbow–shoulder) of both arms, and between joints and the club, during the full golf swing

ATHLETE

Effects of Interactive Metronome® Therapy on Cognitive Functioning After Blast-Related Brain Injury: A Randomized Controlled Pilot Trial

YEAR: 2013 **PUBLICATION:** NEUROPSYCHOLOGY **AUTHOR:** Lonnie A. Nelson, Margaret MacDonald, Christina Stall & Renee Pazdan

RESULTS:

Active duty soldiers with mild-moderate traumatic brain injury (TBI) who received Interactive Metronome (IM) training in addition to standard rehabilitation care (SRC), demonstrated statistically significant improvements on 21 out of 26 neuropsychological batteries in the areas of attention, inhibition, processing speed, motor speed, immediate memory, and delayed memory compared to soldiers that only received SRC.

DETAILS:

- n=46 active duty soldiers, 21–49 years of age, approximately 29 months post TBI were randomly assigned to:
  - experimental group: 18 received SRC plus 15 1-hr IM training sessions
  - control group: 18 received SRC only
- soldiers all had blast-related mild-to-moderate TBI and displayed persistent, chronic cognitive deficits
- to control for bias, investigators completing pre-post assessments were blinded to the participants randomized group assignment
- assessments included: Wechsler Test of Adult Reading (WTAR), Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), Integrated Visual and Auditory Continuous Performance Test (IVA-CPT), Delis–Kaplan Executive Functioning System (D-KEFS) Trail Making and Color–Word Interference subtests, Test of Memory Malingering (TOMM), Grip Strength and Grooved Pegboard, Wechsler Adult Intelligence Scale–Fourth Edition (WAIS-IV), including Digit Span, Letter–Number Sequencing, Digit–Symbol Coding, and Symbol Search subtests & Rivermead Post Concussion Symptoms Questionnaire, Mayo–Portland Adaptability Inventory–4, Satisfaction With Life Scale, & The Alcohol Use Disorders Identification Test (AUDIT-C).

ADULT

Chiropractic management using a brain-based model of care for a 15-year-old adolescent boy with migraine headaches and behavioral and learning difficulties: a case report

YEAR: 2013 **PUBLICATION:** JOURNAL OF CHIROPRACTIC MEDICINE **AUTHOR:** Kurt W. Kuhn & Jerrilyn Cambro

RESULTS:

A 15 year old patient with migraine headaches and learning disability demonstrated reduction in neurological soft signs; improvement in timing & rhythm; improvement on tests of attention, academic achievement , and school GPA; and reduction in medication following chiropractic care and Interactive Metronome (IM) training.

DETAILS:

- 15 year old single subject with a history of chronic migraine headaches, learning and behavioral difficulties, including attention-deficit/hyperactivity disorder (ADHD), obsessive compulsive disorder, and Tourette Syndrome
- interventions consisted of spinal manipulation applied to the cervical, lumbar, and pelvic regions of the left side of his body; IM training sessions; and exercises such as rightward pursuits with saccades back to center along with left-sided coordinated activities for 42 visits over 19 weeks.
- at the conclusion of these interventions:
    - timing improved 39% on the IM Long Form Assessment
    - neurological soft signs reduced by 90%
    - performance on the Tests of Variables of Attention (TOVA) was within normal range
    - Conner's Parent Rating improved by 34% to within normal range and not indicative of ADHD
    - California Achievement Test scores increased by 2.5 to 7.1 grade equivalents
    - chronic migraine headaches ceased, vision improved with change in corrective lenses required, general health improved (reduction in asthma symptoms), and tics were essentially gone unless stressed or emotional
    - decreased from 6 different medications to none
    - improved with parents and peers (elected to prom court, voted most outgoing and most academically inclined by school peers)

A Collective Review of Completed Research Projects Evaluating the Effectiveness of the Interactive Metronome® as an Occupational Therapy Intervention

YEAR: 2013 **PUBLICATION:** WHITE PAPER PRESENTED AT NATIONAL AMERICAN OCCUPATIONAL THERAPY ASSOCIATION (AOTA) CONFERENCE 2013 **AUTHOR:** Leonard G. Trujillo

RESULTS:

The Review of the past 5 years of Interactive Metronome (IM) research on motor function (from 2008-2013) revealed a positive impact on fine motor skills. Study participants also indicated their belief that IM is an effective treatment. Although IM has been shown to be an effective treatment modality for use in clinic settings, it should be used in conjunction with more occupational-based interventions.

DETAILS:

- study 1 looked at normal individuals over the age of 55 and compared pre and post-test IM scores and those of the Nine Hold Peg Test (NHPT). Notable improvements ave. 24% and above were achieved.
- study 2 compared those clients following standard of care Active ROM exercise program compared to those who received IM training for 8 sessions. The percentage of change was 24% for the IM participants as compared to 10% following the in-home ROM.
- study 3 looked at 2 CVA cases – Both making notable changes with 30 days longevity retest and 2nd series of IM provided demonstrated performance improvement.
- study 4 compared 22 individuals (post CVA and healthy aging subjects). There were no significant differences in percentage of improvement between groups, which indicates that IM may be just as effective with individuals post-CVA as in healthy aging population.

ADULT

Reading Intervention Using Interactive Metronome® in Children with Language and Reading Impairment: A Preliminary Investigation

YEAR: 2012 **PUBLICATION:** COMMUNICATION DISORDERS QUARTERLY **AUTHOR:** Michaela Ritter, Karen A. Colson & Jungjun Park

RESULTS:

The experimental reading and language intervention group that also received Interactive Metronome (IM) training demonstrated far greater gains in reading rate/fluency and comprehension compared the control group that received the same reading and language interventions alone.

DETAILS:

- n=49 school-age children (grades 2-5) diagnosed with co-occurring language and reading impairments and enrolled in summer language and reading program at Baylor University were randomly assigned to:
  - experimental group: 28 who received the IM training for 15 minutes per day, 4 days per week for 4 weeks in addition to language and reading interventions 4 days per week for 4 weeks
  - control group: 21 only received language and reading interventions 4 days per week for 4 weeks
- pre-post testing included:
  - Dynamic Indicators of Basic Early Literacy Skills–6 Oral Reading Fluency (DIBELS-6 ORF)
  - Read Naturally Test to measure oral reading fluency
  - Gray Oral Reading Test–Fourth Edition (GORT-4) to assess rate, accuracy, fluency, and comprehension of reading
- pre-treatment comparisons: no significant differences between groups existed before the interventions

Timing abilities among children with developmental coordination disorders (DCD) in comparison to children with typical development

YEAR: 2012 **PUBLICATION:** RESEARCH IN DEVELOPMENTAL DISABILITIES **AUTHOR:** Sara Rosenblum & Noga Regeve

RESULTS:

The Significant differences were found in timing abilities (millisecond timing scores on Interactive Metronome, IM) between children with Developmental Coordination Disorder (DCD) and those who are typically developing (TD) with much slower response times in children with DCD. Temporal measures of handwriting performance between children with DCD and those who are TD yielded significant differences with far greater mean in-air time per stroke for all three tasks for the children with DCD. Additionally, moderate correlations were found between timing abilities (IM scores) and temporal measures of handwriting performance in each group. Timing abilities, as measured by IM, accurately predicted handwriting performance time among children with DCD. The authors strongly recommended consideration of IM as an evaluation and intervention tool for children with DCD.

DETAILS:

- n=42 children; ages 7-12 diagnosed with DCD (n=21) and those with typical development (n=21)
- Assessment measures:
    - Interactive Metronome (IM)
    - Computerized Penmanship Evaluation Tool (ComPET)

PEDIATRIC

The Effects of Interactive Metronome® on Bilateral Coordination, Balance, and Upper Extremity Function for Children with Hemiplegic Cerebral Palsy: Single-Subject Research

YEAR: 2012 **PUBLICATION:** JOURNAL OF KOREAN SOCIETY OF OCCUPATIONAL THERAPY* **AUTHOR:** Ji-Hye Jung & Su-Kyoung Kim

RESULTS:

An individual with hemiplegic cerebral palsy (CP) demonstrated significant improvement in bilateral coordination and balance following Interactive Metronome (IM) training.

DETAILS:

- n=1 single-subject experimental research using an ABA design
  - evaluated bilateral coordination without intervention in the baseline phase (A) for four sessions
  - IM training provided for 40 minutes 2x/week for 10 weeks, with a total of 20 sessions, and bilateral coordination was measured after each training
  - during the second baseline phase, data were collected using the same procedure as the first baseline phase, with balance assessed before and after IM training

**Publication currently only available in Korean language.*

PEDIATRIC

Evaluation of the Hardy Brain Camp

YEAR: 2012 **PUBLICATION:** WHITE PAPER **AUTHOR:** Hannah Grossman & Mary E. Brenner

RESULTS:

The group that received IM + ball training improved the most in the area of processing speed (2 years 9.5 months) compared to IM training alone and the control group. The group that received IM training alone improved the most in the areas of reading fluency (8 months) and math fluency (7.5 months) compared to the other groups.

DETAILS:

- n= 62 elementary students, grades 2-5, were divided into 3 groups:
  - experimental 1: 21 received only IM training
  - experimental 2: 20 received IM training plus ball training
  - control: 21 received basic Boys and Girls Club enrichment activities, such as homework help and game playing
- pre-post assessment via Woodcock-Johnson: processing speed, reading fluency and math fluency subtests

Short- and long-term effects of synchronized metronome training in children with hemiplegic cerebral palsy: A two case study

YEAR: 2012 **PUBLICATION:** DEVELOPMENTAL NEUROREHABILITATION **AUTHOR:** Anna-Maria Johansson, Erik Domellof & Louise Ronnqvist

RESULTS:

Two children with cerebral palsy (CP) demonstrated smoother and shorter bimanual movement trajectories, especially for the affected side. Additionally, one child exhibited increased smoothness of the non-affected side. Noticeable improvement in motor learning occurred immediately post training and was maintained at 6 months post training.

DETAILS:

- n=2 children with hemiplegic CP (17 year old girl and 13 year old boy) underwent 4-weeks/12 sessions of IM training
- uni- and bimanual upper limb movements were assessed via kinematic analysis
    - pre-training
    - post completed training
    - 6-months post completed training

PEDIATRIC

Academic and Behavioral Improvements in 2nd-8th Grade Students in the hardy Brain Camp Program: Report on the Hardy Brain Camp Pilot Study of the Boys & Girls Clubs of Greater Oxnard and Port Hueneme and the United Boys & Girls Clubs of Santa Barbara County

YEAR: 2011 **PUBLICATION:** WHITE PAPER **AUTHOR:** Jamshid Damooei

RESULTS:

The Students demonstrated an average increase of 9.1 months in reading, 3.9 months in math, and 1.6 years in processing speed following participation in the Hardy Brain Camp Pilot Program, which includes Interactive Metronome (IM) training.

DETAILS:

- n= 54 students (grades 2-8) were studied before and after participation in the Hardy Brain Camp Program that included 20 sessions of IM training (45 minutes each)
    - difficulties with learning, attention, organization, behavior, poor grades, listening, following directions, completing schoolwork, reading and/or math weaknesses
- pre-post measures
    - Mathematics Performance Inventory
    - Woodcock-Johnson (processing speed, reading fluency, math)
    - WISC Coding and Symbol to measure processing speed

PEDIATRIC

Computer-Based Rhythm and Timing Training in Severe, Stroke-Induced Arm Hemiparesis

YEAR: 2011 **PUBLICATION:** AMERICAN JOURNAL OF OCCUPATIONAL THERAPY **AUTHOR:** Sarah C. Beckelhimer, Ann E. Dalton, Charissa A. Richter, Valerie Hermann & Stephen J. Page

RESULTS:

The Two men in the chronic stage of recovery from stroke demonstrated reduced arm impairment (indicated by FM scores of 12.0 and 14.0) and increases in average functional ability (10.85 and 11.1 points on the AMAT), perceived quality of life (12.0 and132.0 points on the SIS), and perception of overall recovery (110.0 points for each participant on the SIS) following combination of Interactive Metronome (IM) training.

DETAILS:

- n=2 male subjects, 68 year old male 23 years post-CVA & 75 year old male 2 years, 2 months post-CVA
- IM training was provided for 60 minutes, 3 days/week for 4 weeks
- investigators that conducted assessments were blind the intervention provided in the study, including:
    - Fugl-Meyer Scale (FM) – upper extremity section
    - Arm Motor Activity Test (AMAT)
    - Quality of Movement Scale
    - Canadian Occupational Performance Measure (COPM)

ADULT

Effects of motor sequence training on attentional performance in ADHD children

YEAR: 2011 **PUBLICATION:** INTERNATIONAL JOURNAL ON DISABILITY AND HUMAN DEVELOPMENT **AUTHOR:** Gerry Leisman & Robert Melillo

RESULTS:

Elementary school-aged children with ADHD demonstrated significant improvement in behavior following Interactive Metronome (IM) training.

DETAILS:

- Group 1 n=36 male children aged 6 – 11 years, diagnosed with ADHD randomly assigned to group 1
  - demonstrating inattention, hyperactivity, impulsivity, academic underachievement, or behavior problems
  - RECEIVED IM training for a period of 3 months
- Group 2 n=42 male children aged 6 – 11 years, with ADHD randomly assigned to group 2
  - demonstrating inattention, hyperactivity, impulsivity, academic underachievement, or behavior problems
  - DID NOT RECEIVE IM training for the period of 3 months
- Group 3 n= 16 normal male children aged 6 – 11 years were the matched control group
  - RECEIVED 3-month exposure to IM training
- Group 4 n=15 normal male children aged 6 – 11 years
  - DID NOT RECEIVE IM training exposure
- academic performance measures and neuropsychological tests were analyzed pre and post

PEDIATRIC

Improved motor-timing: effects of synchronized metronome training on golf shot accuracy

YEAR: 2009 **PUBLICATION:** JOURNAL OF SPORTS SCIENCE AND MEDICINE **AUTHOR:** Marius Sommer & Louise Rönnqvist

RESULTS:

Experienced golfers who participated in IM training demonstrated significant gains in sensorimotor timing & golf shot accuracy, demonstrating less variability & greater consistency of performance from one shot to the next, compared to the control group who did not demonstrate any significant improvement.

DETAILS:

- n= 26 experienced male golfers (mean age 27 years; mean golf handicap 12.6) were randomly assigned to 2 groups:
  - experimental: n=13 IM training, 45-50 minutes each for 12 sessions (over 4 weeks)
  - control: n=13 training the golf swing
- golf shot accuracy was measured for 3 different clubs using a golf simulator

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

YEAR: 2008 **PUBLICATION:** CONTEMPORARY ISSUES IN COMMUNICATION SCIENCE AND DISORDERS **AUTHOR:** Jessica J. Sabado & Donald R. Fuller

RESULTS:

The An adolescent female diagnosed with LLD demonstrated substantial improvement in language skills following Interactive Metronome (IM) training.

DETAILS:

- n=1 13 year old female with diagnosis of LLD
- participated in 15 sessions of IM training, 50 min each (no other language interventions where provided during the study)
- pre-post assessments:
  - Expressive One-Word Picture Vocabulary Test (EOWPVT)
    - pre: SS 93, PR 66, AE 11 years, 4 months
    - post: SS 124, PR 95, AE >19 years
  - Oral and Written Language Scales (OWLS)
    - pre: SS 86, PR 18, AE 9 years, 6 months
    - post: SS 99, PR 47, AE 12 years, 9 months
  - post assessments were conducted 1 month following cessation of IM training

PEDIATRIC

Improvements in interval time tracking and effects on reading achievement

YEAR: 2007 **PUBLICATION:** PSYCHOLOGY IN THE SCHOOLS **AUTHOR:** Gordon E. Taub, Kevin McGrew & Timothy Z. Keith

RESULTS:

Students that participated in Interactive Metronome training performed statistically better on measures of timing, reading efficiency, reading fluency and phonological processing as compared to same age peers that participated in recess. The IM group demonstrated improved timing that was 2 standard deviations greater than the control group, and timing improved the most in those with initial poor timing.

DETAILS:

- n=86 students (37 male, 48 female) ages 7-10 in 1st – 4th grades were randomly assigned to:
    - experimental group: 18 sessions of IM training, 50 minutes each
    - control group: recess
- none of the students participated in language/reading instruction/activities during the study
- pre-post measures of reading achievement:
    - millisecond timing via Interactive Metronome (IM)
    - Woodcock-Johnson III (WJ III)
    - Comprehensive Test of Phonological Processing (CTOPP)
    - Test of Word Reading Efficiency (TWRE)
    - Test of Silent Word Reading Fluency (TSWRF)

The Effect of Interactive Metronome® Training on Children's SCAN-C Scores

YEAR: 2006 **PUBLICATION:** WHITE PAPER, Doctoral Dissertation, Nova Southeastern University **AUTHOR:** Joel L. Etra

RESULTS:

Children who were identified as having difficulty with attention demonstrated statistically significant improvement in timing and performance on auditory processing subtests of filtered speech, figure-ground, and dichotic listening.

DETAILS:

- n=8 children (6 male, 2 female) ages 8-14 years considered by parents & teachers to be deficient in attention; 2 of the children were diagnosed with Asperger's
- none of the children were receiving services for Auditory Processing Disorder
- pre-post measures:
  - Interactive Metronome (IM) for timing & rhythm
  - Test for Auditory Processing in Children (SCAN-C)
- intervention: 15-17 sessions of IM training, 60 minutes each, 2-3 times per week

PEDIATRIC

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

YEAR: 2005 **PUBLICATION:** PHYSIOTHERAPY THEORY AND PRACTICE **AUTHOR:** Melinda L. Bartscherer & Robin L. Dole

RESULTS:

A young boy demonstrated significant improvement in fine and gross motor skills following Interactive Metronome (IM) training. His parents also reported greater flexibility, cooperation and attention span.

DETAILS:

- n=1, 9 year old boy with nine-year-old boy with developmental delay and trouble with attention
- pre-post assessment via Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)
    - o pre: significant delay in both gross and fine motor skills, with the greater deficiency in fine motor skills (below the 1st percentile when compared to children of similar age)
    - o post: improved in most areas assessed by BOTMP, most notably to 14th percentile for fine motor skills
- intervention: Interactive Metronome (IM) training for 7 weeks totaling 15 sessions (1,500-2,000 repetitions per session)

PEDIATRIC

The role of functional MRI in defining auditory-motor processing networks

YEAR: 2004 **PUBLICATION:** WHITE PAPER presented at National Physical Medicine & Rehabilitation Conference 2004 **AUTHOR:** Dr. Neal Alpiner

RESULTS:

Normal adults with extensive experience with Interactive Metronome (IM) training participated in this fMRI study along with 1 untrained control to demonstrate that the brain can be trained through synaptic modulation to augment existing neural pathways. Brain structures activated bilaterally by IM training in this study include: Cingulate Gyrus, Temporal Gyrus, and Superior Frontal Gyrus. “Repetitive auditory-motor training, specifically IM holds promise for neuroplasticity of higher and lower brain centers.”

DETAILS:

- n=7 normal adults (age 26-64; 4M, 3F) with extensive training in Interactive Metronome (IM) and n=1 control subject that had no IM training experience
- subjects placed in fMRI scanner, and used internal cycling noise (“chirping”) to simulate IM auditory sounds to recreate learned auditory-motor behaviors
    - 5/7 subjects revealed increased activity at right Calcrine Sulcus
    - 3/7 showed bilateral increased activity at Cingulate Gyrus
    - 5/7 subjects showed increased activity at left posterior Temporal Gyrus
    - 2 patients show bilateral increased temporal activity
    - 3/7 patients show increased activation at right superior Frontal Gyrus
    - 4/7 patients showed increase at left Superior Frontal Gyrus with 1 patient revealing bilateral activation
    - 3/7 patients showed activation at left Posterior Central Gyrus
    - 1 patient without IM training had absent activity

Pathways Center Final Statistical Analysis

YEAR: 2003 **PUBLICATION:** WHITE PAPER **AUTHOR:** Lee E. Jacokes

RESULTS:

Children at the Pathways Center demonstrated improvement in several areas following Interactive Metronome (IM) training, which were maintained for the most part 6 months post-study. Statistically significant improvements were measured in the areas of: balance, bilateral coordination, handwriting, sensory processing, attention, behavior, & fundamental cognitive skills needed for effective concept development and reasoning.

DETAILS:

- n=13 clients of the Pathways Center
- pre-post measures (immediately post-IM training, at 3 months and at 6 months):
    - Clinical Evaluation of Language Fundamentals, Third Edition
    - Bruininks-Oseretsky Test of Motor Proficiency
    - Sensory Profile – Care Giver Questionnaire
    - Interactive Metronome Parent Questionnaire
    - Self Perception Survey
    - Handwriting Evaluation Tool
    - The Listening Test
    - Draw A Person

PEDIATRIC

Processing speed and motor planning: the scientific background to the skills trained by Interactive Metronome® technology

YEAR: 2003 **PUBLICATION:** WHITE PAPER **AUTHOR:** Susan J. Diamond

RESULTS:

This author reviewed the literature pertinent to brain plasticity, hemispheric interaction, motor planning, attention, memory and language, the role of the evoked potential electrical signal, and the role of soft signs to discover more about the brain interactions witnessed following IM training.

DETAILS:

- "Interactive Metronome (IM) likely increases speed of brain processing, and reduces "noise" or variability, making it more efficient as a signal processor. Efficient signal processing has been demonstrated to be associated with higher IQ scores and better task performance."
- some of the topics covered include:
  - brain regions activated by a precise menu of movements
  - intimate connection between motor planning and sensory processes
  - how learning acquisition and retrieval stages differ and are influenced by which side of body is engaged
  - how widespread brain activations occur with even simple movements, and affect brain activities including memory
  - and sequencing as well as sensory input areas
  - how motor routines alter hemispheric interactions in specific ways
  - the role of the corpus callosum
  - central nervous system inefficiency & motor deficits in ADHD
  - response inhibition deficits associated with ADHD, Tourette's, OCD and other disinhibition syndromes
  - how response speed and the ability to inhibit responding appropriately are both associated with learning, with ADHD, and with developmental difficulties
  - how response times in discrimination tests can be improved by a movement program
  - brain activation processes involved in motor learning, and how early learning of skilled movements involves a subset of the same widely distributed brain network for motor execution
  - how movement plays a role in establishing patterns that go into long term memory

Learning Problems and the Left Behind

YEAR: 2003 **PUBLICATION:** WHITE PAPER presented at The Annual Meeting of the National Association of Elementary School Principals **AUTHOR:** Dr. Cindy Cason

RESULTS:

Students who received IM training performed significantly better on tests of reading & math fluency and improved 1-2 grade levels in reading comprehension and fluency as compared to matched controls.

DETAILS:

- n=80 subjects
  - experimental group: 40 4th and 5th grade students identified as Title I eligible and scoring in the lowest three stanines on the reading subtest of Stanford Achievement Test - Edition Nine participated in 12 sessions of IM training (1 hour each) in group setting with 4 students:1 trainer
  - control group: 40 matched peers based upon School Ability Index scores from the Otis Lennon School Ability Test
- pre-post measures:
  - Woodcock Johnson III: reading and math fluency subtests
  - STAR reading assessment
  - Stanford Achievement Test results for the testing prior to training and post training were reviewed

Interactive Metronome- Underlying neurocognitive correlates of effectiveness

YEAR: 2003 **PUBLICATION:** WHITE PAPER **AUTHOR:** Dr. Patrick Gorman

RESULTS:

The "The Interactive Metronome (IM) incorporates motor planning, rhythmicity, and sensory integration over the exercises presented. These elements have been shown through research, some of which is reviewed here, to facilitate neuronal stimulation. Consistent with theories of neuropsychological functioning and cortical organization, this treatment can facilitate greater attention, mental processing, and cognitive abilities."

DETAILS:

- according to the DMS-IV, impairments in attention, motor planning, coordination, mental organization, and sequencing are common to many different clinical disorders
- the brain is malleable and capable of transforming in the presence of the right amount of stimulation
- sensorimotor synchronization involves multiple areas of the brain – it is a whole brain activity – what is fired together is wired together
- the importance of "rhythm" for cognitive performance cannot be overstated – "...attention and awareness play integral roles in directed behaviors"

Training in timing improves accuracy in golf

YEAR: 2002 **PUBLICATION:** THE JOURNAL OF GENERAL PSYCHOLOGY **AUTHOR:** Terry M. Libkuman & Hajime Otani

RESULTS:

Golfers who participated in the experimental Interactive Metronome (IM) training demonstrated significantly better performance in the golf simulator compared to the control group. Timing training appears to improve shot accuracy by fine-tuning the tempo and rhythm of the golf swing and synchronizing cognitive intention with motor execution.

DETAILS:

- n=40 (6 female, 34 male) 25-61 year old golfers were randomly assigned to
    - experimental group: participated in 12 sessions of IM training (50 minutes each) in a group setting; each participant partitioned off from the other to minimize distraction
    - control group: received a letter containing 12 pages of golf tips taken from popular golf magazines to be read once daily during the study period
- Full Swing Golf Simulator was used to measure golf shot accuracy pre & post (15 shots with driver, 9, 7 and 5 irons)

Timing in child development

YEAR: 2002 **PUBLICATION:** FRONTIERS IN HIGH SCOPE PRESS **AUTHOR:** Kristyn Kuhlman & Lawrence Schweinhart

RESULTS:

Metronome timing was strongly correlated with motor control/coordination, the ability to sustain attention and concentration, age, and kindergarten achievement. Timing was discovered to be developmental with older children demonstrating better metronome and musical timing than younger children. Additionally, metronome and musical timing were significantly correlated with performance on the California Achievement Test (children at or above the 80th percentile had significantly better metronome timing than children at the 59th percentile or below). Metronome and musical timing were both more strongly correlated with a child's ability to focus than household income or parents' highest level of education.

DETAILS:

- n=585 4-11 year old children
- objective measures:
    - Interactive Metronome: timing skills
    - High/Scope Beat Competence Analysis Test: musical timing
- validity verified via:
    - parent questionnaires
    - teacher questionnaires
    - kindergarten-teacher child achievement reports
    - California Achievement Tests for grades 1 through 4

PEDIATRIC

Theoretical and Clinical Perspectives on the Interactive Metronome®: A View From Occupational Therapy Practice

YEAR: 2001 **PUBLICATION:** AMERICAN JOURNAL OF OCCUPATIONAL THERAPY **AUTHOR:** Jane Koomar, Jeannetta D. Burpee, Valerie DeJean, Sheila Frick, Mary J. Kawar & Deborah Murphy Fischer

RESULTS:

The Six (6) esteemed professionals from the field of Occupational Therapy provide their clinical perspectives on the Interactive Metronome (IM) and its effectiveness with children who have Sensory Processing Disorders.

DETAILS:

- IM training, when used along with a sensory integration approach, may facilitate the ability to benefit fully or achieve even greater gains from sensory integration therapies
- IM training can be adapted to meet the individual needs of the child in a meaningful way that is intrinsically motivating to the child
- temporary disorganization may occur in the child with Sensory Processing Disorder during and after IM training sessions, but typically resolves and is followed by greater clinical improvement
- children use an inordinate amount of cognitive resources to accomplish daily activities at great expense to attention and ability to self-regulate – IM training appears to facilitate the conscious control initially then transitions conscious control to a level of automaticity, freeing up valuable cognitive resources for improved focus and behavior
- skilled therapists are exploring expanded applications of IM in their practice settings to address such things as vestibular function, body core strength and support, and other goal-directed activities

PEDIATRIC

Effect of Interactive Metronome® Training on Children with ADHD

YEAR: 2001 **PUBLICATION:** AMERICAN JOURNAL OF OCCUPATIONAL THERAPY **AUTHOR:** Robert J. Shaffer, Lee E. Jacokes, James F. Cassily, Stanley I. Greenspan, Robert F. Tuchman & Paul J. Stemmer, Jr.

RESULTS:

School age boys who received Interactive Metronome (IM) training demonstrated statistically significant improvement on 53 of 58 variables measured ($p<.0001$). Same age boys in a video-game control group also demonstrated improvement on 40 of 58 variables; however, the boys who received IM training experienced substantially greater improvement than the video game group, suggesting IM produced significant additional benefits beyond the experience of a computer game. The no-intervention control group did not improve based upon statistical analysis.

DETAILS:

- n=56 boys ages 6-12 with diagnosis of ADHD were randomly assigned to 1 of 3 groups:
  - experimental group: 19 received 15 sessions of IM training, 1 hour each, over 3-5 weeks
  - video game control group: 19 played 15 sessions of video games, 1 hour each, over 3-5 weeks
  - control group: 18 received no intervention
- both experimental and video game control group parents and children were told purpose of study was to explore non-pharmacological treatment of ADD/ADHD with computer-based treatment programs
- upon completion of the study, both video game and no intervention control group participants also received IM training
- pre-post measures:
  - Tests of Variables of Attention (TOVA)
  - Connors' Rating Scales – Revised (teacher & parent versions)
  - Wechsler Intelligence Test for Children – Third Edition
  - Achenbach Child Behavior Checklist
  - The Sensory Profile
  - Bruininks-Oseretsky Test for Motor Efficiency
  - Wide Range Achievement Test – 3
  - Language Processing Test

PEDIATRIC