Keep the BEAT

The Interactive Metronome® Is a New Computer-Based Technology to Measure and Improve Rhythmicity, Timing, Reciprocity and Cognitive Functioning

By Stanley I. Greenspan, MD	Chairman, Scientific Advisory Committee, Interactive Metronome, Inc.
Lee Jacokes, PhD	Vice President of Research, Interactive Metronome, Inc.

For a considerable time, there has been a view that a human being's capacity for timing and rhythmicity plays an important role in a variety of behaviors including motor planning, sequencing and cognitive functions, such as attention and academic achievement[1,2]. Concern about timing as a human capacity goes back centuries to philosophical arguments of Aquinas, Newton, Leibnitz and Kant about the nature of time and how humans come to perceive it[14].

The measurement of timing became more robust in the middle of the 19th century with the introduction of the psychophysical methods of Weber and Fechner[3], the empirical study of the accuracy of the perception or estimation of temporal intervals[4] and the 1860 to 1896 investigations of "time-sense."[5] Now, assessing time perception involves the estimating of the duration between two bracketing events representing the beginning and ending of an interval of time[6,7].

Rhythmicity is an extension of time perception, referring to the ability to consistently over time repeat both fixed and/or variable length intervals[8,9]. That rhythmicity is important to human functioning is supported by developmental studies that find both fetuses and newborns perceiving time and estimating duration of events[10,11]. Others have found newborns able to discriminate speech rhythms of different cultures[12]. Jaffe, et al. has demonstrated the importance of rhythmicity to infant-mother dialog and the relationship of rhythmicity to early cognitive development[13].

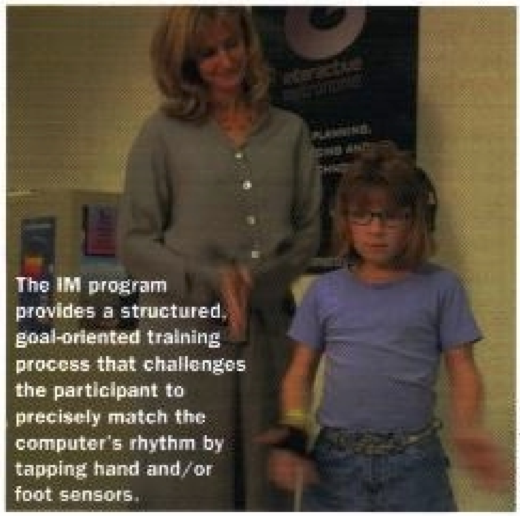
A number of studies have found timing related to measures of overall school achievement, including mathematics and reading, to language and mathematics performance and in differentiating average readers from above-average readers. Weikart, et al. in an unpublished study found connections between timing and rhythmicity and selected areas of academic performance as did Au and Lovegrove[14,15]. In addition, problems in timing and rhythmicity are seen in children and adults with attentional, motor and cognitive challenges. Different areas of the central nervous system appear to contribute to this capacity, including the cerebellum, prefrontal cortex and the basal ganglia.

Photo by Don [illegible]

In summary, there has been evidence that timing and rhythmicity is an important central nervous system function related to a number of attentional, cognitive and motor skills. While more research is needed to confirm and extend these findings, it may be useful to consider the developmental pathways through which timing and rhythmicity exerts its influence on higher-level cognitive functioning.

Exploring Pathways that Influence Processes

How does the vital capacity for rhythmicity and timing influence higher-level cognitive and academic abilities? There are a number of steps to this process. First, timing and rhythmicity are necessary in order to learn to sequence and plan actions (i.e., to be purposeful with one's environment). This ability for motor planning and sequencing is a foundation in human development that begins in early infancy. The infant actually begins to learn to interact with his environment in a rhythmic and timed way in utero, when we can observe him respond to sounds and to types of touch and movement. He is also hearing his mother's heartbeat and sensing her breathing rhythms. Almost immediately after birth, newborns will respond to sights and sounds and begin patterns of looking and listening. These early interactions with the world are organized in time and rhythmic sequences, as are the infant's cycles of alertness, sleep and wake, as well as other biological rhythms (which are partially endogenous, but also partially influenced by the environment).



The IM program provides a structured, goal-oriented training process that challenges the participant to precisely match the computer's rhythm by tapping hand and/or foot sensors.

The infant uses his timed and rhythmic interactions with the world to begin two distinct patterns. One is to further establish his synchrony with his caregivers, as we observe when babies in the early months of life are involved in shared looking, smiling, rhythmic motor activity and a variety of affective expressions

with their caregivers. This capacity for synchrony, based on coordinated rhythmic activity, keeps developing through life.

The second pattern, which builds on the first, is for the capacity to plan and sequence actions. The infant's capacity for timed and rhythmic interaction with the world outside his own body enables him to begin patterns of interaction with his caregivers. Caregivers are also usually capable of engaging in timed and rhythmic interaction. Rapidly, a shared process of rhythmic interactive patterns is established. Over the early months of life, the infant learns (as his central nervous system is growing) that this rhythmic interactive relationship can be used in a purposeful or causal way (he sees that his smile leads to mom's smile). In other words, initially rhythmic interactions are used to establish a relationship with caregivers outside oneself and help establish an outer reality or world, as well as a relationship with caregivers. Then this infant/caregiver relationship becomes more purposeful and causal. It is a two-way causality (i.e., a reciprocal exchange of signals).

Initially, these reciprocal interactions with caregivers (i.e., purposeful, back-and-forth exchanges) involve simple smiles, looks, affective expressions and other motor behaviors, such as reaching, taking and returning.

Over time, reciprocal, affective exchanges become the basis for the early sense of purpose or causality. During the first two years of life, they grow into more complex planning and sequencing capacities, a sense of self and the ability for pattern recognition, as well as for regulating behaviors, mood and attention and social skills[16,17].

This capacity for planning and sequencing, used to establish a sense of self and social relationships, enables the infant and toddler to learn complex problem-solving, such as taking a parent by the hand and showing her the desired food. Even later on, toward the middle part of the second year, the toddler uses this ability to plan and sequence to investigate and problem-solve with his environment on his own. He may search for a hidden toy or figure out where his mother is when visiting a new house. Eventually, this same capacity to plan and sequence becomes the basis for forming symbols and combining or sequencing ideas (saying things like, "I want juice now" or "Where is Daddy?"). It then becomes the basis for thinking (answering questions such as "Why do you want to go outside?" with "Because I want to play."). Subsequently, it is the basis for sequencing ideas together into a complex logical pattern, such as in writing an essay about a book or in other higher-level cognitive and academic tasks. In just about all advanced thinking and problem solving, the ability to plan and sequence behaviors and thoughts is at the foundation[16,17].

Throughout this process, there is an intimate relationship between timing, rhythmicity and synchrony and motor planning, sequencing, problem-solving and affective reciprocity. Through his reciprocal emotional interactions with his caregivers, the child continues to be involved in timed and rhythmic back-and-forth communication. These back-and-forth communications, which build on his capacity for timing and rhythmicity, in turn give rise to these higher-level planning and sequencing capacities, ultimately involving complex reflective

CASE STUDY No. 1

An 11-year-old boy who had suffered a brain injury while in the second grade was now in the sixth grade, emotionally traumatized and unable to write a single sentence. Prior to starting IM training, he had spent an entire school year not being able to produce any written work. When his training was completed, he sat down and wrote a one-page letter to his girlfriend.

No. 1

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CASE STUDY No. 2

After IM training, a 4-year-old boy with cerebral palsy finds it easier to climb stairs without assistance. His mother also has noticed a new level of confidence, such as wanting to play with a neighborhood boy whose faster movements had previously frightened him.

No. 2

thought and verbal communication. Recent research supports this model[14]. It shows that the rhythmicity and timing of infant-caregiver reciprocal interactions correlates with early cognitive capacities. Our own research also supports these same conclusions for school-age children and further shows that problems with timing and rhythmicity are associated with difficulties with modulating attention, behavior and motor performance[8,13].

Challenges Compromise Core Processes

We see these two core processes compromised in a variety of challenges involving attention, language, motor planning and motor coordination, social interactions and learning disabilities, including nonverbal learning disabilities, as well as during the aging process.

In all these different challenges, most noticeable is a difficulty in planning and carrying out complex problem-solving actions (i.e., motor planning and sequencing). For example, during the aging process, there is, along with memory loss, a difficulty in carrying out multi-step actions. Sometimes, in fact, what appears to be a memory problem is more a problem in complex sequencing. Children with attentional problems often have what are referred to as problems with their executive functions (i.e., their ability to plan and sequence complex actions, such as following complex directions on a test). For some children, planning and sequencing is harder when it's verbal sequencing; for others, when it involves visual design or the execution of the motor plan—and for others, all the above.

Clinically, we observe that individuals with these challenges also often have challenges in their ability for engaging in long chains of complex affective (emotional) reciprocity (i.e., the rapid reading of and responding to emotional signals with another person to negotiate and problem-solve). It is not surprising that many children with sequencing difficulties also have difficulties reading and responding to complex social cues, since they are part and parcel of the same process.

Even more basic, however, is the foundation for affective reciprocity, which is the basic capacity for timing and rhythmicity. As we discussed earlier, the capacity for timing and rhythmicity begins the developmental process in early infancy. Therefore, when we look very closely at the components leading to adaptive interactive reciprocity, problem-solving and thinking, one of the most important ones is the individual's capacity for timing and rhythmicity. Clinically, we observe that an emerging research is supporting the assertion that the capacity for timing and rhythmicity, plus the opportunity to interact with others who are highly reciprocal (i.e., contingent or responsive) enables children of all ages as well as adults to learn to sequence and problem-solve. As indicated earlier, Jaffe, et al.[14] found that the ability of a baby to interact with a caregiver in a rhythmic and timed way was correlated with early cognitive capacities. Also, as indicated, we found that the ability to perform motor activities in a timed and rhythmic manner correlated with a variety of academic and cognitive measures during the school years[8], and that children with attentional problems and motor problems, as well as children in special education, tend to have more difficulties with their basic capacities for timing and rhythmicity[8,13].

CASE STUDY No. 3

A young girl who has issues of impulse control became less frustrated in school and began to physically act more appropriate after IM training. At one of her final sessions, the girl, who is big for her age and has difficulty understanding social cues, greeted her mother with a 'Mommy hug.' She explained that she used to give everyone 'Daddy-sized hugs,' but that "mommies should get Mommy hugs." Then she added, "Sometimes it's my strength that gets me into trouble."

CASE STUDY No. 4

An 11-year-old with midline issues (which affect balance) was tested using the balance subtest of the Bruininks-Oseretsky Test for motor proficiency. Before the Interactive Metronome, she scored as an 8-year-old. Following her training, she scored as a 12-year-old.

A Higher-Level Hierarchy

It appears that there is a hierarchy associated with advanced cognitive and social skills. The levels of the hierarchy are as follows:

- Rhythmic and timed interactions with the environment
- Rhythmic and timed interactions (approaching synchrony) with other human beings

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- Interactive reciprocity with others
- The capacity to plan, sequence and problem-solve in interaction with others
- The capacity to create and sequence symbols
- The capacity for reflective and anticipatory thinking

Assessments and interventions should involve all levels of the hierarchy. A comprehensive assessment and intervention program would, therefore, assess and work with rhythmicity and timing, the synchrony of interactions with others, interactive reciprocity, problem-solving, creating and using symbols and reflective and anticipatory thinking. Some of these levels are already worked with in many intervention programs for children with behavioral and/or learning problems, problems with attention and various academic challenges, as well as in working with challenges seen in aging populations. A missing piece, however, even in programs that attempt to be comprehensive, is work on the early levels of the hierarchy. For example, psychotherapy, cognitive behavior therapy and most special education approaches work at the higher levels of the hierarchy, as does family counseling. Many rehabilitation programs for children and adults, including elderly populations, work at the middle levels of the hierarchy. Medications tend to attempt to work at a basic biological level to improve attention, planning and sequencing (the middle of the hierarchy). In the future, a primary effort must be made to work at the first three levels of rhythmic and timed interactions with the environment, rhythmic and timed interactions with other human beings, and interactive reciprocity in a variety of affective and sensory processing contexts of graduated complexity. A number of us have been conducting research on a new approach to precisely measure and exercise the capacity for timing and rhythmicity and motor planning and sequencing. The Interactive Metronome®[20], a computerized version of the traditional music metronome used for centuries to monitor and maintain timing and rhythmicity, has enabled research to confirm and extend the findings on timing and rhythmicity described earlier[18], and demonstrate that it is possible to improve this basic capacity[19].

In conclusion, we have reviewed the importance of an individual's capacity for rhythmicity and timing for high-level cognitive, social and academic skills. We have described recent findings and presented a developmental model to explain the pathways through which the effects of rhythmicity and timing exert their influence. We have also stressed the importance of a comprehensive approach that includes all levels of the developmental hierarchy in assessing and intervening with developmental, cognitive and behavioral challenges. ◇

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Editor's Note: *Interactive Metronome, Inc., is based in Weston, Fla., with its national research and support center in Grand Rapids, Mich. The company offers its patented Interactive Metronome® training only through a growing network of hospitals, clinics and schools throughout the United States and Canada. For more information, visit www.interactivemetronome.com or call 954-385-4660.*