

Temporal Processing (Metal Timing)

Your brain has the capacity to detect differences in time as small as a microsecond, through milliseconds, minutes, and hours.

Interestingly our ability to keep track of the *order* in which things happen, and the time *between* events can be altered relatively simply. Imagine you have a button to push. When you do so you simultaneously hear a bang and see a flash. You push the button several times. Now, unknown to you, the wiring for these stimuli allows the bang to start happening *after* the flash by a few hundredths of a second. Your brain still tells you they are simultaneous. Why? Because subconsciously your brain is in a habit of delaying the conscious recognition of sound associated with visual stimuli. Visual stimuli travels through a more convoluted neural pathway than auditory stimuli before registering as conscious awareness, so it takes longer. Next, we take the delay out so that the bang and the flash are once again truly simultaneous. Now you report that the bang is happening *before* the flash.

All this is good news. It tells us our perception of *temporal processing* can be set and reset through environmental stimuli. Interactive Metronome works precisely in this zone. It allows the brain to *reset*, and *improve* temporal awareness, thereby enabling the trainee to make better sense of the world. The "world"? Well, yes. Mauk & Buonomano's (2004) paper *The Neural Basis of Temporal Processing* explains how Timing in the brain is responsible for detecting where a sound is coming from as sound hits one ear microseconds before the other, for waking up and putting to sleep our brain every 12 hours or so, and for focusing attention, reading comprehension, remembering information, processing speech and motor coordination (millisecond timing). When *temporal processing* is mis-timing for one or more of these activities, then getting it right (or making substantial improvement), really can make a world of difference. Timing is at the heart of virtually all we do.

Mauk, M.D. & Buonomano, D.V. (2004). *The neural basis of temporal processing. Annual Review of Neuroscience*, 27, 307-340.

There is a definite trend we see among individuals who undergo Interactive Metronome (IM) training, a program that improves timing in the brain or what is known as "temporal processing." They typically demonstrate improved motor coordination and ability to focus. Most also experience other benefits like improved reading comprehension and fluency, less aggression and better self-control, more legible handwriting, etc. This study may help us understand why we typically see improvement in BOTH cognitive and motor skills once timing skills are improved. Rubia & Smith (2004) show with fMRI that both motor timing and the timing associated with cognitive abilities are controlled by the same regions of the brain, "suggesting that both functions are probably inseparable and mediated by common neural networks." This is a good read for anyone interested in learning more about the specific brain structures and "networks" involved in human timing and their relation to

cognitive and motor skills. In many conditions, like ADHD, Autism, Dyslexia, Parkinson's, Traumatic Brain Injury, Stroke, ...we see that the person's ability to achieve and be more independent is impacted by deficits in BOTH *cognitive* and *motor skills*. Interactive Metronome, a patented training modality commonly used for these conditions, is the only program that addresses both of these skills simultaneously.

Rubia, K. & Smith, A. (2004). The neural correlates of cognitive time management: A review. Acta Neurobiologiae Experimentalis, 64, 329-340.

These statements were made by Lewis & Walsh (2005), prominent neuroscientists who study timing in the brain. "Our brains measure time continuously. We are aware of how long we have been doing a particular thing, how long it has been since we last slept, and how long it will be until lunch or dinner. We are ready, at any moment, to make complex movements requiring muscle coordination with microsecond accuracy, or to decode temporally complex auditory signals in the form of speech or music. Our timing abilities are impressive, diverse and worthy of investigation. But they are not very well understood." In this paper entitled, Time Perception: Components of the Brain's Clock, they briefly outline the problems with identifying the exact mechanism for human time estimation. "Regardless of their diversity, the models [or theories about timing in the brain] all agree that temporal information is processed in many ways: it is remembered, compared to other temporal information, combined with sensory information, and used in the production of motor outputs." While we wait for neuroscientists to refine their methodology and identify the holy grail of mental timing, we don't have to wait before we introduce the concept of timing into habilitation & rehabilitation programs for individuals with developmental disorders, acquired brain injury from TBI or stroke, or certain degenerative diseases. There exists a growing body of literature describing the neural timing deficits in ADHD, Dyslexia, Autism, Reading Disorders, Auditory Processing Disorder, Parkinson's, and Huntington's. By addressing timing in the brain with Interactive Metronome (IM) alongside functional therapy interventions you are not only addressing areas of ability that impact achievement and independence but also the heart of the problem, that of deficient timing. This can only lead to more efficient treatment and better overall outcome.

Lewis, P.A. & Walsh, V. (2005). Time perception: Components of the brain's clock. Current Biology, 15(10), R389-R391.

I like this description about timing in the brain by Dr. Penny Lewis (2006). "Time measurement [in the brain] is fundamental to almost everything we do: music and speech, for instance, are just time-coded variations in sound, and movements are carefully timed contractions of muscles. We perceive our lives as a flow of events in time, and plan our futures in the same way. If our timing system gets damaged, as it does in patients with Parkinson's Disease, Schizophrenia, and certain types of brain injury, all of these

abilities can be impaired.” Did you realize that mental timing was so important? Why do we still conduct therapies without incorporating timing and rhythm? Certainly, after review of the ever-growing body of research demonstrating its importance, we now know how important timing is to speech, language, cognition, and motor skills. Surely, we will begin to incorporate the foundational skill of timing more and more into our interventions for children and adults who are seeking greater achievement, independence, and quality of life. Interactive Metronome (IM) is a patented treatment tool for doing just that. It has been successfully used with individuals of all ages, from early intervention with infants to treat hemiplegia, sensory, communication/language, and cognitive skills to geriatric patients with aphasia, decreased independence with self-care and basic ADLs, cognitive impairments that affect safety judgment, and increased fall risk.

Lewis, P.A. (2006). Emotion, memory, and the perception of time. The University of Liverpool. Unpublished white paper.

Scientists agree that our brain contains a “clock,” or at least one, maybe more than one. What they can’t precisely agree on, but generally seem to understand each other’s viewpoints on, is the central location of the ticker... Is it in the basal ganglia, the striatum, the dorsolateral prefrontal cortex, the cerebellum??? There are good arguments for each location, ... perhaps they are all involved and work in a “network” of sorts or perhaps they are all individual clocks that keep time in our brain for various different functions ... processing speech or music, coordinating movements, paying attention, etc. Dr. Penny Lewis, in this 2002 article titled Finding the Timer, discusses new and important research by Constantinidis et al. (2002) that may help shed more light on the location and mechanism for mental timing. Of course, more research has been published since then, but are we any closer to knowing?? Fortunately, we don’t have to know the exact location of the ticker to know how important it is or that we professionals absolutely must assess and treat timing in the brain just as we do the various skills that are controlled by timing in the brain!! Interactive Metronome is an assessment and treatment tool that measures timing in the brain and improves it. It is flexible and is ideally administered alongside other functional interventions to build and strengthen abilities.

Lewis, P.A. (2002). Finding the timer. Trends in Cognitive Sciences, 6(5), 195-196.

Here is another study, one of MANY, that show a clear relationship between working memory and timing in the brain (Fortin et al., 2007). Essentially, if timing in the brain is disrupted, then working memory does not work very efficiently or effectively leading to a host of problems at home, school, work, and play. If you’ve been searching the Internet for a program or treatment to address school performance, a developmental delay or disorder, or overall brain fitness, then you’ve surely seen all the buzz about the importance of working memory for cognitive performance. Given the importance of timing

in the brain for working memory, and thus cognitive performance, it is critical to assess timing in the brain to see if that is the root of the problem. Interactive Metronome is a patented program that both assesses and improves timing in the brain, providing measurable scores each step of the way. Persons may then derive more benefit from the various cognitive fitness programs available once his/her brain is focusing, processing information, and utilizing cognitive resources like working memory more efficiently and effectively.

Fortin, C., Champagne, J, and Poirier, M. (2007). Temporal order in memory and interval timing: An interference analysis. Acta Psychologica, 126(1), 18-33.

Here is another favorite of mine when it comes to papers describing the human clock system, *How Do We Tell Time?* (Buonomano & Karmarker, 2002). It is easy to read, a huge bonus (you know what I mean if you have been following this stuff!!!), and goes into detail about the various levels of timing in the brain: microseconds, milliseconds, seconds, circadian rhythms... The authors also discuss the various theories that abound such as whether we have a distributed network of clocks or whether there is one central clock that does it all. All??? Right, the brain clock is intimately involved in our abilities to do the following: understand and produce intelligible speech (articulation, phonological processing disorders), read and write, organize our thoughts and communicate our ideas clearly and concisely (like I am doing!), attend to task, switch attention from one thing to another, multitask (mothers, you know what this one is!), sequence the steps to perform everyday tasks, listen to a class lecture and take notes, remember and learn new information, reach for a glass of water without knocking it over, walk with good speed, symmetry, and balance, and on and on... You might be asking by now, "What is wrong with my clock, with my child's clock, with my significant other's clock??" as you or they may be displaying difficulty with some of the skills I just described. The brain's clock can be disrupted (and the synchronicity of it can be out of whack) when there is a problem with childhood development (ADHD, Autism, Dyslexia...), injury to the brain (Traumatic Brain Injury, Stroke, Aneurysm...), or disease (Schizophrenia, Parkinson's, Huntington's...). The Interactive Metronome is a patented, flexible program that improves timing and synchronization in the brain. Professionals can easily incorporate IM training into treatment for speech, language, cognition, and motor skills (i.e., professionals in Speech & Language Therapy, Cognitive Rehabilitation, Physical Therapy, Occupational Therapy, Psychology Services, etc).

Buonomano, D.V. & Karmarker, U.R. (2002). How do we tell time? Neuroscientist, 8(42), 42-51.

In this 2004 issue of *Trends in Cognitive Sciences*, Nobre & O'Reilly comment on an important research study by Coull et al. (2004) that showed involvement of the fronto-striatal loop in mental timing-related cognitive and motor functions. This area of the brain has been implicated in the skills of

sequencing, attention-shifting and decision-making, particularly under time-pressure, as well as the planning and sequencing of motor movements. Here is yet another connection between thinking and motor skills...they appear to share at least some of the same neural circuitry. Perhaps this, at least in part, explains why the overwhelming majority of individuals who complete Interactive Metronome (IM) training typically demonstrate improvement in BOTH cognitive and motor skills. IM training involves synchronizing the body to move to a steady beat. Immediate feedback is provided (audio, visual, or both) to help the individual improve their overall mental and physical timing skills that form the basis for speech, language, thinking, behavior, and coordinated movement.

Nobre, A.C. & O'Reilly, J. (2004). Time is of the essence. Trends in Cognitive Sciences, 8(9), 387-389.

Here is a novel research idea. Rao et al. (2001) examined the various areas of the brain known to be involved in mental timing under fMRI during a time-perception task to see how timing in the brain unfolded in a sequential way. For example, they noticed that the basal ganglia lit up first and that it was uniquely associated with encoding time intervals. Also engaged early in the process were other parts of the neural timing network responsible for attention and temporary maintenance (or recall if you will) of time intervals in memory. Later in the process, as the brain compared current timing information to that from memory (is this the same, more, or less amount of time?), the right dorsolateral prefrontal cortex was activated. Also, late to activate was the cerebellum. "Our results illustrate a dynamic network of cortical-subcortical activation associated with different components of temporal information processing." What does this mean? Areas of the brain known to be involved in attention, memory/learning, and motor skills are part of this brain network for timing. Timing in the brain, in turn, determines how well a person can focus, learn, and move. Interactive Metronome is a patented training program that improves timing in the brain through a series of mind-body exercises that require a person to move to a steady beat. Most critically, immediate feedback is provided after each movement to help a person know how far off the beat (s)he is and make corrections to improve timing & rhythm. Improvement in focus, memory, reading, and motor skills occurs as a result of improved mental timing skills.

Rao, S.M., Mayer, A.R., and Harrington, D.L. (2001). The evolution of brain activation during temporal processing. Nature Neuroscience, 4(3), 317-323.