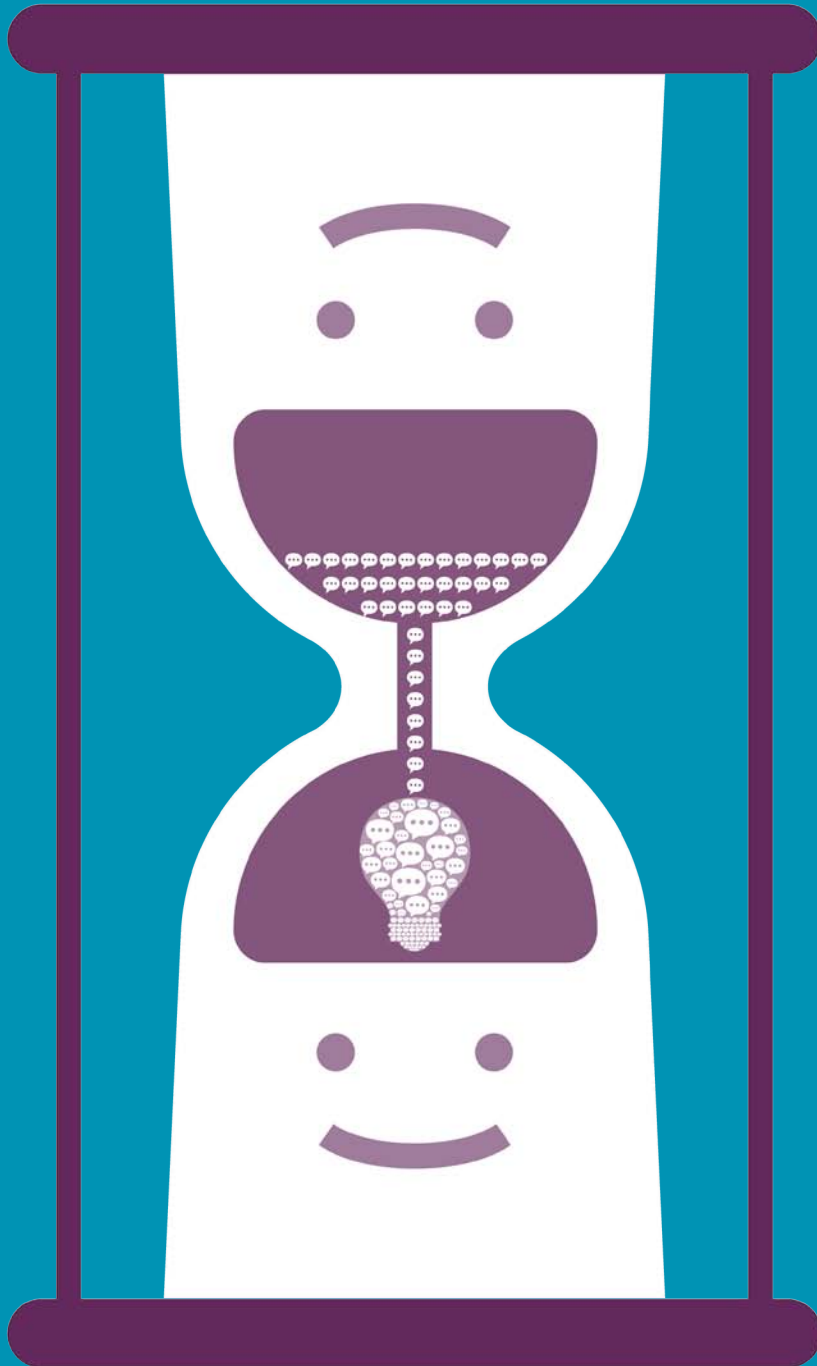


A Matter of Time



9
*things
you
should
know
about
your
brain*

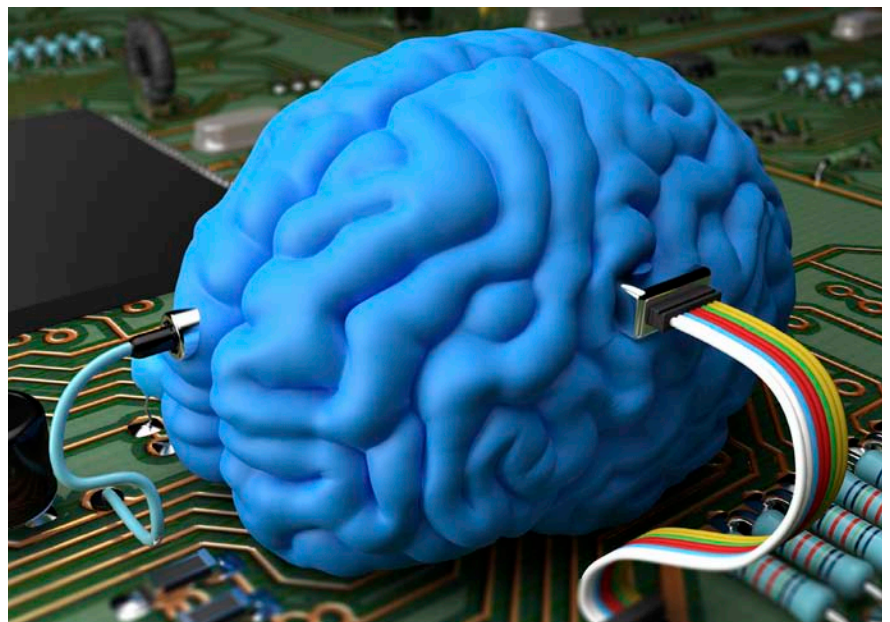


Let's clear something up...we love brains. Not in the weird zombie way; we don't want to eat them. We want to laud their accomplishments, promote their health and train them to be the best they can be. We want to be in a long-term relationship with your brain and we sort of want it to be healthy in the waning years.

The average human brain is about three pounds, which makes it only two percent of the total body weight for a 150 pound person; however, the brain uses a whopping 20% of the blood flow and oxygen in your body! Pretty selfish, eh? Well, now hold on there. Your brain pulls its weight. After all, that wrinkled ball of fat and nerves is the only thing keeping you alive. It is, quite literally, the brains of the operation.

Ever wondered how fast your brain really is? Or maybe you wondered what that ball of fat is actually made of? Join us as we take a look deep inside the human brain (and some animal brains).

Sit back, relax and enjoy the brain food.



1 - your brain has 86 billion cells



Just a few years ago, it was estimated that people had as many as 100 billion; however, those were just simple, theoretical estimates. New research suggests we aren't as smart as we thought we were.

14 billion brain cells is the equivalent of a baboon's brain, or half of a gorilla's brain.

Don't worry about those 14 billion neurons; it isn't just the number of neurons that matters.

2 - each brain cell has 7,000 synaptic connections

...and each of those brain cells (neurons) has the ability to fire every 5 milliseconds, or a whopping 200 times per second!

All neurons are not created equal. While the average may be 7000, some neurons do not pull their weight... leaving others to pick up the slack. It appears all neurons have the ability, but some engage and others just stay out of the way. Researchers at Carnegie Mellon University have likened the phenomenon to Facebook® users. Yep, you can't escape Facebook®!



3 - your brain is really, really, really fast

We have the numbers to prove it. Let's use that brain power we keep talking about to do some math.

86 billion neurons
x 200 fires per second
x 7,000 connections per fire =

120,400,000,000,000,000 calculations per second.

Yes, per second!



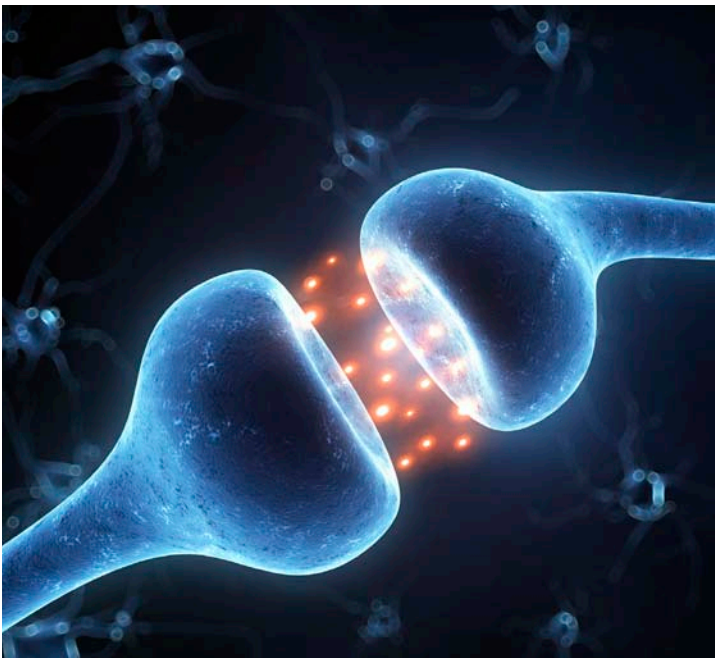
Now, as we stated, that is just raw computing power; that isn't indicative of how many real actions and decisions you could make per second. So, how long does that take? MIT neuroscientists have shown that it takes 13 milliseconds to process an image, shattering the old notion of 100 milliseconds. Since identifying and responding to an image is a rapid, continual process, it is a good baseline for calculating decision-making time. The same study also shows that it takes as much as 100-140 milliseconds to initiate eye movement, which is a good measure of fine motor control.

What does that all mean? Like we have said repeatedly, it means that your brain is amazing! The human brain can complete almost 77 complex processing tasks and initiate between 7-10 precise movements per second. That is, assuming the brain is working at peak efficiency. And efficiency is crucial in such a complicated process. One study shows that "like memory, human intelligence is probably not confined to a single area in the brain, but is instead the result of multiple brain areas working in concert." Your brain's functional networks must link together and coordinate efficiently and effectively if any of those millions of billions of signals are to get anywhere.



4 - your brain is actually thousands of networks

Interestingly, our brains rely on connected networks because one network simply couldn't do the job. In a study published in the journal *PLoS Computational Biology*, Peter Latham, a neuroscientist from University College London, and his colleagues show that the brain stores information in bundles of about **500 memories**. Each new memory, word, skill, etc. in the bundle means more neurons firing...basically, more parts of your brain talking. Since there is a vast amount of random, meaningless noise produced during this communication, each brain network is limited by size or it risks being drowned out by this noise. Once you fill a network, any additional memory will turn the volume up loud enough that it garbles the signal; essentially, that memory would be the straw that broke the camel's back. Fortunately, there is no limit on the number of networks. Tens of thousands, maybe millions, of these networks can communicate in the brain's version of the Internet. This network is always checking for redundant memories, cataloging new ideas and tagging information. It is a constant process, like Google® crawling the vast array of webpages—some were there from the start and others are being created right now without your knowledge.



*Like Google®, it never stops adding new information. Each new smell, each new thought. Neurotransmitters continually cycle through the brain, helping to send these billions of signals per second. It only takes your brain **five seconds** to release its store of neurotransmitters, send ALL of them through the brain and recollect them. That full cycle represents billions upon billions of thoughts and actions... all in just five seconds! Synchronizing all this communication is how Interactive Metronome® is able to help the brain work more effectively.*



5 - your brain is comprised of two types of matter

The brain is not just one type of matter, but in fact two distinct substances that have very different functions. But what do they do, you ask? Well...

Grey Matter

- 40% of brain matter
- Uses 95% of brain's oxygen
- Comprised mostly of neuronal cell bodies
- Responsible for muscle control
- Controls sensory control: sight, hearing, speech, tactile perception, etc.
- Holds memories
- Used in decision-making
- Responsible for self-control

White Matter

- Comprised mostly of myelinated axons
- Responsible for communication among brain's functional networks
- Associated with processing and cognition
- Controls automatic functions: temperature, hormonal balance, water intake, blood pressure, pulse, etc.



White matter tracts are responsible for the communication between the brain's functional networks. That should come as no surprise considering that white matter is mostly composed of axons and myelin sheath, essentially wiring and its insulation. The grey matter may initiate a good deal of the processing tasks, but white matter makes sure those orders are carried out. In fact, the corpus callosum, the largest white matter tract, is what connects the right and left hemispheres of the brain.

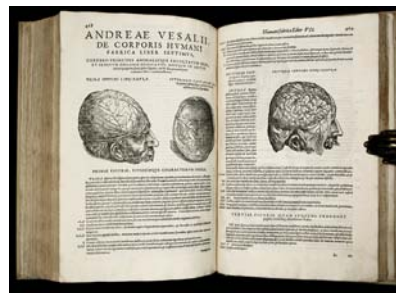
As we said earlier, the brain is organized in an unlimited amount of functional networks. The white matter is what allows these networks to act in concert. White matter tracts connect every functional part of your brain (even some not so functional).



Many researchers believed that grey matter's role in language, memory and emotion made it more important, so they neglected white matter for hundreds of years. For hundreds of years, white matter's role in brain communication was not only mysterious, but considered relatively unimportant.



It is surprising that science neglected white matter for hundreds of years. Even with the crude medical technology of the past, researchers clearly saw that the differences in the brain's structure. The anatomist Andreas Vesalius distinguished between white and grey matter in 1543, in the seventh book of his masterpiece *De Humani Corporis Fabrica*, meaning neuroscientist have only been studying half of the story for a quite some time.

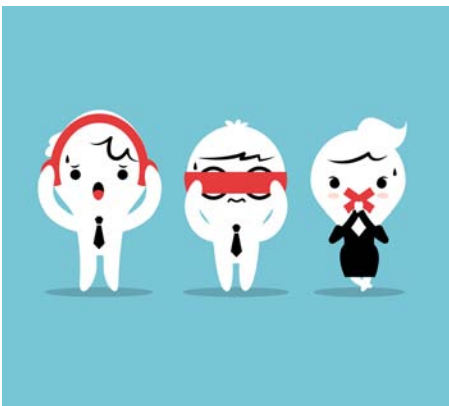


Nonetheless, it took over 300 years before the French neurologist Jean-Martin Charcot was able to begin illustrating the importance of white matter in his work. Often known as "the Napoleon of the neuroses," Charcot was determined to understand the workings of the brain. His research is responsible for much of our early understanding on multiple sclerosis (MS), Parkinson's disease, amyotrophic lateral sclerosis (ALS, or Lou Gehrig disease) and a variety of hysteria and movement disorders that have since be renamed or categorized.



6 - there are 3 types of white matter

Three types of white matter tracts are responsible for bearing the load. Projection tracts are the vertical tracts that connect to the spinal cord and cerebrum. This white matter is what moves the signal out of the brain and on to the body, making it incredibly important for coordinating movement and responses. The white matter that runs left to right between the hemispheres, running through the corpus callosum and the smaller anterior and posterior commissures, are the commissural tracts. The major function of these is exactly what their placement would suggest; they connect the right and left sides of your brain, the creative and the practical. Finally, association tracts run all throughout their own hemisphere. These are really the runners between your brain's functional networks because they help link up your memory and processing centers in the grey matter. Fortunately, these are the easiest to bypass in case of damage, meaning that alternative routes can form after we relearn tasks over time.



White matter connects all four of the brain's lobes and every defined brain region. Dr. Christopher Filley, professor of neurology and psychiatry at the University of Colorado Medical School, says, "This suggests that the cortical regions act in concert to perform mental operations and no cortical area acts in isolation. Without functioning white matter, the brain could be like a group of people in proximity to each other but unable to communicate with each other."

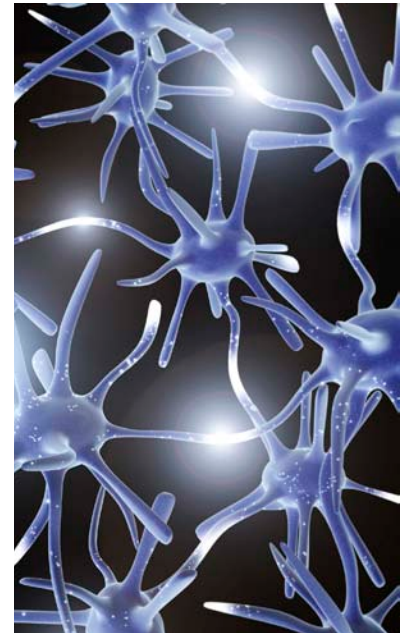
7 - the same problem leads to hundreds of diagnoses

Understanding conditions like MS, sensory processing disorder, ALS, dyslexia, autism, dementia and Parkinson's has been a major catalyst in brain research.

Research during the past decade has implicated white matter as performing the critical task of connecting and synchronizing different brain regions or networks so they can perform a wide variety of complex human cognitive or motor behaviors. The white matter system is considered the communication backbone system for the flow of information in the brain... White matter integrity or dysfunction has been implicated in a wide variety of cognitive disorders or abilities, including cognitive control, math and intellectual giftedness, fluid intelligence or reasoning, processing speed, reading, decrease in cognitive functioning, meditation, working memory, vascular cognitive impairment, ADHD, autism, and cognitive and language maturation in infants.

Taken from Dr. Kevin McGrew's (Director of the Institute for Applied Psychometrics and co-author of the Woodcock-Johnson Battery III and IV) blog "White matter matters: Brain synchronization via the brain's communication subway system"

Over the past 50 years, a great deal of research has been directed at the importance of white matter. In 1965, science really began to study the brain's structure as a means to diagnose and treat neurological disorders. As seen with the agenesis of the corpus callosum (ACC), the brain struggles to develop properly if the inter-hemispheric communication is hampered. Additionally, many processing disorders highlight the importance of sending the right signal to the right place; something as seemingly simple as misfiring neurons can lead to learning disabilities, behavior problems, emotional issues and a host of other cognitive impairments. The grey matter may represent the bulk of your memory and learned skills, but it is useless without the white matter carrying those signals around your brain and to your body.



Taking away the brain's ability to talk to itself literally robs you of the ability to think efficiently and effectively. It is easier to understand the cognitive impairments associated with white matter maladies when you understand how the brain communicates. It is no wonder that the symptoms of white matter injuries seem to affect every aspect of daily life. As Dr. Lonnie Nelson said during his presentation on the DVBIC study results:

White matter connections are long bundles of axons that connect different cortical (gray matter) operators, where basic calculations take place. The loss of white matter connections (which happens in blast injury) is what keeps areas of the cortex from being able to share information across domains. This results in inefficient processing, slowed speed of processing, and problems with sensory integration. Repair of these white matter connections is likely what accounts for the improvements in cognition that we observed after IM.

Although Dr. Nelson was speaking about blast-related brain injuries in veterans, the same principle applies to all brain injuries. Whether you are young or old, severe and traumatic blows to the head affect the whole brain, both grey and white matter. Without the white matter, however, the brain simply can't speak to itself, which can leave people feeling trapped in their own body.

8 - your brain keeps time and has rhythm

Your brain is incredibly fast, but it also must rely on timing and rhythm to keep all the communication in order. Rhythm and timing are essential to human development.



The rhythmic beat of waltzes from the 18th century can still be heard in modern pop music. Afro-Cuban musicians have spent years crafting in depth polyrhythms called “guaguanco” that has become the defining characteristic of the culture. Gentle lullabies are used to soothe crying children. Heavy metal music inspires the violently intense dancing of “mosh pits.” Pulsing electronic beats can fill dancehalls with hundreds grinding to the same beat. Music and rhythm speak to humans; it is inherently human.



A study by Kristyn Kuhlman and Lawrence J. Schweinhart of High/Scope Educational Research Foundation found significant correlations between the students' mental timing as measured by IM and their academic performance in reading, math, language, science, social studies and personal study skills. The study, *Timing in child development*, was one of the first to show that you can not only accurately measure timing and rhythm in children, but that it can be directly related to gains in other areas. It shows that brain timing plays a foundational role in a child's academic performance.



But why? Nathan Urban, a neuroscientist at Carnegie Mellon University, has come to one conclusion, "The brain absolutely has rhythm." In "Your Brain's Got Rhythm, And Syncs When You Think," author Jon Hamilton writes about Urban's work with neuronal synchronicity:

*The internal cadences of the brain and nervous system appear to play an important role in everything from walking to thinking. And abnormal rhythms have been associated with problems including schizophrenia, epilepsy, autism and Parkinson's disease. The rhythms of the brain begin with the firing patterns of individual brain cells. **They're little clocks. They have an intrinsic frequency.***

Urban makes a great analogy about how the brain's neurons fire together. He says, "It works a bit like a room full of people clapping their hands. At first, each person claps to his own beat. But if you ask them to clap together, they'll start listening to their neighbors and adjusting their rhythms until the claps are synchronized." This is important because brain cells that fire together develop stronger connections that are essential to memory, attention, coordination and learning.

Are you beat deaf? ...and yes, that is a real thing

Neil Young and the Beach Boys have stopped performances because audience members' off beat clapping was becoming a problem. Dr. Jessica Phillips-Silver is studying rhythm with a team at the International Laboratory for Brain, Music and Sound Research in Montreal and has found that there is a very small portion of the population that is "beat deaf." She has a Ph.D. in neuroscience and auditory development, and has devoted herself to this "form of musical brain disorder."





If we can be “beat deaf,” can animals pick up a tune and dance?

As it turns out, parrots and Asian elephants, but they might be the only other animals. Not even our closest relatives, chimpanzees and orangutans, can break it down like we can. Despite what thousands of videos of dogs, cats, turtles and bears would suggest, those animals can't really dance. Research suggests that while these animals may have been mimicking behavior or responding to other cues, they weren't really trying to match the beat. No, only humans, parrots and elephants seem to do that. Since parrots and elephants are terrible musicians, it is fair to assume that humans are the only animal with both the ability to produce music and a seeming need to move around when we hear it. Why does that matter? Well, if rhythm matters, timing matters.



9 - repairing white matter is a matter of time

Interactive Metronome® (IM) is believed to improve the resolution and efficiency of an individual's internal brain clock(s) and temporal processing. In turn, it is hypothesized that this results in more efficient brain connectivity, communication, and synchronization via increased integrity of the brains white matter tract communication system, producing more efficient communication between critical brain networks. In particular, research and theory suggests that IM training increases the efficacy of the parietal-frontal brain network, the brain network most associated with general intellectual functioning, working memory, controlled attention and executive functions.

Taken from the Dr. Kevin McGrew's "Three-level Hypothesized Explanation of the IM effect (McGrew, 2012)"



Just knowing that new connections can develop in our white matter tracts is an exciting prospect. No longer must individuals live with debilitating neuromuscular conditions and cognitive impairments; now, with IM training, people of all ages can directly address the underlying problem. Restoring the critical timing and rhythm of brain communication is essential to restoring function. Truly efficient neuron firing can only come when each message sent is received, meaning that the brain's functional networks must be healthy and in sync. The domain-general mechanism of timing is a "jack of all trades" mechanism that manifests itself in sleep cycles, speech patterns, the ability to attend over time and overall efficacy of brain communication. This timing in the brain, or temporal processing, has been shown to be



deficient in several common conditions, including everything from ADHD to severe autism spectrum disorder.

University of Oregon psychologists have recently called into question the efficacy of "brain training" games, exercises and apps. A study published in the *Journal of Neuroscience* claims that this training only helps with the specific task and does not carry over new challenges. What does that mean for Interactive Metronome®? Well, fortunately, IM is so much more than brain training; IM training physiologically changes the brain, leading to improvement in all areas, not just one specific task.

When it comes to brain training, training the right mechanisms makes all the difference. Researchers at the University of Oregon were looking at a domain-specific mechanism, specifically the ability to perform a stop/go task. Domain-specific tasks are tasks that have become automated through years of practice. One group received training in similar inhibitory control exercises for three weeks while the control group had no such practice. It is natural to assume that training in such a specific task will only help that task.



Part of what makes IM so unique is its ability to improve domain-general mechanisms. Domain-general mechanisms function across a wide range of processes. It is this timing that affects the rate our brains process inputs (temporal processing) and respond to those stimuli.

Imagine a Walmart® distribution warehouse without a manager. It would be chaos. Boxes would keep coming down conveyor belts with no rhyme or reason. Soon, trucks aren't being loaded properly, or on time. Accidents begin to happen as boxes bump into each other and pile up at the end of the belts. In time, the stores that rely on the warehouse are out of inventory. If they go without inventory long enough, they very well could shut down. That warehouse is like a brain out of sync and those boxes are nerve impulses that signal the body to move, breath, swallow, speak, react, love or cry.

IM training can be the “logistics specialist” for the brain’s networks. In the previous example, the boxes are always there and there is no distinction between what may be in that box. Interactive Metronome® can’t change the signal. It can’t make you smarter, but what you do after IM can. IM training acts as a supervisor to ensure the “boxes” (nerve impulses) actually reach the “truck” (the final action, thought, feeling, etc. intended by the brain’s signal) on which they need to be loaded. Although, IM training does not literally make you “smarter,” it does help clients work at peak performance.



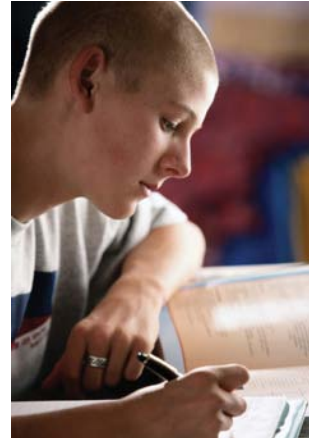
When the brain’s functional networks are synchronized and communicating, our neurons can fire at their peak levels. This frees up cognitive function that can be used for coordination, control, balance and attention. With proper direction and practice after IM, the newly freed cognitive capital can actually help make every “box” valuable by cutting down some of the noise. More efficient communication equals less missed signals and less neural clutter bogging down each of our brain’s functional networks. So, as we said, while IM may not make you smarter, your rewired brain makes it easier for you to put in the work and get there.



Conditions like autism and Parkinson’s show that the loss of just a few connections can rob us of the ability to control cognitive processes, behavior and movement. Timing in the brain, temporal processing, is essential to your brain’s ability to understand spatial relationships, control movement and process information. Much of our lives revolve around timing. Playing music involves timing, as does baking, sports, and just about any activity in life.

In *Improvement in interval timing tracking and effects on reading achievement*, Taub et al (2007) theorized that Interactive Metronome® primarily addresses thinking speed and working memory, thereby improving our ability to focus and learn. In the study, they demonstrated that IM training has a significant positive effect on reading achievement (affecting 4 of 5 critical pre-reading skills) in elementary school students. They proposed that IM training was primarily improving “processing speed,” which in turn improved the students’ ability to allocate resources for attending and holding information in working memory...all essential for fluent reading. Taub et al propose that the wide array of positive treatment results seen following Interactive Metronome® training can be attributed to its impact on timing in the brain and two critically important skills, working memory and controlled attention.

A study published in the Sept. 28, 2012 Communications Disorders Quarterly reveals that students who received 15 minutes of IM training four days a week in addition to language and reading intervention demonstrated significant improvement in reading rate, fluency, and comprehension over students who only received language and reading instruction.



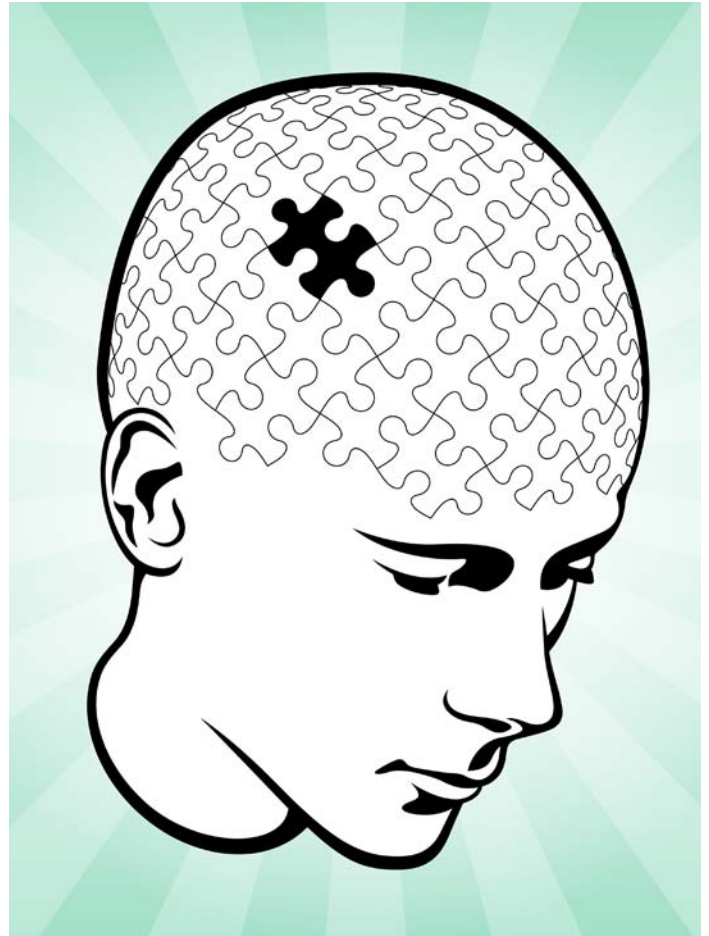
Research shows that engaging whole body movements in combination with cognitive tasks leads to overall better outcomes. Interactive Metronome® is the only training program that improves timing in the brain and coordinated movement in an organized, systematic, flexible and engaging format. IM is a patented and unique training tool that challenges thinking and movement simultaneously, providing real-time millisecond feedback to help synchronize the body's internal clock. This, in turn, allows an individual to reach their full potential academically, socially, professionally and athletically in only minutes a day, a few days a week.

So, don't get discouraged; brain training may be limited, but IM training will take you to the next level. If you are thinking about improving your cognitive performance, remember, it's about TIME.

It is a crazy life. Meetings, church, workouts, business lunches, family dinners, children's games, hobbies, PTA, recitals, and somewhere in there you have to find time for yourself. You balance it all as well as a triple-beam, but it isn't getting any easier.

It all starts in pre-school, but it continues in college, internships and the job market. Soon, it isn't just about getting good grades and showing up for work. People rely on you and you have to be your best. Improving deficient Neurotiming® might just be the last piece of the puzzle. Try IM training and see improvements in the following areas:

- **Attention and concentration**
- **Memory and processing**
- **Reading and speech fluency**
- **Fine and gross motor skills**
- **Bilateral coordination**
- **Mood regulation**
- **Behavior and self-esteem**
- **Activities of daily living (ADLs)**



For more information, please visit us at
www.interactivemetronome.com

...or contact your representative at
(877) 994-6776 (Toll Free - US only)

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(954) 385-4660