IM-HOME blog posts by Dr. Kevin McGrew

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Meet Dr. Kevin McGrew, PHD

Dr. Kevin McGrew is the Director of the Institute for Applied Psychometrics (IAP). He received a master's degree in School Psychology at Moorhead State University and his doctoral degree in Educational Psychology at the University of Minnesota. He was a practicing school psychologist for 12 years. He spent 10 years as a Professor of Applied Psychology at St. Cloud State University. Dr. McGrew is currently a Visiting Professor in Educational Psychology at the University of Minnesota and serves as the Research Director for the Woodcock-Muñoz Foundation, Associate Director for Measurement Learning Consultants, and Research and Science Director for Interactive Metronome.

Dr. McGrew conducts research in the areas of theories of human intelligence, personal competence, intelligence testing, school learning, and the application of neurotechnology to cognitive performance and learning. He has published over 60 different journal articles, books or book chapters in his areas of expertise. He is a coauthor of the Woodcock-Johnson Battery III. Detailed information can be found at the *MindHub*™ Director page. Dr. McGrew disseminates information regarding human intelligence and the human brain clock at two professional blogs (IQs Corner; Brain Clock Blog).

[2 The original "Time Doc" was Jim Cassily, the inventor of Interactive Metronome. I might better be considered "Time Doc-2"].

All of these blog posts are available at the IM-HOME web page. The URL links in this PDF are not active but can be accessed via the original posts at IM-HOME. Visit the page for posts that have occurred since this Vol 1 archive was created:

http://tinyurl.com/7525egp

Also visit The MindHub and Brain Clock blog for additional information:

www.themindhub.com
www.brainclock.net

The Brain Clock: My journey to understand the science of mental timing interventions

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"Run Gordon Run...this sounds like high-tech snake oil!"

That was my knee-jerk advice to friend and colleague, Dr. Gordon Taub, when he called me in 2004 to assess my interest in consulting on a *"synchronized metronome tapping" (SMT)* invention called Interactive Metronome (IM). IM was supposedly directed at improving the academic

achievement of elementary school students. My skepticism was grounded on the fact that for many years in education (and special education in particular), *non-academic interventions* focused on remediating underlying cognitive deficits (e.g., psycholinguistic process training; visual-motor or spatial integration training; motor planning retraining) were subsequently found to be ineffective in improving reading, writing and math. Yes, performance could be improved on tests of the specific cognitive processes trained, but the results did not transfer to academic improvement in the classroom.

By the early to mid-1980's non-academic cognitive process intervention programs had been debunked as ineffective for improving school achievement. It was from this skeptical lens that I offered Dr. Taub my advice. I went as far as telling Dr. Taub that I could not risk my professional reputation by being associated with yet another "magic bullet" claim for school learning, especially for "at risk" learners. The magic bullet lesson had been burned well into my school psychology psyche after a decade of debate, discussion and controversy that had surrounded the efficacy of non-academic interventions for improving reading, writing and math.

Fast forward seven years, and I am now writing this post as the *Director of Science and Research for Interactive Metronome*. What happened? Why the 180 degree change in my support for IM and other temporal processing-based neurotechnology interventions?

The first step in my journey occurred when I visited the school-based IM intervention directed by Dr. Taub. I tried the technology and observed the students in the experimental treatment group. The cognitive demands were intriguing. This was "not your father's" process remediation program from the 1970's and 1980's. My interest piqued when we analyzed the results of the intervention and found that the students who received the IM intervention, when compared to a control group, displayed statistically significant gains in certain fundamental reading skills---specifically those skills that were consistent with the apparent underlying

cognitive abilities required by the IM training. We subsequently published the results in 2007 in the peer-review journal Psychology in the Schools.

At this point, the educational psychologist researcher voice in me wanted to know "why?" How could a high tech clapping machine produce significant improvement in reading skills as well as improvements in other diverse domains such as golf, tennis, ADHD, TBI and stroke rehabilitation? I embarked on a scientific quest to find an explanation for "what is happening under the IM hood." I was overwhelmed when I discovered that many diverse scientific disciplines had been studying the concepts of mental timing or the idea of a brain clock or series of brain-based timing mechanisms. I found literature in the research areas of the psychology of music, neurobiology, neuroscience, biological psychology, and neuropsychology, to name a few. The wide-ranging breadth of the literature was daunting to digest. But, the common findings, hypothesis and theories offered across this diverse set of literature convinced me that the IM effect was due to its ability to "fine tune" the resolution of a critical brain clock (or clocks), which in turn improved various cognitive or motor functions. The possibility that the IM technology was based on serious science drove me to dig deeper. As a result, I started posting research findings at my primary IQ's Corner blog. Eventually, the sheer mass and specialized nature of the research literature discovered necessitated the development of a specialized sister blog devoted to temporal processing and the human brain clock—The Brain Clock Blog.

I am now convinced that the IM-effect is impacting a fundamental and critical cognitive mechanism (or set of mechanisms) involved in a wide array of human cognitive and motor performance domains. In my forthcoming series of blog posts I will describe my mental-timing journey and will focus on providing, in as simple terms as possible, explanations of the "why" of brain clock-based interventions like IM.

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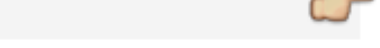
"I am now convinced that the IM-effect is impacting a fundamental and critical cognitive mechanism (or set of mechanisms) involved in a wide array of human cognitive and motor performance domains."

Cognitive and intelligence researchers have long sought for (and argued about) the "holy grail"of intelligence—an *underlying core essence or mechanism* that plays a role in most all intellectual and human performance situations. It is typically referred to as *g, or general intelligence*. The general consensus touches on the concept of neural efficiency. Such a general mechanism or process is considered a *domain-general* cognitive mechanism as it works across multiple domains of human ability, or in other words...if you improve this one area of ability, it in turn improves several areas of ability in the same person like cognitive skills (focus, attention, memory), speech/language abilities (articulation, auditory processing, reading), and motor skills (coordination, gait, balance). It works *across* multiple domains of human ability. Some have referred to such general mechanisms as a "jack-of-all-trade" cognitive mechanism.

This contrasts with *domain-specific* cognitive mechanisms, which are compartmentalized (modular) brain-based components. For example, we all have learned to drive a car. We have all automatized the act of driving so we can drive with little in the way of deliberate cognitive thinking—the resources of our immediate mind are freed up to listen to the radio, think about work, mull over our plans for the day, etc. If you practiced your driving one hour a day for four weeks straight, you may improve your driving behavior. However, you would not expect this practice to transfer to improvement in other domains of your life such as speaking, reading, or golf. This is an example of a circumscribed set of behaviors that have been learned and that are under the control of a set of narrow domain-specific cognitive mechanisms and brain networks. Domain-specific mechanisms are important for automatic efficient human performance but, in general, improvement via training or exercise is typically restricted to within the specific set of skills and behaviors.

In contrast, a domain-general mechanism is one that if changed, may result in *changes in performance across diverse areas of human functioning*. Improving a domain-general cognitive mechanism via intervention or environmental manipulation should result in improvements across multiple domains. You get more "bang for your buck"if you can improve multiple areas of human functioning via one general treatment, in contrast to many different treatments for multiple skill domains. The search for such a magical lever has been pursued for decades by researchers in psychology and learning. Thus, when I first learned that both empirical research and clinical experience demonstrated that IM could improve (a) motor functioning of individuals strokes or cerebral palsy, (b) speech and language disorders, (c) sports performance [golf and tennis], (d) ADHD behavior, and (e) reading, to name but a few, I concluded that the only viable hypothesis is that IM was impacting a fundamental domain-general brain-based cognitive mechanism (click herefor Brain Clock blog posts and articles related to domain-general mechanisms and research).

Evidence for a domain-general brain clock comes from numerous sources. Researchers across various disciplines and labs, using different methods and focusing on different aspects of human timing, have consistently demonstrated that humans do have some form of brain clock (or system of clocks) that play a pivotal role in a wide array of human cognitive and motor behaviors. For those who want to learn more about the foundational research check out the *Mental Timing Scholars and Research Labs* and the *Key Articles* in the blog roll sidebar at the Brain Clock blog. I will be extracting information from these sources in future blog posts.

Another source of research that validates the concept of a domain-general brain clock, and one that I find particularly fascinating, is that*disorders of the brain clock may be central to a diverse set of clinical disorders* (click here for links to more disorder-specific information). Amy Vega and I summarized a portion of this research in a special white paper (The efficacy of rhythm-based [mental timing] treatments with subjects with a variety of clinical disorders: A brief review of theoretical, diagnostic, and treatment research). After a review of four *different* types of rhythm-based timing treatments, of which IM was just one, we concluded that: 

"we believe that collectively the preponderance of positive outcomes (across the 23 listed studies) indicates that rhythm-based mental-timing treatments have merit for clinical use and warrant increased clinical use and research attention...positive treatment outcomes were reported for all four forms of rhythm-based treatment. Positive outcomes were also observed for normal subjects and, more importantly, across a variety of clinical disorders (e.g., aphasia, apraxia, coordination/movement disorders, TBI, CP, Parkinson's disease, stroke/CVA, Down's syndrome, ADHD)...One notable observation of interest is that 15 of the 23 studies (the RAS, AOS-RRT and SMT treatment studies) all employed some form of auditory-based metronome to pace or cue the subjects targeted rhythmic behavior. In all other studies, rhythm-pacing used some form of manual tapping or beat sound (e.g., drum). We conclude that the use of external metronome-based rhythm tools (tapping to a beat, metronome-based rhythmic pacing, rhythmic-cuing via timed pulses/beats) is a central tool to improving temporal processing and mental-timing."

The convergence of research by mental timing scholars studying normal cognitive processes, when supplemented with research that has implicated the integrity/efficiency of the human brain clock in many clinical disorders, is consistent with the notion of a domain-general master internal brain clock. As a researcher with an interest in applying theories of intelligence, cognition and information processing to benefit individuals at-risk for, or already diagnosed with, various cognitive or motor disorders, this discovery was exciting.

The finding that IM-specific, other timing- or rhythm-based treatments, as well as lab experiments that have successfully changed the speed of the human brain clock (slowing it down or speeding it up), suggests that it is possible to "fine tune"the human brain clock and improve the quality of life of individuals. This is one of the major reasons why I continue my journey to understand the human brain clock. This is the main reason why I now blog for IM-Homeand continue my separate Brain Clock blog. This is important and "timely"information.

My personal and professional experience and task analysis of IM-Home: Focus and controlled attention.

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I am departing from my original plan for this post, as I want to share my personal experience with IM-Home to date. I have completed my 16th session and have been task analyzing the demands of the IM.

My first conclusion is that IM is challenging! When I tell others that I am using a high-tech "clapping" machine that uses a cowbell sound, I am typically greeted with skepticism, much like my original skepticism. It sounds simple and easy. Trust me--it is a very cognitively demanding therapy.

Being an extremely visually oriented person with expertise in the analysis of numbers (applied psychometrics and statistics), I immediately gravitated to the IM visual and numeric feedback on the computer screen. In fact, I focused almost exclusively on the numbers. I more-or-less ignored the auditory feedback in my ears. Within a week I found it relatively easy to be "on target" and when off target, quickly and automatically adjust my pace to be in synch with my tireless IM taskmaster. However, I found that when I was in a groove and being "super right- on" (exactly on the beat) for a number of consecutive trials, my mind would start to wander to random thoughts. No sooner would my mind wander for a brief second then the feedback told me that I was no longer in rhythm. This happened constantly. Just when I was feeling like I had mastered the task, my mind would always start wandering.

During one of my weekly consults with my IM-Home Specialist, April Christopherson, OTR/L, she told me that in order to master IM I needed to close my eyes or turn my back to the visual and numeric feedback. I needed to rely on the sound tones delivered through the headphones. So I followed her directions and immediately was constantly out-of-synch. I had a hard time differentiating the sounds sent to the right or left ear. At times I occasionally found myself "chasing the wrong tone." That is, I focused on the guide tone from the left ear (indicating I was clapping too fast) and thought it was the target instead of paying attention to the metronome sound. I was chasing my tail. Needless to say, I would become seriously derailed, and I would need to peek at the screen to establish what I was doing wrong. But I persisted and eventually I learned to focus harder on the auditory feedback.

I again found myself getting on target for a decent series of consecutive trials, but as sure as it snows in Minnesota, my string would be broken by a stray thought. The only way to produce a lengthy string of synchronized bursts was to attain a level of focus or concentration that was, frankly, foreign to me. Although this may sound corny, I "had to become one with the tone"...I had to "be the tone." This required me to focus all my mental energies on the "on target" tone occurring in the middle of my head and suppress any random or spontaneous thoughts that tried to capture my attention.

In the cognitive psychology literature, *attentional capture* is minimized by a process called *inhibition* (ignoring task irrelevant distractions--in my case, self-generated random thoughts). Not only must I resist alternative thought temptation, I must also *shift* and allocate my attention in a flexible and optimal way in response to different types of auditory feedback. Finally, although not consciously aware of the process, my personal mind manager must constantly monitor the feedback and *update* my immediate *working memory* so my mind can adjust and correct my tempo. *Inhibition, shifting, and updating* are the three primary cognitive processes believed to be involved in each person's personal mind manager--collectively referred to as the *executive functions* of the brain. I will discuss these cognitive concepts in future posts.

I have always had a very active or busy mind, even when performing other tasks. Such an unquiet mind has contributed to my professional success as I am constantly thinking of new ideas, hypothesis, solving problems, or generating new insights. When I talk to others about the degree of my spontaneous self-talk, I've concluded that I am at the high end of the population for a busy mind. Sustained concentration, vigilance, or focus has never been a personal strength. I have been rewarded for my intellectual insights, curiosity, and creative output. A spontaneous self-generating mode of constant thinking has suited much of my professional work. In IM-Home, I have met an opponent that can dominate me if I don't marshal all my attentional resources.

Currently, the clapping machine owns me. For me, *synchronized metronome clapping* is a new challenge--a challenge requiring me to learn more sustained and controlled focus. I must stay in the immediate awareness with the tones. When I become "one with the 'right-on' tone", I am in a cognitive place I have seldom visited. I have yet to find the vocabulary to describe the sensation of a long burst of success on consecutive IM trials, as to stop to describe it requires my mind to wander away from what it is I am trying to describe. I have tried to evaluate the sensation of these glimpses of super focus, but inevitably my attempts are short-lived as I am scolded with tones to either my right or left ear, reminders that I am no longer in rhythm. Maybe this state is what people with exceptional focus call "being in the zone" or in a state of "flow", which is the single-minded emersion in a single activity that draws on focused motivation and attention.

My personal experience-based professional task analysis implicates the psychological abilities of *executive function* (click here and here), controlled attention, and working memory, brain functions I have hypothesized to be central to the IM-effect. How these cognitive functions are related to brain timing will be the topic of future posts.

It is clear to me that IM is a very challenging task for individuals who have poor or under-utilized focus or controlled attention. My sessions are forcing me to shut down my *default brain network* (which is the network that has been described as producing *REST*--rapid episodic spontaneous thinking; click here and here), invoke my executive function manager processes, and focus on controlling my attention. Mind-wandering is not allowed. It must be suppressed. I am both frustrated and excited when completing my sessions. I am being pushed to the edge of my personal attentional control envelope.

Yes---but have the sessions transferred to real world behaviors? Have I seen any improvement in focus during my day-to-day functioning? Although it is possible that I may be trying to convince myself of the value of my time spent on IM training, I have had two recent episodes of what I viewed as enhanced focus. Last Friday (after completion of my 13th IM-Home session) I had an exceptionally productive morning work session. I was juggling multiple projects and responding to phone calls and emails. When I looked up I discovered it was almost noon. Time had flown. More importantly, I felt I had worked more efficiently. I had been productive on multiple fronts and the work, which was at times difficult and challenging, was completed with serenity. I did not need to write down every little thought or task to be completed later. Instead, my mental checklist functioned without the aid of sticky notes. Hmm.... could it be due to IM?

The second experience occurred three days later (after session 15) when I spent the majority of my day driving into and around town completing errands. While driving I perceived a sense of clarity in my field of vision. I was more aware of the various objects and the terrain ahead and around me. I was attentive to cars farther down the road, was more conscious of changing traffic signals (both immediate and those further down the road), I was scanning the ditches for possible deer, etc. Once I perceived this qualitatively different state of driving, I deliberately tried to sustain it via control of my focus. I consciously was inhibiting my typical internal busy mind and was more aware of my immediate surroundings. I found I was able to maintain this focused state for significant bursts of time (approximately 5 minutes for each burst of concentration).

Are these two incidents random experiences, an attempt to rationalize my IM therapy and relationship with the IM company, or... might they be flashes of improvement in ability to turn on and off my controlled attention due to my IM therapy? I don't know. These are personal introspective observations and conclusions not subject to experimental investigation or measurement. At this point in time I can only conclude that I know that during the IM sessions significant demands are placed on my executive functions and controlled attention. Whether these two personal enhanced focus experiences are the direct outcome of IM is yet to be proven. I do know that these two experiences are consistent with the brain clock research literature regarding the positive effects of *fine-tuning the resolution of the human brain clock.*

Finally, given that I am a high functioning, well-educated and successful professional, I can only imagine the potential benefits of IM-based therapies for children with clinical disorders (e.g., ADHD or Autism), particularly those that have controlled attention and executive function abilities that are seriously disrupted or delayed. Also, given that contemporary neuroscience research has suggested that the areas of the brain responsible for the abilities that produce focus are the latest developing areas of the brain (the prefrontal cortex), typically not coming to full maturation until adolescence, it would only be logical that children and youth without clinical disorders would benefit from IM more than I. I would predict more noticeable and immediate gains in those much younger than I, as their brains are more modifiable (often called neuroplasticity). These speculations are consistent with my own research that demonstrated significant gains in reading skills in typical school-age children, as well as other IM-specific research with a variety of childhood clinical disorders.

I look forward to more sessions and personal data collection as I continue my personal and scientific IM journey.

The Brain Clock: It is possible to fine-tune the human brain clock

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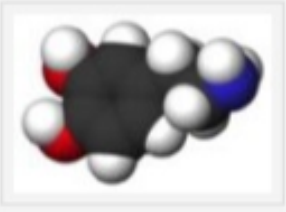
In this fourth installment of my introduction as an IM-Home blogger, I share one more piece of the puzzle that convinced me that brain clock-based interventions hold considerable promise.

In my first post I reported how my scientific skepticism initially kept me arms-length from an IM school-based study, the positive results which stimulated my subsequent search for scientific and theoretical research to explain the IM effect. This search resulted in the Brain Clock blog and the conclusion that synchronized metronome tapping and other rhythm-based interventions must be improving a central "jack-of-all-trades" cognitive mechanism (the topic of my second post). The recent IM-Home "Sound of Music" post, which was abstracted from a post at the *Brain Clock* blog, featured the link between rhythm-based music therapies and recovery from brain injury, in the case for Congresswoman Gabby Giffords.

Research evidence that continued to "close the door" on my initial IM skepticism, and which now has me blogging at the *Brain Clock* and the *IM-Home* blogs and, more recently, has me near completion of the 15th session of my first personalized IM-Home phase of therapy, was the discovery of research that consistently demonstrated that the resolution of the human brain clock could be changed—it could be slowed down or sped up! *The human brain clock could be fine-tuned*. I was enthralled! As I will share in future posts, I have personally found that the IM-Home training places considerable demand on my working memory, executive functions and attentional control (focus). I have weaned myself from reliance on the visual feedback to focusing primarily on the auditory feedback. This was initially hard for me as I am a very strong visual thinker and processor. The switch to auditory feedback has improved my mental focus (sustained concentration and attentional control). But I digress. I will share these personal experiences, in the context of explaining the cognitive operations that I believe are being sharpened by IM, in future posts.

It is fine and dandy to isolate a central brain clock important for human learning (or re-learning)--but such a discovery would hold little interest for me unless itled to practical interventions. Convinced that an internal brain clock mechanism existed, I sought rigorous research that demonstrated that the brain clock could be "fine-tuned"—resulting in improved human performance. My scholarly excursions revealed three classes of *clock speed manipulation* studies that showed that the speed of the human brain clock could be manipulated. In his introductory chapter to the edited book Functional and Neural Mechanisms of Brain Timing (2003), Dr. Warren Meck (Duke University; one of a number of *Brain Clock mental timing scholars*) summarized research that demonstrated that certain drugs could *speed up* the brain clock (e.g., cocaine and methamphetamine) and others could *slow it down* (haloperidol). These drugs impacted the perception of time by increasing levels of dopamine in certain regions of the brain to speed up the clock's pacemaker or blocking dopamine receptors to slow down the clock's pacemaker. I shall talk more about the role of dopamine in future posts as it is an important cog in the operation of the brain clock.



In her chapter in the Meck edited book (Temporal Experience and Timing in Children) Sylvie Droit-Volet reported research that *children as young as three years of age* display evidence of a functional brain clock. More importantly, on a demanding time perception task, Dr. Droit-Volet demonstrated that by immediately preceding the presentation of the task with repetitive click's or flashes, it was possible to improve the young children's performance on the timing task. It was hypothesized that the repetitive sensory stimulation preceding the timing task increased the *arousal and attentional resources* of the children, which in turn increased the accuracy of mental timing. I saw this as an important finding as it is a non-drug based method for fine-tuning the human brain clock.
Finally, although one should never attempt these experiments at home, another designated *Brain Clock Mental Timing Scholar*, Dr. John Weardon, has reported in a number of papers and book chapters (click here and here) that as early as 1927 and 1933 experiments in raising and lowering a person's body temperature produced cognitive timing behavior consistent with a faster or slower clock speeds, respectively. 👉

Although man's interest in time has been present since the late 1700's to 1800's, early research was lab-based and had little practical impact. Furthermore, manipulating body temperature or administering drugs to improve the resolution of the brain clock, although possible, suffered from many moral and ethical issues. Fortunately, "more recently, time perception has become a major object of research in the field of the cognitive neurosciences (see Lewis & Miall, 2003; Nobre & O'Reilly, 2004). According to Dr. Weardon, "the last 20 to 30 years have seen a mini-'Golden Age' in the study of time perception in humans, with many fundamental processes being elucidated for the first time, and major discoveries made." Clearly the *clock speed manipulation* studies reported above have benefited from the increased contemporary focus on the human brain clock.

As I will articulate in future posts, it is my working hypothesis that numerous emerging brain training or brain fitness neurotechnologies and interventions, although focusing on similar and dissimilar cognitive abilities and brain mechanisms, may all be impacting (to different degrees, directly or indirectly) the human brain clock. My interest in rhythm- and metronome-based technologies is grounded in the belief that the brain clock is central to many important human cognitive and motor abilities. Therefore, we should make the most efficient use of our "time" and investigate the merits of neurotechnologies that have at their core a focus on brain and motor rhythm and micro-second timing. Go directly past Go... go directly to the brain clock.

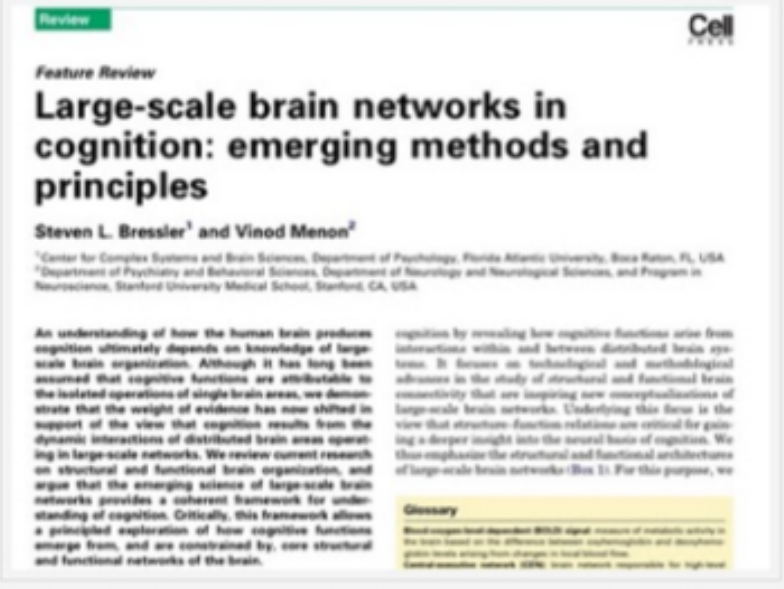
The brain as a set of networks: Fine tuning your networks

The brain as a set of networks: Fine tuning your networks

Man has always known that the brain is the center of human behavior. Early attempts at understanding which locations in the brain controlled different functions were non-scientific and included such practices as phrenology. This pseudoscience believed that by feeling the bumps of a person's head it was possible to draw conclusions about specific brain functions and traits of the person.

Eventually brain science revealed that different regions of the brain where specialized for different specific cognitive processes (but it was not related to the phrenological brain bump maps). This has been called the modular or functional specialization view of the brain, which is grounded in the conclusion that different brain areas acted more-or-less as independent mechanisms for completing specific cognitive functions.

One of the most exciting developments in contemporary neuroscience is the recognition that the human brain processes information via different *brain circuits or loops*, which at a higher level can be studied as *large-scale brain networks*. Although the modular view still provides important brain insights, the accumulating evidence suggests that it has serious limitations and might in fact be misleading (Bresslor and Menon, 2010). One of the best summaries of this cutting edge research is that by Bresslor and Menon.



Review

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Feature Review

Large-scale brain networks in cognition: emerging methods and principles

Steven L. Bressler[1] and Vinod Menon[2]

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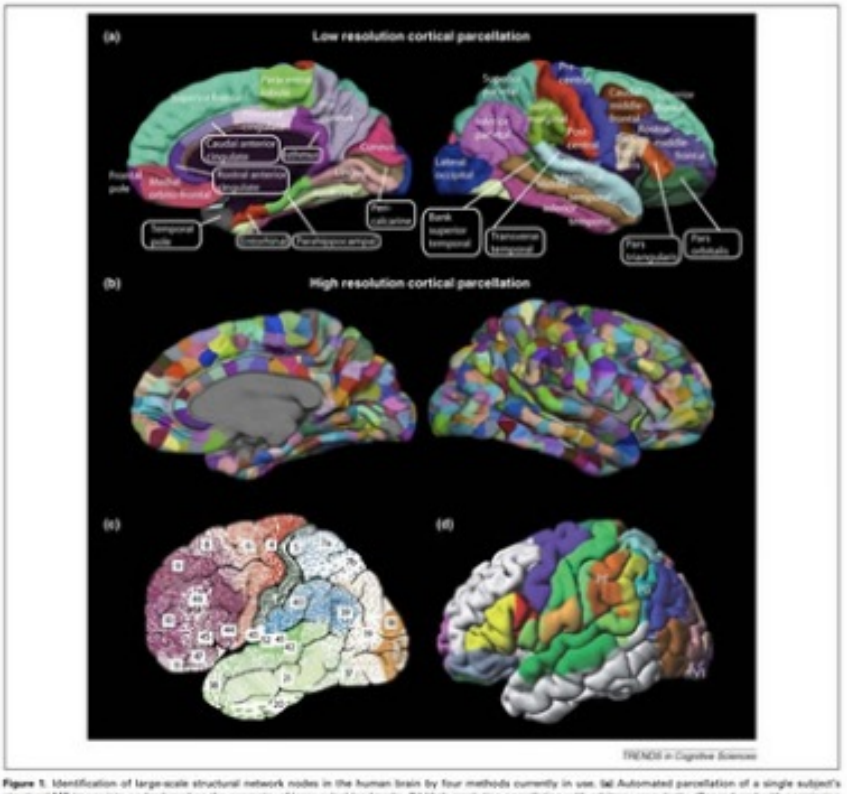
An understanding of how the human brain produces cognition ultimately depends on knowledge of large-scale brain organization. Although it has long been assumed that cognitive functions are attributable to the isolated operations of single brain areas, we demonstrate that the weight of evidence has now shifted in support of the view that cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks. We review current research on structural and functional brain organization, and argue that the emerging science of large-scale brain networks provides a coherent framework for understanding of cognition. Critically, this framework allows a principled exploration of how cognitive functions emerge from, and are constrained by, core structural and functional networks of the brain.

Large-scale brain network research suggests that cognitive functioning is the result of *interactions or communication between different brain systems distributed throughout the brain*. That is, when performing a particular task, just one isolated brain area is not working alone. Instead, different areas of the brain, often far apart from each other within the geographic space of the brain, are communicating through a fast-paced synchronized set of brain signals. These networks can be considered *preferred pathways* for

sending signals back and forth to perform a specific set of cognitive or motor behaviors.

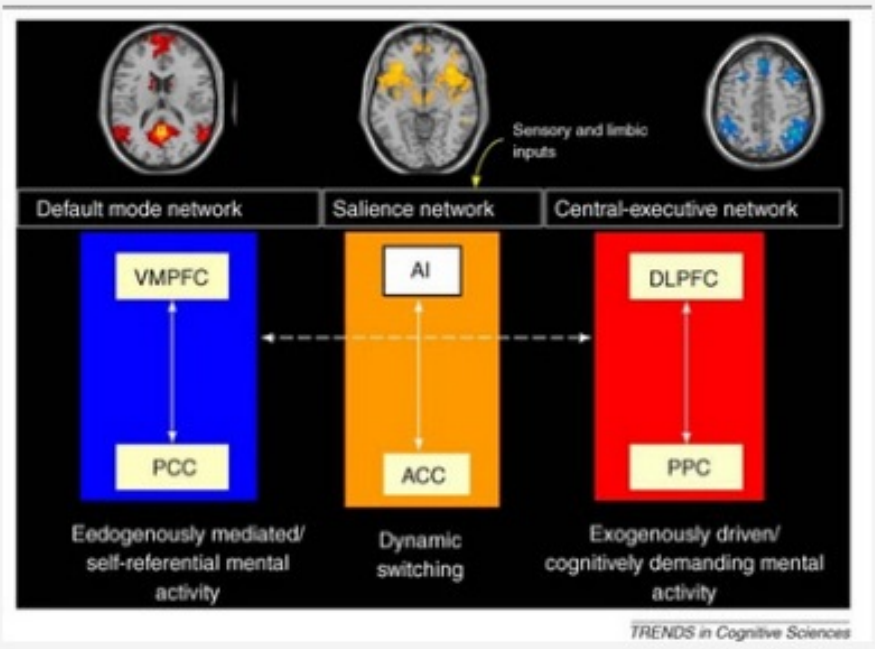
To understand preferred neural pathways, think of walking on a college campus where there are paved sidewalks connecting different buildings that house specialized knowledge and activities. If you have spent anytime on a college campus, one typically finds foot-worn short cuts in the grass that are the preferred (and more efficient) means by which most people move between building A and B. The combined set of frequently used paved and unpaved pathways are the most efficient or preferred pathways for moving efficiently between buildings. The human brain has developed preferred communication pathways that link together different brain circuits or loops in order to quickly and efficiently complete specific tasks.



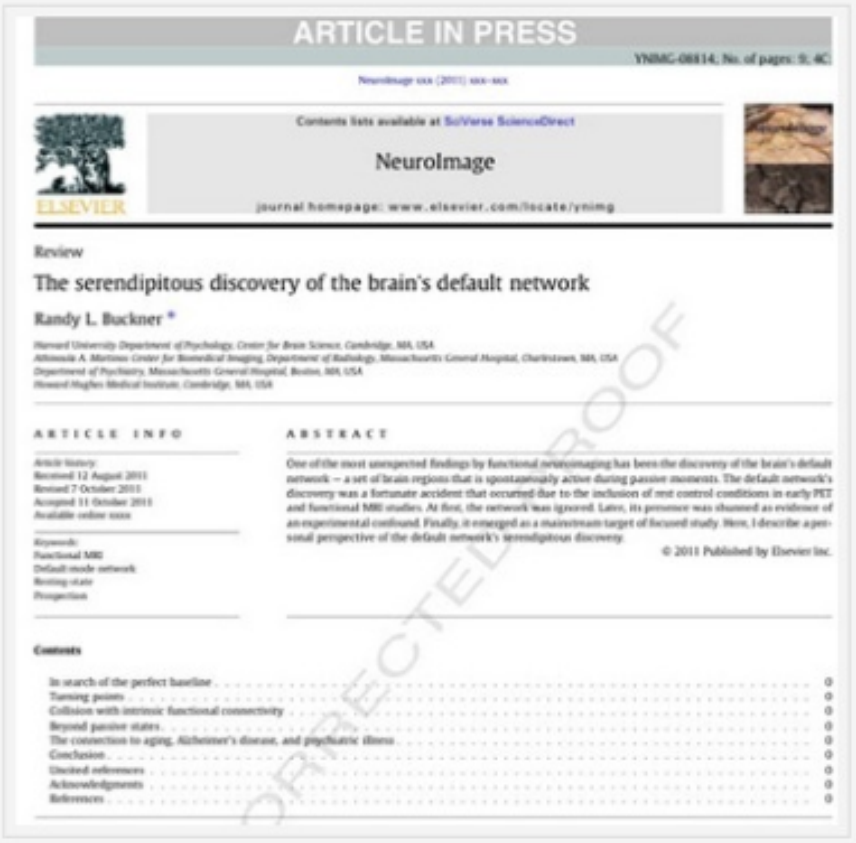
According to Bresslor and Menon (2010), "*a large-scale functional network can therefore be defined as a collection of interconnected brain areas that interact to perform circumscribed functions.*" More importantly, component brain areas in these large-scale brain networks perform different roles. Some act as *controllers or task switchers* that coordinate, direct and *synchronize* the involvement of other brain networks. Other brain networks handle the flow of sensory or motor information and engage in conscious manipulation of the information in the form of "thinking."

As illustrated in the figure above, neuroscientists have identified a number of core brain network nodes or circuits. The important new insight is that these various nodes or circuits are integrated together into a grander set of higher-level *core functional brain networks*. Three important core networks are receiving considerable attention in explaining human behavior.

Major functional brain networks



The *default mode (DMN) or default brain network* (shown in blue) is what your brain does when not engaged in specific tasks. It is the busy or active part of your brain when you are mentally passive. According to Bresslor and Brennon the "*DMN is seen to collectively comprise an integrated system for autobiographical, self-monitoring and social cognitive functions.*" It has also been characterized as responsible for *REST* (rapid episodic spontaneous thinking). In other words, this is the spontaneous mind wandering and internal self-talk and thinking we engage in when not working on a specific task or, when completing a task that is so automatized (e.g., driving a car) that our mind starts to wander and generate spontaneous thoughts. As I have discussed previously (at IM-HOME blog), the default network is responsible for the *unquiet or noisy mind*. And, it is likely that people differ in amount of spontaneous mind wandering (which can be both positive creative thinking or distracting thoughts), with some having a very unquiet mind that is hard to turn off, while others can turn off the inner thought generation and self-talk and display tremendous self-focus or controlled attention to perform a cognitively or motorically demanding task. A very interesting discussion of the serendipitous discovery and explanation of the default brain network is in the following soon to be published scientific article.



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Review

The serendipitous discovery of the brain's default network

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ABSTRACT

One of the most unexpected findings by functional neuroimaging has been the discovery of the brain's default network — a set of brain regions that is spontaneously active during passive moments. The default network's discovery was a fortunate accident that occurred due to the inclusion of rest control conditions in early PET and functional MRI studies. At first, the network was ignored. Later, its presence was shunned as evidence of an experimental confound. Finally, it emerged as a mainstream target of focused study. Here, I describe a personal perspective of the default network's serendipitous discovery.

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The *salience network* (shown in yellow) is a *controllor or network switcher*. It monitors information from within (internal input) and from the external world around us, which is constantly bombarding us with information. Think of the salience network as the air traffic controllor of the brain. Its job is to scan all information bombarding us from the outside world and also that from within our own brains. This controller decides which information is most urgent, task relevant, and which should receive priority in the queue of sending brain signals to areas of the brain for processing. This controlling network must suppress either the default or executive networks depending on the task at hand. It must suppress one, and activate the other. Needless to say, this decision-making and distribution of information must require exquisite and efficient *neural timing as regulated by the brain clock(s)*.

Finally, the central-executive network (CEN; shown in red) "*is engaged in higher-order cognitive and attentional control*." In other words, when you must engage your conscious brain to work on a problem, place information in your working memory as you think, focus your attention on a task or problem, etc., you are "thinking" and must focus your controlled attention. As I understand this research, the salience or controller network is a multi-switching mechanism that is constantly initiating dynamic switching between the *REST* (spontaneous and often creative unique mind wandering) and thinking networks to best match the current demands you are facing.

According to Bresslor and Melon, not only is this large scale brain network helping us better understand normal cognitive and motor behavior, it is providing insights into clinical disorders of the brain. Poor synchronization between the three major brain networks has been implicated in Alzheimer's, schizophrenia, autism, the manic phase of bipolar and Parkinson's (Bresslor and Melon, 2010), disorders that have all been linked to a brain or neural timing (i.e., the brain clock or clocks). I also believe that ADHD would be implicated. If the synchronized milli-second based communication between and within these large networks is compromised, and if the network traffic controller (the salience network) is disrupted in particular, efficient and normal cognition or motor behavior can be compromised.

I find this emerging research fascinating. I believe it provides a viable working hypothesis to explain why different brain fitness or training neurotechnologies have shown promise in improving cognitive function in working memory, ADHD, and other clinical disorders. It is my current hypothesis that various brain training technologies may focus on different psychological constructs (e.g., working memory; planning; focus or controlled attention), but their effectiveness may all be directly or indirectly facilitating the synchronization between the major brain networks. More specifically, by strengthening the ability to invoke the salience or controller network, a person can learn to suppress, inhibit or silence the *REST*-producing default brain network more efficiently, long enough to exert more controlled attention or focus when invoking the thinking central executive network. Collectively these brain fitness technologies may all improving the use of those abilities called *executive function*, or what I have called the *personal brain manager*. Those technologies that focus on *rhythm or brain timing* are those I find most fascinating. For example, the recent example of the use of *melodic intonation therapy* with Congresswoman Gabby Giffords (she suffered serious brain trauma due to a gun shot) demonstrates how rhythm-based brain timing therapies may help repair destroyed preferred and efficient neural pathways or, develop new pathways, much like the development of a new foot worn pathway in the grass on a college campus if a preferred pathway is disrupted by a new building, temporary work or renovation, or some other destruction of a preferred and efficient network of movement path.

To understand the beauty of the synchronized brain, it is best to see the patterns of brain network connections in action. Below is a video called the "Meditating Mind." I urge you to view the video for a number of reasons.

A number of observations should be clear. First, during the first part of the video the brain is seen as active even during a resting state. This is visual evidence of the silent private dialogue (*REST*) of the default mode or network of the brain. Next, the video mentions the rhythm of increased and decreased neural activation as the brain responds to no visual information or presentation of a video. The changes in color and sound demonstrate the rich rhythmic synchronization of large and different parts of the brain, depending on whether the brain is engaged in a passive or active cognitive task. The beauty of the rapidly changing and spreading communication should make it obvious that efficient rhythmic synchronization of *timing* of brain signals to and from different networks or circuits is critical to efficient brain functioning.

Finally, the contrast between the same brain under normal conditions and when engaged in a form of meditation is striking. Clearly when this person's brain is mediating, the brain is responding with a change in rates and frequency of brain network activation and synchrony. As I described in my personal IM-HOME based experience post, mastering Interactive Metronome (IM) therapy requires "becoming one with the tone"...which sounds similar to the language of those who engage in various forms of meditation. Could it be that the rhythmic demands of IM, which require an individual to "lock on" to the auditory tone and stay in that synchronized, rhythmic and repetitive state for as long as possible, might be similar to the underlying mechanics of some forms of meditation, which also seek to suppress irrelevant and distracting thoughts and eventually "let the mind go"---possibly to follow a specific train of thought with complete and distraction free focus.

Yes...this is speculation. I am trying to connect research-based and personal experience dots. It is exciting. MyIM-HOME based induce personal focus experience makes sense from the perspective of the function and interaction between the three major large-scale brain networks.

On-demand-focus

On-demand-focus

Is there similarity between the attentional focus required during IM-Home training and that attained by experienced meditators? Emerging scientific evidence suggests the answer is "yes."

In two prior IM-Home posts (here and here; one reproduced at the CreativityPost blog), I suggested that the requirement to quiet my unquiet or busy mind, via *controlled focus* on the IM auditory feedback cowbell tone, might be similar to the sense of being *"in immediate awareness"* as described by those who meditate. Furthermore, I hypothesized that both IM and meditation training might be training the mind to silence the ever-present random self-talk of the *default brain network*. By silencing this network, it becomes possible to attain singular focus on a stimulus or immediate experience. The constant wandering of our minds, which can be focused on both positive and negative thoughts and ideas, can be trained to disappear by invoking certain *executive functions* (our personal brain manager) and high levels of *attentional control*. The video of an experienced meditator watching identical visual images in both non-meditative and meditative states provides clear evidence that the networks of the brain function differently during these two different states.

In this context, I was excited to read an article in the prestigious *Proceedings of the National Academy of Science* consistent with my hypotheses and experience. In Brewer et al.'s Dec 13, 2011 PNAS article *"Meditation experience is associated with differences in default mode network activity and connectivity"*, the author's state:

Many philosophical and contemplative traditions teach that 'living in the moment' increases happiness. However, the default mode of humans appears to be that of mind-wandering...and with activation in a network of brain areas associated with self-referential processing. We investigated brain activity in experienced meditators and matched meditation-naive controls as they performed several different meditations (Concentration, Loving-Kindness, Choice less Awareness). We found that the main nodes of the default-mode network (medial prefrontal and posterior cingulate cortices) were relatively deactivated in experienced meditators across all meditation types...Our findings demonstrate differences in the default-mode network that are consistent with decreased mind-wandering. As such, these provide a unique understanding of possible neural mechanisms of meditation.

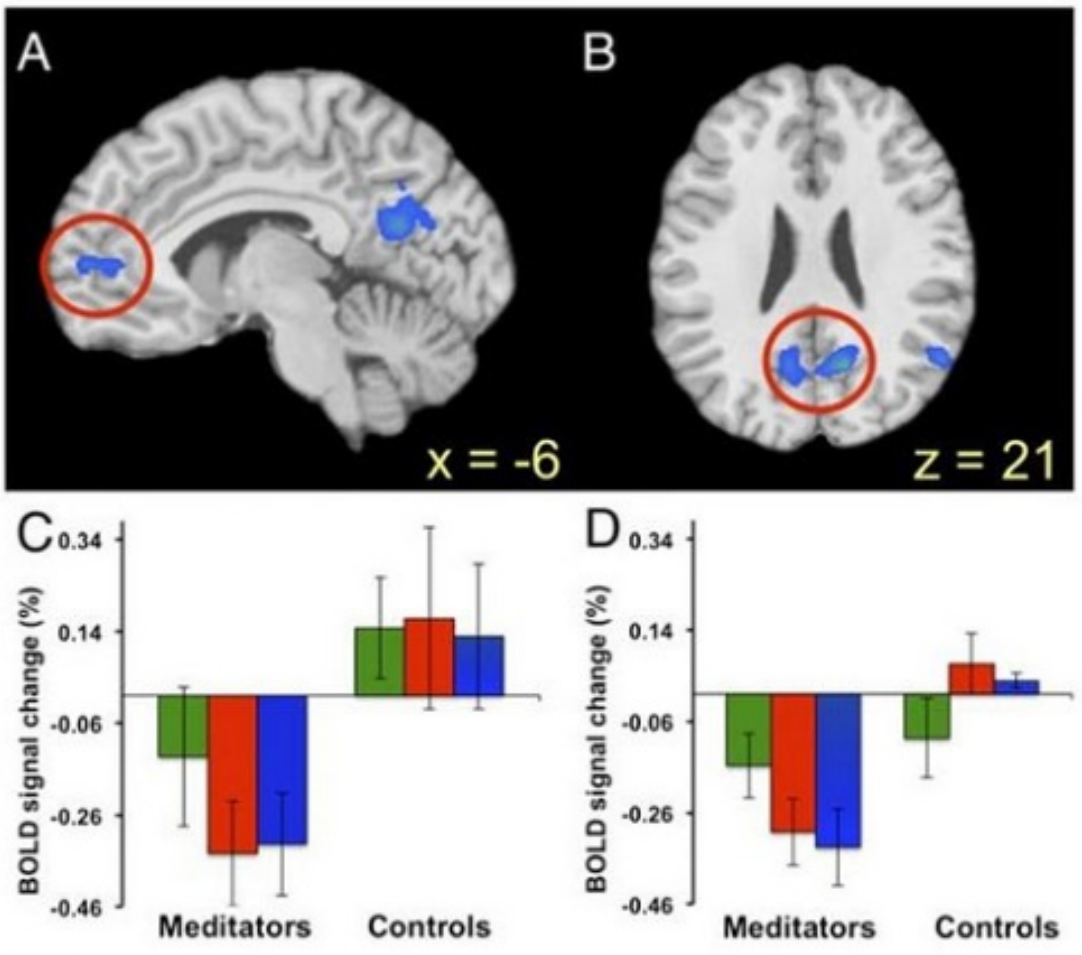


Fig. 1. Experienced meditators demonstrate decreased DMN activation during meditation. Brain activation in meditators > controls is shown, col-

These authors suggest that we spend approximately *50% of our time* in the mind-wandering default mode! As I described in a prior post, I believe that individuals differ in their amount of spontaneous mind wandering, and I am on the high end of the busy mind continuum. For those who want to read the original article, I have provided access to an annotated version via the Brain Clock Blog.

This possible IM-meditation connection (suppressing and controlling the default mind wandering brain network) has increased my motivation to continue my IM training. Unfortunately, due to the holidays I have not been able to complete any IM sessions this past week. However, I have discovered that *knowing* that I can turn my default wandering mind off for brief periods of time (2-5 minutes) has resulted in myself invoking on-*demand-focus*. This typically occurs when I am driving, a period of time when my mind is extremely busy with a number of private conversations. I remember the newfound skill required during my IM sessions and make a conscious decision to focus only on the immediate task of driving. I can successfully invoke controlled focus for 2-5 minutes at a time. I would like to make them longer, but this is the best I can do now. I am confident that increased IM training will extend the time I can engage in what I call *deliberate on-off focus*--or *on-demand-focus*.

My confidence in my ability to invoke *on-demand-focus* has empowered me to use and practice it in non-IM real world settings. In the field of educational psychology, this type of competence-specific confidence is called self-efficacy, a motivational trait that facilitates performance in the domain where the competence is felt. An analogy is the childhood story of the *Little Engine That Could*... that chanted *"I--think--I--can, I--think--I--can"*--but in my case it is *"I--know--I--can, I--know--I--can."* This is the essence of self-efficacy—an apparent indirect positive outcome of my IM training. Furthermore, the fact I am aware of this emerging skill and have confidence to deploy it, indicates that I am *"thinking about my thinking,"* which is what cognitive psychologists call metacognition.

In summary, my personal IM experience and research readings suggest that IM training has similarities to formal meditation techniques. Both methods train the mind to block out mind wandering self-talk and invoke focus in the immediate moment. My success may be partially due to an indirect non-cognitive benefit of IM—increased self-efficacy in my ability to focus and exert controlled attention. What I find exciting is my newfound (yet still not fully developed) ability to invoke *on-demand-focus*. Having such a mind tool can only facilitate my cognitive efficiency and ability to perform in situations where I need to focus like a laser beam.

Brain or neural efficiency: Is it quickness or timing?

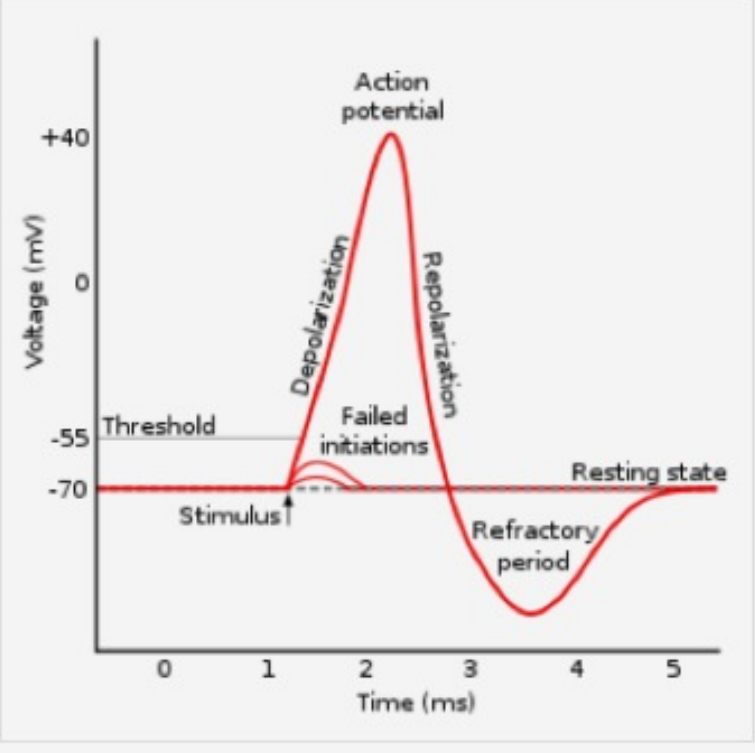
Brain or neural efficiency: Is it quickness or timing?

It is time I return to where I first started the description of my journeyto understand *Interactive Metronome* (IM) and the human brain clock. To recap, I firstbecame interested in the human brain clock after consulting on a school-based IM intervention study that produced positive results. Next, I reviewed research and theory that suggested that for a brain-clock based intervention (IM) to work across multiple human performance domains, the technology must be modifying some form of jack-of-all-trades *central* brain mechanism. I subsequently was excited to discover research that suggested that the human brain clock could be fine-tunedvia non-drug interventions. Finally, it was the research discovery described below that sealed my fate as a scholar interested in the applied potential of brain-clock based neurotechnology interventions.

Neural or brain efficiency: Is it mental quickness or timing?

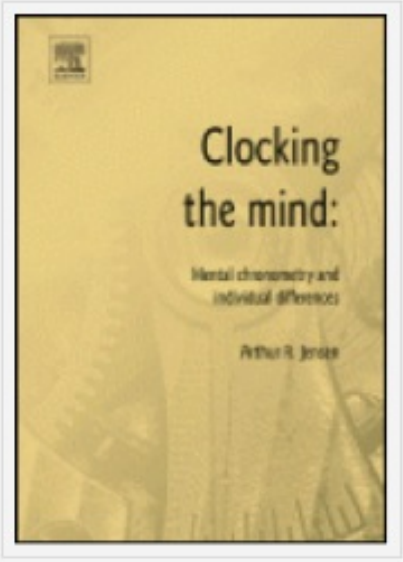
Neural efficiency and mental quickness. Cognitive and intelligence researchers have long sought the "holy grail "of intelligence—an *underlying core essence or mechanism* that plays a role in most all intellectual and human performances. It is typically referred to as *general intelligence*or simply, *g*. The general intelligence (*g*) concept is typically explained as being the result of neural efficiency. In simple terms, *neural efficiency hypothesis* states that the faster the brain's synapses fire the more efficient and faster the transmission of information within the brain, both at the level of individual nerve synapses and eventually at the level of fine-tuned communication across the various brain networks. Neural efficiency is not a thing or structure of the brain but an indicator of how well the brain is working. For example, in most cars the engine parts are generally the same. There is no "horsepower" part, but the collective synchronization of the various parts of the engine produce different levels of horsepower for different engines or the same engine under different conditions. In simple terms, neural efficiency is analogous to mental efficiency or horsepower. The neural efficiency hypothesis has been *the* dominant theory for explaining differences in general intelligence. It is associated with one of the most prominent intelligence scholars for decades, Dr. Arthur Jensen. 👉

Neural efficiency explains how quickly, after a neuron has fired, that it can recharge itself and fire again. Faster recharging rates allow for more frequent firing of nerve synapses during cognitive tasks. Think of flushing a toilet. Once flushed, one cannot immediately push the lever and flush it again. One must wait for the water reservoirs to refill to a certain level before the handle can be pushed and the toilet flushed again. This recharging period is akin to the *refractory period*with brain neurons. Once fired, they enter the refractory or resting period to recharge before they can fire and transmit information again. The neural efficiency hypothesis postulates that people who are more intelligent have neurons that have a shorter refractory or recharging period. Thus, their neurons can fire faster during a cognitive task if required, which is believed to produce better intellectual performance. To complete the analogy above, a toilet with a faster refill period can flush and discharge fluid more rapidly if the need arises



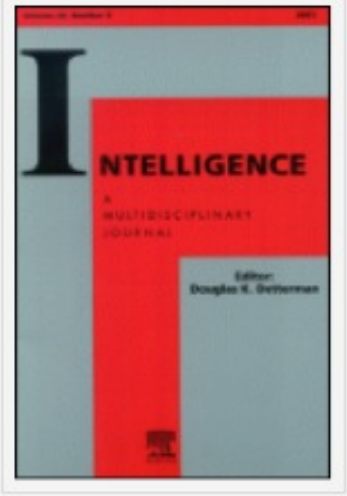
(Image from Wikipedia)

Most neural efficiency research has studied how *quickly* individuals can respond to very simple cognitive tasks which have taken a number of forms. This literature is summarized in Jensen's 2006 seminal book Clocking the Mind: Mental Chronometry and Individual Differences. Research has demonstrated that people differ in their *reaction time*(and other types of simple mental response "quickness") tasks, and the speed is correlated with general intelligence (*g*) as measured by IQ tests. It is believed that those with quicker reaction time have more efficient firing of neurons—*higher neural efficiency*. The dominance of the *reaction time-neural efficiency-general intelligence (g)* theory in the field of intelligence cannot be understated. It is *the* dominant theoretical and empirically-based explanation for the neural or brain mechanisms the may explain human general intelligence.



Neural efficiency and mental timing. It is against the dominant Jensen-based, reaction time-neural efficiency-general intelligence backdrop (hereafter referred to as the *reaction time g* position), that I was very excited when I discovered research by Dr. Rammsayerand colleagues that challenged the prevailing wisdom.

In a 2007 article in the prestigious journal Intelligence, which is where Jensen and others have dominated in their presentation of the *reaction time g* position, Rammsayer and Brandler published the article "*Performance on temporal information processing as an index of general intelligence.*" This is listed as one of the key research articles (Temporal g-gen IQ) at the Brain Clockblog.



The subjects were administered a comprehensive intelligence battery of 15 different cognitive abilities (psychometric general intelligence or *psychometric g*), *reaction time g* measures that produced 8 different reaction time scores, and 8 different measures of different aspects of the *internal master brain clock (temporal g).* The important difference is that *reaction time g* focuses on quickness of responding while *temporal g* focuses on the perception, discrimination or reproduction of the timing of stimuli over time. The difference between *reaction time g* (quickness) and *temporal g* (timing) may sound elusive and can be understood by understanding the basic types of tasks used in each.

In mental quickness (*reaction time g*) studies the typical task requires a person to gaze at a computer screen and watch for a certain image or flash to be displayed. The person is sitting with their primary finger resting on a button, and when they see the target stimulus they move their finger as quickly as possible and press another key. The time to do this is the reaction time. *Temporal g* tasks vary considerably, but in the case of a task like IM, an individual is not just sitting and waiting for a chance to react quickly, and then sitting back and waiting for the next time to react quickly again. Instead, the person is engaged in a *constant* attempt to stay on beat. In the IM task, the person is constantly focusing attention, responding steadily, and constantly receiving feedback, which is used to modify the rate of clapping (speeding up or slowing down slightly). The mental effort expended is much more demanding in a *temporal g* task like IM.

An analogy would be running. When poised at the starting line for a race, a runner hears the start gun and attempts to start running as quickly as possible when the start gun discharges. This is akin to *reaction time g*—how fast can you react once you hear the target sound (the gun). Then he could stop and get poised again waiting for another start, upon which he would hear the gun again and again try to get started as quickly as possible. In contrast, once a race starts, runners need to maintain a constant focus on the synchrony of their breathing, arm and leg movements, and the rhythm of their pace, while exerting *constant effort over a sustained period of time*. The later is akin to *temporal g*, or IM. It is much more demanding in terms of sustained focus on coordinating the timing and synchronization of multiple physical and mental movements for more than just a brief quick moment. Thus, *temporal g* cognitive tasks like IM require much more constant and complex controlled attention and focus than simple *reaction time g* tasks.

Without delving into statistical gymnastics, the analysis of this study found that the classic and revered *reaction time g* dimension correlated .34 with tested intelligence (*psychometric g*) while *temporal g* correlated *.56* ! The higher the correlation numbers the stronger two things are related, with a correlation of 1.0 indicating one thing can perfectly predict another. These numbers are easier understood if they are converted to percent of relationship explained. When converted to percent figures, the *temporal g* dimension, which is reflecting brain clock timing and not reaction time, accounted for 31% of *psychometric g* while *reaction time g* accounted for 12 %. *Temporal g*was 2.5 times more associated with measured psychometric intelligence (*g*) than classic *reaction time g*. For someone who has spent his career in the field of intelligence testing and research, this is a finding of major significance. Of course, this was only one study with 100 subjects and would be viewed with caution if the only study. But the systematic program of research by this group is impressive and deserves serious attention.

I recently posted 16 referencesfrom this research group that collectively support the importance of the human brain clock and, more importantly, my scientific opinion that measures of brain clock timing (and not reaction time) are most likely better measures of*neural efficiency*. Furthermore, my primary excitement stems from the connection between the successes of brain-clock based neurotechnologies (such as IM) and the *temporal g* or processing research. It is my hypothesis that these timing technologies are fine-tuning the resolution of the brain clock--which is a crucial mechanism for neural efficiency and, in turn, intellectual functioning. *The focus on mental or brain timing, and not brain or mental quickness, is the key.* As mentioned in a prior post, brain timing is implicated in a wide variety of clinical disorderssuch as ADHD, autism, speech and language disorders (aphasia, apraxia), cerebral palsy, gate disorders, Huntington's, schizophrenia, and Parkinson's disease. In contrast, little research has linked mental quickness with clinical disorders and, more importantly, with interventions or treatments for clinical disorders.

This post completes the description of my initial journey, which has recently taken me to using the IM-Home technology, which in turn has provided me IM-specific insights into possible cognitive explanations for the success of IM (click hereand here).

Now you know "the rest of the story" of the initial phase of my journey to understand the human brain clock.

IM is measuring and changing something real and important

IM is measuring and changing something real and important

No human investigation can be called real science if it cannot be demonstrated mathematically

Leonardo da Vinci, Treatise on Painting (1651)

Progress in science depends on new techniques, new discoveries and new ideas, probably in that order

Sydney Brenner (1980)

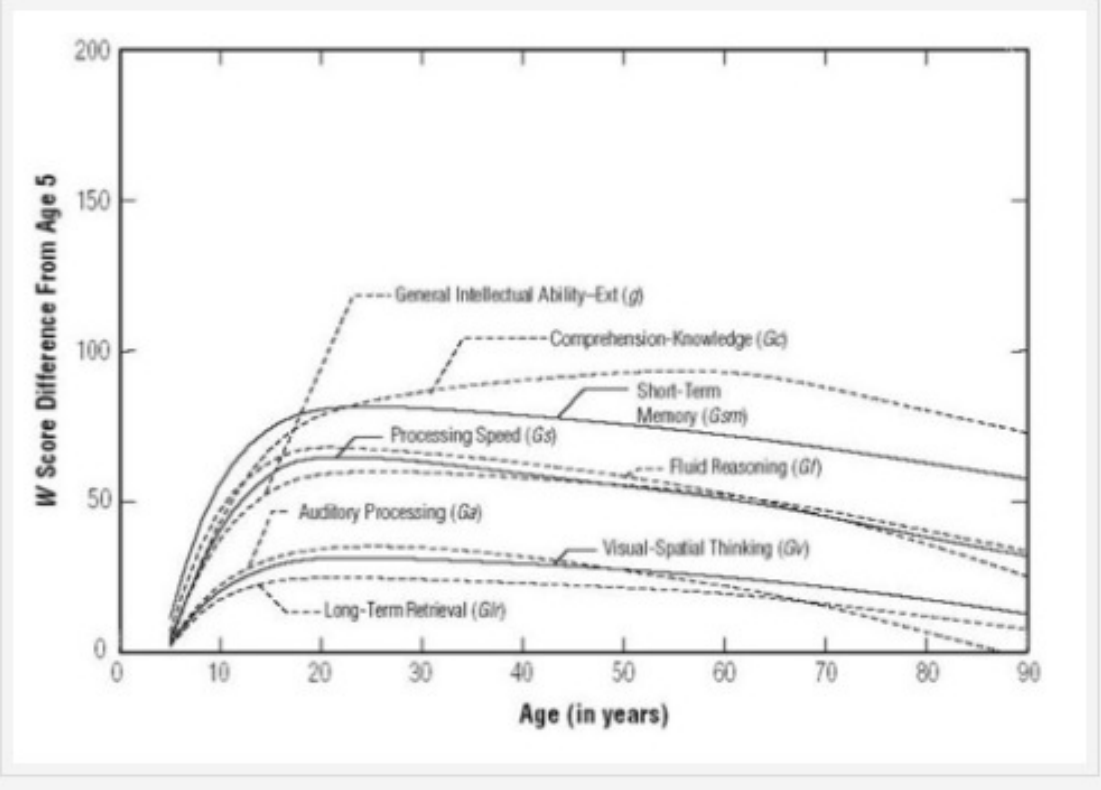
At the core of the IM intervention technology is a precise measurement system. To users and clinicians the IM measurement system is transparent. Yet, without the valid and precise measurement system, IM would not work.

In my "Brain or neural efficiency: Is it quickness or timing?" post, I advanced the hypothesis that the effectiveness of Interactive Metronome may be due to IM operating on a fundamental dimension of brain or neural efficiency, which intelligence scholars also relate to general intelligence (g). I have also suggested that this mechanism improves control of attention and may allow individuals to "quiet a busy mind" and invoke "on-demand focus."

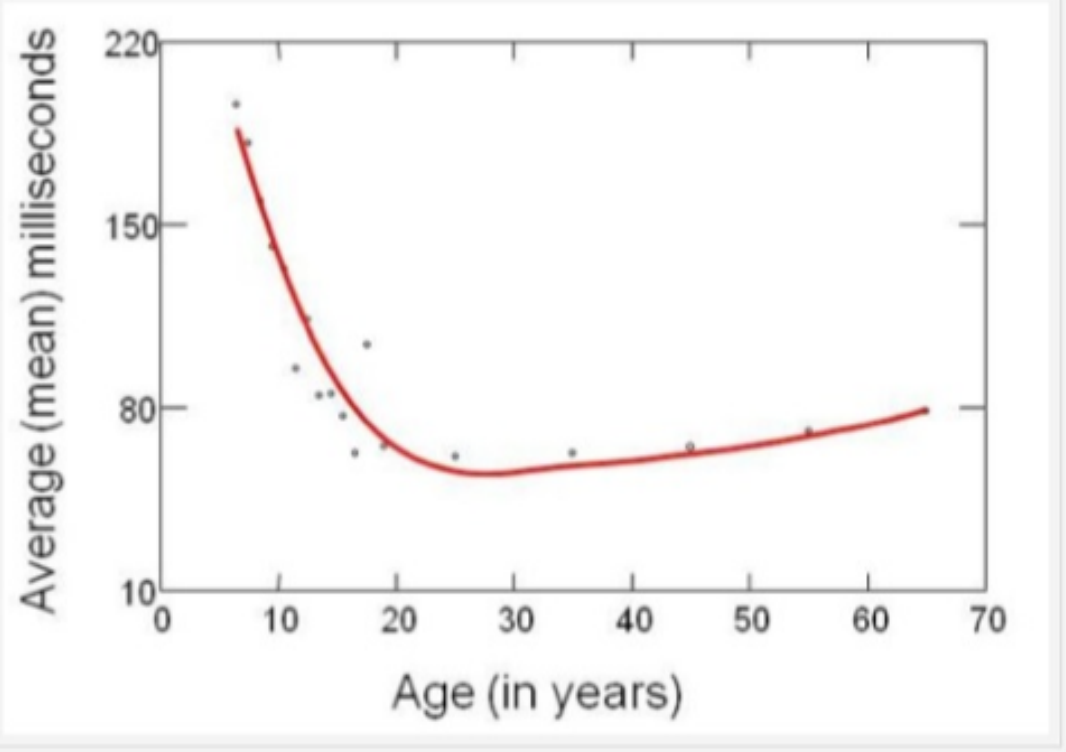
As an applied intelligence test developer (click here), I have been intrigued by the underlying precise millisecond-based measurement system which is the heart of IM technology. IM technology would not work if the underlying measurement system could not reliably measure differences in synchronized metronome tapping between individuals and changes within the same individual over repeated sessions.

Wanting to know how precise the underlying IM measurement system is, I extracted the average millisecond scores from an unpublished 2003 Interactive Metronome document that reported average times for different age groups. The sample consisted of the initial IM Long Form Assessment performance of 1,583 clinical and normal subjects ranging in age from 6 thru 60+. It is important to note that the sample was not a nationally representative normal sample and was comprised of more clinical subjects receiving IM therapy. Nevertheless, I wondered if this less-than-optimal set of data might demonstrate a pattern of increasingly shorter response times as individuals became older. Why did I want to examine this? 👉

Developmental increase in proficiency on tests and measures of human abilities is considered one form of evidence that a test or measurement system is reliably and validly measuring an important human ability. In the case of intelligence, valid measures of cognitive abilities show developmental growth curves where the youngest subjects obtain the lowest raw scores and the average raw scores gradually increase with increasing age. They eventually level out and then start a decline as old age sets in. Below are growth curves from seven cognitive ability scores from the Woodcock-Johnson Battery—III, a test battery of which I am a co-author. The important observation to note is that, despite the specific cognitive ability measure, all curves show low scores for the younger ages followed by acceleration of growth to a certain point. Each curve then plateaus at a certain age range, after which age-related cognitive decline is noted, but at different rates for different abilities. These curves are presented in the WJ III Technical Manual (McGrew & Woodcock, 1991) as a form of developmental validity evidence—which provides one piece of evidence that the WJ III tests are valid measures of different and important human intellectual abilities.



Scholars in intelligence have studied and postulated about the different rates of growth and decline for different abilities. These are serious data about human intelligence and the measures used to capture differences in human abilities. Within this context, I was *ecstatic* when I plotted the initial IM Long Form Assessment data (which is analogous to the first time a person is "tested" with the IM measurement system) and discovered the following plot.



The first thing the reader should note are the individual data points (the dots). The points show some random "bouncing around" which we measurement folks call *sampling error*. The critical point is that they follow a systematic trend that can be estimated by fitting a mathematical curve to the data points. This was the same procedure used to develop the WJ III cognitive curves in the first figure. In the second figure, the IM timing curve is demarcated in red. We who develop test norms and study human ability growth curves generate these smoothed growth curves as they are the best estimate of the real reality of the data if extremely large number of individuals had been tested at each age (there would be much less bounce).

One does not need to be a rocket scientist to interpret the smoothed IM growth curve. Individuals at the youngest ages, on the average, show the largest millisecond discrepancy from the IM reference tone. Then, with increasing age, the average IM target-to-response for individuals decreases systematically as children age. At approximately 25 years of age the curve "bottoms out," and then as individuals get older, IM millisecond timing scores increase (or get less accurate). The systematic nature of this curve is *amazing*, considering it is based on a less-than-optimal sample for determining what constitutes average.

If the reader is having a hard time relating the IM timing curve to the WJ III cognitive ability curves, I have taken the liberty of simply rotating and flipping the IM timing accuracy growth curve in the figure below. *Violla (aka, walla—"there it is")!* The curve has the same general shape as the WJ III cognitive ability growth curves! The reason for the difference between the WJ III growth curves and the first IM timing growth curve is that the meaning of high and low scores are reversed—higher IM times mean lower skilled performance while lower scores on the WJ III battery are associated with lower performance (and vice versa).

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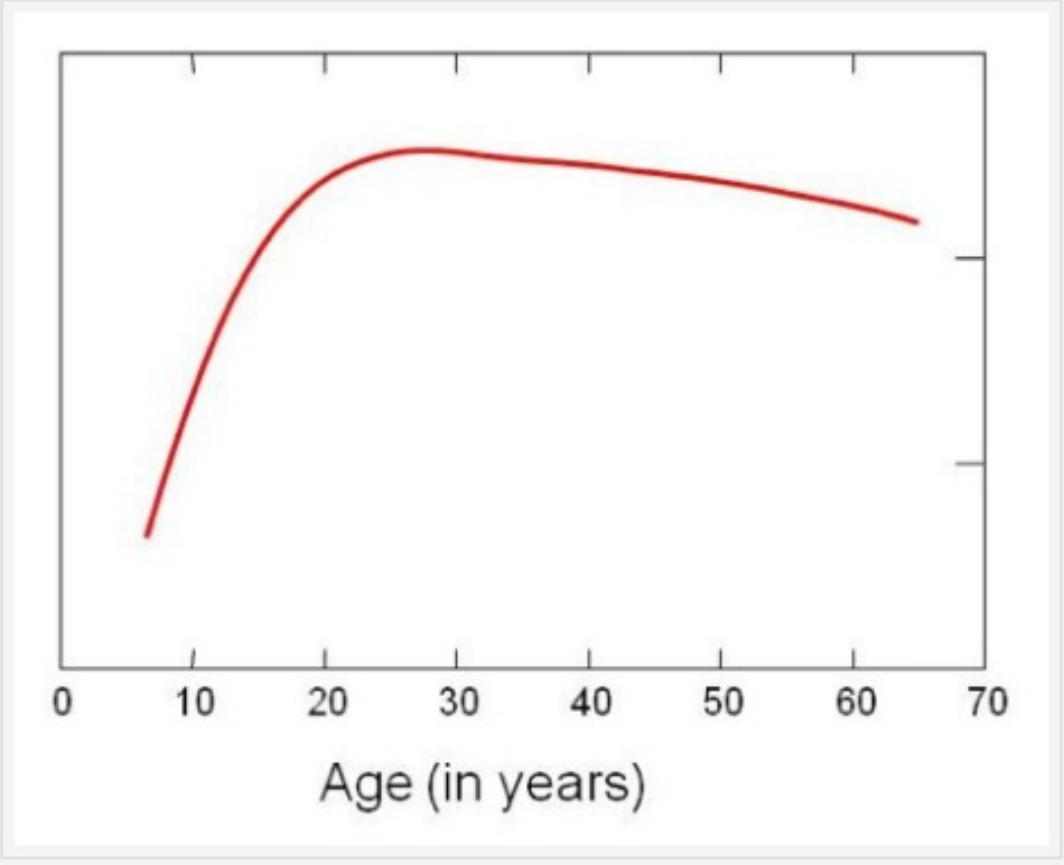
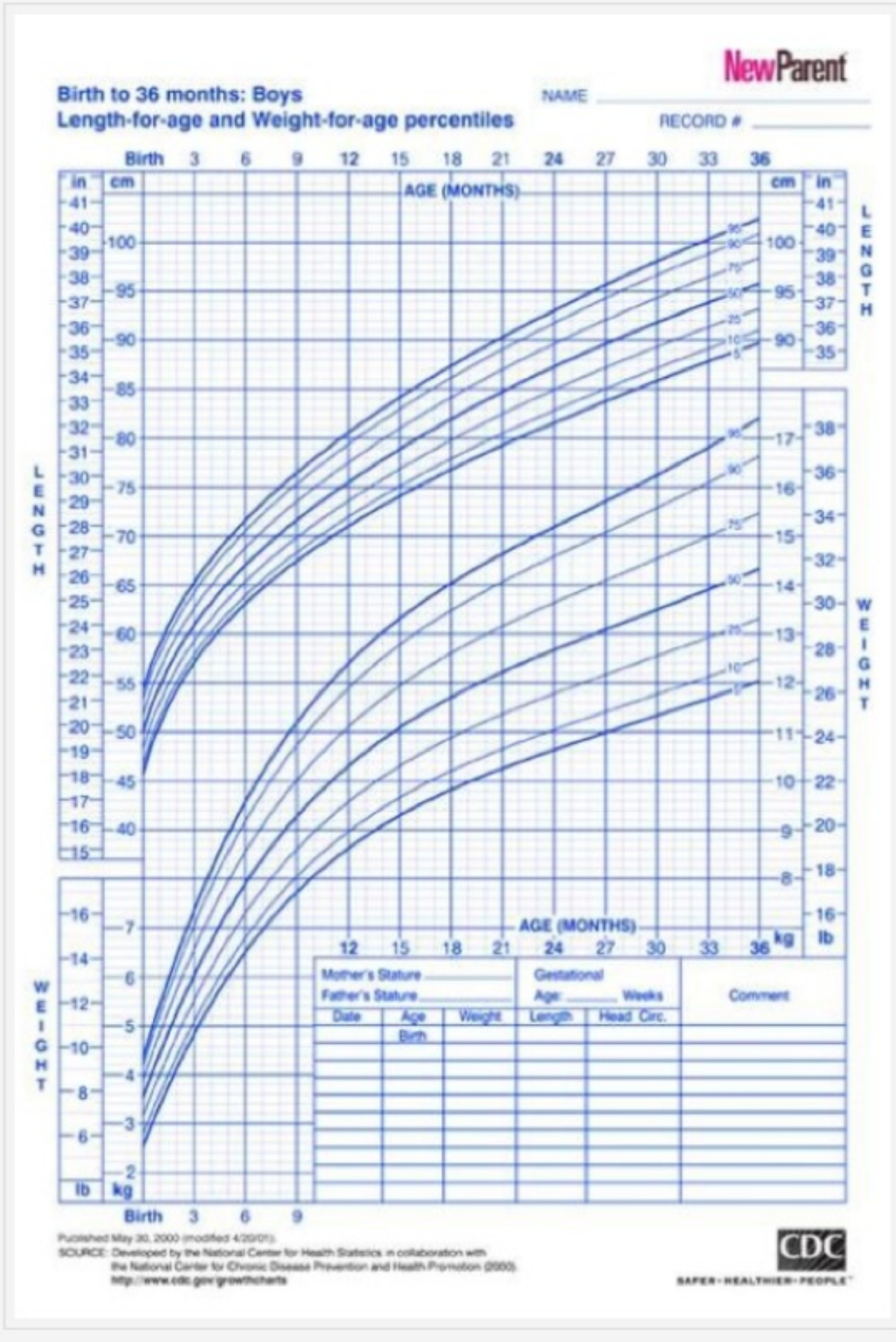


Readers who are parents may have seen similar growth curves during well-child visits with the family doctor. Below are growth charts for weight and length for male children from birth to 36 years. Although covering a much smaller age span than the WJ III cognitive and IM timing curves above, the shape of the curves is identical for the comparable age ranges (gradually increasing with age). The middle dark line in each set (labeled 50 for 50th percentile) is conceptually identical to the above single curve plots. These physical measurement curves show the systematic and developmental nature of physical growth.


NewParent
Birth to 36 months: Boys
Length-for-age and Weight-for-age percentiles
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Weight
Length
Head Circ.
Birth
Published May 30, 2000 (modified 4/20/01).
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).
http://www.cdc.gov/growthcharts
CDC
SAFER·HEALTHIER·PEOPLE

Why am I so excited about the IM timing growth curve? Because it demonstrates, similar to the physical and intelligence growth curves, that the underlying measurement unit used as the core of IM therapy *is measuring a human ability that follows a similar and expected developmental pattern*. Such curves are believed to be due, depending on the specific ability, to the influence of education and experiences as well as genetically-driven biological maturation of the central nervous system (CNS). The IM timing curve is one form of evidence that *the IM measurement system is measuring a fundamental human capacity*. This is extremely exciting! It is one more piece of evidence that the IM core measurement technology is measuring and working on a core critical human ability. Coupled with other validity evidence previously discussed here and elsewhere, this additional piece of scientific evidence has convinced me that the IM measurement and intervention system is most likely measuring a fundamental aspect of the development of the central nervous system (e.g., neural efficiency). The cognitive abilities I have suggestedfall under the broad umbrella term of *executive functions*, and more specifically *controlled attention (focus)* and *working memory*.

A caveat before I close. The smoothed IM timing curve should not be used by IM providers to evaluate how typical, normal, or close-to-average a person is on their initial IM Long Form Assessment. The mixed nature of the sample (normal and clinical subjects; more of the later) argues against such use. Also, the curve only represents the *average* at each age and calculating and plotting the typical *variability* around the curve would also be necessary. I deliberately left out the variability data curves so as not to encourage misuse of the information.

However, IM providers can evaluate their client's performance by using the official IM Indicator Table. A copy is reproduced below. This table can be used to determine whether a client's performance is in the "ballpark" for their age. Providers simply locate the clients age in the row at the top then go down that column to find the millisecond score or range that includes their specific IM Long Form Assessment timing score. The verbal description associated with each level (extremely deficient to exceptional) can be used to make *quality of performance* statements reflecting where an individual is at the time of the initial assessment. The scores and labels should not be used for diagnostic purposes. Instead, they can be used to describe, in approximate ball park terms, where an individual is at the time of the assessment when compared to others of the same age and to make comparisons about that same client's performance over time.

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Age		**7 to 8**	**9 to 10**	**11 to 12**	**13 to 15**	**16+**
Extreme Deficiency	280+	270+	260+	240+	215+	200+
Severe Deficiency	175-279	170-269	160-259	155-239	150-214	147-199
Below Average	120-174	90-169	80-159	75-154	72-149	70-146
Average	90-119	65-89	55-79	45-74	43-71	41-69
Above Average	56-89	45-64	38-54	36-44	33-42	30-40
Exceptional	40-55	32-44	28-37	26-35	23-32	22-29
Superior	Below 40	Below 32	Below 28	Below 26	Below 23	Below 22

In summary, I have traversed a number of empirical domains in my journey to understand IM. The finding of such powerful and clear *developmental evidence* for the underlying IM measurement system is one of the final dots I connected which convinced me of the promise of IM. The IM program is founded on a valid scientific measurement system of an important human cognitive ability (or constellation of related abilities).

You are a Time Machine

Time and space are the two fundamental dimensions of our lives. All forms of human behavior require us to process and understand information we receive from our environment in either spatial or temporal patterns. Even though mental timing (temporal processing) research is in a stage of infancy (when compared to spatial processing) important insights regarding the human brain clock have emerged.

Below is a list (albeit incomplete) of some of the major conclusions regarding the human brain clock. The sources for these statements come from my review of the temporal processing and brain clock literature during the past five years. Most of this information has been disseminated at the Brain Clock blog or the Brain Clock Evolving Web of Knowledge (EWOK). The goal of this post is to provide a Readers Digest summary of the major conclusions. This material can serve as a set of "talking points" at your next social event where you can impress your friends and family as you explain why you use the high-tech IM "clapper" (with a cowbell tone no less) either as a provider or as client.

Our brains measure time constantly. It's hard to find any complex human behavior where mental timing is not involved. Timing is required to walk, talk, perform complex movements and coordinate information flow across the brain for complex human thought. Think about moving your arm and hand to grasp a coffee cup. The messages to perform this task originate in your brain, which is not directly connected to your arm, hands and fingers. The ability to perform the necessary motor movements is possible only because the mind and extremities are connected via timing. Precisely timed neural messages connect your brain and extremities. You are a time machine.

Humans are remarkably proficient at internally perceiving and monitoring time to produce precisely timed behaviors and thinking. "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..." (Lewis & Walsh, 2005, p. 389).

To deal with time, humans have developed multiple timing systems that are active over more than 10 orders of magnitude with various degrees of precision (see figure below from Buhusi & Meck, 2005). These different timing systems can be classified into three general classes (viz., circadian, interval, and millisecond timing), each associated with different behaviors and brain structures and mechanisms. The fastest timing system (millisecond or interval timing) is involved in a numerous human behaviors such as speech and language, music perception and production, coordinated motor behaviors, attention, and thinking. This fast interval timing system is the most important timing system for understanding and diagnosing clinical disorders and for developing and evaluating effective treatment interventions for educational and rehabilitation settings. It is this timing system, and the relevant research, that is relevant to understanding Interactive Metronome.

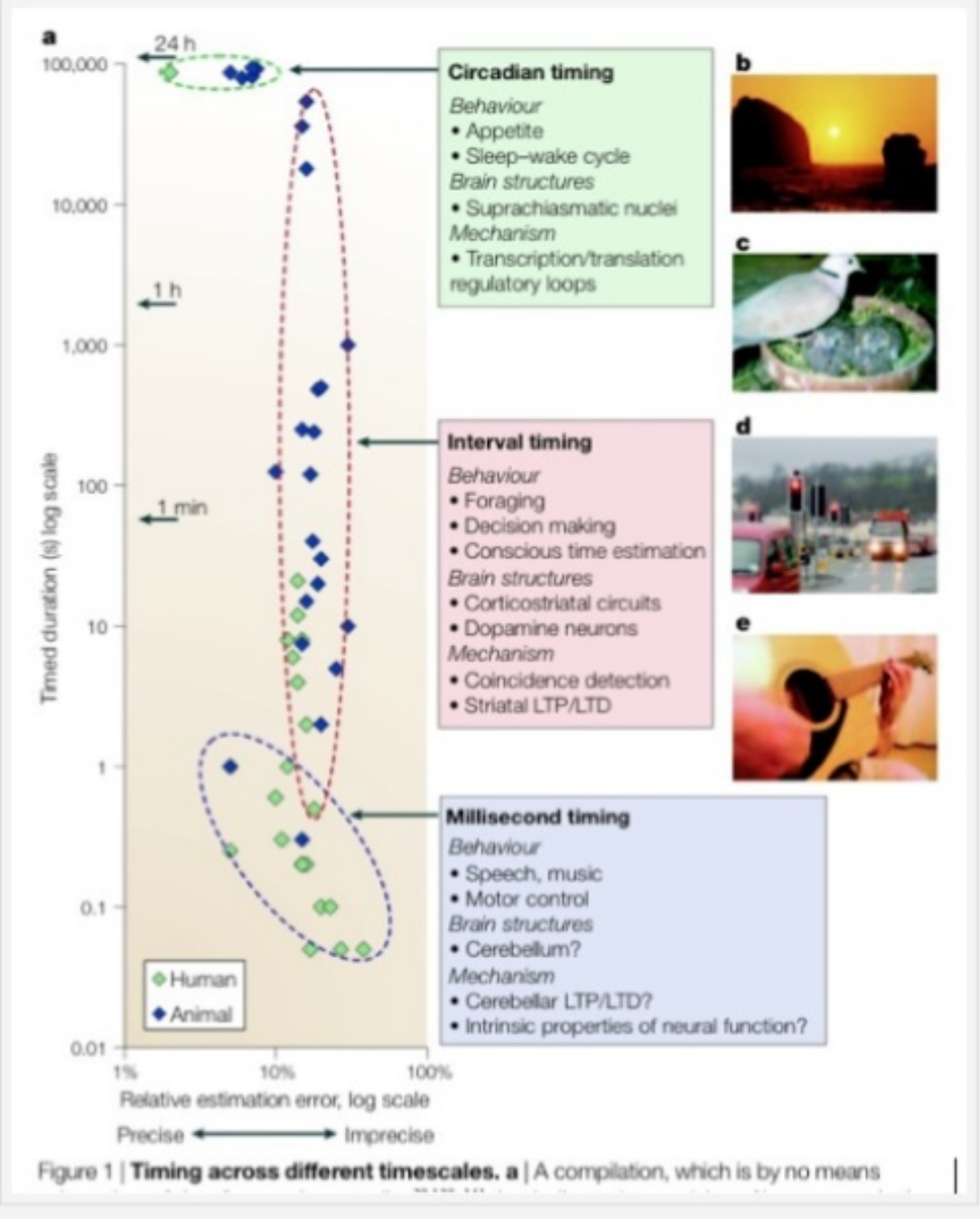
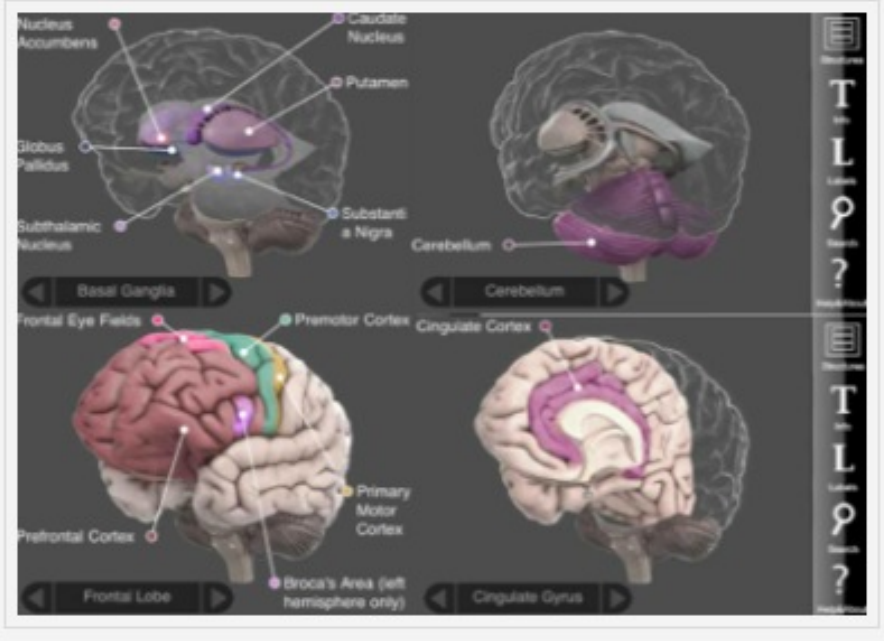


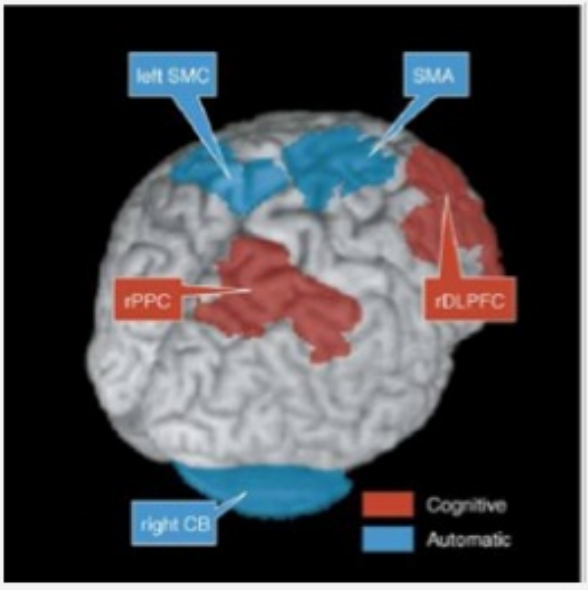
Figure 1 | **Timing across different timescales. a** | A compilation, which is by no means

Although there is consensus that the human brain contains some kind of clock, the jury is still out on the exact brain mechanisms and locations. It is also not clear whether there is one functional master clock or a series of clocks deployed in different brain areas. The areas of the brain most consistently associated with milli-second interval mental timing are the cerebellum, anterior cingulate, basal ganglia, the dorsolateral prefrontal cortex, right parietal cortex, motor cortex, and the frontal-striatal loop. That is a mouthful of technical brain terms. But, if you can memorize them and have them roll of your tongue with ease you will "shock and awe" your family and friends ☺ of these areas of the brain are illustrated below. Now, if you really want to demonstrate your expertise, get your own illustrated "brain-in-a-pocket". These images were generated by the free 3D Brain app available for your iPhone or iPad. Even cooler is the fact that you can rotate the images with your finger! You can give neuroanatomy lessons anytime...anywhere!



Research suggests that mental interval timing is controlled by two sub-systems. The automatic timing system processes discrete-event (discontinuous) timing in milliseconds. The cognitively-controlled timing system deals with continuous-event timing (in seconds) that requires controlled attention and working memory. Both systems are likely involved in IM. For example, the synchronized clapping requires motor planning and execution, functions most associated with the automatic timing system. However, the cognitive aspects of IM (focus, controlled attention, executive functions) invoke the cognitively controlled timing

system. Aren't these brain images awesome?



The dominant model in the brain clock research literature is that of a centralized internal clock that functions as per the pacemaker–accumulator model.

Briefly, this is a model where "an oscillator beating at a fixed frequency generates tics that are detected by a counter. For now I am just going to tease you with an image of this model. You can read more about this model at the Brain Clock blog.

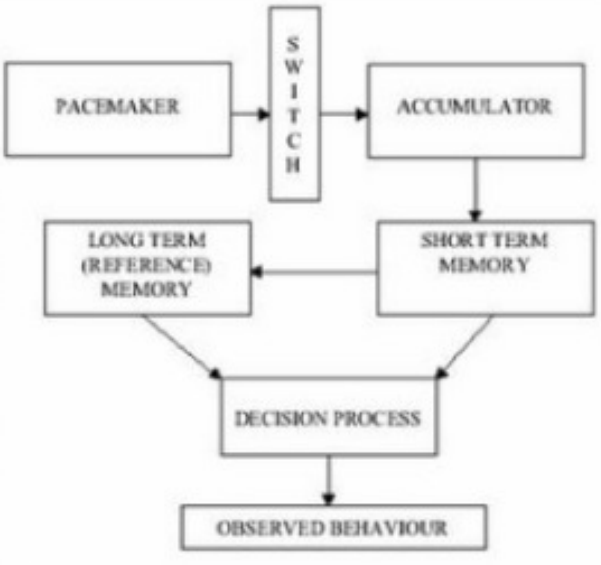


Fig. 1. Outline of the scalar expectancy theory (SET) system. The upper level shows the pacemaker-accumulator clock, the middle level the long-term reference memory and the short-term working memory, and the lowest level the decision mechanism.

Research suggests that the brain mechanisms underlying mental timing can be fine-tuned (modified) via experience and environmental manipulation. Modifiability of mental interval timing and subsequent transfer suggest a domain-general timing mechanism that, if harnessed via appropriately designed timing-based interventions, may improve human performance in a number of important cognitive and motor domains.

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Alertness versus focus: Same or different?

Alertness versus focus: Same or different?

Often upon completing a brief description of the benefits of IM to an individual, which centers on the benefits of increased controlled attention or "on demand focus", people often ask me why not just drink one of those highly advertised energy drinks. These drinks claim to increase alertness, attention, energy and focus. Drinking an energy drink is much easier when compared to committing to IM training for three weekly hour sessions over a period of 4-5 weeks

In general, the primary claim of these energy drinks is increased alertness. Thus, it is important to understand that alertness is not the same as controlled attention or focus. Given all the claims circulating in the "cognitive enhancement" market place (energy drinks, brain fitness technologies), it is important that the discourse be scientifically-based and grounded in a professional consensus of terms. So let me attempt to add some order to the increasing confusion of terms.

I first turn to the highly respected Annual Review of Psychology for an article published by Posner and Rosthbart (2007).Their comprehensive research review makes a distinction between three different attention networks—alerting, orienting, and executive attention. These three different attention networks are orchestrated by different areas of the brain (see figure below). They also differ in the primary neurotransmitters utilized by each system---alerting (acetylcholine), orienting (norepinephrine), and executive (dopamine). Although related and often working collaboratively, they are different forms of attention.

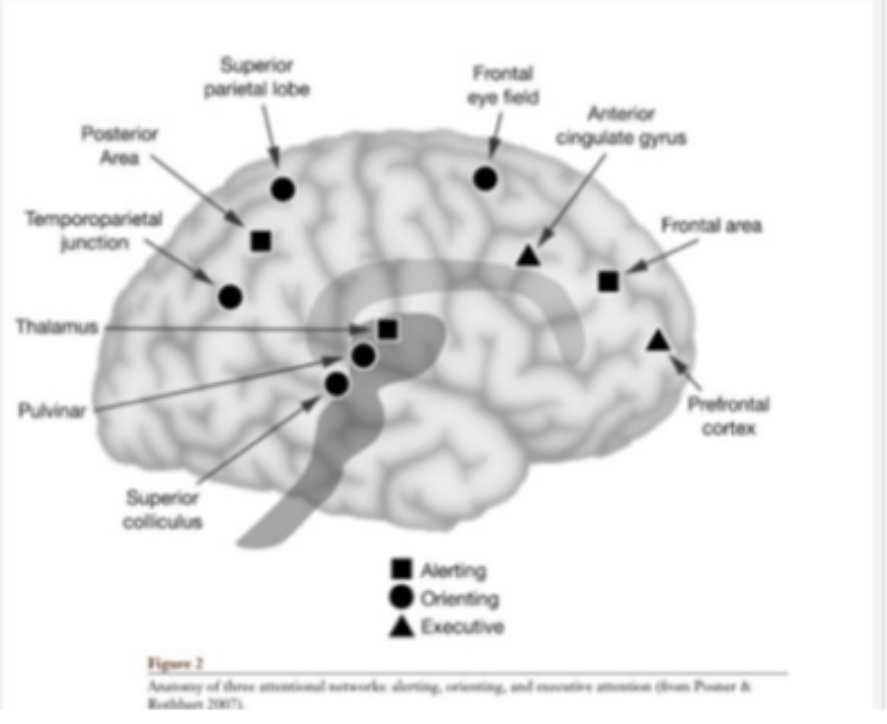
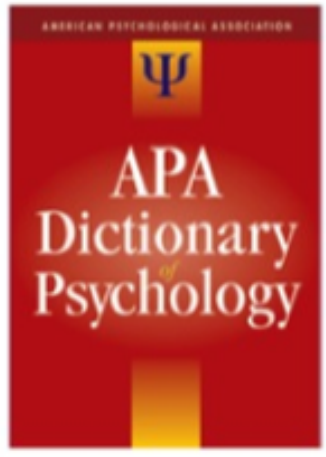


Figure 2

Anatomy of three attentional networks: alerting, orienting, and executive attention (from Posner & Rothbart 2007).

In Posner's and Rosthbart's review alerting is defined as achieving and maintaining a state of high sensitivity to incoming stimuli. This is similar to the definition of alertness in the APA (American Psychological Association) Dictionary of Psychology which is "the state of being awake, aware, attentive and prepared to act or react, as opposed to being inattentive or drowsy."



My analogy is the night guard or sentry in a fox hole whose job is to stay alert and perform a constant wide scan of the terrain for sights or sounds of possible activity. Alertness requires a wide scan of the environment and not a narrow selective focus on anything in particular. It is this type of wide-scan attention that energy drinks most likely facilitate.

Then, if the guard hears or see's something, (s)he will move his head and body in the apparent direction of the stimuli. This is orienting attention, which Posner and Rosthbart describe as the process of improving the perception of the signal by aligning attention with the incoming signal. This definition is consistent with that from the APA Dictionary of Psychology that defines orienting as the act of directing the body or of moving toward an external stimulus." Although I have no scientific basis upon which I base my statement, it would be my educated guess that increased alertness via consumption of an energy drink might make the orienting response more efficient.

Finally, once oriented, the guard hones in on the source of the sound or light with a very narrow focus...much like a laser beam. The guard may use binoculars or the scope on his/her rifle to magnify the images, narrow down the scope of the stimulation, and to block out other irrelevant stimulation. This is analogous to focus or controlled executive attention which the APA Dictionary of Psychology defines as "the concentration or centering of attention on a stimulus." This professional dictionary further defines controlled or selective attention, which is the essence of "focus," as "attention concentrated on certain stimuli in the environment and not others, enabling important stimuli to be distinguished from peripheral or incidental ones." This type of laser beam focus, with the blocking or suppression of responses to irrelevant stimuli, is the essence of focus and the focus I have described as a core essence of IM training.

Given the above clarification of terms, I would argue that energy drinks may increase alertness, but being altered does not necessarily mean one is focused. In fact, the definition of alertness is the polar opposite of focus—alertness is a wide scan of all possible incoming stimuli while focus is the narrowing of this scan on a very focused target. One can be alert and not focused, one can be alert and focused, but I doubt if one can be un-alert and focused.

Focus is the laser beam of attentionand is a brain tool that requires considerable practice and effort to attain, with the reported maximum period of focus being in the range of 20-30 minutes. It is quite difficult to turn off irrelevant thoughts and stay "locked on" cognitive tasks. To develop and maintain the ability to control attention and engage in "on-demand focus" cannot be attained simply by drinking a special drink—it requires regular sustained, motivated practice with appropriate training methods and technologies (e.g., IM, mindfulness meditation). Just like weight loss, there is no magic, simple bullet or secret elixir to shed pounds. The consensus is that to lose weight one must alter one's diet and engage in regular exercise. So it is with increasing one's focus. It requires sustained, regular exercise and practice.

The "Time Doc" (K. McGrew) Voice of America interview on focus and "quieting the busy mind"

Why is a scholar in intelligence theory and testing spending time working with and researching the brain-clock based neurotechnology of Interactive Metronome? I have now explained this connection on my recent Internet radio show interview. In it you will learn why IM technology appears to increase focus (controlled attention; working memory) in a manner similar to mindfulness meditation and other brain fitness programs. You will learn that these technologies help to "quiet the busy" mind that is due to the default brain network, via the strengthening of the salience and central executive networks. The connection with general intelligence (g) is also discussed via Jensen's neural efficiency hypothesis and the temporal g notion of neural efficiency. If you want to read more, check out the Time Doc's posts at the IM-Home blog (check for posts under my name or under the category of "science"... and be sure to click on "see other stories" if it does not give you all the posts) These include the Time Doc's own personal experience with the IM-Home brain clock based technology.

My radio interview with Maureen Palmer (OT), on Voice of America (Focus Point Review) is now available for off-line listening via MP3 or iTunes format (as a podcast). You can access these and listen for free. If you have an iPod, iTouch, iPad, I would recommend downloading the free podcast. To find the file you go to the following link and look for this section with the links. Click on either the MP3 or iTunes options...and enjoy. Given it is off-line you can skip thru commercial's, fast-forward, pause, etc.

After the shows are completed they are available for later listening as MP3 files or free Podcasts from iTunes. I will share this off-line URL information later.

Watch now! or download the podcast Here.

ADHD as a brain network dysfunction—IM as a tool to "fine tune" and control this network.

ADHD as a brain network dysfunction—IM as a tool to "fine tune" and control this network.

The explosion of research on *large scale brain networks*, and the "resting state" or "default mode or default network" in particular, has been dizzying. I previously reviewedkey brain network research describing the interaction between the *default*, *salience* (attention) and *executive controlled* networks. The most important conclusion, which was reinforced by my personal experiencewith Interactive Metronome (IM), is that problems with controlled attention (focus) may be responsible for a number of the behavioral symptoms of ADHD—and this is due to the poor ability to suppress the random self-talk "background noise" of the default brain network. [Click herefor related IM-HOME ADHD posts; click herefor ADHD- related Brain Clock.]

In prior posts I advanced the position that the efficacy of IM technology in improving focus or controlled attention is that it helps to "quiet the busy mind" due to the REST (random, episodic, spontaneous thought or thinking) of the default brain network. In simple terms, poor ability to suppress or quiet the default network results in poor controlled attention when trying to engage in controlled, deliberate cognitive tasks. The pirates of the default network are constantly engaged in "attentional capture" escapades—efforts to capture the brains gold—focus and controlled attention.

A new research review in Trends in Cognitive Sciences (January 2012, Vol. 16, No. 1) supports the hypothesis that ADHD may be a default brain network disorder. The authors state *"In 2007, Sonuga-Barke and Castellanos suggested that ADHD could be considered a default network disorder"*...and the authors of the current article agree.

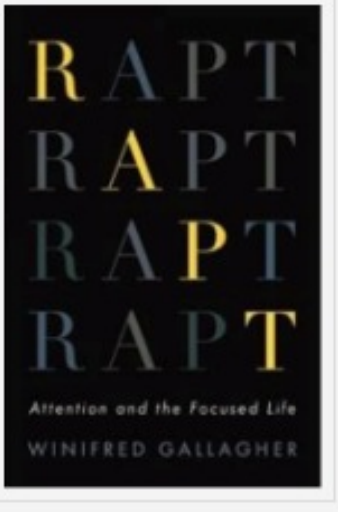
Individuals with ADHD may have trouble stopping (inhibiting) the spontaneous intrusion of default network generated random thoughts when engaged in tasks that require laser-beam focus on a cognitively demanding task (e.g., solving math problems; reading). Either the default network does not function properly or is not synchronized well with other brain networks responsible for engaging controlled attention to shut down or inhibit the intrusion of thoughts generated by a busy mind. A comprehensive review of the ADHD research in Neuropsychopharmacologyalso concluded that studies of the brain when it is at "rest" (default mode) reveal that one of the primary problems in ADHD "may lie in dysfunction of brain regions that, as discussed above, support a proposed 'default network'. Specifically, it may be the case that an abnormally high default mode network activity may interfere with CFP attention network activity." CFP refers to cingulo-fronto-parietal activation.

I am not alone in my belief that a faulty default network, or a default network that is not well controlled by other cognitive control networks (sometimes referred to as poor network *coherence*), is important for understanding ADHD and other cognitive disorders. Check out "The Brains Background Noise" and "Diagnosis by Default" for other reports along these lines. Also, a very interesting studylinking the busyness of one's wandering mind and working memory and attention fits nicely into this growing body of literature.

The ability to invoke "on-demand-focus", to quiet the spontaneous internal self-talk and thinking we all enjoy when appropriate, is an important cognitive tool that can be trained. Forms of meditationappear to operate along these lines. As summarized in my prior posts, IM is a cognitive tool that can help individuals hone their ability to invoke on-demand-focus. The attention-capturing pirates need to be kept at bay when the brain's precious limited golden resource of attentional control (focus) is needed.

RAPT: Attention and focus

I have been reading Winfred Gallagher's 2009 book "RAPT: Attention and the focused life." In many of my blog posts I maintain that Interactive Metronome (IM) training requires controlled attention—focus. I have further suggested that "on demand focus" is a potentially powerful tool. By this I mean one wants to train your brain to invoke focused attention when facing cognitively demanding tasks. However, 100% laser beam focus is not attainable, nor would one want to constantly be super focused. The mind wandering of the default brain networkneeds to be shut down to focus. However, unfettered mind wandering can allow for creative thought (and also the flip side—ruminations of irrational or bad thoughts).



It is with this background that I find RAPT to be of considerable interest. I do not agree 100% with all Gallagher suggests, as with any single prescription for the ultimate way to live one's life, it tends to overreach at times. Also, the laser like focus on the most critical information in your working memory (which is what IM is about) is a much narrower concept than a more global philosophy of life ("your life is the creation of what you focus on—and what you don't") . Nevertheless, the book does include important insights regarding the more narrow focus I write about as an outcome of IM training.

RAPT is on target in confirming the link between controlled attentional focus and some forms of meditation. Achieving intense focus or flow-like states can enhance cognitive performance, and perhaps (as the author suggests) a more rewarding life. RAPT is correct in indicating that the development of laser-beam focus, where one shuts down the spontaneous private talk directed by the attentional capturing pirates, is a difficult skill—but it can be trained.

The author has a way with words and metaphors to explain constructs and research-based findings that is not in my repertoire. The following select quotes are consistent with my reading of the mental timing/attentional control research literature and my conclusion that IM can train on demand focus. I wish I had written them (*italics* is the emphasis I have added).

- "Everyone knows what *attention* is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. It implies a withdrawal from some things in order to deal effectively with others.
- *Attention* is a "*cobra feeling*: an almost muscular albeit mental bearing-down on a subject or object, which you rise above, hood flaring to block distractions, and hold steady in your unblinking focus"
- "There's no tidy 'attention center' in the brain. Instead, an *ensemble ofalerting, orienting, and executivenetworkscollaborate* to attune you to what's going on in your inner or outer world in a coherent way"
- "...when you *focus*, you're spending *limited cognitive currency* that should be wisely invested... your attentional system selects a certain chunk of what's there, which gets valuable *cerebral real estate*"
- "...research increasingly shows that with some reflection, experimentation, and *practice*, all of us can cultivate this profoundly attentive state and experience it more often"
- "...the *mastery of focus is a skill*, which like any other takes *discipline and effort to develop*"
- Quoting Dr. David Lykken..."Many extraordinary achievers are distinguished by their ability to pay RAPT attention...these individuals have vast stores of '*mental energy*...to shut out distractions, to persist in search of a solution' for a challenging problem over long periods without tiring"

Individualized IM "on-demand focus" training

As summarized in prior posts, neurocognitive research suggests that the predominant gear of our minds transmission is neutral. Our mental engine is working (idling) but to those observing us, our brain is not moving—we often do not appear cognitively engaged in any complex thinking or processing.

The typical person spends up to half their time engaged in the spontaneous chasing of miscellaneous thoughts down various rabbit holes of our minds. Our thought promiscuous mind wanders here-and-there when daydreaming ("zoning out") or becoming trapped in a cycle of negative unchecked thoughts (e.g., rumination over negative unhappy thoughts; mania; obsessions). However, the unconstrained busy or wandering mind can also produce creative insights and thoughts. An unquiet or busy mind can be good or bad depending on the demands facing the individual at any given time. More importantly, the amount of optimal mind wandering may vary for different people.

It was within this context that I found the following scientific article of interest.

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday Attention: Variation in Mind Wandering and Memory in a Lecture. *Applied Cognitive Psychology, 26(2)*, 234-242.

The intriguing aspect of this study is that it did not study mind wandering of the default brain network in a laboratory setting. Instead, this study investigated mind wandering in a real world setting—attending to and comprehending a teaching lecture. Most of us can recall the experience of sitting in a class or attending a lecture and finding our focus on the speaker's words wax and wane. Often our thoughts will wander far beyond the boundaries of the classroom. However, my interpretation of the results from this study, combined with other recent research, suggests a twist—not *all* mind wandering for *all* people is detrimental during *all* learning tasks.

These investigators defined mind wandering as "*a decoupling of attention from an external stimulus to internal thoughts.*" In other words, mind wandering is unplugging the umbilical cord of focused attention from an important task and plugging it in to the spontaneous thought generation of the default brain network. In most learning contexts mind wandering has been found to have a detrimental impact on reading and listening comprehension. If one is trying to comprehend a writers or speakers words and ideas the hijacking of attention (away from the material) to the playground of spontaneous random thinking will likely interfere with learning.

While watching and listening to a video lecture the research subjects received random signals to record what they were thinking about at that particular moment. This allowed the researchers to determine the amount of mind wandering during the lecture. Not surprisingly, the study reported that spontaneous mind wandering increases the longer a lecture progresses. This is not an earth shattering finding for anyone who has listened to a long speech or lecture. The value of the study is that it confirms the same findings reported in laboratory settings (mind wandering increases the longer a person is involved in a task).

Of primary interest was the author's discussion of possible reasons for increased mind wandering as a function of increased time involved with a task. Two different explanations are offered. First, there are likely individual differences in mind wandering. Some individuals are more prone to mind wandering and, if not equipped with self-monitoring tools to recognize when to shut down the wandering mind and focus on the important task, they will comprehend and learn less.

The second interpretation is more intriguing. It suggests mind wandering may increase with practice and increased skill in performing a task. If an individual has attended many classes, speeches or lectures, they may have acquired specialized listening comprehension skills that allow them to recognize when the immediately presented information is not critical (e.g., off-task tangential speaker comments; jokes; etc.) and, instead of wasting the precious brain resources of focused attention, a person puts their brain in neutral—and possibly some spontaneous mind wandering. Practice is believed to reduce the degree of involvement of the air traffic controller of the brain (executive control or functions), thus "freeing up" resources for mind wandering during a familiar automatic task. In this context mind wandering is not interfering with learning and, in fact, may be facilitating learning by saving the mental energy required for focused attention when the speaker's content once again becomes more salient. Attentional control (focus) is a brain tool that can be used as tasks permit—on-demand-focus.

Attentional control can be trained by shutting down the default brain network when necessary. IM and some forms of meditation seem to do this, and it is likely that other brain fitness technologies are also working on attentional control via a focus on working memory training.

You want and need the ability to muster *selective on-demand-focus*. That is, it may be appropriate to engage in creative mind wandering when performing an automatic task. This can be positive either in terms of creative thought or saving attentional resources for when the task quickly shifts to require focused attention. However, if you are in an environment that places constant demands on your working memory (e.g., driving a rental car on a major freeway in a strange large city), you need to invoke your on-demand-focus and shut down the internal self-talk for sustained periods of time. Recent research suggests that those with better working memory can engage in the positive creative mind wandering when performing something that is easy and automatic, but if you have weak working memory, you may not be able to do this...or should not try to do so.

Training to improve focus or controlled attention may need different goals for different people. For individuals with strong working memory capacity, brain clock based (IM) training can increase the ability to engage in *selective on-demand focus*. In such individuals this training may facilitate the ability to engage in positive mind wandering when doing something automatic and simple but, when the situation quickly switches to one requiring spot-on-focus, the brain tool of controlled attentional focus can be invoked to "lock on" to the important information to deal with the task at hand. In the context of IM training, a possible strategy would be to introduce the guide sounds earlier during training if the client demonstrates readiness. Training should then begin to focus on bursts and highest in-a-row to encourage more controlled attentional focus. 

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For individuals with weak working memory capacity, brain-clock based controlled attentional training should likely first target on increasing the person's ability to invoke sustained focus for longer periods of time. Over time this should improve the efficiency of their weaker working memory. For these individuals training that shuts down wind wandering at all costs may be the most important immediate goal. In the context of IM training, this suggest the strategy of gradually increasing the duration of IM training exercises to become gradually longer and longer. As the client demonstrates increased proficiency at longer durations the intensity of feedback can then be increased. By increasing the duration of IM exercises one is systematically increasing the opportunity for more mind wandering—thus providing more opportunities to learn to shut down the busy or wandering mind. Increasing emphasis on getting "bursts" is a way to encourage the patient to (at will) turn on laser beam focusing ability.

There is only one proven law in psychology—the law of individual differences. Just as people differ in intelligence, types of cognitive abilities, personality, etc., people will differ in their current working memory capacity and ability to invoked on-demand-focus. Brain clock based brain training such as IM, as well as any brain fitness technology, needs to be customized to reflect the individual differences and differential training goals of individuals.

Time Travels with the Time Doc—Trip 1: Quieting the Busy Mind

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I have been blogging about brain-clock research at my home base (Brain Clock Blog) for many years and more recently have been blogging at the IM-Home website and blog. A problem with sharing information via blogging is that we bloggers make desired connections via hyperlinks. We insert them so the reader will read prior posts for related or background information. Often readers don't want to take the time to bounce back and forth between linked stories.

To address this problem, I am trying something new. I have taken a single topic or concept that may be scattered across my various blog posts (as well as other sources) and am putting the essence of the material into mini-PDF e-briefs. I add additional commentary to the original sources to emphasize key points.

I am calling this series "*Time Travels with the Time Doc2*" The first trip is now available and is called "*Time Travels with the Time Doc—Trip 1: Quieting the busy mind.*" The brief e-publication is available for viewing and downloading at the Research and Reports section (scroll to bottom of the page) of the MindHubTM.

[2 The original "Time Doc" was Jim Cassily, the inventor of the core Interactive Metronome technology. I might better be considered "Time Doc-2." Stay tuned for a post that describes the early days of the development of IM by Jim. This current series is dedicated to Jim Cassily].

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