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Cognitive Functioning of Drumming and Rhythm Therapy for Neurological Disorders

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Cognitive Functioning of Drumming and Rhythm Therapy for Neurological Disorders

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University of Tennessee - Knoxville Senior Honors Thesis Project

Logan Deyo

Introduction ♩ *A Drummer's Experience*

"Life is about rhythm. We vibrate, our hearts are pumping with blood, we are a rhythm machine, that's what we are." – Mickey Hart, drummer of the Grateful Dead

Drumming for the past 8 years has not only has been an avid hobby of mine, but also has provided me with a creative way to challenge myself outside of the classroom and has served as a method of therapeutic release. Whenever I strap on my headphones and sit in front of my old red Pearl drum kit, I mentally prepare to assemble my own thesis with the drumsticks serving as my pen and the music as my subject material. I crank up the Red Hot Chili Peppers and listen to the groove of the beat, keying into the various rhythmic elements of the music. I begin to tap on the hit-hat with my right hand with a continual steady repetition like a sentence, occasionally striking the snare drum as a period. The bass pedal serves as an overarching rhythm-keeper that grammatically ties all the other elements together with the crash cymbal providing an exclamation point. Drum fills are placed throughout the paragraph like commas and semicolons, each fill different than the next. As the song comes to close and the build up of adrenaline subsides, a sense of accomplishment is achieved and physical and mental exhaustion has set in. This is a drummer's experience.

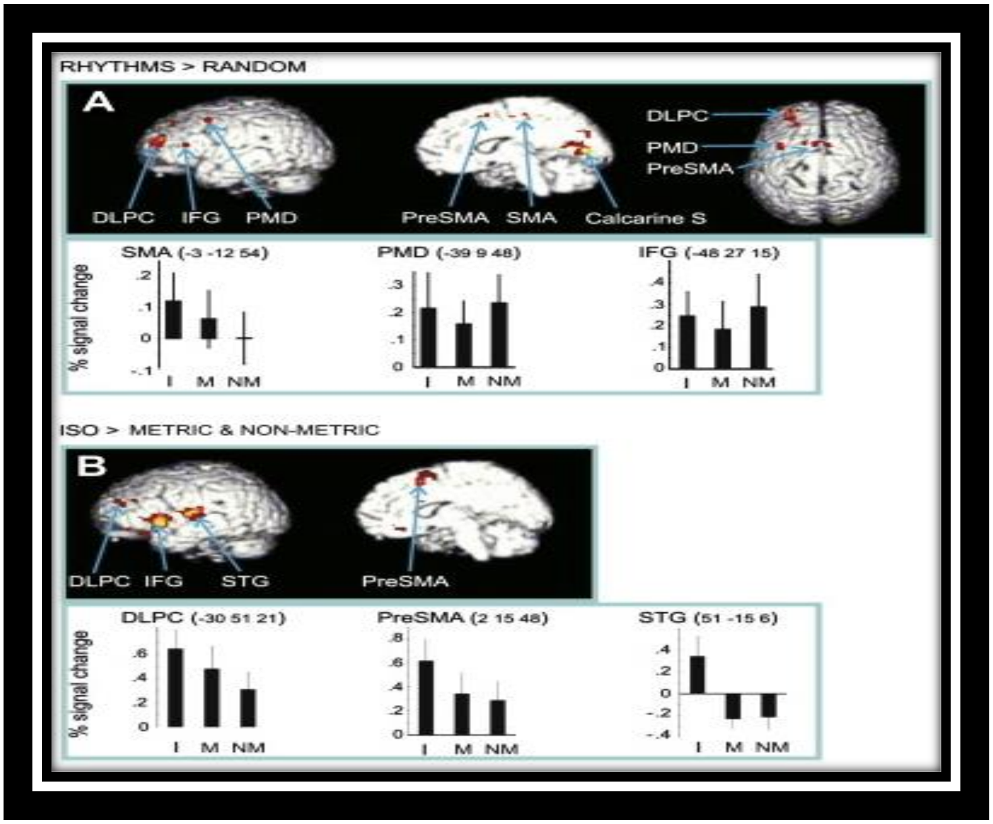
Have you ever found yourself tapping your foot, nodding your head, or drumming with your fingers along to your favorite song? Chances are you have, and are unaware of the extensive neural connections firing throughout your brain attempting to keep timing and coordinate your movements. Drummers such as Mickey Hart of The Grateful Dead, Neil Peart of Rush, and me (to a far lesser extent) have mastered these movements and timing, being able to coordinate both feet and hands to create polyrhythmic beats of intricate rhythms. While most people struggle to tap one foot and move one hand in alternation, drummers have the gifted minds to control all four of their limbs to strike a hi-hat, stomp a bass pedal, raise the hi-hat, and crash a cymbal to create a blend of percussive sounds. Fascinatingly, this rhythmic chaos was able to stimulate the brain of Mickey Hart's grandmother, who had not spoken in a year due to progressing Alzheimer's disease, to say her grandson's name. Dr. Adam Gazzaley, professor of neurology at University of California-San Francisco, along with Mickey has been studying these neural connections to better understand rhythm in higher-order brain function and how to enhance rhythm through intervention and treatment. Many other studies have explored the various effects on cognitive functions from drumming and have shown a common theme: drumming, alike to providing rhythm for the entire band, can provide a feeling of “togetherness” that brings people together in unison and can be utilized as therapy for a range of neurological disorders.

Part I ♩ *A Drummer’s Mind*

Despite beliefs that drummers are simple-minded musicians, clashing and banging on their drums alike to a Neanderthal, recent studies suggest that drummers are natural intellects and have extensive auditory-sensorimotor functioning. It is evident that listening to music activates regions in the temporal lobes of the brain involved in auditory processing, however the development of functional magnetic resonance imaging (fMRI) has allowed researchers to identify additional areas in the brain utilized when listening to music. Research featuring fMRI has shown that multiple areas in the frontal, occipital, and cerebellar lobes along with the temporal lobes integrate to facilitate memory and music perception, control sensorimotor function, and subsequently capture accurate timing: all elements actively used when drumming. Therefore, drumming appears to be its own language that requires the musician to interpret the music being played around him and translate this perception into an understandable form, a drumbeat.

One such study shows that different neural connections are associated with each of these elements, providing evidence that drummers have multiple rhythmic abilities. In regards to sensorimotor function, neuroimaging based upon beat tapping experiments to a metronome show connections between the cerebellum, basal ganglia, and primary motor cortex [1]. These are all areas known to be involved with coordination and motor control modulation that facilitate neurotransmission of action potentials throughout the body. Rhythm memory and perception, analyzed by subject reproduction of a wide array of different rhythms, however is a dissociable process that leads to sensorimotor stimulation. Rhythm memory and perception proves to be a more complex process and utilizes cognitive processing and planning areas of the brain such as the premotor cortex and supplementary motor area (SMA) [1]. These areas have a strong interconnected network that can translate auditory information and plan for motor coordination over a long duration of time. The notion that drum tapping and rhythm memorization are two overlapping, yet dissociable processes is also consistent with rhythmic cognitive functioning in many neurological disabilities. For example, children with cerebellar lesions have difficulties with beat tapping tasks, yet rhythmic discrimination remains unaffected [1].

The majority of people can recognize a simple repetitive rhythm and recreate the beat when tapping their fingers or feet; however, the complexity of a beat including interruptions in the beat sequence or abrupt changes in the beat can confuse the brain. This complexity requires a higher functioning of specific areas of the brain involved in beat perception that drummers and other musicians have the ability to recognize and reproduce without hesitation. One such study focuses on rhythmic perception and complexity by using fMRI to identify various areas of the brain involved in these processes. The study features participants that listen to three different rhythm sequences that vary in predictability including a simple repetitive isochronous rhythm (ISO), moderately difficult yet consistent metrical rhythm (METRIC), and a complex inconsistent non-metrical rhythm (NON-METRIC) [2}. The participants attempt to tap their fingers along with the beat as an fMRI machine illuminates the region of the brain being either excited or inhibited. Each rhythm utilizes some of the same areas of the brain, however increasing complexity either heavily relies on one specific area or instead incorporates additional areas for assistance. Figures 1 and 2 highlight these specific areas shown by fMRI and display the signal change in stimuli response for each respective rhythm. These areas and their proposed functions are reviewed in the chart below.



<u>Figure 1</u>

<u>Part A</u>: Areas of the brain greater activated by rhythms as compared to random beats: the supplementary motor area (SMA), dorsal premotor complex (PMD), and inferior frontal gyrus (IFG). Percent in signal change shows the degree of stimulation for each area when associated with ISO (I), METRIC (M), and NON-METRIC (N) rhythms. A positive response corresponds to an increase in metabolic activity of the area from resting state (excitation), whereas a negative response corresponds to a decrease (inhibition).

<u>Part B</u>: Areas of the brain greater stimulated by isochronous (ISO) rhythms than METRIC and NON-METRIC rhythms as shown by the percent signal change. These regions are supplementary to the SMA, PMD, and IFG, and include the dorsolateral prefrontal complex (DLPC), the pre-supplementary motor area (preSMA), and the superior temporal gyrus (STG).

As evident from Part A of Figure 1, the SMA is stimulated by a simple ISO rhythm; as rhythm complexity increases, excitation of this area declines. This finding is consistent with the SMA's proposed function: execution of simple movements given a visual/auditory cue [3]. The SMA will activate sensorimotor areas to initiate tapping, however other areas of the brain will be recruited for more complex rhythms. The PMD is highly stimulated by all three rhythms, especially by a NON-METRIC rhythm, and is involved in the planning and selection of spatial motor sequences [4]. The PMD serves a major role in understanding meter and pinpointing a patterned rhythm, which is a vital beneficiary of drumming. The IFG complements the PMD by controlling motor function for accurate timing and precision of these patterned rhythms [5]. Thus, the PMD is highly stimulated from a NON-METRIC rhythm as the participant attempts to cognitively account for the lack of consistency along with this beat and to execute accurate tapping.

Part B from Figure 1 shows areas of the brain greater stimulated by an isochronous rhythm than the metric and non-metric rhythms. An isochronous rhythm can be considered as a simple pulsating beat such as the steady beat of the bass pedal. One area of importance, the DLPC is involved in two processes: understanding spatial relationships and manipulating this information into working memory [6]. This area elicits a major response for all three rhythms and serves as a vital area for rhythmic perception. A steady beat can be easier to understand and sustain within working memory, thus eliciting a greater response than the more complex rhythms. The pre-SMA precedes SMA response working in conjunction with the SMA for its function. The STG is responsible for processing sounds and contains Wernicke's area, which is the major area involved in language comprehension [7]. ISO rhythms highly stimulate the STG, however more complicated rhythms appear to inhibit STG's activity. This is possibly an effect of the participant's brains either being unable to recognize and process the more complicated rhythms. In relation, a native language can be easily understood, however a foreign language would be undetected and may invoke an inhibiting response in the STG.

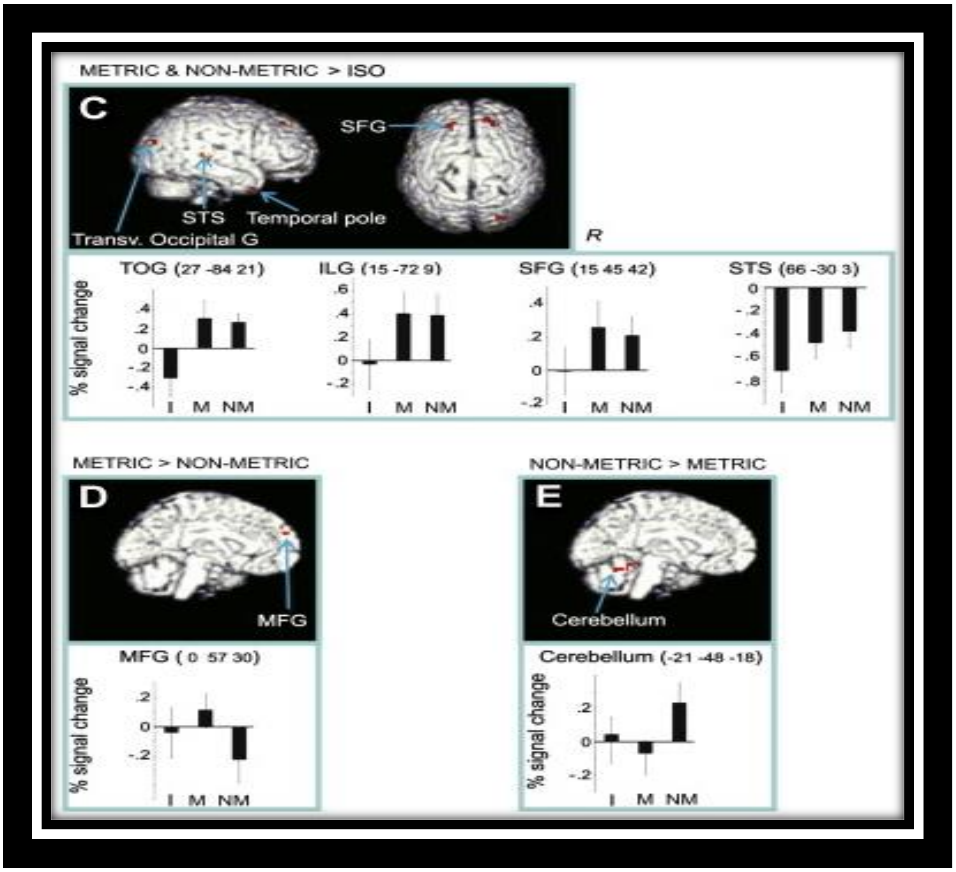


Figure 2

Part C: Areas of the brain greater stimulated by METRIC and NON-METRIC rhythms than ISO rhythms as shown by the percent signal change: the transverse occipital gyrus (TOG), inferior lingual gyrus (ILG), superior frontal gyrus (SFG), and superior temporal sulcus (STS).

Part D: Area of the brain greater stimulated by METRIC rhythms than NON-METRIC rhythms as shown by percent signal change: the medial frontal gyrus (MFG).

Part E: Area of the brain greater stimulated by NON-METRIC rhythms than METRIC rhythms as shown by percent signal change: the cerebellum.

As rhythm complexity increases from isochronous to metric and non-metric rhythms, higher cognitive areas of the brain become involved as shown by Part C of Figure 2. These metric and non-metric rhythms can be considered as more intricate beats involving variation of pattern, such as the songs When the Levee Breaks by Led Zeppelin (METRIC) and Tom Sawyer by Rush (NON-METRIC). For both metric and non-metric rhythms, the TOG, ILG, and SFG are highly stimulated, whereas isochronous rhythms elicit no such response. The TOG has been found to be involved in "scene processing", as in individualization of objects within a scene for further processing [8]. The TOG helps filter and sort certain elements of the rhythmic frame in order to incorporate these parts into working memory by other areas of the brain. Since an isochronous rhythm involves essentially one simple beat, the TOG becomes inhibited, whereas more complex beats render excitation of this area. The ILG facilitates language processing and works in conjunction with the TOG to sort trends within the rhythmic frame [9], alluding to the notion that drumming is an actual language form. At the end of this processing pathway, the SFG integrates all the sorted elements of the rhythm into working memory and synchronization [10]. As evident from Part C, the SFG was slightly excited, indicating a difficulty or relative inability to process the more complex rhythms into working memory.

Unlike the TOG, ILG, and SFG, the high-order STS is actively inhibited for all three rhythm types as it is involved in the control of social processes, from perception of social actions such as body movements and eye gaze to complex social cognition process such as empathizing with others [11]. The activity of the STS was studied in autistic subjects that showed damaged neural connections in this area leading to a lack of normal inhibitory control. Subsequently, the over-expression of its functions resulted in lack of eye contact, appropriate body movements, and general focus and attention for autistic individuals {11}. All of these functions of the STS need to be inhibited for high drumming performance in order to control accurate rhythm perception and precise sensorimotor function. Similar to the processing nature of the TOG, ILG, and SFG, metric rhythms slightly stimulate the MFG, an area involved in the decision-making and executive process of temporal, spatial, and object stimuli [12].

The single-most important area involved in high performance drumming is the cerebellum. Since non-metric rhythms are the most complex and difficult to match, the level of excitation seen in Part E indicates the importance of cerebellar function for advanced drumming skills. Unlike areas of the brain involved in *relative* rhythm perception, the cerebellum is involved in *absolute* timing; therefore, not as involved in perceiving the rhythm, but instead more concerned in exactly matching the rhythm [13]. The cerebellum mainly functions in controlling smooth motor coordination, posture, and balance and executes absolute timing by serving as a mediator between cortical and neuromuscular stimuli [14]. As cortical stimuli activate sensorimotor function and the limbs begin to move attempting to match the rhythm being played, the cerebellum acts to clean up these movements. Via feedback loop, the cerebellum receives and assesses information from proprioceptors in the limbs and has the ability to executively change the movements being made with rapid, yet fluid result. Proprioceptor activation allows for drummers to evaluate the location of their limbs in space resulting in accurate striking of each drum or cymbal, while the cerebellum actively corrects any mistake made.

As rhythms in a single song interchange between isochronous, metrical, and non-metrical rhythm within seconds, the brain of an experienced drummer can respond instantaneously, despite the numerous different areas and connections involved. In relation, another study shows that musicians have significantly faster reaction times and elevated rhythm-change detection performance versus non-musicians [15]. This reaction time and ability to recognize and anticipate changes in meter enable the drummer to facilitate these seamless transitions. As the brain utilizes specific areas to focus on one rhythm, working memory is simultaneously stimulated in another region preparing for the next rhythmic sequence. These neural connections integrate with sensorimotor regions to control all four limbs to produce four separate rhythms with perfect unity, displaying true multiple rhythmic skills. This is an incredible testament to the abilities of the brain, and in regards to all musicians, may be an ability that is acquired at birth and can be further polished through training.

Areas of the Brain Stimulated from Drumming

Specific Area	**Abbreviation**	**Function**
Supplementary Motor Area	SMA	Execution of simple movements
Dorsal Premotor Area	PMD	Planning and selection of spatial motor sequences
Inferior Frontal Gyrus	IFG	Understanding meter and pinpointing a patterned rhythm
Dorsolateral Prefrontal Complex	DLPC	Understanding spatial relationships and manipulating information into working memory
Pre-supplementary Motor Area	Pre-SMA	Precedes SMA response and assists in function
Superior Temporal Gyrus	STG	Processing sounds and language
Transverse Occipital Gyrus	TOG	Individualization of objects within a scene for further processing
Inferior Lingual Gyrus	ILG	Facilitating language processing and sorting trends within the rhythmic frame
Superior Frontal Gyrus	SFG	Integration of rhythmic elements into working memory and synchronization
Superior Temporal Sulcus	STS	Control of accurate rhythm perception and precise sensorimotor function
Medial Frontal Gyrus	MFG	Decision-making and executive process of temporal, spatial, and object stimuli
Cerebellum	N/A	Control of smooth motor coordination, posture, and balance Execution of absolute timing

Part II ♩ *A Drummer's Power*

We all feel the effects of music that has the ability to conjure a certain emotion whenever we listen to our favorite song. Whenever I hear the initial rapid hi-hat tapping and steady boom of the base drum of "Everlong" by Foo Fighters, I think of my pregame soccer playlist before tournaments and become alertly focused on any task. However when the song changes to the grooving *chicka* guitar riffs of "Buffalo Soldier" by Bob Marley, I am instantly transported to days on the lake with my father in complete content. Sadness or joy, excitement or tranquility, anger or love; any song can be connected with a certain event in our lives and generate feelings that vary from person to person. Music can also facilitate a feeling of unity: a rhythmic connection that can exist between a romantic couple and a crowd at a musical festival. This sense of unity can even expand to unite communities, such as post-Hurricane Katrina New Orleans with "The Saints are Coming" by U2, or a whole nation, such as post-earthquake Haiti with "We Are the World 25". This is the awe-inspiring power of music and rhythm. However, can rhythm serve an even larger purpose in the field of medicine?

Recent studies have shown that not only can drumming be a musical hobby or profession, but can also serve as a form of rhythm therapy for all ages of people suffering from neurological conditions. As neurological disease continues to plague much of the population, music-supported therapy (MST) has emerged to be an innovative and positive approach towards aiding brain function. From Alzheimer's and Parkinson's disease to ADHD, any neurological lesion or damaged connectivity between areas involved in rhythm perception can severely hinder the detection of patterns from internal and external stimuli. This effect results in the malfunction of sensorimotor connection or social functioning seen in symptoms such as a shuffling gait in Parkinson's, aphasia in Alzheimer's, and distractibility in ADHD. Although MST may never provide any complete curative measure, long-term training of cognitive function utilizing this type of therapy can help develop a sense of pattern that ultimately improves focus, establishes regularity, and works toward restoring normal brain function. Most importantly, these positive changes improve quality of life: the main goal of MST.

MST operates from the notion that strong beats activate rhythmic areas of the brain and produce resonating brainwaves in conjunction with the music. This can be achieved through a variety of rhythmic methods including electronic drum and piano key tapping. The speed and tone of the beat mediate the type of brainwave stimulated and register a range of patient responses including increased alertness from fast pulsating beats or relaxation from slow progressive beats [16]. Studies with elementary and middle school boys diagnosed with attention deficit hyperactivity disorder (ADHD) show that a course of 20-minute treatment sessions with these rhythmic beats yielded results similar to the effects of ADHD medications such as Ritalin and Adderall [16]. These fast beats increased their concentration, and the boys consistently performed better on IQ tests while also exhibiting better behavior and social skills. With results similar to medication regimens, MST allows for a non-invasive method of treatment without the reliance on prescriptions, which can overall save money and prevent side effects or drug abuse.

In addition to improving concentration, rhythmic therapy also stimulates cognitive functioning by increasing blood flow through the brain. This effect is especially important for the elderly with Alzheimer's disease, who have memory deficiencies and have difficulty performing everyday tasks. One study evaluates elderly cognitive performance when adding a set of rhythmic with results showing that the majority had increased accuracy on a range of common tests [16]. This increased cerebral blood flow may also promote the neuro-rehabilitation of stroke patients, with severe motor deficiencies, by fostering neuroplastic changes. Another study analyzing sensorimotor interaction to music therapy shows that stroke patients experienced increased neuro-stimulation and function of an affected hand [17]. Visualized by fMRI and Transcranial Magnetic Stimulation, the damaged motor cortex shows excitation coupled with the stimulation of the hand, indicating a re-established connection. Listening to music daily also shows increased gray matter volume in the superior frontal gyrus of stroke patients that leads to improved function of working memory and emotional recovery [18]. Evidently, MST can reconnect disrupted neural connections and also rebuild lesions in expediting the healing process of a damaged brain.

The most significant strides of improvement attributed from MST have been linked to Parkinson's disease (PD). This neurological disease is distinctly characterized by a shuffling gait of short, asymmetric steps without any defined pattern that arises from the loss of smooth motor control and timing; essentially, a delayed internal rhythm clock. This deficiency is a product of disrupted timing within the supplementary motor area, which allows for the execution of simple and seamless movements such as walking. The delay is believed to be due to a disruption in either the neurons of the pre-SMA, which sets the plans for the SMA to carry out its respective function, or the cerebellum, which provides neuro-feedback to the SMA in regards to control of smooth movements [19]. As both the pre-SMA and cerebellum are activated and interconnected with the SMA when stimulated by music, an auditory cue (i.e. a rhythm) has the ability to synchronize the brain of PD patients and provide a sense of pattern. MST provides this rhythmic cue to reset the internal clock in correct motion and re-establish normal gait.

One study analyzing the brain of PD patients when listening to real and imagined music and shows that areas of the cerebellum are activated from real music, whereas the pre-SMA is stimulated from imagined music [18]. In both cases, movement was enhanced and the patient's steps were longer and more symmetric. Furthermore, this finding suggests that the cerebellum and the pre-SMA operate on different neural connections to assist the SMA. Another study focuses on specific characteristics of ambulation within a control PD group and a PD group after entrainment of gait to rhythmic beats [19]. Results show that post-MST PD patients exhibit walking with a longer stride, more symmetrical steps, and a lower cadence: all indicative of smooth and orderly ambulation (Figure 3). The findings from the studies are significant in that active MST with real music can provide an initial structure of rhythm for walking, while continued gait normality can be maintained from an imagined form of this rhythm. As gait dysfunction is a major ailment for PD patients, MST has been proven to significantly improve gait symptoms and thus, the quality of life for these individuals.

Figure 3

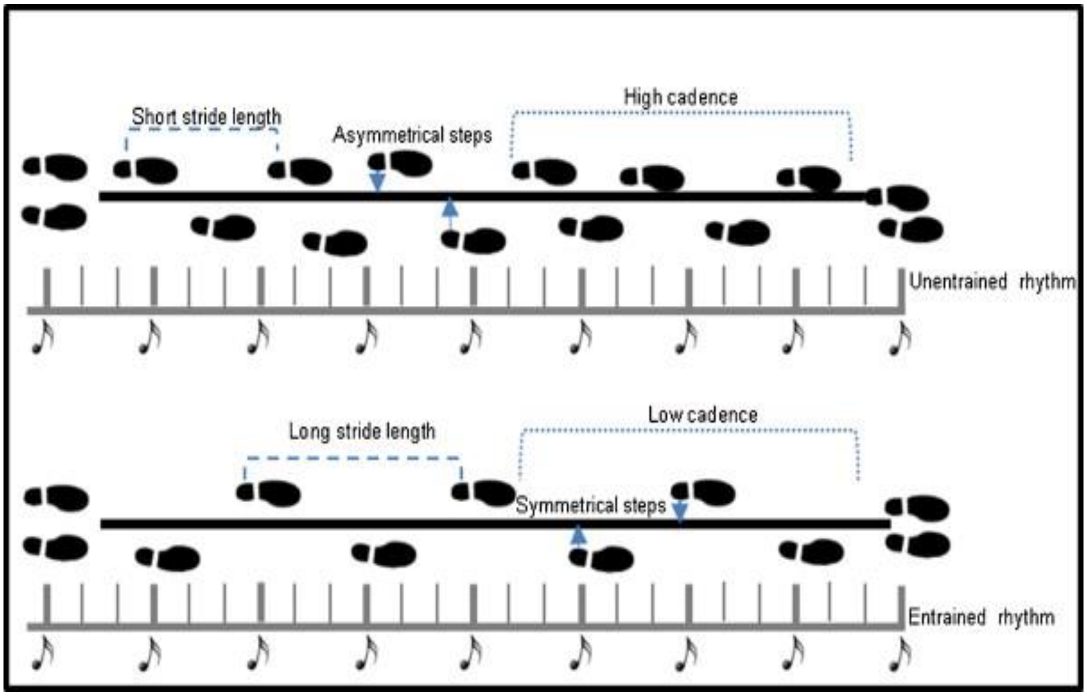


Figure 3 – Representation of ambulation for the control PD group (top) and the PD group entrained from MST (bottom)

Dr. Adam Gazzaley, along with Mickey Hart, has been a major proponent of understanding how the brain works in conjunction with rhythm in attempt to enhance brain function and improve therapy methods. Dr. Gazzaley's "Rhythm and the Brain" project utilizes electroencephalography (EEG) and novel "glass brain" technology that strips the cortex of the brain to show a three-dimensional neural network of the inner brain. Using Mickey as the subject, the EEG cap electrodes detect any neural signal produced when drumming and illuminate these specific areas on the glass brain screen. As a result, the brain is visualized to show extensive communication with rhythmic oscillation characteristics [20]. Dr. Gazzaley's research thus far has shown promising results and continues to seek understanding of the brain influenced by rhythm. With the beneficial effects of current MST already proven, the Rhythm and Brain project serves as a major piece in the future of rhythm therapy for neurological disorders.

Conclusion ♩ *A Drummer's World*

Imagine yourself standing at a live concert surrounded by a mass of devoted fans. As the lights dim and the band takes the stage, everyone shouts and screams in adoration. The drummer begins clashing his drumsticks together and everyone begins clapping their hands along with the beat. An extensive neural network traversing across temporal, parietal, and frontal regions of the brain continually fires in attempt to relatively perceive the rhythm, facilitate memory and syncopation, and match the rhythm with fluid movements. You may lose track of the timing of your clapping, however regulatory areas such as the cerebellum assess the alteration and quickly adjust. The other musicians join and begin to jam on their instruments; nonetheless, the beat of the bass drum and snap of the snare provide a unifying timekeeper amongst the members of the band and the crowd, as your brain continues to groove to the steady rhythm.

As the strong rhythm surges through the song, cerebral blood flow elevates and your level of concentration increases. Although you may have never heard this song before, an innate motive seems to drive your sense of rhythm to be able to clap along or bob your head with perfect timing. The notion that this overarching rhythm created by the drummer has the ability to enhance brain function is a testament to the power of this instrument. As a result, drum therapy has been experimented as a form of music-supported therapy that attempts to unlock restraints upon the brain and improve cognitive functioning. Ultimately, long-term drum therapy has the potential to rebuild neurological damage and drastically improve quality of life. Although in its infancy, MST has been a promising treatment and continues to be increasingly understood for individuals affected with ADHD, Alzheimer's and Parkinson's disease, and stroke-induced neural damage. The drummer, therefore, can be viewed as more than just a musician, but also a physician of music. I can guarantee that Neil Peart and Mickey Hart would agree with me when I say – this is a drummer's world.

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