RHYTHM: A Case for Digital Music Medicine

By Nina Kraus, PhD

Some years ago, the *Journal of Neuroscience* published an experiment we ran demonstrating that specific brain activity underlies specific rhythmic tasks.[1] The BBC picked it up and covered it in a short article. Shortly thereafter I got a phone call from someone from Interactive Metronome (IM) who had seen the news coverage. IM had been in the digital music medicine intervention space for a decade or more at that time, but it was not really on my radar.

According to its (current) website homepage, "IM is proven to improve cognition, attention, focus, memory, speech/language, executive functioning, comprehension, as well as motor and sensory skills." There is an array of peer-reviewed research backing up the website's assertions with gains reported in the realms of physical dexterity, strength, balance, and coordination,[2,3] reading and language skills,[4-6] and cognition.[3,5,7] There is evidence of IM being an efficacious therapeutic approach for the treatment of stroke,[8] cerebral palsy,[9] brain injury,[10] and ADHD.[11] But the questions of *why* and *how* IM brings about these improvements remained.

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The caller turned out to be the founder of IM, and while he had every confidence in his product, he too wanted to better understand the why and how. He was intrigued by our approach to measuring brain activity and hoped we would look for signs of what goes on in the brain with IM use. I was not particularly hopeful we would find anything and, truth be told, was skeptical of the whole idea. But, eventually, we added research into IM into our ongoing work.

IM is a rhythm-based program. It requires no specialized skill to perform. There is no need to carry a tune, read music, count out measures, learn fingering, master embouchure, or purchase a musical instrument. IM requires only to clap or tap a foot along with a beat and respond to accompanying feedback–a low barrier. As such, it is an appealing way to package a music intervention.

RHYTHM INTELLIGENCES. The ability to create and perceive rhythm is not an all-or-none proposition.[12] Drumming along to a metronome is not the same as drumming to the beat of a piece of music or drumming a rhythmic motif. The ability–and the inability–to perform those tasks is somewhat independent.[13] There are different rhythm intelligences.

There is a demarcation, in particular, between what I call "beat keeping" and "rhythm pattern production." Beat keeping is maintaining a steady interval. At its most basic, it can be tapping along to a metronome. It can be tapping along to the beat or pulse of music. It can even be maintaining a steady beat without a metronome or a piece of music to pace you. A musician uses her knowledge of where the pulse is, constantly predicting *precisely* where the beat will fall, and either sticking to it or intentionally leading or lagging the pulse, incorporating syncopation into the interpretation of the piece.

Producing a rhythm pattern, on the other hand, requires joining several taps of different durations and inter-tap timings into a *sequence*. The seven taps that comprise "shave and a haircut, two bits" is a rhythm pattern. To produce this rhythm, the whole sequence must be kept in mind, not just the current tap. This same motif has four equally spaced beats. Music inherently has both a beat and a rhythm pattern, notated by time signature and note/rest durations, respectively.

RHYTHM AND COGNITION. Beat keeping and rhythm pattern production relate to different cognitive skills. The ability to keep a beat is poor in poor readers,[14] while children who are good at beat keeping have stronger reading skills.[15] Good beat keepers also perform higher on tests of attention, inhibitory control (what sounds to ignore), linguistic skills, and the ability to detect tiny timing differences between sounds.[15,16] Prereaders who can keep a beat are better at performing tasks associated with language development and reading readiness.[17] School-age children who are better at keeping a beat are better at rapidly naming a visually presented object, a skill highly related to reading ability.[18]

On the other hand, the cognitive skills that align with rhythm pattern production involve memory–short-term and working.[16] Proficiency on this type of rhythmic task also patterns with the ability to understand speech that is obscured by noise,[19] which on the face of it makes logical sense. When the sounds of speech, the consonants and vowels, are rendered indistinct, the listener increasingly relies on the rhythm patterns in the utterance, the phrase- and sentence-long waxing and waning of energy, to resolve the ambiguity in the sounds themselves.

BRAIN RHYTHMS AND TIMESCALES. So, what did we find out about the biological underpinnings of a rhythmic approach to health? To unpack the difference in brain responses that align with beat keeping and rhythm-pattern production, we should think about *timescales of processing.* Neuroscientists have long recognized the brain's activity is organized over a range of timescales. Slow delta waves (~second), fast gamma waves (milliseconds), and several Greek letter-named ranges in between have been identified and postulated to be mechanisms for communication through-

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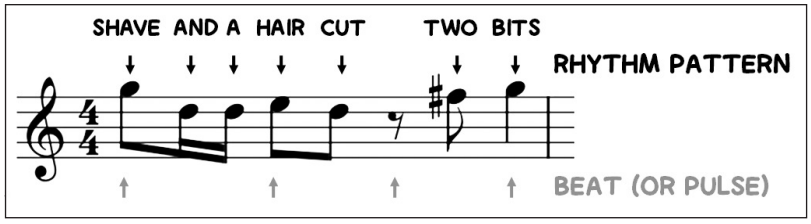

Figure 1. The rhythm pattern is determined by the note values; here, a mix of eighth, sixteenth, and quarter notes, with an eighth rest (top row of arrows). The bottom row of arrows depicts the four beats, which may occur during either a note or a rest.

out the brain. Oscillations at various timescales have been linked to different processing responsibilities of the brain.[20]

The brain's processing of speech sounds is distributed across these same millisecond-to-second timescales (fast phonemes, slower syllables, still-slower sentences). We can use the idea of the distribution of processing by time as a basis to consider the differences between beat keeping and rhythm pattern production. Beat keeping is fundamentally an in-the-moment activity. Any single "tap" is either correct or incorrect based on a very tiny sub-second determination. Conversely, reproducing a series of taps to create a rhythm sequence requires integration over time—up to a few seconds or more: shave and a haircut, two bits.

Good beat keepers of any age show better *fast* neural processing of the rhythmic sounds within speech. Their brains' ability to lock onto the fast components in speech sounds is stronger than those who struggle to keep a beat.[16,17] There is also evidence for greater precision and stability in the brain's millisecond-level, processing of sound in good beat keepers.[1,21] Correspondingly, the brain responses that correspond to beat-keeping are on a fast, millisecond-level scale, conveyed in responses dominated by subcortical activity.

Rhythm pattern production likewise relates to the precision and consistency of physiological brain measures, but in contrast to beat keeping, it aligns with *slower* brain activity.[16] Neural activity on the longer hundreds of millisecond-plus scale, corresponding to the integration time required for producing a rhythmic pattern, comes mostly from the cortex. With its simultaneous nested rhythms, the brain seems to employ a divide and conquer approach to accomplish rhythm activities falling at different points along the timing continuum.

BEET AND PLUM. Broadly speaking, then, there are two general categories of rhythm ability, and they pair up with distinct types of brain processing and distinct real-life skills:. Beat Engages Exquisite Timing (BEET) and Pattern Learning Unlocks Memory (PLUM). But are beets and plums destined to remain in separate dishes? This is where things get interesting as far as IM is concerned. Remarkably, IM engages *both* reading and memory skills and *both* slow and fast brain dynamics. On its surface, IM is unambiguously a beat-keeping task. Your job is to listen to a pacing sound, anticipate its timing, and precisely clap along to it. Sensors worn like gloves record your clap timings, and you are given real-time visual or auditory feedback for guidance. The feedback tells you whether you are behind or ahead of the beat, or right on target. However, there is something in its implementation—whether it is the wide, circular arm swings and total body engagement you are encouraged to use, the exact form the feedback takes, the time interval between beats (longer than most beat-keeping tasks), a combination of the three, or something else entirely—that makes IM an activity that traverses the BEET/PLUM divide. I like to think it depends on the real-time, living *interaction* between hearing sound and adjusting our movements accordingly. This interaction is about modulating the sound we hear with the sounds we produce. This sensitivity to the space between you and the sound is emblematic of sound's power to connect us with the world.

Unusually, IM correlates with performance on rhythm skills that fall into both classes of rhythm production—beat keeping *and* rhythm patterns—activities that often do not correlate with one another.[22] Moreover, it tracks with language *and* memory skills.[5,6] Fittingly, IM also tracks with performance on the real-life skill of moving to the beat of music.[22]

With respect to its neural underpinnings, IM performance tracks with both fast/milliseconds *and* slow/seconds timescale brain physiology.[5,6] Thus, it appears that engaging in carefully chosen rhythm activities trains the very timing circuits that underlie the neural processing of language and memory.

A carefully crafted, rhythm-based digital music medicine approach—like IM—can cover a lot of ground. It has the potential (1) to relate to other rhythm activities on both sides of the BEET/PLUM divide, (2) to generalize to cognitive spheres (language, music, and memory) and, most germane from my standpoint as a researcher of sound and the brain, (3) to link to brain activity at multiple timescales (from milliseconds to

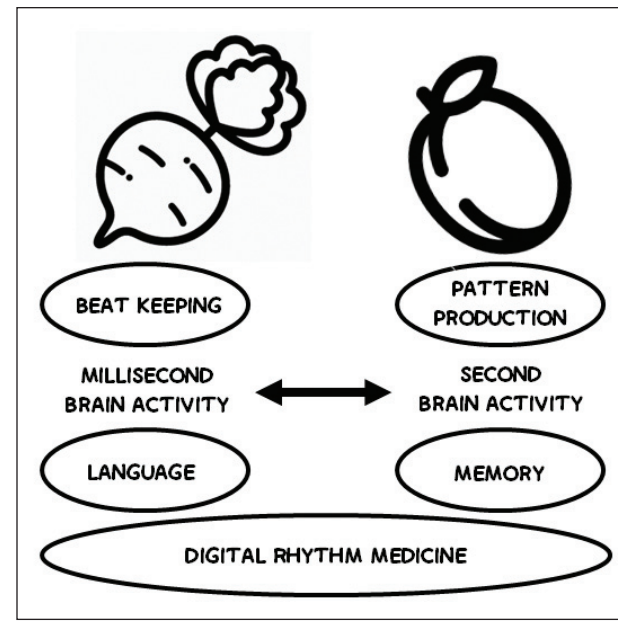

Figure 2. Beat-keeping (BEET) and rhythm pattern production (PLUM) skills align with different timescales of auditory brain activity and with different cognitive skills. Performance on IM spans it all.

seconds). So, with the evidence we have for music making as a potent way to change the biology and function of the brain for the better,[23] the fact that rhythm is a fundamental ingredient of music, and the flexibility and scalability this sort of program offers in the classroom and the clinic, and potential for

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scalability to the classroom, it is my view that digital rhythmic medicine has earned a place at the table when therapeutic and educational decisions are made.

References for this article can be found at http://bit.ly/HJcurrent.