Rethinking Rhythms: Cognitive Ethnomusicological Consideration for Vocal versus Instrumental Rhythms and Discussion about the Role of Periodicity in Rhythm

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Abstract

As there is no one accepted definition of rhythm, rhythm is a problematic concept. On the basis of previous studies in psychology and cognitive ethnomusicology, this paper proposes that rhythm should be considered as temporal relationships of successive events that are perceived and produced by the body. With the embodied cognition theory, this paper is not only to examine indications for an existence of two rhythms, that is, vocal and non-vocal/instrumental rhythms, in the pre-historic time and in ancient cultures but also to provide findings of what is currently known about the functional neuroanatomy of vocally and manually produced rhythms. This paper also demonstrates how periodicity allows a confluence of the vocal and instrumental rhythms in terms of entrainment with a case study. This study provides music scholars an opportunity to rethink rhythm in their discussion about temporal parameters of music.

Key Words: Rhythm, Periodicity, Entrainment, Embodied Music Cognition

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1. What is Rhythm?

In music scholarship, rhythm has been always one of the primary research questions. This may be because music has been considered as the temporal art. However, there is no clear understanding of rhythm as a founding father of comparative musicology and ethnomusicology Curt Sach stated “The answer, I am afraid, is, so far, just-a word: a word without a generally accepted meaning. Everybody believes himself entitled to usurp it for an arbitrary definition of his own.”[1] Rhythm is a word that is used ubiquitously and the word seems to encompass every single concept that relates to time, for instance, beat, pulse, tempo, meter, and so on.[2]

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1) Curt Sachs, “Rhythm and Tempo: An Introduction,” *The Musical Quarterly* 38/3 (1952), 384.

2) Hsiang-Ning Kung, “Cultural Influence on the Perception and Cognition of Musical Pulse and Meter,” Ph.D. Dissertation (The Ohio State University, 2017).
Kung pointed out that most scholars considers beat and pulse as interchangeable terms but made an argument for necessity of a clear distinction between beat and pulse from a cognitive ethnomsuciological perspective. Pulse has relatively broader connotations that pertain to one’s perception so it can be applicable for cross-cultural contexts. In contrast, beat is the theoretical basic temporal unit that is generated due to the Western notation system. In summary, pulse is mind-body oriented whereas beat is notation-oriented. She also showed that there are cultural differences in understandings of meter. She argued that the current conception of meter as the hierarchical temporal structures is created by Western music notations. With empirical evidence she demonstrated that meter is both percept and concept that are shaped by certain types of learned behaviors and this understanding of meter is more applicable in the context of various music cultures.

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From a perspective of cognitive psychology, a phenomenal time researcher Frassie removed the confusion derived from various understandings of rhythm.[3] He defined rhythm as a succession of events in temporal domain without any assumption of periodicity or cyclicity that is in general built on grouping of repetitive pattern or regularity. Based on Frassie's definition, Will considered it as "*qualities* attributed to ordered successions of events and their temporal relationships, without implying particular kinds of regularities or pattern repetitions,"[4] which shows an emphasis on experiential aspects of rhythm. Within a framework of embodied cognition that argues for a significant role of perception and action through the body for our conceptualization of the world[5], experiential components of rhythm, that is, the *qualities* according to Will's understanding, are *the bodily perceived and produced* temporal relationships of successive events without pattern repetition or regularity. On a premise of that rhythm is *bodily experienced through perception and action (production)* in music, this paper will discuss how two behaviors of music performance, singing and instrument-playing, affect our experience of rhythm in

3) Paul Fraisse, "Rhythm and Tempo," *The Psychology of Music*, edited by Diana Deutsch (New York: Academic Press, 1982), 149-180.

4) Udo Will, "Temporal Processing and the Experience of Rhythm: a Neuro-psychological Approach," *The Philosophy of Rhythm: Aesthetics, Music*, Poetics, edited by Peter Cheyne, Andy Hamilton, and Max Paddison (Oxford: Oxford University Press, 2019), 216.

5) Francisco J. Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991).

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music-making and how *periodicity*, that is, repetitive pattern or regularity by Frassie and Will, puts vocal and instrumental rhythms together from a cognitive ethnomusicological perspective.

2. One Rhythm? or Two?

2.1. Prehistoric Indications for Vocal and Instrumental Rhythms

In bodily activities involved in music performance,[6] there are two ways to produce rhythms: one is vocalization and the other is non-vocal sound production through manual interaction with musical instruments. Accordingly, these two distinguishable behaviors of sound production generate vocal and instrumental rhythms respectively. An existence of the different types of rhythm has been recognized since the pre-historic time. Montagu's search for origins of music came from the question "vocalization versus motor impulse: which came first, singing or percussive rhythms?."[7]

6) Even language can deliver verbal messages through vocal or non-vocal, manually produced sounds. However, human behavior in language is primarily relying on vocal performance namely, speech. Interestingly some cultures have language that is produced by other than human voice. that is, speech surrogates. They include African talking drums, Whistled language of the island of La Gomera, and the Hmong flute language. Theodore Stern, "Drum and Whistle 'Languages': An Analysis of Speech Surrogates," *American Anthropologist* 59 (1957), 487-506; Thomas A. Sebeok and Donna Jean Umiker-Sebeok, *Speech Surrogates: Drum and Whistle Systems* (The Hague: Mouton, 1976); Nick Poss, "Hmong Music and Language Cognition: An Interdisciplinary Investigation," Ph.D. Dissertation (The Ohio State University, 2012).

7) Jeremy Montagu, "How Music and Instruments Began: A Brief Overview of

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As shown in this view, are vocal and instrumental music associated with distinctive acoustic parameters, pitch and rhythm respectively? The below discussion will show it is more complex than that Montagu's dichotomous view because the way we produce sound (vocal versus non-vocal sound production) determines characteristics of its own rhythm, and other acoustic parameters too. At any rate, speculating about the anatomical changes of the early human ancestors, Morley hypothesized that the physiological development of human vocal organs contributes to better control of pitch (intonation), duration, timbre, and intensity and so on.[8] He also discussed that human vocalization had become functional fully together with the development of the brain and ears for human acoustic communication systems, for instance, language. With regard to instrumental music in the prehistoric period, flint blades has been argued as portable lithophone and proposed as one of the earliest sound tools.[9] This seems quite plausible but the primary function of the flint stone is not sound production. So far, the oldest known man-made music instruments were found in the caves, Hohle Fels, Vogelherd, and Geißenklösterlein the southwestern part of Germany.[10] Compared to flint blades, the bone flutes found in this

the Origin and Entire Development of Music, from Its Earliest Stages," *Frontiers in Sociology* 2/8 (2017). DOI:10.3389/fsoc.2017.00008

8) Iain Morley, *The Prehistory of Music: Human Evolution, Archaeology, and the Origins of Musicality* (Oxford: Oxford University Press, 2013).

9) Ian Cross, Ezra Zubrow, and Frank Cowan, "Musical Behaviours and the Archaeological Record: a Preliminary Study," *Experimental Archaeology* 1035, edited by James Mathieu (British Archaeological Reports International Series, 2002), 25-34.

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area show a highly sophisticated thinning technology for manufacturing bone artifacts (e.g., polishing bone surface, carving notch, refining finger holes) and indicate specific environment that allows early Europeans to access to bird bones or Mammoth ivory. Although we could only imagine the soundscape of these bone flutes, it seems that manual interactions with the instruments involves not only music performance but also production of the instruments.

2.2. Prehistoric indications for vocal and instrumental rhythms

Interestingly a distinction of vocal and instrumental music has been made in various ancient societies. The earliest writing is the *Nāṭyaśāstra,* a Sanskrit treatise on the performing arts. It is traditionally attributed to the sage Bharata, who treated singing and instruments separately. In the twenty-eighth chapter, for instance, Bharata distinguished different types of music and clearly stated two different origins of sounds, the human throat and instruments:

> "7. Thus the song (*gāna*), the instrumental music (*vādya*) and the acting (nāṭya) having different kinds of appeals (*vividhāśraya*, lit. depending on different kinds) should be made by the producers of plays like a brilliant entity (*alātacakra-pratima*). 8. That which is made by the stringed instruments and depends [as well] on various other

10) Nicholas J. Conard, Maria Malina, and Susanne C. Münzel, "New Flutes Document the Earliest Musical Tradition in Southwestern Germany," *Nature* 460/7256 (2009), 737-740.

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> instruments, and consists of notes (*savra*), Tāla (time-measure) and verbal themes (*pada*) should be known as the Gāndharva. 9. As it is very much desired by gods and as it gives much pleasure to Gandharvas, it is called Gāndharva. 10. Its source is the human throat (lit. body), the Vīṇā and the flute (*vaṃśa*). I shall describe the formal aspects of (lit. arising from) their notes."[11]

The distinction between vocal and instrumental music was indicated in the ancient Greek and Rome. For example, Hagel's analysis on the surviving ancient Greek musical notations reveals two distinguishable sets of the notation systems depending on whether it is instrumental or vocal music.[12] This suggests that the Ancient Greeks differentiated vocal and instrumental music. Following the Ancient Greek philosophical tradition, Anicius Manlius Severinus Boethius (480~524) synthesized his predecessors' ideas about music and education in his *De institutione musica,* a foundation of the Western classical music theory and philosophy.[13]

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11) Bharata Muni, "Chapter Twenty Eight on the Instrumental Music," *The Nâṭyaśāstra: a Treatise on Ancient Indian Dramaturgy and Histrionics Ascribed to Bharata Muni*, Vol. 2, translated by Manomohan Ghosh (Calcutta: Manisha, 1961), 2-3.

12) Stefan Hagel, "The Evolution of Ancient Greek Music Notation," *Ancient Greek music: A New Technical History* (Cambridge: Cambridge University Press, 2009), 1-51.

13) Calvin Bower, "Boethius," *Grove Music Online Oxford Music Online. Oxford Music Online*. Oxford University Press, accessed May 8, 2020. DOI:10.1093/gmo/9781561592630. article.03386. As one component of the 'quadrivium', music is one of the fourfold paths to the knowledge of essence together with arithmetic, geometry, and astronomy.

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Boethius classified and ranked music into three categories: *musica mundane* (music of heaven), *musica humana* (music o fhuman),[14] and *musica instrumentalis* (music of instrument). Here Boethius' *musica instrumentalis*, attributed to musical instruments (e.g., string, wind, and percussion), catches our attention due to its indication for a potential distinction between vocal and instrumental music despite of an absence of clear remark on vocal music in music classification.

3. How are Vocal and instrumental Rhythms Different?: Functional Evidence for Two Rhythms

3.1. Perception of Vocal and Instrumental Rhythms

In terms of perception, one component of embodied cognition, humans have a well-developed ability not only to detect events from either vocal or instrumental sounds but also to integrate acoustic information and to build its temporal structures. For past few decades, the advances in various brain imaging techniques such as electroencephalogram (EEG), magnetoencephalogram(MEG), and functional magnetic resonance imaging (fMRI), have allowed researchers in the field of cognitive auditory neuroscience to

14) According to Boethius, *Musica mundane* is an omnipresent force of the universe that governs the courses of spheres, the structure of the elements, and the seasons of the years. Boethius argued that *musica mundane* is acoustically imperceptible because the fast motion of the universe does not generate audible sound. As a unifying force, *musica humana* integrates the body and soul into a harmonious entity.

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characterize electrical activities of the brain, to describe changes in magnetic fields produced by electrical currents occurring naturally in the brain, and to localize neural structures in association with auditory rhythm perception. Intrigued by the timbre of human voice, Belin and his colleagues performed three fMRI experiments with vocal and non-vocal sounds as the stimuli.[15] They identified the upper bank of the superior temporal sulcus (STS) and the superior temporal gyrus (STG) as the *voice selective areas* but their experiments showed a greater voice-selective activation on the right STS and STG. Developing their previous study, Belin's research team repeated the experiment to ask whether this functional asymmetry is due to an involvement of speech processing.[16] They found that speech sounds elicit greater responses bilaterally compared to other stimulus types, for instance, non-speech including laughing, sighing, moaning, crying, etc. Interestingly, the anterior part of the STG is more strongly activated by non-speech vocal sounds than by the corresponding scrambled sounds.[17] This leads them to interpret the right anterior

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15) Pascal Belin, Robert J. Zatorre, Philippe Lafaille, Pierre Ahad, and Bruce Pike, "Voice-Selective Areas in Human Auditory Cortex," *Nature* 403/6767 (2000), 309-312.

16) Pascal Belin, Robert J. Zatorre, and Pierre Ahad, "Human Temporal-Lobe Response to Vocal Sounds," *Cognitive Brain Research* 13/1 (2002), 17-26.

17) Five different classes of stimuli were used in this experiment: 1) vocal sounds can be either speech or non-speech, 2) bell sounds, 3) human non-vocal sounds (hand clapping, etc.), 4) white noise, and 5) scrambled vocal sounds that preserve the amplitude of the corresponding vocal sounds but do not sound like voice. Their speech and non-speech stimuli do not include the sounds that do not involve the vibration of vocal fold (e.g. whispering, whistling, etc.).

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STG as the area for processing paralinguistic information of human voice. In line another fMRI study by Binder and his colleagues identifies the bilateral STS as the *voice selective region*.[18] A MEG study by Gunji and his colleagues showed that greater source strength of a sustained field is elicited by the vocal stimuli around the Heschl's gyri.[19] Considering the *voice sensitivity* as a distinct neural representation of brain activity for vocalized sounds, Lee and his colleagues found a greater voice sensitivity in the bilateral STS and STG in response to human vocal sounds than to other sounds.[20] Levy's team investigated whether there are specific temporal characteristics for processing of human voice via an EEG.[21] They

18) J. R. Binder, J. A. Frost, T. A. Hammeke, P. S. F. Bellgowan, J. A. Springer, J. N. Kaufman, and E. T. Possing, "Human Temporal Lobe Activation by Speech and Nonspeech Sounds," *Cerebral Cortex* 10/5 (2000), 512-528. Since the main concern of the study is not timbre difference between voice and non-voice but speech processing as shown in their stimulus selection that 1) noise, 2) frequency-modulated tones,3) reversed speech, 4) pseudo words and 5) words. They reported not only that the STG responses to both speech and non-speech is relatively symmetric but also that response from the mid-portion of the STS is more preferential to speech than to non-speech using an fMRI paradigm.

19) Atsuko Gunji, Sachiko Koyama, Ryouhei Ishii, Daniel Levy, Hidehiko Okamoto, Ryusuke Kakigi, and Christo Pantev, "Magnetoencephalographic Study of the Cortical Activity Elicited by Human Voice," *Neuroscience Letters* 348/1 (2003), 13-16.

20) Yune Sang Lee, Jonathan E. Peelle, David Kraemer, Samuel Lloyd, and Richard Granger, "Multivariate Sensitivity to Voice during Auditory Categorization," *Journal of Neurophysiology* 114/3 (2015), 1819-1826.

21) Daniel A. Levy, Roni Granot, and Shlomo Bentin, "Processing Specificity for Human Voice Stimuli: Electrophysiological Evidence," *Neuroreport* 12/12 (2001), 2653-2657; Daniel A. Levy, Roni Granot, and Shlomo Bentin, "Neural Sensitivity to Human Voices: ERP Evidence of Task and

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looked for the voice specific electrical activities produced by the brain while people listened to the stimuli consisting of song and the three different families of musical instruments, strings, woodwinds and brass. Levy and his colleagues identified *the voice specific response* that is a positive component peaking at around 320 ms after vocal stimulus onsets. Expanding the *voice selective areas/region*s, the *voice sensitivity,* and the *voice specific response*, Hung explored whether acoustic rhythms are processed differently depending on type of the sound source. For this she used vocal and clapstick rhythms as stimuli and found that behavioral differences (e.g., reaction time) and different neural responses to vocal versus instrumental rhythms in the primary auditory cortex.[22] The results show that vocal rhythms are processed preferentially than manually produced rhythms by reporting the greater activation in the STG with vocal rhythm. The specialization and preference for vocal sounds and rhythms in the brain allow us to communicate with each other through fast and automatic perception of rich acoustic information, which further plays an important role in social interaction.

3.2. Action for Production of Vocal and Instrumental Rhythms

With regard to action, the other component of embodied cognition

Attentional Influences," *Psychophysiology* 40/2 (2003), 291-305.

22) Tsun-Hui Hung, "One Music? Two Musics? How Many Musics? Cognitive Ethnomusicological, Behavioral, and fMRI Study on Vocal and Instrumental Rhythm Processing," Ph.D. Dissertation (The Ohio State University, 2011).

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in addition to perception, we produce vocal and instrumental rhythms via different motor-effector organs of the body. As shown the somatotopic motor representation also known as Homunculus, vocal production is controlled by the ventral part of the primary motor cortex (PMC) while instrumental sound production is mediated by the medial and dorsal part of the PMC, which indicates an involvement of different neural networks for vocal versus instrumental rhythm production. Pa and Hickok, for instance, suggested separable sensorimotor networks for the vocal tract and the hand/limb motor-effector system.[23] In their fMRI experiment, the participants were asked either to hum melodies or to play the corresponding melody on a keyboard. A comparison of the brain activations for these two different tasks reveals that the humming condition showed a greater activation in a region of the sylvian fissure whose function is known for speech processing, while there was a greater activation in the anterior intraparietalsulcus for the manual condition.

The production of vocal rhythm involves movements of various vocal apparatus (see figure 1).[24] In addition to voice production, the

23) Judy Pa, and Gregory Hickok, "A Parietal-Temporal Sensory-Motor Integration Area for the Human Vocal Tract: Evidence from an fMRI Study of Skilled Musicians," *Neuropsychologia* 46/1 (2008), 362-368.

24) Human vocalization involves an interplay of three subsystems including the supralaryngeal vocal tract resonating system, the larynx vibrating system and the subglottal respiratory system. The supralaryngeal vocal tract resonating system consists of the nasal cavity, oral cavity, and pharynx. The vibratory system includes the larynx whose vibration changes air pressure to sound waves of voice. The respiratory subglottal system comprises lungs, diaphragm, and trachea. All three systems play important roles in varying pitch, intensity, contour, and the duration of

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larynx, a part of vocal apparatus, plays a role in diverse behaviors such as breathing, swallowing, and so on. Voice production in humans is under the direct control of the laryngeal motor cortex (LMC). Belykand and Brown pointed out that a two-part structure of the LMC (note the dorsal and ventral LMC of figure 1) is unique to humans, compared to other animal species.[25] Their comparative review of vocal brains across animal species indicates that this human-specific feature may allow vocal production learning through evolution. It is interesting to note that the authors argue that vocal production is not a simple motor capacity but a sensorimotor mechanism that allows us to convert perceived sounds to a set of motor commands to reproduce sounds so a pitch of the perceived sound corresponds to that of vocally reproduced sounds. For instance, musical onomatopoeia that signifies not only sounds of an instrument but also action to the instrument has been widely observed in the context of music learning in various cultures.[26]

sounds, etc. In terms of differences of physiological control for singing vs. speech, singing involves a more opened vocal tract and requires greater control of airflow than speaking.

25) Michel Belyk and Steven Brown, "The Origins of the Vocal Brain in Humans," *Neuroscience & Biobehavioral Reviews* 77 (2017), 1771-1793.

26) Yong Jeon Cheong, "Sound of Action: Musical Onomatopoeia as Embodied Signs," *Book of Abstracts: the 44th International Council of Traditional Music World Conference* (University of Limerick, Ireland, July 16, 2017), 77.

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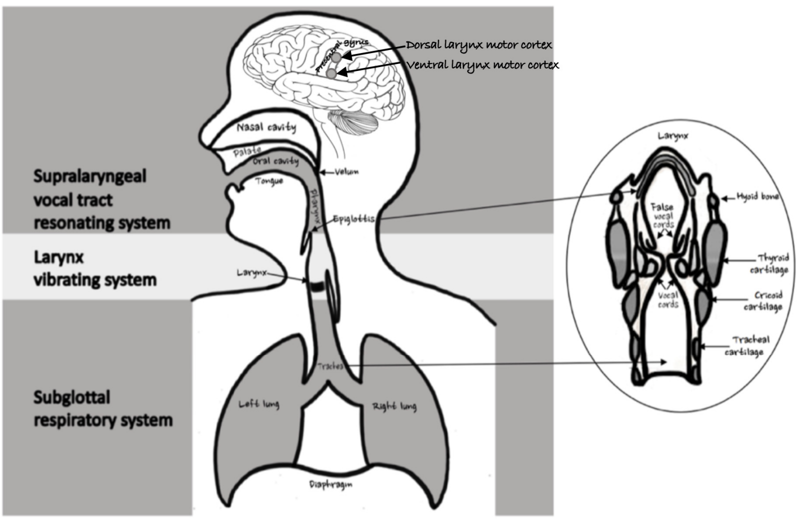
[Figure 1] Human vocalization system



A study by Halwani and his colleagues investigated how vocal and instrumental musical training affect the arcuate fasciculus (AF), a white matter bundle that connects Broca's area to the Wernike's area, two language areas of the brain, by looking at any structural differences of the AF between non-musicians, instrumentalists and singers.27) They found that both instrumentalists and singers have a larger AF volume than non-musicians. More interestingly, singers' AF shows more complex connectivity than instrumentalists. According to an interpretation of these researchers, vocal training

27) Gus F. Halwani, Psyche Loui, Theodor Rüber, and Gottfried Schlaug, "Effects of Practice and Experience on the Arcuate Fasciculus: Comparing Singers, Instrumentalists, and Non-Musicians," *Frontiers in Psychology* 2 (2011). DOI:10.3389/fpsyg.2011.00156

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contributes to increased sensitivity for feedback of the inferior somatosensory cortex and feedforward information of the inferior parts of the motor and premotor areas to monitor breathing and proprioception of the vocal apparatus. This study suggests different effects between vocal and instrumental sound/rhythm production on the brain.

Instrumental rhythm is created by any sounds from human activities except for voice production and is often produced manually. This type of rhythm involves upper limb movements of human body, however, some musical instruments (e.g., drum) require the movements of lower limbs and the coordination of both your upper and lower limbs to generate instrumental rhythms. Changes in the brain due to instrumental training, have been well studied compared to effects of vocal training. One of these changes is that long-term instrumental training influences processing of temporal information of acoustic inputs and of auditory feedback in the production of sequential finger movements in music performance.[28] For instrumentalists, perception of sounds of a specific musical instrument facilitates the activations of the motor cortices in a time-locked manner.[29] In terms of brain plasticity, the

28) van der Steen, M. C (Marieke), E. B. D. Molendijk, E. Altenmüller, and S. Furuya, "Expert Pianists Do Not Listen: The Expertise-Dependent Influence of Temporal Perturbation on the Production of Sequential Movements," *Neuroscience* 269 (2014), 290-298.

29) Yuta Furukawa, Kazumasa Uehara, and Shinichi Furuya, "Expertise-Dependent Motor Somatotopy of Music Perception," *Neuroscience Letters* 650 (2017), 97-102; Shinichi Furuya, Yuta Furukawa, Kazumasa Uehara, and Takanori Oku, "Probing Sensorimotor Integration during Musical Performance," *Annals of the New York Academy of Sciences* 1423/1

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studies about effects of musical training have presented how our musical activities influences various function of the brain.[30)] Investigating differences in a network for audio-motor coordination between musicians and non- musicians, cognitive scientists have found greater activities of the supplementary motor area and the premotor cortex that are important for the planning and initiation of motor movements for musicians than for non-musicians.[31)]

4. Periodicity and Its Effect on Vocal and Instrumental Rhythms: A Case Study

An involvement of movement of different body parts for the production of vocal and non-vocal sounds leads to a considerable difference between speech (vocal) and instrumental rhythms. Speech

(2018), 211-218.

30) Gottfried Schlaug, "Musicians and Music Making as a Model for the Study of Brain Plasticity," *Music, Neurology, and Neuroscience: Evolution, the Musical Brain, Medical Conditions, and Therapies,* edited by Eckart Altenmüller, Stanley Finger, and François Boller (Amsterdam: Elsevier, 2015), 37-55. Musical training changes the brain structure as well. Compared to non-musicians, musicians are known for a thicker corpus callosum, a bundle of commissural fiber that permits inter-hemispheric communication, and for a more developed central sulcus.

31) Marc Bangert, Thomas Peschel, Gottfried Schlaug, Michael Rotte, Dieter Drescher, Hermann Hinrichs, Hans-Jochen Heinze, and Eckart Altenmüller, "Shared Networks for Auditory and Motor Processing in Professional Pianists: Evidence from fMRI Conjunction," *NeuroImage* 30/3 (2006), 917-926; Simon Baumann, Susan Koeneke, Conny F. Schmidt, Martin Meyer, Kai Lutz, and Lutz Jancke, "A Network for Audio-Motor Coordination in Skilled Pianists and Non-Musicians," *Brain Research* 1161 (2007), 65-78.

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rhythm is irregular while instrumental rhythm shows *periodicity*.[32)] Even when people are asked to tap while listening to music where melodies are irregular, for instance, *alap* that is introductory section in Hindustani music performance, pulses that they spontaneously produce are *quasi-periodic*.[33)] In order to explain this phenomenon *entrainment*[34)] has been proposed because pulse is considered as the experience of one's internal periodicity that can arise spontaneously when making repetitive motor actions. Periodic movements of the body, especially limb parts, emerge autonomously from dynamics of its movements in the contexts not only of music-making but also of everyday life. For instance, MacDougall and Moore found a dominant peak of locomotion activities of daily life is ~ 2Hz (i.e., 120 beat per minute), and proposed that this spontaneous tempo of locomotion is 'resonant frequency'.[35)] The

32) Will, "Temporal processing and the experience of rhythm: a neuro-psychological approach," 216-230.

33) Udo Will, Martin Clayton, Ira Wertheim, Laura Leante, and Eric Berg, "Pulse and Entrainment to Non-Isochronous Auditory Stimuli: The Case of North Indian Alap," *Plos One* 10/4 (2015), 1-26.

34) Martin Clayton, Rebecca Sager and Udo Will, "In time with the music: The concept of entrainment and its significance for ethnomusicology," *ESEM CounterPoint* Vol. 1 (2004), 1-82. Cognitive ethnomusicologists introduced the concept entrainment to the ethnomusicology in order to stimulate research on effects of cultural factors on synchrony observed in music performance at various levels. Entrainment refers to the interaction and consequent synchronization of two or more rhythmic processes or oscillators.

35) Hamish G. MacDougall and Stephen T. Moore, "Marching to the Beat of the Same Drummer: The Tempo of Human Locomotion," *Journal of Applied Physiology* 99/3 (2005), 1164-1173.

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resonance model of tempo perception by van Noorden and Moelant demonstrates that 120 BPM is not only the preferred rate of repeated motor actions but also the perceived tempi in various musical genres including Flemish polyphony, French baroque music, Romantic piano music, Classic jazz of the late thirties, and contemporary hitparade music.[36] Using the modulation spectrum, the spectrum of the temporal envelope of sounds, Ding and his colleagues confirmed ~ 2Hz as a dominant peak frequency of beats with solo instrumental music, symphonic music, jazz, and rock.[37] Another interesting finding of this study is that two versions of rock, one with vocals and the other without vocals, also show dominant peak frequency of ~ 2Hz. In contrast, speech rhythms are irregular and a dominant frequency of speech recognition peaks is around ~ 4Hz unless they are organized in a certain form (e.g., prosody, song, etc.).[38] This indicates an important role of *periodicity* in an interaction between speech (vocal) and instrumental rhythms. The following analysis will show how a periodic body movement (e.g., tapping, rocking, etc.) increases regularity in speech rhythm in the context of lullaby practice. On August 6th of 2012, a mother whose username is

36) Leon van Noorden and Dirk Moelants, "Resonance in the Perception of Musical Pulse," *Journal of New Music Research* 28/1 (1999), 43-66.

37) Nai Ding, Aniruddh D. Patel, Lin Chen, Henry Butler, Cheng Luo, and David Poeppel, "Temporal Modulations Reveal Distinct Rhythmic Properties of Speech and Music," *Neuroscience and Biobehavioral Reviews* 81 (2017), 181-187.

38) Roger K. Moore, "Finding Rhythm in Speech: A Response to Cummins," *Empirical Musicology Review* 7(1-2) (2012), 36–44; Ding and others, "Temporal Modulations Reveal Distinct Rhythmic Properties of Speech and Music" 181-187.

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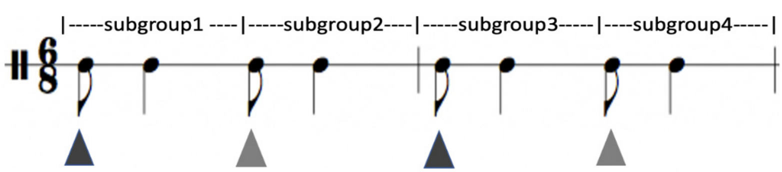
‘nabihome’ posted her performance of a traditional Korean lullaby called *jajangga* on YouTube.[39] In order to investigate synchronization between singing and rocking movement, the entrainment analysis proposed by Clayton and his colleagues was applied.[40] This requires three steps: 1) extraction of hypothetical pulses in singing, 2) extraction of hypothetical pulses in rocking movement, and 3) alignment of the pulses between singing and rocking movement. For the first step, the basic rhythm formula (see figure 2), consisting two bars with 6/8 time signature, was established from the transcription and the durations between the first and fourth beat were measured via Praat.[41] This yields 136 singing pulses and the duration between pulses range from 0.678 s to 1.476 s with the mean of 0.893s.

[Figure 2] Basic rhythm formula: the first beat marked by dark gray triangle and the fourth beat marked by light gray triangle



39) Nabihome, “*jajangga,*” You Tube Video, August 6, 2012, https://www.youtube.com/watch?v=H8TwhytQzlI

40) Clayton and others, “In time with the music: The concept of entrainment and its significance for ethnomusicology,” 1-82.

41) Paul Boersma, “Praat: Doing Phonetics by Computer,” *Glot International* Vol. 5, 9/10 (2001), 341-345.

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For the second step, the video clip was loaded to a video editing software called Final Cut Pro. The durations between two reference points of the rocking movements were measured. The reference points consist of cycle (a) and (b): cycle (a) is the time when the baby is the furthest from the mother whereas cycle (b) is the baby is positioned the closest to her (see figure 3). This step yields 135 rocking pulses from both cycle (a) and (b) were identified with the duration ranging from 0.133s to 1.433s with the mean of 0.890s. The figure 3 is a circular plot showing distributions of cycle (a) and (b) with regard to singing. The observed values at 0° of the circular plots indicate the perfect synchronization between singing and rocking. The observations at 0° are the perfect in-phase relationship between singing and rocking movements while those at 180° present the out-of phase relationship between them. Kuiper's uniformity tests for cycle(a) ($V = 2.294$, $p<0.01$) and (b) ($V = 2.893$, $p<0.01$) turn out to be significant. The results indicate that rocking movements are not randomly distributed, rather associated probably with some patterns of periodic body movements. Given that the reference points of cycle (a) and cycle (b) are related to the baby's positions and that the distribution of cycle (a) is more dispersed than cycle (b), the comparison of two circular plots would demonstrate an interesting point: the singing with inward movement is in the better synchronization [cycle (b)] than that with outward movement [cycle (a)]. In other words, singing is better entrained when the mother rocks her baby toward her than when she moves her baby to the opposite direction.

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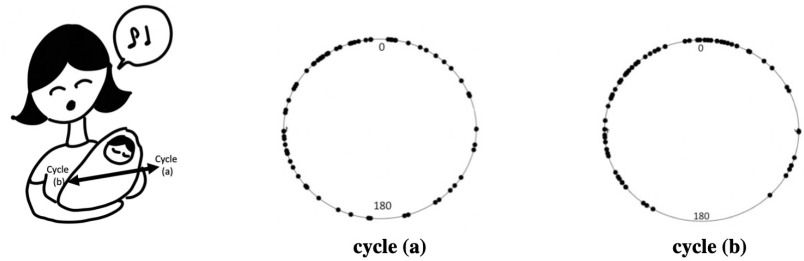
[Figure 3] Two reference points of rocking movements and distribution of two cycles



The third step examines the phase relationship between singing and rocking movement throughout the performance time (see figure 4). The phase relationship represents how much singing is aligned with rocking. The calculation of the relative phase, the latency between one event in singing and its corresponding rocking movement in time, is one way to check the phase relationship of singing and rocking movement in time. In order to measure degrees of synchrony between singing and rocking, three sections could be found: the section [A] from the beginning to 35s, the section [B] from 35s to 80s, and the section [C] from 80s to 120s. The best synchrony was found in the section [A] (see the blue mean line at the Degree 0 on Y-axis). As the gap between 0° and the mean line becomes larger, the difference in latency between singing and rocking increases in the section [B]. The transcription shows that, relative to other sections, the section [B] is characterized by various rhythm variants with three different types of subdivision of notes.[42] In the

42) The rhythm variants are produced by replacing subgroup rhythms of the

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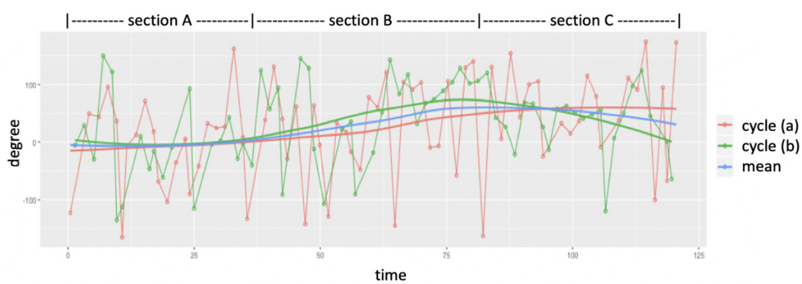
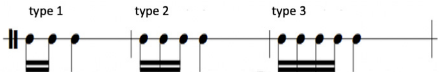
section [C] the latency difference decreases, especially for the cycle (b) as the use of the rhythm variants is reduced and the basic rhythm formula is restored. This shows synchrony between singing and rocking movement in the lullaby performance with some degree of fluctuation. Given a larger lag between singing and rocking in the section [B] than other sections, the fluctuation seems to be correlated to the rhythm variants. It is also interesting that changes in alignment between singing and rocking occur faster when the mother is moving her baby toward her (i.e., cycle (b)) than when she is moving the baby away (i.e., cycle (a)).

[Figure 4] Relative Phase



basic rhythm formula (see figure 2) with the following three types of rhythms.



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5. Conclusion

We humans experience the world in time and rhythm is a core element of temporal experience. However, there is a confusion in understanding of rhythm. Based on findings of studies in the field of cognitive sciences, this study clarified the definition of rhythm. It further argued for an importance of experiential components of temporal experience by defining rhythm as *the bodily perceived and produced* temporal relationships of successive events without pattern repetition or regularity within a framework of embodied cognition.

We make meanings of-and-in our lives through our perception, actions and interactions to the world. Music is one of the most important human behaviors that demonstrate how we make our lives meaningful in time through our body. Since we make music in two ways, singing and instrument-playing, there exist two rhythms, vocal and instrumental rhythm. This is supported with archeological and historical evidence. Neuroimaing and neurophysiology studies have found evidence for the specialization and preference for vocal sounds, for instance, the *voice selective areas/region*s, the *voice sensitivity,* and the *voice specific response.* This is an additional indications for vocal and instrumental rhythm. The most distinctive difference between speech (vocal) and instrumental rhythm is that the vocal rhythm is irregular but instrumental one shows periodicity. This periodicity emerges from the resonant frequency of body movement (i.e., ~ 2 Hz), which alludes to the fact that an involvement of different effector organs in sound production leads

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to two different rhythms. In music-making, however, vocal and instrumental rhythms are often in synchronization so a confluence of the two rhythms seems to be associated with periodicity. The entrainment analysis on a case study on lullaby demonstrates how periodicity aligns vocal and instrumental rhythms. This study tells us that it is time to rethink rhythm in music scholarship.

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개 요

리듬이란 무엇인가? 하나로 수렴된 정의가 없다는 사실이 보여주듯이 리듬은 혼란스러운 개념이다. 본 논문은 심리학과 인지 민족음악학의 이전 연구들을 토대로 리듬의 개념을 재정립하고자 한다. 체화된 인지 이론(embodied cognition theory)에 근거하여 본 논문은 리듬을 신체를 통해 지각 및 행위화된 연속적 사건들의 시간정보로 보며, 두 개의 리듬 즉, 1) 음성/성악 리듬(vocal rhythm)과 2) 비음성/기악 리듬(non-vocal/instrumental rhythm)의 존재를 암시하는 선사시대 흔적과 고대문화 자료를 검토한다. 또한 인간의 발성 기관과 손을 통해 생산되는 리듬의 차이점을 기능적 신경 해부학적측면에서 살펴본다. 다른 동물 종과는 다르게 인간은 성악리듬과 기악리듬을 동시에 생산할 수 있다. 이를 가능하게 하는 기본 메커니즘을 신체에서 자연 발생한 공명 진동수(resonance frequency)가 만들어낸 주기성(periodicity)으로 규명하고 사례 연구를 통해 주기성이 성악과 기악리듬을 어떻게 음악활동에서 결합하는지 살펴본다. 본 연구는 음악학자들로 하여금 리듬이란 무엇인가에 대해 재고해야할 필요성을 보여준다.

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