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NEST2020 ABSTRACTS

Monkey see, monkey tap: Mimicry of movement dynamics during coordinated tapping

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Many everyday behaviors, such as having a conversation, dancing, playing a team sport, require precise interpersonal coordination of the timing of actions. One question that emerges in research on interpersonal coordination is to what extent mimicry of movement dynamics plays a role in movement execution. Two experiments addressed this question using an interpersonal synchronize-continue tapping paradigm in which continuous motion tracking was used to examine movement dynamics. Pairs of individuals tapped with their index finger in synchrony with an auditory metronome and then continued tapping at the same tempo when the metronome stopped. On some trial blocks, pairs of individuals tapped together (inter-personal tapping), but on other trial blocks, individuals tapped alone (solo tapping) either with their tapping partner present or absent from the testing room. Tap amplitudes (how high individuals moved their finger off the table) and tap dwell times (the amount of time a person keeps their finger on the table) were correlated between tapping partners when they tapped together but not when they tapped alone. Results indicate that during coordinated tapping, individuals mimic some aspects of movement dynamics; moreover, some aspects of mimicry carry over to both timing performance and to solo tapping after individuals have tapped together.

Larger group sizes in a drumming circle paradigm do not increase individual variability or speeding up of the collective stable pattern

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Music is often performed in group and may have evolved as a collective experience. We study the constraints, both enabling and limiting, inherent in group synchronization seen as a system of interacting processes. Do groups larger than a dyad facilitate or hamper anticipation and stability? In mechanistic terms, compounding the noise, delays, and mirroring among individuals is expected to hinder performance. As a system of interacting dynamic processes, however, collective performance creates different affordances for synchronization and stability. The drumming circle is a convenient experimental paradigm because it requires minimal musical skill and allows manipulations of group size, connectivity, and leadership. We examined 2-, 4-person drumming circles of non-professional musicians performing a synchronization-continuation task in Solo and Group conditions. Variability was lower for the Group as a whole than in Solo or Individuals-in-Group. Evidence for the reactive inter-individual adaptation previously reported in dyadic tapping in terms of auto-correlations and Granger causality was also observed in the 2-person groups but not in the 4-person groups. A possible formal explanation is that the central moment of group timing acts as stabilizing feedback allowing variable individuals to come into a consistent group. In a subsequent study we addressed a larger group size of a drumming octet and a more complex drumming pattern. Contrary to previous reports, we found that speeding up, a common phenomenon observed in the dyadic setup, is not exaggerated by larger group sizes, in fact it could even be reduced for starting tempos that are already high.

A predictive coding model of sensorimotor entrainment

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The dynamics of a human subject maintaining sensorimotor entrainment have been repeatedly modeled as a combination of two processes: phase and tempo error correction. However, such models do not account for an observed delay in initiating a tempo correction response. I propose that this is because they do not take into account the influence of "locking-in," the experience reported by many musicians of developing certainty in the underlying isochronous structure which may produce resistance to tempo change. In this talk, I present a new variation on the two-process model of entrainment error correction based in the Bayesian theory of Predictive Coding that naturally accounts for certainty in addition to phase and tempo estimates. I will present a computational implementation of this model, show how its results provide a better match for experimental observations, and explain how this model could shed new light on a range of human entrainment effects including the multiple-effector advantage, the advantage of both isochronous and non-isochronous metrical subdivision, and the therapeutic effect of rhythmic auditory stimulation in Parkinson's disease.

The Pairwise Approximate Spatiotemporal Symmetry (PASS) Algorithm: A Method for Segmenting Time Series on the Basis of Similarity Between Signals

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It is often useful to consider the similarity that exists between signals collected in experimental settings, especially when these signals come from human dyads and the goal is to understand how people use similarity of behavior to communicate information nonverbally. Symmetry, an approximate form of similarity, is theorized to have functional communicative utility in a variety of dyadic contexts, like dance (Boker, Covey, Tiberio, & Deboeck, 2005), conversation (Ashenfelter, Boker, Waddell, & Vitanov, 2009), and attachment (Evans & Porter, 2008), among others. The Pairwise Approximate Spatiotemporal Symmetry (PASS) algorithm was developed to quantify the similarity that exists between two measured signals in a spatiotemporal way. The algorithm starts by using the windowed cross correlation (WCC) procedure (Boker, Xu, Rotondo, & King, 2002) to capture similarity between time series in windowed segments that are assumed to be locally stationary. These segments are lagged to capture similarity information that is not instantaneous. The resulting WCC matrix, containing a structured set of correlations between lagged windows, contains information relevant to both spatial and temporal similarity. The WCC procedure aggregates spatial information but not time information, so that correlation patterns may be observed visually across time. The PASS algorithm aggregates temporal similarity information so that quantifiable conclusions about time-based similarity can be drawn. This is done by first correlating these lagged correlations in the WCC matrix at each reference time point with a given number of future time points, and then by determining which time points are most unlike future time points using Mahalanobis Distance (Mahalanobis, 1936). The PASS algorithm conducts the analysis in both temporal directions so that symmetry patterns can be elucidated in prospective and retrospective time. Thus, a given time series can be partitioned into segments that are either reflective of symmetry or are not. Several symmetry metrics are offered. This method has been tested on four simulated examples: simulated noise, sine curves, and segmented noise and sine curves with equal and unequal intervals. Likewise, this method has been tested on an empirical example involving the behavioral motion of therapists and clients in a therapy session. Results suggest that the PASS algorithm is efficient at meaningfully segmenting pairwise time series with regard to pairwise symmetry.

Neurodynamic responses to syncopated rhythms reveal the neural origins of pulse perception

Ed Large

University of Connecticut

In this talk, I consider rhythms that have no energy in their modulation spectrum at the frequency people experience as the main beat, or *pulse*. We call these “missing pulse rhythms.” I will describe an EEG experiment in which we identified the neural loci of pulse perception by exploiting the special properties of missing pulse rhythms. Because the pulse frequency is absent from the stimulus, we can distinguish those brain areas that reflect mainly stimulus frequencies, from those areas that generate the pulse frequency. We measured SS-EPs using a 256-channel, high-density EEG, and we localized participants' neural responses using individual MRI images. For an isochronous control (periodic rhythm at the pulse frequency), we observed the pulse frequency in bilateral primary auditory cortex (A1), bilateral premotor cortex (PMC), right supplementary motor area (SMA), and left and right putamen – areas consistent with previous fMRI studies. For a random control (unstructured rhythm with no energy at the pulse frequency), we observed no pulse frequency activity in any of these areas. Critically, for two missing-pulse rhythms, we observed significant energy at the pulse frequency in right PMC and SMA, and in left and right putamen, but not in A1. The results are consistent with a model in which pulse emerges from the interaction of a stimulus with oscillatory activity in multiple brain regions. They also show how the model can be refined by pointing to the actual brain areas where such activity can be observed.

Next-Generation Gradient Frequency Neural Networks: A Tensorflow Library for Design and Optimization of Dynamical Systems in Neuroscience

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Gradient Frequency Neural Networks (GrFNNs) are a canonical mathematical model able to simulate the dynamical oscillatory properties between populations of neurons. Because of their higher-order terms, GrFNNs can amplify a driving force at various resonant frequencies through hopf bifurcations, limit-cycle or double-limit-cycle acitivity. Among other things, GrFNNs can model beat tracking in the motor system. To optimize a GrFNN, one must first determine the desired steady state behavior, and then find plausible values for its parameters. Steady state behavior is observed when the input can be described mathematically (i.e. a pure tone, or a song with a steady beat frequency). However, optimizing a GrFNN is harder when the input is noisy or more difficult to characterize (like music with a varying beat). Other parametric state-of-the-art methods for beat tracking are optimized via gradient descent, a method where the error between the model's output and an ideal objective is calculated to then update the parameters and reduce the error. We have used tensorflow to automatically optimize GrFNN parameters using gradient descent. Additionally, using tensorflow has allowed us to make GrFNNs more biophysically meaningful, because we can optimize networks with canonical models with spiking neural activity. We also use real electrophysiolgical data to further constraint the activity in these models. Our models can carry out cognitively-meaningful tasks, like beat tracking or pitch finding. Once a model is optimized, we can study how its neurons interact to carry out a cognitively-meaningful task.

Rhythmic resynchronization ability predicts melodic intonation therapy performance and reading fluency

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Melodic intonation therapy (MIT) has a long history of application for patients with non-fluent aphasia. The fundamental technique involves tapping to the onsets of syllables while speaking/singing. We refer to this as the MIT task. Research has also shown impairment of rhythmic ability in many clinical populations with language related deficits. In this study, we explored the relationship between rhythmic ability, performance on the MIT task, and reading fluency and comprehension in healthy English- and Mandarin-speaking adults. We used a resynchronization task to assess subjects' rhythmic ability by asking subjects to synchronize taps with a metronome that exhibited occasional tempo and phase perturbations. Subjects' resynchronization ability was assessed by phase variability immediately following the perturbation while they were trying to synchronizing taps to every tone in the rhythmic stimuli. We assessed ability to perform the MIT task by asking subjects to synchronize taps to the onset of each syllable they produced while reading sentences as naturally as possible. Performance on the MIT task was measured by the variability with which subjects synchronized taps to syllable onsets. Finally, language skills were measured using reading fluency and comprehension assessments for both native English and Mandarin speakers. We observed that participants' resynchronization ability correlated strongly with performance on the MIT task, and their resynchronization ability also correlated strongly with language fluency scores. Both findings generalized across English and Mandarin speakers. Implications for developing intervention and rehabilitation methods based on rhythmic synchronization training are discussed.

Memory in time: Neural tracking of low-frequency rhythm dynamically modulates memory formation

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Tufts University

Time is a critical component of episodic memory. Yet it is currently unclear how different types of temporal signals are represented in the brain and how these temporal signals support episodic memory. The current study investigated whether temporal cues provided by low-frequency environmental rhythms influence memory formation. Specifically, we tested the hypothesis that neural tracking of musical rhythm serves as a mechanism of selective attention that dynamically biases the encoding of visual information at specific moments in time. Participants incidentally encoded a series of visual objects while passively listening to background, instrumental music with a steady beat. Objects either appeared in-synchrony or out-of-synchrony with the background beat. Participants were then given a surprise subsequent memory test (in silence). Results revealed significant neural tracking of the musical beat at encoding, evident in increased electrophysiological power and inter-trial phase coherence at the perceived beat frequency (1.25 Hz). Importantly, enhanced neural tracking of the background rhythm at encoding was associated with superior subsequent memory for in-synchrony compared to out-of-synchrony objects at test. Together, these results provide novel evidence that the brain spontaneously tracks musical rhythm during naturalistic listening situations, and that the strength of this neural tracking is associated with the effects of rhythm on higher-order cognitive processes such as episodic memory.

Rhythm beyond time: expertise, effector, and movement shape rhythmic acuity

Michael Schutz

McMaster University

Body movement can affect our perception of both rhythm and meter. However the perceptual implications of different types of movement and their interaction with musical training remain open questions. This talk will describe an ongoing series of experiments raising intriguing questions about how training and expertise affect both the quality and consequences of musical movements.

Our experiments use stimuli consisting of several repetitions of a woodblock pattern followed by a silent "timekeeping" period, and finally a probe tone on-time for 50% of trials. Participants indicate whether the probe tone is correct under in two conditions: (1) listening while tapping (movement) or (2) listening while stationary (no-movement). Participants receive equal numbers of movement and no-movement blocks. This design is well suited for examining movement's effect on time, as well as the lesser-studied role of movement type (finger tapping, stick tapping), and effector-specific training (finger tapping for pianists, stick tapping for percussionists). We tracked both movement timing as well as its effect on rhythm perception amongst numerous groups (i.e. those with no musical training, highly trained pianists, highly trained percussionist) and with different types of movement (traditional finger tapping, tapping on a piano keyboard, tapping with a drumstick on a drumpad).

Our results (some of which are published) illustrate that (1) movement can not only change but objectively improve rhythm perception, (2) this effect of movement is stronger in those with extensive musical training, however (3) surprisingly, effects of musical training vanish in the no-movement condition, and (4) stick tapping lead to the best performance—even for those heavily trained on finger tapping (i.e. pianists). We will discuss the implications of these findings, as well as applications in future research on sensorimotor integration.