NEST 2017

THE NEW ENGLAND SEQUENCING AND TIMING MEETING

Meeting Schedule and Abstracts

NEST 2017 Schedule

Saturday, March 25, 2017	
9:00 am to 9:30 am	Registration & Welcome Breakfast
9:30 am to 10:00 am	The Prolonged Development of Beat and Meter Perception: Evidence from children, adolescents, and adults. ***Speaker:*** Jessica E. Nave-Blodgett
10:00 am to 10:30 am	Assessing Musical Beat Perception Based on Simulated Low-level Neural Activity ***Speaker:*** Nathaniel Zuk
10:30 am to 10:45 am	**-- Coffee Break --**
10:45 am to 11:15 am	The Link Between Timing, Movement, and Low-Frequency Tones ***Speaker:*** Michael J. Hove
11:15 am to 12:15 pm	Rhythmic Perceptual Priors Revealed by Iterated Reproduction ***Speaker:*** Nori Jacoby
12:15 pm to 1:15 pm	**-- Lunch Break --** Provided On-Site
1:15 pm to 1:45 pm	When Narrative Arcs Combine: Tonal Harmony Affects the Processing of Sequential Images ***Speaker:*** Morgan Patrick
1:45 pm to 2:45 pm	Synchronization of Canonical Oscillators to Syncopated Rhythms: The Effect of Temporal Receptive Field ***Speaker:*** Ji-Chul Kim
2:45 pm to 3:00 pm	**-- Coffee Break --**
3:00 pm to 3:30 pm	Interpersonal Coordination Dynamics in Crew Rowing: Effects of Movement Rate ***Speaker:*** Laura S. Cuijpers
3:30 pm to 4:00 pm	Limits in Timing Precision are Not a Real Limit for Task Success in Throwing ***Speaker:*** Zhaoran Zhang
4:00 pm to 5:00 pm	Pitchers and Pianists: Timing in Discrete and Rhythmic Motor Skills ***Speakers:*** Dagmar Sternad, Dena Guo, and Keith Harrigian
5:00 pm to 6:30 pm	**-- Post-Meeting Drinks and Discussion --** Geno's Grille: Storrs Center
6:30 pm to 9:00 pm	**-- Reception at Ed's House –** Food Will be Served

Morning Session

9:00 am to 9:30 am	Registration & Welcome Breakfast
9:30 am to 10:00 am	The Prolonged Development of Beat and Meter Perception: Evidence from children, adolescents, and adults. ***Speaker:*** Jessica E. Nave-Blodgett

Abstract:

Music is a fundamental part of our daily lives. When we listen to and participate in musical activities such as performance or dance, we are confronted with rich, multimodal temporal patterns. In Western cultures, musical patterns are thought to be perceived hierarchically, with recurring patterns of stronger (downbeat) and weaker (upbeat) events. Knowledge of the metrical hierarchy can facilitate solo and group synchronization to music. Although prior research suggests that infants are sensitive to the beat, an open question is when young listeners become aware of hierarchical metrical structures in music. We presented young children (5-10 years), adolescents (11-17 years), and young adults (18+ years) with auditory and visual metronomes that matched or mismatched the beat and measure of human-performed music, and we asked them to provide goodness of fit ratings. Children rated beat-matching metronomes as better fitting than beat-mismatching metronomes, but they did not differentiate between beat-matching metronomes that did or did not match higher (measure) levels of the musical meter. Furthermore, the youngest children (5-6) showed no evidence of beat or meter perception with visual metronomes, giving similar ratings to all metronomes. Adolescents (age 11-17 years) successfully distinguished between beat-matching and beat-mismatching metronomes, although only the oldest adolescents (15-17) exhibited sensitivity to synchrony at the measure level. By adulthood, listeners consistently rated both auditory and visual metronomes that matched the music at the beat and measure levels as fitting the music better than metronomes that matched only the beat of the music. This suggests that beat and meter perception go through an extended period of development and refinement. Beat perception may develop earlier in the auditory modality than visual, and hierarchical perception of meter may not emerge until relatively late in adolescence.

10:00 am to 10:30 am	Assessing Musical Beat Perception Based on Simulated Low-level Neural Activity ***Speaker:*** Nathaniel Zuk

Abstract:

Prior research has shown that musical beats are salient at the level of the auditory cortex, as measured by recording cortical activity in humans. Several models have been developed that infer beat timing from stimuli with discrete temporal events, usually clicks or pure tones, which simulate our perception of beats and the observed neural activity in the cortex. Yet below the cortex there is a considerable amount of low-level

processing that could influence our perception of beats. But how low-level processing shapes beat perception, especially in real music, is still unclear.

Here, we use a model of the auditory nerve [Zilany et al, *J Acoust Soc Am*, 135, 283-286 (2014)] and a model of midbrain-level modulation filtering [Carney et al, *eNeuro*, 2 (2015)] to simulate low-level neural activity to various beat-inducing stimuli. Inspired by models of pitch processing, we then use a "beat sieve" to compute the salience of the beat based on the autocorrelation of the summed activity across audio frequencies (125-8000 Hz). Firstly, we show that beats are most salient for low-frequency sounds and that neurons carrying low-frequency information produce a stronger beat salience. Secondly, we show that the model predicts a maximum beat salience between 60-150 BPM, in agreement with several studies on the preference for tempo and the predominant tempos in music. Lastly, we show that for complex rhythmic patterns and real music the maximum beat salience occurs at the event frequency rather than at the beat frequency itself. This suggests that detecting regularities in bottom-up responses is not sufficient for perceiving a beat in real music; an additional, potentially cortical-level, mechanism is necessary.

10:30 am to 10:45 am	**-- Coffee Break --**

10:45 am to 11:15 am	The Link Between Timing, Movement, and Low-Frequency Tones ***Speaker:*** Michael J. Hove

Abstract:

Auditory and motor systems are intimately linked. Auditory rhythms can activate motor and timing networks and induce movement in listeners. Movement and timing are more influenced by some auditory stimuli than others. In a series of studies, we have established that movement and timing are especially influenced by low-frequency (bass) tones. Here, I will present an overview of our behavioral and cognitive neuroscience studies that establish this link. In finger-tapping studies, we have shown that lower-frequency tones have a greater influence on tap timing (both in tap-to-tone asynchrony and error correction). We have shown that songs rated high on groove ('the musical quality that compels movement') had more spectral flux in bass frequencies. In a transcranial magnetic stimulation (TMS) study, musical stimuli with more bass increasingly affected the motor system (i.e., cortico-spinal excitability). Using EEG (mismatch negativity), we showed that the brain better detects timing deviations in lower-pitched tones, and modeling suggests that encoding in the auditory periphery contributes to this effect. A new study presented music over sound-isolating earphones with or without a subwoofer that produced tactile bodily sensations; results showed that the auditory+tactile condition yielded higher groove ratings and induced more movement. In sum, the link between low-frequency tones and movement that we've repeatedly observed appears to have physiological underpinnings (in auditory encoding and somato-motor activation) and explains the musical convention for low-pitched instruments to lay down the rhythm.

11:15 am to 12:15 pm	Rhythmic Perceptual Priors Revealed by Iterated Reproduction ***Speaker:*** Nori Jacoby

Abstract:

Probability distributions over external states (priors) are essential to the interpretation of sensory signals. In many areas of perception and cognition, humans appear to combine current observations with internal beliefs about the environment (the prior) in a process approximating statistical inference (Knill & Richards 1996, Weiss et al. 2002). We propose a novel method to characterize perceptual priors and apply it to the study of simple (two- and three- interval) rhythms. Simple rhythms have been previously studied using discrimination (Clarke 1987, James & Marvin 2015), categorization (Sadakata et al. 2006, Desain & Honing 2003) or production paradigms (Povel 1981, Repp, et al. 2012, 2013). We argue that results obtained using these methods can be re-interpreted as manifesting subjects' reliance on perceptual priors. To characterize priors for this domain we developed a method based on iterated reproduction of random temporal sequences (Jacoby & McDermott 2017). Listeners were asked to reproduce random "seed" rhythms; their reproductions were fed back as the stimulus, and over time became dominated by internal biases, such that the prior could be estimated by applying the procedure multiple times. Our results with this method are consistent with previous proposals that subjects bias their perception and production of rhythmic patterns towards rhythmic "categories" or "attractors" comprised of intervals approximately related by integer ratios. The novelty of our approach it that it is (a) highly efficient; (b) comprehensive, enabling the full characterization of the entire perceptual space of 2- and 3- interval rhythms; (c) intuitive (it does not rely on musical notation), allowing it to be applied irrespective of the participant's musical or cultural background; and (d) hypothesis-neutral, allowing any possible pattern of results to be detected. Using the method, we measured listeners' priors over the entire space of two- and three-interval rhythms, examining Westerners with different levels of musical expertise as well as members of the Tsimané, a native Amazonian society with very limited exposure to Western music. We found that priors in Westerners showed peaks at rhythms with simple integer ratios, but only those that are prevalent in Western music. Priors were similar for musicians and nonmusicians, suggesting that they are shaped primarily by passive exposure to the music of a culture. Priors in a native Amazonian society also exhibited modes at integer ratios, but were otherwise qualitatively different from priors in Westerners, in ways that are consistent with the structures prevalent in their music. The results were similar for several different modes of reproduction (e.g. finger tapping and rhythmic vocalization of a repeated syllable), but did not extend to the reproduction of spoken phrases, indicating that integer ratio priors are at least somewhat specific to music. Our results are consistent with biological constraints that favor integer ratios in musical rhythm (Large and Snyder 2009), but indicate that any such constraints are strongly modulated by culturally specific musical experience (Polak et al. 2016).

12:15 pm to 1:15 pm	**-- Lunch Break --** Provided On-Site

Afternoon Session

1:15 pm to 1:45 pm

When Narrative Arcs Combine: Tonal Harmony Affects the Processing of Sequential Images

Speaker: Morgan Patrick

Abstract:

Tonal music provides an effective accompaniment to visual narrative in a variety of contexts. Presumably this is because auditory and visual modalities pass complementary sequential information to a unified perceptual experience. Indeed, both Western tonal harmony and narrative syntax are hierarchical, recursive systems that unfold tension and release in time, suggesting a common processing mechanism during audiovisual integration. However, the precise nature of that mechanism remains unclear. In this study, we tested for effects of structural cues across music and visual narrative by measuring online processing and recognition when chord progressions were synchronized to picture stories. Subjects were presented with 6-panel Peanuts comic strips whose constituents were either logically coherent or structurally and semantically unrelated (scrambled). Accompanying musical chord progressions were either tonal or atonal. Individual chords were aligned with picture onsets, and subjects monitored for picture targets in sequences presented panel by panel. Subjects were significantly faster to identify picture targets of comic strips when the musical accompaniment was tonal and the picture sequence was coherent, as compared to when music was atonal or pictures were scrambled. Furthermore, the magnitude of tonal facilitation was significantly greater for coherent picture stories than for scrambled, indicating an interaction between sequential information across the two modalities. Finally, highly salient musical phrase endings – cadences – facilitated online visual processing speed regardless of picture narrative coherence, providing empirical support for the attentional magnetism of musical phrase endings in multimedia contexts, even when visual scenes were semantically incoherent. No effect was found for tonality on post-trial recognition. Implications for domain-general narrative processing mechanisms are discussed, with an eye toward framing tension-release trajectories in music as syntactic in nature.

1:45 pm to 2:45 pm

Synchronization of Canonical Oscillators to Syncopated Rhythms: The Effect of Temporal Receptive Field

Speaker: Ji-Chul Kim

Abstract:

Human perception of periodic pulse or beat in complex rhythms has been modeled with various signal processing methods and oscillator models. Many oscillator models of rhythmic synchronization have temporal receptive fields, the windows of time during which oscillators are more sensitive to external signals. However, how the temporal receptive field of an oscillator determines the way it synchronizes to complex rhythms has not been fully investigated. Here we study the synchronization of a canonical model of Hopf oscillation to complex rhythms, focusing on the effect of temporal receptive field.

We compare canonical oscillators having either fixed or adaptive temporal receptive fields with differing degrees of concentration. The responses of canonical oscillators to syncopated rhythms are examined in terms of resonant frequencies, phase alignment, relaxation time and the number of stable phase-locked states. We find that different temporal receptive fields lead to different patterns of synchronization and that a narrow temporal receptive field is necessary for selective phase-locking to onset events on the beat while ignoring syncopated, off-beat events. The distinct types of synchronization observed for different temporal receptive fields are compared and related to standard signal processing methods such as the Fourier transform, autocorrelation and comb filtering.

2:45 pm to 3:00 pm	**-- Coffee Break --**

3:00 pm to 3:30 pm	Interpersonal Coordination Dynamics in Crew Rowing: Effects of Movement Rate ***Speaker:*** Laura S. Cuijpers

Abstract:

In crew rowing, synchronization between crew members is regarded as one of the main determinants for optimal crew performance. To coincide in a common rhythm, rowers need to be accurate and consistent in the timing of their strokes. In rowing practice stroke rates vary from 18 strokes per minute (*spm*) during endurance training up to 42 *spm* during racing. Modelling a rowing crew as a system of coupled oscillators predicts the stability of crew coordination to decrease with increasing stroke rate, which would enhance detrimental movements of the boat and thereby impede crew performance. Therefore, inspired by studies on interpersonal coordination dynamics, we examined the consistency and accuracy of crew coordination at different stroke rates, in both on-water and off-water (i.e., ergometer) rowing. In the off-water study, 11 pairs rowed on two physically coupled ergometers placed on slides (hence, they could move as one 'boat') at rates ranging from 30 *spm* to 'as fast as possible'. Kinematics of rowers and handles, and ergometer displacements were captured. Results showed that the consistency and accuracy of crew coordination were not systematically affected by stroke rate. In the on-water study, 15 pairs rowed at stroke rates between 18 and 34 *spm* in a double scull (a two-persons boat). Oar angles of both rowers and boat movements in terms of linear accelerations and angular velocity, and boat speed were recorded with an on-board measurement system based on Arduino. Here, both accuracy and consistency of crew coordination worsened for rates below 26-30 *spm* whereas above 30 *spm* crew coordination was not systematically affected by stroke rate. In sum, rowing crew coordination improved rather than deteriorated at higher movement rates, which would not fully align with coupled oscillator predictions. In general, this supports the idea of an optimal movement rate for which (interpersonal) coordination is most consistent.

3:30 pm to 4:00 pm	Limits in Timing Precision are Not a Real Limit for Task Success in Throwing ***Speaker:*** Zhaoran Zhang

Abstract:

Accuracy and precision of timing in motor skills has received long-standing interest as it sheds light on the limitations of information transmission in the central nervous system. Throwing a ball is an exemplary motor skill that requires extremely precise timing of the ball release for accurate throwing to a target (Calvin, 1983; Chowdhary & Challis, 1999). Naturally, reducing error and variability in timing is presumed key, although model-based timing requirements appear unrealistic and measured timing limits have varied considerably (Hore, Watts, & Tweed, 1996; Timmann, Watts, & Hore, 1999). Our own research has emphasized that throwing is a task with redundancy, where multiple solutions can achieve success, particularly those that are tolerant to timing errors (Cohen & Sternad, 2009, 2012). This study aimed to determine whether humans improve throwing accuracy by improving timing precision or error tolerance to overcome limitations of the nervous system. Based on our model-based analysis of the solution space, we compare performance in four different tasks, each with a distinct topology of the solution space. Comparative analysis aims to examine the robustness of our results across tasks, and how solutions are determined by the solution manifold.

Subjects threw a ball tethered to a post to hit a target in a virtual environment. The ball's trajectory in the virtual workspace was fully determined by the angle and velocity at release; error was defined as the distance between ball's trajectory and target. The solution manifold defined those angle and velocity combinations that achieved a perfect hit. Timing error measured the inaccuracy of release from optimal release time. Timing window was the duration in the hand trajectory that overlapped with the solution manifold. Four different solution spaces were created by four different target locations. Four groups of 10 subjects each practiced one task variant for 6 days (240 throws per day).

Results showed that subjects learned to both decrease timing error and increase timing window. While on day 1 and 2, both timing error and timing window predicted performance error, on later days performance error was more sensitive to the change of timing window than timing error. This result was valid for all task variations except task 4, which had a solution space that obviated the ability to increase timing tolerance. Only timing error improved and predicted performance error through 6 practice days.

These findings demonstrate that humans are able to overcome their natural variability in timing by creating windows or opportunities that allow imprecision in timing without affecting the result. Further, we show how the task configuration determines its challenge on timing. Some of the exquisite coordinative skill may not achieved by reducing variability alone, but also by circumventing physiological limitations and adopting strategies that make intrinsic limitations in timing matter less.

4:00 pm to 5:00 pm	Pitchers and Pianists: Timing in Discrete and Rhythmic Motor Skills ***Speakers:*** Dagmar Sternad, Dena Guo, and Keith Harrigian

Abstract:

The sense of time, both perceiving and moving in time, is an innate ability underlying all of our behaviors. Not only rhythmic skills, like playing the piano, but also discrete skills, like throwing a ball to a target, require precise timing. Are these different manifestations of timing generated by the same mechanism? We explore rhythmic and discrete timing and its relation in a large sample of subjects. Using a virtual throwing task and a finger tapping task, the study assesses the hypothesis that rhythmic and discrete timing are two independent aspects of human timing, as rhythmic and discrete movements engage very different cortical activation (Schaal, Sternad et al., 2004). Collecting data from a very large and diverse population allows us to examine the two timing abilities across age, gender, and previous athletic and musical ability.

Data from 458 individuals (5-70+ years, 50% female) was collected at the Museum of Science in Boston as part of a research exhibit over a period of 10 months. To test discrete timing, subjects played a virtual throwing game, in which subjects threw a virtual ball 100 times to hit a target displayed on a screen. Based on a model-based task analysis, timing error and timing window were evaluated (Cohen & Sternad, 2012). To test rhythmic timing, subjects tapped a constant rhythm first with a metronome (15 sec) and then continued without a metronome (35 sec). Having calculated each subject's preferred frequency, he/she performed six trials at 80%, 100%, or 120% of their preferred frequency (two trials per frequency). Timing error, variability and drift during continuation served to evaluate the quality of rhythmic timing (Yu, Russell, Sternad, 2003).

In the throwing task, results showed that both task error, timing error, and timing window decreased over the relatively short practice time of 100 throws. There was a highly significant effect of gender on task performance, where male subjects were significantly better than female subjects. An age-dependence was only found for younger subjects who expectedly performed worse. There was no significant impact of previous sports or musical experience on discrete timing ability.

Results in the rhythmic tapping task showed a significant drift toward their preferred period when tapping at 80% and 120% of their preferred period. This drift was less pronounced in subjects with musical experience, speaking to the sensitivity of our measures. Timing error and variability decreased with age, although without any gender effect. Preliminary analyses directly compared the rhythmic and discrete timing ability of subjects who completed both tasks. As already indicated by the different effects, there was little consistency in performance within subjects.

Even though this study was conducted in a very little-controlled environment that posed several data analysis challenges, the results were remarkably clear and consistent with laboratory results. Such robust results may lend themselves as biomarkers for clinical applications. In addition, the wide range of participants afforded correlating discrete and rhythmic timing across age, gender and experience. Many more questions are ready to be examined in this large data set.