NEST 2024

New England Sequencing & Timing

Annual Meeting

April 6, 2024
University of Connecticut
Weston A. Bousfield Psychology Building
Room A106

Please use this **Live Stream link** for virtual conference attendance.

Gala reception with cocktails, dinner, and jam will occur at Ed Large's home after the event.

Music Dynamics Lab
UCONN
https://musicdynamicslab.uconn.edu/

Registration & Breakfast: 9:00-9:20		
9:20	**Edward Large** University of Connecticut	Welcome
Session 1: 9:30-10:30		
9:30	**Hayes Brenner** University of Connecticut	Preferences Towards Integer Ratios in Rhythm Reproduction Are Predicted by Neural Oscillations and In-Phase/Anti-Phase Dynamics
9:50	**Spencer Ferris** University of Connecticut	Learning to Produce Challenging Multi Frequency Coordination Patterns with Transformed Visual Feedback
10:10	**Ben Kubit** Northeastern University	Earworms and Neural Replay of Mental Representations for Recently Heard Music
20 Min BREAK		
Session 2: 10:50-11:40		
10:50	**Helene Serre** Northeastern University	Preferred Period and Resonance Tuning in a Rhythmic Motor Task: Long-term Stability and Cognitive and Mechanical Contributions
11:10	**Dagmar Sternad** Northeastern University	Throwing a ball in virtual and real environments: Timing demands created by the thrower in relation to their environment
10 Min BIO BREAK		
Session 3: 11:50-12:50		
11:50	**Tri Nguyen** Brown University	Effects of Visuotemporal Interference on Motor Learning
12:10	**David Rosenbaum** University of California, Riverside	Preparedness In Thought and Action
LUNCH: 12:50-1:50		

Session 4: 1:50-2:50		
1:50	**Susan Tilbury** University of Connecticut	Neural Resonance and the Embodiment of Musical Groove
2:10	**Leo Yao** University of Southern California	Groove and Beat Alignment Perception in Cochlear Implant Users
2:30	**Mara Breen** Mount Holyoke	Exploring the Neural and Behavioral Development of Metric Processing in 6-to-10 Year-Olds
20 Min BIO BREAK		
Session 5: 3:10-4:10		
3:10	**Steven Masi** University of Connecticut	Using Visual Metronomes to Examine Multi-Frequency Stabilities
3:30	**James Gutierrez** Northeastern University	Connecting Musical Reward, Resilience, and Personality
3:50	**Prianka Bose** New Jersey Institute of Technology	Son Clave Rhythm: A Biophysical Model and Synchronization Study
10 Min BIO BREAK		
Session 6: 4:20-5:20		
4:20	**Mike Hove** Fitchburg State University	The Rhythmic Power of Bass: How Low Frequencies Drive Movement
4:40	**Molly Henry** Max Planck Institute	Understanding Neural Entrainment Using Noninvasive Brain Stimulation
Gala reception with cocktails, dinner, and jam will occur at Ed Large's home after the event.		

Abstracts

Talk Session 1

9:30 **Preferences Towards Integer Ratios in Rhythm Reproduction Are Predicted by Neural Oscillations and In-Phase/Anti-Phase Dynamics**

Hayes Brenner, Ji Chul Kim & Edward Large (University of Connecticut)

Recent empirical research has shown that when perceiving and reproducing auditory rhythms, humans display a preference toward rhythms in which inter-onset intervals (IOIs) are related by small integer ratios. The findings suggest that, while listeners show preferences for rhythms that are common in their own musical culture, attraction toward integer ratios may be a universal feature of rhythm perception. To date, models of rhythm perception that display integer ratio bias have not incorporated rhythm learning, and models of rhythm learning that display enculturation have not demonstrated integer ratio bias. We argue that both learning and intrinsic attraction toward integer ratios are necessary for a complete psychologically plausible model of rhythm, and both derive from constraints on physiological mechanisms. We previously proposed that oscillatory networks with Hebbian learning could work as a general model of rhythm development; in this paper, we show that such a model is capable of learning complex rhythms by internalizing both the amplitude and phase relations between neural oscillators. By incorporating physiological constraints such that individual oscillations are either in-phase or anti-phase with one another, the networks replicate attraction toward integer ratio rhythms. Predictions for future behavioral and neural experiments are discussed.

9:50 **Learning to Produce Challenging Multi Frequency Coordination Patterns with Transformed Visual Feedback**

Spencer Ferris, Steven Masi & Steven J. Harrison (University of Connecticut)

The capacity to perform bimanual coordination patterns depends upon motor and perceptual constraints. The importance of perceptual constraints is revealed in experiments showing that challenging coordination patterns can be produced with minimal training if visual information about limb movement is transformed in specific ways. We investigated a form of visually transformed feedback in which a challenging movement pattern (i.e., 3:4 coordination) is transformed into a simple visual pattern (i.e., 1:1 motion). Prior investigations show that this transformation allows rapid acquisition of the coordination pattern. We observed that training a person to produce a challenging pattern with this transformation transfers into an ability to produce any pattern using this transformation. Specifically, we compared FSCAN and TSCAN procedures that required participants to sequentially perform a wide range of multifrequency patterns. In the FSCAN, participants coordinated their movements to flashing lights. This procedure revealed select movement patterns to be stable, consistent with previous observations of motor constraints. In the TSCAN, participants used transformed feedback to perform each pattern. In contrast to the FSCAN, this procedure revealed all investigated movement patterns to be stable. This provides evidence in support of the independence of perceptual and motor constraints on bimanual coordination.

10:10 **Earworms and Neural Replay of Mental Representations for Recently Heard Music**

Ben Kubit (Northeastern University), Elizabeth H. Margulis & Kenneth Norman (Princeton University) & Petr Janata (University of California, Davis)

Involuntary musical imagery (INMI) is a common experience, often referred to as an "earworm" or having a song "stuck in your head." Previous work has leveraged the phenomenon to understand how memory for music is maintained across time, demonstrating a functional role of INMI in music memory consolidation (Kubit and Janata, 2023). However, the neural basis of INMI remains to be fully characterized, particularly the extent to which INMI entails the replay of neural representations for music. In the present study, we combine computational models of music perception, multivariate functional magnetic resonance imagining (fMRI), and machine learning to (1) examine the reliability of patterns of music-evoked brain activity during perception, (2) identify spontaneous epochs of music memory replay, and (3) relate such replay to measures of memory consolidation and self-reported INMI experienced in the scanner. We measured blood-oxygen-level-dependent (BOLD) fMRI signal while 36 participants heard novel musical loops across repeated exposures, as well as two days later while listening to the same, now familiar musical loops. Before, during, and after both sessions, we also recorded BOLD activity during periods of rest likely to contain INMI experiences. Within each subject, we trained classifiers to identify regions-of-interest that reliably represented loop-specific information during both fMRI sessions and tested whether classifier performances were predicted by the similarity between the time-varying tonal structure of each loop. We found patterns of loop-specific activity that met both criteria in the auditory cortices of all subjects, as well as evidence for the replay of loop-specific activity during rest periods that occurred after music exposure while subjects were not listening to music. Preliminary results suggest that the effects of neural replay and self-reported INMI on memory consolidation are both similar and distinguishable. Capturing brain activity during episodes of INMI provides direct evidence for the neural underpinnings of a very common form of spontaneous thought in humans and also for the adaptive role of such spontaneous thought as a form of consolidation that refines the acuity of mental representations.

Talk Session 2

10:50 **Preferred Period and Resonance Tuning in a Rhythmic Motor Task: Long-term Stability and Cognitive and Mechanical Contributions**

Helene Serre, Mahdiar Edraki & Dagmar Sternad (Northeastern University)

When moving rhythmically, be it walking or finger tapping, what determines one’s movement frequency? Previous research has shown that when manipulating an object that has its own dynamics, such as a pendulum or a mass-spring system, spontaneously chosen periods closely correspond to the eigenfrequency of the system. While these studies have provided evidence for the tendency to exploit objects’ dynamics, little attention has been given to deviations or perturbations of such behavior. Preferred tempi in rhythmic movements such as finger tapping are known to be specific to the individual. If there are interindividual variations, are these due to inconsistency over time or due to idiosyncratic and cognitive considerations? The aim of the present study is to answer four questions: 1) How does the spontaneous tempo relate to the limb's eigenfrequency? 2) Does the preferred motor tempo differ between participants? 3) If so, is the preferred motor tempo consistent over days within participants? 4) How does cognitive load affect the motor tempo? Over ten days, 8 participants were asked to rhythmically swing a hand-held pendulum at their own pace in three different conditions: 1) swinging the pendulum as regularly as possible, concentrating on the action; 2) counting backwards by seven while maintaining rhythmic movements; 3) adding two three-digits numbers while maintaining rhythmic movements. Participants performed five trials of 30 seconds per condition. They performed all conditions with two pendulums that differed in length and mass. Results showed that the swinging frequency differed between the two pendulums and was close to each pendulum's natural frequency. Regardless of the mechanical conditions, swinging frequency was specific for each participant, and their respective frequency was consistent across days. Within-participant period varied significantly between cognitive conditions, depending also on the day and pendulum. Further work examines the effect of cognitive difficulty on the frequency fluctuations within a trial, and the potential synchronization between speech and the rhythmic upper-limb movement.

11:10 **Throwing a ball in virtual and real environments: Timing demands created by the thrower in relation to their environment**

Dagmar Sternad (Northeastern University)

Throwing a ball is a uniquely human skill that requires a high degree of coordination to successfully hit a target. Correct timing of the ball release appears crucial as biomechanical analyses reported required timing accuracies to be as short as 1-2ms, which however appear physiologically challenging. Our previous work demonstrated that humans can overcome these stringent timing requirements by shaping their hand trajectories to not only decrease their timing error, but also created extended timing windows, where ball releases achieve target hits despite temporal imprecision. This was shown in healthy adults performing four different throwing tasks in a virtual environment, each with a distinct geometry of the solution space and different demands for timing. Model-based analyses of arm trajectories revealed that subjects first decreased timing error, followed by lengthening timing windows in their hand trajectories.

The new study questioned whether these fine-grained model-based results were still visible and relevant in a real version of the task that extended the skittles model from 2D to 3D and was far less controlled. We tested 23 adults and 26 children (7-12 years) in the laboratory on a skittles device that was designed to closely mimicked all parameters in the virtual task. While the hand path was highly constrained in the laboratory, the real task allowed a variety of hand trajectories that resulted in large variations of the ball release time and location. Nevertheless, the calculations of timing window and timing error were still possible. Results again demonstrated an increase in timing window with practice. In addition, and almost more interestingly, the analyses revealed that the geometry of the solution space depended on the ball release position. This means that throwers can create their solution space by choosing the location of ball release. With the skillful shaping of the hand trajectory, they then exploit the solution manifold that they created for themselves. These findings give a new insight into throwing as a skill that by which the thrower's shapes their actions to the environment, i.e. the target position.

Talk Session 3

11:50 **Effects of Visuotemporal Interference on Motor Learning**
Tri Nguyen (Brown University)

Motor control of complex, visually guided behaviors such as dart throwing, skiing, or dancing, requires the complete configuration of motor parameters for multiple degrees of freedom (e.g. joints, muscle groups) as well as precise timing. Learning to dynamically coordinate the motor system during these tasks also involves both efficient exploration of the critical parameter space and exploitation of known successful solutions. The efficiency of the solution search within this workspace relies on both reliable information on timing and timely feedback. How would a disruption to these crucial time elements interfere with the exploration and exploitation of relevant motor parameters during learning? In this experiment, we manipulated the visuotemporal component of a virtual throwing task to examine subjects' learning strategy. We utilized two generalizations of recurrence quantification analysis (RQA), joint RQA and cross RQA, to show that visuotemporal interference did not hamper the subjects' ability to exploit and reproduce previously executed motor solutions. However, the timing interference limited exploration of the relevant motor parameter space and motor learning. Overall, the results supported previous findings on the role of timing in implicit learning. It is also consistent with the literature on the importance of balancing exploration and exploitation in a solution search and reducing the number of dimensions in motor learning of novel, complex movements.

12:10 **Preparedness In Thought and Action**
David Rosenbaum (University of California, Riverside)

In my lab we have come to believe that the key to preparedness is keeping options open. We have discovered that three strategies serve this purpose: (a) Front-loading; (b) Mind-clearing; and (c) Energy-saving.

Talk Session 4

1:50 **Neural Resonance and the Embodiment of Musical Groove**
Susan Tilbury & Edward Large (University of Connecticut)

The pleasurable urge to move to music (PLUMM, a.k.a. groove) is a ubiquitous, in many instances involuntary, human response to groove-based music. From an ecological perspective, perception-action interdependence would suggest that the embodied response to musical groove is a fundamental aspect of its perception. Timing deviations in the form of syncopation are necessary to the experience of groove, with rhythms proceeding in an arc from low syncopation (low groove), to moderate syncopation (high groove), to high syncopation (low groove). Predictive coding explains this phenomenon in terms of weighted priors and violations of expectation. In contrast, our theory accounts for groove in terms of direct perception via nonlinear resonance in nested perceptual-motor systems. Here, we present a dynamical systems account of musical groove in terms of nested multifrequency oscillator networks with Hebbian plasticity. Nonlinear coupling elicits cascading dynamics, resulting in steady-state behaviors and motor learning. Thus, the physical dynamics of interacting organism-environment systems can explain why it feels so good to move to the groove, without the need for brain-bound cognitive models.

2:10 **Groove and Beat Alignment Perception in Cochlear Implant Users**

Leo Yao (Keck School of Medicine, University of Southern California)

Background: Modern cochlear implant (CI) technology is excellent for speech comprehension, but struggles with music perception. CI users have trouble with pitch, timbre, and harmony perception, but have good rhythmic and temporal perception Looi et al. (2012). Groove perception, however, has not thoroughly investigated. The purpose of this study is to investigate differences in groove perception between CI users and NH listeners. Methods: Twenty CI users and fourteen NH listeners completed two online tasks. Participants rated 20 songs and their corresponding drum beats taken from the Lucerne Groove Research Library (https://www.grooveresearch.ch/) on familiarity, pleasure, and urge to move (groove). They also completed a beat alignment test (BAT) created by Iversen and Patel (2008). Participants were played 36 songs and determined if a beep track was "on" or "off". These beeps were either aligned with the beat, misaligned due to a tempo shift, or misaligned to a phase shift. We hypothesized that CI users would perceive less groove due to deficits in pitch and timbre perception. We predicted that familiarity would have a strong positive correlation with groove and pleasure ratings for both groups, and CI users would perform worse at the BAT. Results: Preliminary results show that NH listeners performed better than CI users in the BAT. CI users were especially worse during the phase misalignment condition. For the rating task, there was a strong positive correlation between groove and pleasure ratings, as well as groove and familiarity ratings for both groups. Familiarity had a greater positive effect on CI users' urge to move ratings. Conclusion: Music is one of the great joys in life, but unfortunately CI users aren't able to appreciate it as fully. Understanding how CI users perceive musical groove differently could lead to greater music appreciation through technological improvements such as more refined signal processing, or through other methods such as musical training.

2:30 **Exploring the Neural and Behavioral Development of Metric Processing in 6-to-10 Year-Olds**

Mara Breen (Mount Holyoke), Ahren B. Fitzroy (Microsoft) Katerina Drakoulaki (Mount Holyoke)

Metric structure cues important information, which can guide attention across time. Neuro-imaging studies demonstrate that the perception of metric stress is established in infancy (Kujala et al., 2023; Winkler et al., 2009) and behavioral evidence of metric stress perception emerges between preschool and adolescence (Nave-Blodgett et al., 2021). The current study further explores the developmental trajectories of neural and behavioral measures of metric processing in school-age children using an imagined meter paradigm. In adults, implicit coding of metric strength has been shown to predict neural markers of attention, group processing, and anticipation (Fitzroy & Sanders, 2015, 2020). Using an adapted version of the adult task, in the current study we collected high-density (64-channel) electroencephalography (EEG) and behavioral (accuracy) data from 6-to-10-year-olds. Participants completed 40 one-minute-long listening trials where they heard an isochronous stream of undifferentiated tones as repeating subjective groups of three (ternary meter) or four (quaternary meter), without counting aloud or silently, and without tapping. There were ten trials for each combination of listening pattern (ternary, quaternary) and presentation tempo (fast = 450ms inter-beat intervals [IBIs], slow = 625ms IBIs). Data from 39 children, distributed across four age cohorts, has been collected and analysis will be completed for the presentation. Event-related markers (ERPs) of implicit meter and accuracy on the behavioral task will be quantified across the cohorts and compared to adults to assess the maturational trajectory of metric processing.

Talk Session 5

3:10 **Using Visual Metronomes to Examine Multi-Frequency Stabilities**
Steven Masi (University of Connecticut)

Whether we consider a chef slicing vegetables or a parent clothing their child, everyday tasks often require the movements of the left and right arms to be coordinated in oscillatory, rhythmic patterns. In such bimanual coordination tasks, we can think of each hand's pattern in terms of phase differences and frequency differences, with some phase and frequency relationships being more stable than others. To reveal the stabilities of phase relationships, Zanone and colleagues used a scanning procedure in which participants coordinated each hand with flashing lights. The flashing was gradually altered to set a range of target phase relationships (e.g., a 90° target phase relation in which one hand leads the other by a quarter cycle). Stable phase relations are revealed by identifying those phase relationships with the smallest difference between target and actually produced phase relationships. We have found that frequency ratio stabilities (e.g., 1:1, 2:1, etc.) can be revealed using a similar procedure in which two flashing lights set the target movement frequencies of the left and right hands. We are using this paradigm to investigate how frequency ratio stabilities are affected by practicing novel multi-frequency coordination patterns and by manipulating physical task constraints (e.g., manipulating pendulum natural frequency and inertia).

3:30 **Connecting Musical Reward, Resilience, and Personality**
James Gutierrez (Northeastern University)

Physician Debasish Mridha states that "Music can heal the wounds that medicine cannot touch." While it is well established that music functions in emotion regulation promote recovery from injury, and facilitates well-being generally, the relationship between individual resilience and the types of musical rewards one pursues is not as well understood. This study seeks to establish (1) what specific types of musical rewards predict individual resilience (the capacity to recover from challenging circumstances) and (2) which personality profile(s) are associated with the pursuit of these musical rewards, and resilience. To investigate these relationships, undergraduate students (to date n=553, expected to at least double) completed an online questionnaire, integrating the extended Barcelona Music Reward Questionnaire (eBMRQ), the Resilience Scale, and the Big Five Personality Index. The eBMRQ was developed to examine how people experience reward associated with music along six categories: Music Seeking, Mood Regulation, Emotion Evocation, Sensory Motor Behavior, Social Rewards, and Absorption; the Resilience scale quantifies an individual's perceived ability to recover from difficulty; and the Big Five Index – based on Lexical theory – distinguishes five universal traits: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Analysis of the current dataset shows that Sensorimotor Reward (i.e. physical engagement with music) is strongly correlated with higher resilience (r=.767, p<.001), supporting previous studies that highlight the relationship between resilience and physical engagement. Personality trait Openness shows a moderately strong relationship to musical reward overall (r=.454, p<.001), though not resilience, while traits Conscientiousness (r=.250, p<.001) and Neuroticism (r= -.297, p<.001) show the strongest relationships with resilience, though neither relate to Sensorimotor Reward. Data collection and analysis is ongoing through May 2024.

3:50 **Son Clave Rhythm: A Biophysical Model and Synchronization Study**
Prianka Bose (New Jersey Institute of Technology)

Son Clave, a rhythmic pattern typically associated with 4/4 or 12/8 time signatures, can be condensed into a concise sequence of 5 beats within a larger 16-beat or 12-beat cycle. In this study, our primary objective is to construct a robust biophysical model capable of replicating non-isochronous rhythm patterns, with a specific focus on the intricate rhythms found in Son Clave compositions. Additionally, we delve into deciphering its periodic nature and accurately determine its cycle length by employing statistical analysis and machine learning techniques for Son Clave forecasting, a concept connected to synchronization continuation.

Talk Session 6

4:20 **The Rhythmic Power of Bass: How Low Frequencies Drive Movement**
Mike Hove (Fitchburg State University)

In this talk, I will discuss moving to music and the musical features associated with body movement. People often move to music with a repetitive rhythm and strong bass. The connection between bass and movement is rooted in physiology, such as auditory encoding and vibrotactile activation. This explains why low-pitched instruments conventionally lay down musical rhythm. Our new research examines the effects of bass in subgenres of metal. I conclude with applications, such as using bass to improve social cohesion and combat hearing loss.

4:40 **Understanding Neural Entrainment Using Noninvasive Brain Stimulation**
Molly Henry (Max Planck Institute)

Neural entrainment is the phenomenon by which the brain synchronizes to rhythms in the environment, and fluctuations in neural excitability are reflected in behavior, suggesting that neural entrainment is an efficient way to regulate attention in time. Using auditory stimuli, entrained activity cannot be distinguished from evoked activity. Noninvasive brain stimulation can be used as a tool to probe entrainment separately from evoked activity because it does not evoke neural responses that weren't present to begin with. In this talk, I will give a tour of some of our recent research using noninvasive brain stimulation to better understand on neural entrainment.

Local Arrangements

Registration

There will be a $25 registration fee which can be paid on site by cash, check or Venmo (breakfast, lunch and dinner will be provided).

Technology

Presenters will be asked to share their slides via the standard HDMI port. Please bring any dongles!

A **Live Stream** link for virtual presentations is available **here**.

Wi-Fi is available via the UConn-Guest network or EDUROAM network.

Venue

University of Connecticut
Bousfield Psychology Building, Room A106

Address: 406 Babbidge Rd, Storrs, CT 06269
Google map: https://maps.app.goo.gl/NUXT1UnKjdjJ78Rq9

Evening cocktails & dinner will occur at Ed Large's home.

Parking

Parking is available in the following lots:

- South Parking Garage (there will be signs to the conference site; see here for parking fee; payment is required at the time of entry and can be made via the Flowbird mobile app or at the kiosk near the elevator on the first floor.)
- There are also a limited number of on-street parking spaces on Whitney Road that are free on Saturdays.
- Lot S (free on Saturday)
- Fine Arts Lot 1 (free on Saturday)

Handicap Parking is available at the back of the Bousfield Building & in the South Garage.

If you need transportation from the parking lot, please contact the UConn Accessible Van Service: **(860) 486-4991** to make arrangements.

Due to UConn Bound Day, parking may be limited. Other parking venues can be found on UConn's parking map (ArcGis interactive, PDF). Please make sure **not** to park in spots marked as restricted or limited: you WILL get a ticket!

Food & Refreshments

Registration costs will cover breakfast, lunch, and dinner.

If you need to purchase your own meals, a few restaurants within walking distance offer vegan/vegetarian, gluten free, and other options. Here are some of our favorites (links go to Google maps):

- Dog Lane Cafe (Vegetarian, GF options)
- Kathmandu Kitchen & Bar (Vegan/vegetarian options)
- Little Aladdin Mediterranean (Halal, vegetarian options)
- Moe's Southwestern Grill (Vegan/vegetarian, GF options)

A CVS pharmacy and Price Chopper are also available within walking distance.

Acknowledgements

UConn Music Dynamics Lab

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And all our friends and colleagues in NEST who continue to contribute to this wonderful meeting!