NEW ENGLAND SEQUENCING AND TIMING (NEST)

Nineteenth Annual Meeting

Time: Saturday, March 7, 2009, 8:30 a.m. – 5:00 p.m.

Place: Haskins Laboratories, 300 George Street, New Haven, CT

Organizer: Bruno H. Repp

Assistant: Jackie Thompson

PROGRAM

8:30 – 9:00 Continental breakfast (provided)

9:00 – 9:25

DYNAMICS OF RHYTHMS AT RESONANCE: VARIABILITY OF UNIMANUAL PENDULUM OSCILLATION AT AND AWAY FROM RESONANCE

Dobromir G. Dotov, Damian G. Stephen, Till D. Frank, & Michael T. Turvey[1]
(University of Connecticut and [1]Haskins Laboratories)

A vast array of research provides evidence that variability of motor behavior is not just noise extrinsic to the movement determinism but actually plays an essential role in establishing a system's functionally appropriate behavior (for a review, see Riley & Turvey, 2002). Can studying the variability of unimanual pendulum oscillation be informative about dynamic constraints on motor behavior and coordination? We focused on the coordination of the rhythmic motor behavior of swinging a hand-held pendulum with an auditory metronome, at metronome rates that approached or deviated from the resonant frequency of the hand-pendulum system. Our results provide preliminary support for our hypothesis that variability at non-resonance rates should be special in informative ways. At the level of frequency entrainment (defined as the consistency with which the behavioral cycle frequency matched the stimulus cycle frequency on a cycle per cycle basis), drift-diffusion analysis (Van Mourik, Daffertshofer, & Beek, 2006) indicated increased noise in the conditions with non-resonant stimulus rates. With regard to the fluctuations at the level of wrist motions, detrended fluctuation analysis (Peng, Havlin, Stanley, & Goldberger, 1995) provided a higher scaling coefficient for fast trials, a signature of more complex noise that can be interpreted in accord with the literature as indicative of a system under stress as it is forced farther away from its equilibrium rate (Gilbert, Dorfman, & Gaspard, 2000).

9:25 – 9:50

INERTIAL REFERENCE FRAMES IN INTERLIMB RHYTHMIC COORDINATION

Paula Lanna Silva (University of Connecticut)

Research in dynamic touch has shown that when a person, without benefit of vision, attempts to align one arm with respect to the other, he or she does so by aligning vectors representative of the directions of each limb's mass moments (V_{mm}) and not the geometric axes of the limbs. The question of the present study is whether V_{mm} constitutes information exploited by the haptic perceptual system in the context of interlimb rhythmic coordination. If so, changes in the relative orientation of V_{mm} of right and left limbs ($\Delta V_{mm} = V_{mm}$ *left* $- V_{mm}$ *right*) should predictably affect the relation between limbs giving rise to the intended coordination pattern. In order to test this hypothesis, participants were instructed to oscillate a pair of cross-shaped hand-held pendulums, occluded from sight, at a common tempo and 0 degrees phase relation. V_{mm} shifts of the right wrist pendulum-system were introduced to manipulate the magnitude and the sign of ΔV_{mm}. These shifts were obtained by attaching more weight to the part of the cross-piece in front or behind the hand, respectively. The greater the weight asymmetry introduced, the greater the shift obtained. Relative to interlimb coordination performed at $S\Delta V_{mm} = 0$, the observed steady states of relative phase (ϕ) were significantly shifted. The magnitude and direction of the shifts followed the magnitude and sign of ΔV_{mm}. As opposed to what happens with detuning manipulations, the observed phase shifts were not associated with an increase in the amount of variability. In addition, there was no decrease in dynamic stability estimated through cross recurrence quantification analysis and drift-diffusion analysis. These results suggest that the observed changes in ϕ were specified by a shift in the proprioceptive reference frame provided by V_{mm} and were not a function of a general perturbation to the system or of a detuning effect. More generally, this study suggests that theorizing and modeling of interlimb coordination could benefit from a better understanding of the dynamics of information-action coupling supporting these tasks.

9:50 – 10:15

SYNCHRONIZING WITH THE FUTURE OF A CHAOTIC TIME SERIES

Nigel Stepp (University of Connecticut and Haskins Laboratories)

Synchronization, an integral part of coupled dynamical systems, comes in several forms, e.g. state, phase, and lag synchronization (see Pikovsky, 2003). One such form of synchronization, so-called anticipating synchronization, allows for one system to synchronize with the future of another (Voss, 2000). Many aspects of synchronization have been exhibited in human movement and coordination experiments; however, synchronization involving anticipation directly has been less thoroughly investigated. In the present experiment, participants were asked to track a moving target presented on a computer display by means of controlling a similar on-screen object with a pressure sensitive tablet and stylus. The presentations of the participant's own movements, however, were held in a buffer for varying amounts of time, introducing delay between movement and presentation. Task success subsequently requires anticipation on the part

of the participant. Evidence is presented that the effect of delay on task performance is similar to that predicted by anticipating synchronization.

10:15 – 10:45 Coffee break

10:45 – 11:10

DYNAMICS OF A COMPLEX BIMANUAL TASK DURING PRACTICE AND LONG-TERM RETENTION

Dagmar Sternad, Se-Woong Park (Northeastern University), and Tjeerd Dijkstra (Radboud University Nijmegen)

Despite anecdotal evidence that people can still ride a bicycle even if they have had no practice for 10 years, there is little research that substantiates this remarkable phenomenon. What is learnt and how are skills retained over many years even without practice? On the other hand, it is also known that a high level of skill, such as piano playing, requires continued and extensive practice. Using a polyrhythmic bimanual task we examine the acquisition of this skill over 20 practice days and its retention after 6 months and 8 years. Using a task where the two hands move continuously in a 1:3 frequency ratio, our analyses focused on fine-grained assessments of phase synchrony, harmonicity and cross-talk between the two hands. Results showed that variability of relative phase decreased over the 20 practice sessions, indicating that the task was non-trivial task and was learnt. Unlike in 1:1 coordination, subjects displayed preferences for different relative phase values of 0, 180, or even 90 degrees. Most interestingly, their performance was not significantly worse after a 6-month and an 8-year retention interval. In sum, subjects improved their performance with practice and, surprisingly, they retained the skill even after an 8-year retention interval.

11:10 – 11:35

TIMING AND SPATIAL ACCURACY IN MIRROR DRAWING

Ramesh Balasubramaniam (McMaster University)

Mirror drawing is a challenging task because appropriate hand actions must be planned and directed despite receiving visual feedback that is reversed by the mirror. The purpose of this study was to investigate whether visual transformation impacts the timing and spatial variability of explicitly and implicitly timed bimanual drawing tasks differently. To examine these issues, ten healthy participants bimanually drew various template shapes (circles, lines, vertical triangles, and horizontal triangles) under normal (untransformed) and mirror-reflected vision conditions. Drawing movements were paced by a metronome, and all templates were drawn in both symmetrical and asymmetrical coordination modes. Our results show that mirror feedback increased timing errors on implicit timing tasks but not explicit timing tasks. Mirror feedback also resulted in greater spatial variability and decreased interlimb coordination. These results provide insight into the role of visual information in the timing and performance of different types of bimanual drawing tasks.

11:35 – 12:00
SYNCHRONIZATION WITH AMBIGUOUS AUDITORY RHYTHMS DURING UNSTRUCTURED DANCE
Tim Brick (University of Virginia)

A repeating, rhythmic auditory stimulus will quickly be segmented by a listener into a single repeating gestalt-like unit. For some rhythms, listeners show strong agreement about the beginning of such a unit; other rhythms are more ambiguous, having two or more segmentation points that could be considered the beginning of the gestalt unit. A listener presented with an ambiguous rhythm will still quickly report hearing a single such unit, exclusive of the other possibilities, and is unlikely to report hearing any other segmentations during the same presentation. I will present evidence from two motion-capture experiments where participants were asked to dance to computer-generated rhythmic auditory stimuli. I will suggest that dancers are still sensitive to alternate segmentations of an ambiguous rhythm, even after a single interpretation has been formed.

12:00 – 1:00 Lunch (provided)

1:00 – 1:25
FEEDBACK AND GOALS IN TIMING PROCESSES
Howard N. Zelaznik (Purdue University)

The event-emergent timing framework proposed by Ivry, Spencer, Zelaznik, and Diedrichsen (2002) posits that salient events are necessary to employ clock-like timing processes (called event timing). The evidence for this framework has been derived from experiments that contrast discrete-like timing tasks with continuous movement timing tasks. Three experiments are presented that demonstrate that events for timing can be created in a continuous movement task without changing the kinematics. Intermittent tactile feedback (Experiments 1 and 2) as well as auditory goals (Experiment 3) can produce common timing processes between continuous and discrete-like timing tasks. These new results suggest that event timing can play a role in continuous movement timing tasks.

1:25 – 1:50
PHASE AND PERIOD COUPLING IN PIANISTS' SYNCHRONIZATION WITH A CHANGING TEMPO
Janeen Loehr, Caroline Palmer (McGill University), and Edward Large (Florida Atlantic University)

Much is known about how people synchronize simple movements such as single-finger tapping with auditory sequences, but little is known about the mechanisms that support the coordination of complex movement sequences such as those required for music performance. Music performance often requires musicians to coordinate their actions with external cues such as the sounds produced by other performers; the timing of these cues may depart from isochrony due to expressive or motoric constraints. In two

experiments, we examined how pianists coordinate performances of rhythmic (non-isochronous) melodies with a metronome whose tempo changed at the end of a musical phrase (when performers typically slow down) or at the beginning of a phrase (where slowing is not typical). Pianists were better able to coordinate with a metronome that decreased rather than increased in tempo, regardless of when the tempo change occurred. Pianists' adaptation to the changing tempo was consistent with model predictions based on a non-linear oscillator whose phase and period adapt to the metronome. These findings elucidate the mechanisms by which performers adapt to the actions produced by their co-performers.

1:50 – 2:15

THE EFFECTS OF CULTURAL EXPERIENCE AND SUBDIVISION ON TAPPING TO SLOW TEMPI

Sangeeta Ullal, Erin E. Hannon, and Joel S. Snyder (University of Nevada, Las Vegas)

Although dancing and tapping to music occur naturally and frequently, our ability to accurately synchronize our movements with rhythmic patterns is constrained by temporal length and interval structure. Subdivision can improve synchronization at slow tempi, but the ability to utilize subdivisions is constrained by the nature of component interval ratios. Unlike Western music, Indian music contains very slow tempi and complex interval ratios. Therefore Indian listeners may provide a unique opportunity to examine the effects of culture on sensorimotor synchronization. American and Indian participants were asked to perform synchronous tapping to a stimulus sequence with a slow tempo (i.e., inter-event intervals of 3 s), which was accompanied by silence or by an unattended rhythmic pattern subdividing target intervals into groups of two (simple), groups of three (simple), or alternating units of two and three (complex). On a subset of trials, the pattern of subdivision switched halfway through the trial, from simple to simple, simple to complex, or complex to simple. Indians listeners performed comparably across all subdivision patterns, but showed an increase in synchronization error whenever there was a switch of subdivision pattern, regardless of the nature of the switch. By contrast, Western listeners showed higher overall error for the complex subdivisions, and an increase in error any time there was a switch away from simple subdivision.

2:15 – 2:40

PHASE CORRECTION IN SENSORIMOTOR SYNCHRONIZATION IS HIGHLY RESISTANT TO AUDITORY STREAM SEGREGATION

Bruno H. Repp (Haskins Laboratories)

Auditory stream segregation can occur when tones differing in pitch (A, B) are repeated cyclically: The larger the pitch separation and the faster the tempo, the more likely it is that a percept of two separate streams will arise. The present study assessed stream segregation in perceptual and sensorimotor tasks, using identical ABBABB… sequences as well as baseline sequences without B tones. In Experiments 1 and 2, the perceptual task required detection of single phase-shifted A tones; this was expected to be facilitated by the presence of B tones unless segregation occurs. The sensorimotor task required tapping in synchrony with the A tones; here the phase correction response (PCR) to

shifted A tones was expected to be inhibited by B tones unless segregation occurs. Two sequence tempi and three pitch separations (2, 10, and 48 semitones) were used with musically trained participants. Facilitation of perception occurred only at the smallest pitch separation, whereas the PCR was reduced equally at all separations. These results suggested to me that auditory action control is immune to perceptual stream segregation, at least in musicians. In Experiment 3, instead of A tones, the BB tone pairs were occasionally phase-shifted, with the pitch separation being 2 or 46 semitones. Baseline sequences for perception had no A tones. Facilitation of perception, indicating absence of stream segregation, occurred only at the small pitch separation. At the slower of two sequence tempi, the PCR elicited by shifted BB tones was equally large at both pitch separations, but at the faster tempo the PCR was reduced substantially at the large pitch separation. These latest findings indicate that temporal control of action synchronized with a rhythm is not totally independent of the perceptual organization of the rhythm.

2:40 – 3:10 Coffee break

3:10 – 3:35

CONDITIONS UNDER WHICH TIME INTERVALS ARE MEMORIZED OR RELEARNED QUICKLY

Paulo Guilhardi[1], Marcelo S. Caetano, and Russell M. Church (Brown University and [1]New England Center for Children)

Our goal was to identify training conditions under which temporal intervals that are signaled by different stimuli are (1) memorized (i.e., the temporal control of the behavior is readily shown when the stimulus is presented) or (2) quickly relearned (i.e., the temporal control of behavior rapidly emerges with successive stimulus presentations). Rats and humans were trained on three signaled temporal discriminations using either fixed-interval or peak procedures. The sequence of presentation of intervals (intermixed within a session, in blocks of trials within the session, or in blocks of sessions) and the difficulty of the discrimination (similarity across stimuli) were varied. Rats and humans memorized intervals when the temporal discriminations were intermixed within a session and when they occurred in blocks of trials within the session, the latter provided the stimulus discrimination was not difficult. Rats and humans, however, quickly relearned the same temporal discriminations when the temporal discriminations occurred in different sessions or in blocks of trials within the session, the latter provided the stimulus discrimination was difficult. The results allow inferences about underlying cognitive mechanisms determining memorization and quick-relearning strategies of humans and rats.

3:35 – 4:00

THE PROCEDURAL LEARNING OF ACTION ORDER AND TIMING IN CHILDREN

Jacqueline C. Shin (Indiana State University)

How does the ability to learn temporal patterns in action sequences develop in young children? An evolutionary view suggests children would be proficient in this type of

learning. The current study investigated the procedural learning of temporal patterns in elementary school children using the serial reaction time paradigm. The main results indicated that temporal pattern learning increased with age among the children, consistent with observations that cortical and subcortical regions of the brain continue to develop through young adulthood.

4:00 – 4:25

COUNTING SOUNDS: DO MUSICIANS ESTIMATE RELATIVE NUMEROSITY BETTER THAN NON-MUSICIANS?

Sarah Watsky and John Kingston (University of Massachusetts)

Are listeners with musical training better at judging the relative numerosity of overlapping sound sequences than those with no training? Halberda et al (2008) found that subjects with higher math scores were better at estimating the relative number of yellow and blue dots in the visual field. From trial to trial, Halberda et al varied the position, size, and spatial overlap of the dots independently of the ratio of yellow to blue dots. We presented listeners with simultaneous sequences of high and low tones in which the ratios of the number of tones in the two frequency ranges varied between 1:2, 3:4, 5:6 and 7:8. The tones varied randomly in frequency within the high and low ranges, in level, in duration, in the duration of the gap between one tone and the next, and in the extent of temporal overlap between high and low tones. The listener's task was to report whether there were more high or low tones in the stimulus. These manipulations are the auditory analogues of Halberda et al's visual manipulations. As the ratios got closer to 1, performance became poorer for all listeners. However, listeners with musical training did better than those without.

4:25 – 4:50

TIMING AND EXECUTIVE RESOURCES: DUAL-TASK INTERFERENCE PATTERNS BETWEEN TEMPORAL PRODUCTION AND SHIFTING, UPDATING, AND INHIBITION TASKS

Scott W. Brown, Shawn A. Collier, and Jill C. Night (University of Southern Maine)

Three dual-task experiments were designed to assess the contribution of executive cognitive functions to the perception of time. Each experiment combined a serial temporal-production timing task with an executive task emphasizing either shifting, updating, or inhibition. The experiments uncovered evidence of bidirectional interference between the concurrent tasks, such that the executive tasks interfered with timing performance and the timing task interfered with executive performance. Each experiment also included three dual-task conditions, in which subjects allocated attention to the concurrent tasks in specified proportions. The results showed a reciprocal tradeoff in performance on each task: More attention allocated to timing caused timing performance to improve and executive performance to decline, whereas more attention allocated to the executive task produced the opposite pattern. The findings suggest that timing relies on the same processing resources that support basic executive functions.