17TH RHYTHM PRODUCTION AND PERCEPTION WORKSHOP

JUNE 17TH-20TH, 2019

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Welcome Statement

It is our great pleasure to welcome you to the 17th Rhythm Production and Perception Workshop in Traverse City, Michigan. RPPW has a long history, beginning in 1984, with its biennial workshops bringing together psychologists, neuroscientists, and cognitive scientists who share an interest in rhythmic aspects of human experience. As the field of rhythm research grows, RPPW has also grown as an international forum for intellectual exchange. This year we welcome ~90 attendees from all over the world, with 25 presentations and ~50 posters on the program. We are also delighted to have the renowned Dr. Caroline Palmer present her keynote talk on Thursday, June 20th.

Until now, RPPW has been held in various locations around Europe. This is RPPW's first North American appearance, and we hope you enjoy the natural beauty and relaxed atmosphere of 'One of 25 Best Small Towns in America'. RPPW has a tradition of fostering interaction and discussion, and we aim to continue this feel during the conference, with two evening receptions, and especially with our outing on Wednesday afternoon, when we will visit a few top wineries in the region together. Social media creates new occasions for sharing content between conference attendees and the rest of the world. Feel free to tweet throughout the conference with the conference hashtag #RPPW2019.

We wish to express our heartfelt gratitude to the RPPW sponsors who have made contributions to student support: the Society for Education and Music Psychology Research, the Society for Music Perception and Cognition, and the European Society for the Cognitive Neurosciences of Music. The McIn addition, we owe a debt of gratitude to the many trainees from the Timing and Perception lab at Michigan State University, as well as the Music and Neuroscience lab at Western University, for their time and energy.

This may be the first time that North America hosts the RPPW Workshop, but we sincerely hope that it will not be the last!

Jessica Grahn J. Devin McAuley


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Program

Monday June 17th

4:30-9PM Registration and Welcome Reception

Tuesday, June 18th

8:30AM Registration

9:00AM Opening Remarks Jessica Grahn and Devin McAuley

9:10AM Talk Session 1

9:10AM Olivier Lartillot: Computational analysis of tempo and metre: From signal processing to cognitive musicology

9:30AM Justin London: Motown, disco, and drumming: The effects of beat salience and song memory on tempo perception

9:50AM Darren Rhodes: A neural mechanism for timing events and intervals

10:10AM Michael Schutz: Assessing our assessment of timing: exploring the types of sounds used in examining auditory duration perception

10:30AM Coffee Break

11:00AM Talk Session 2

11:00AM J. Devin McAuley: The role of talker rhythm in understanding speech in difficult listening situations

11:20AM Christina Vanden Bosch der Nederlanden: Better phase-locking to song than speech

11:40AM Julia Hyland Bruno: Zebra finches learn vocal sequences within a rhythmic framework

12:00PM Lunch

1:30PM Talk Session 3

1:30PM Maria Niarchou: Can you clap to the beat? Findings from the first large-scale genome-wide association study on rhythm

1:50PM Eniko Ladanyi: Rhythmic priming improves grammatical skills

2:10PM Emma Greenspon: The role of endogenous rates in music and speech production

2:30PM Poster Blitz

2:50PM Poster Session 1 and Coffee [Poster list below]

4:00PM Talk Session 4

4:00PM Haley E. Kragness: The musical dwell time paradigm: A new method for investigating expressive timing

4:20PM Karli Nave: The development of rhythmic categories as revealed through a perception task and a production task

4:40PM Concert Talk Russell Hartenberger and Michael Schutz

5:45PM Evening Reception (Hors d'ouevres and drink ticket/cash bar)

Wednesday, June 19th

8:30AM Registration

9:00AM Talk Session 5

9:00AM Amitabha Bose: A neuromechanistic model for keeping a simple rhythmic beat in the context of music

9:20AM Molly Henry: Pitting metrical structure against subjective accenting in a test of beat-perception ability

9:40AM Rebecca Schaefer: Effects of syncopation and repetition on beat clarity, liking, and urge to move

10:00AM Anne Danielsen: Noise in the click or click in the noise: Investigating probe-stimulus order in P-center estimation tasks

10:20AM Coffee Break

10:50AM Talk Session 6

10:50AM Laura Cirelli: Case report of a dancing infant: Effect of song familiarity and tempo on rhythmic movement and joy

11:10AM Dawn Rose: Embodied entrainment in Parkinson's: Let the music make you move

11:30AM Poster Blitz 2

11:50AM Poster Session 2 [Poster list below]

1:00PM Lunch/Outing

Thursday, June 20th

8:30AM Registration

9:00AM Talk Session 7

9:00AM Jonathan Cannon: A neurocomputational model of beat-based temporal processing

9:20AM Tomas Lenc: Hysteresis in the selective synchronization of brain activity to perceived meter in musical rhythms

9:40AM Rainer Polak: Aesthetic appreciation of timing patterns in music: A comparative study across three cultures

10:00AM Andrew Chang: Romantic interest is revealed by body sway and facilitated by groovy music in speed dating

10:20AM Coffee Break

10:50AM Keynote: Caroline Palmer

11:40AM Poster blitz 3

12:00PM Lunch

1:30PM Talk Session 8

1:30PM Alexander Demos: Synchronizing in duet music performance through a bidirectional delay-coupled dynamical model

1:50PM Dobromir Dotov: Coordination dynamics in a quartet of synchronized drummers: Emergent properties are qualitatively different from those of dyads

2:10PM Ole Adrian Heggli: Evidence for a new synchronization strategy: leading/leading

2:30PM Poster Session 3 and Coffee [Poster list below]

3:50PM Closing Remarks/ Wrap-Up

Poster Session 1, June 18th

1. A new test for measuring perception of dynamic pitch cues in fluctuating noise
   Jing Shen
2. Neural evidence of dynamic attending in Williams syndrome
   Anna Kasdan
3. A pilot study investigating the feasibility of a drum circle intervention for people with Parkinson's
   Dawn Rose
4. Revisiting the bimanual advantage in synchronize-continue tapping
   Carolyn Kroger
5. Are you a 'dweller' or a 'bobber'?
   Kelly Russell
6. Rhythmic organisation of spoken language: Insights from sensorimotor synchronization
   Chia-Yuan Lin
7. A rhythm game for training speech comprehension in English as a foreign language
   Ewa Wanat
8. Universal constraints on rhythm revealed by large-scale cross-cultural comparisons of rhythm priors
   Nori Jacoby
9. The experience of speed when tapping to polyrhythms
   Ned McGowan
10. Music-dance dissonance: A study on the effects of the soul calypso rhythm on flow in west-coast swing
    Virgil Breeden
11. The production of the "pocket": Beats as domains in a corpus of drum grooves
    Fred Hosken
12. Short-term adaptation and cultural influences in complex rhythm performance
    Carson Miller Rigoli
13. Moving together to metal music: Metrical constructions as a plural model of entrainment
    Stephen Hudson
14. Do children prefer musical rhythms with syncopation?
    Daniel Cameron
15. ~~Manipulation of temporal parameters in a polyrhythmic structure and its effect on musical character~~
    ~~*Stefanie Freitas*~~
16. Perceived interpersonal synchrony in argentine tango
    Olivia Xin Wen
17. Effects of pitch characteristics on perceived musical tempo
    Audrey Drotos

Poster Session 2, June 19th

1. All about that bass? Testing the innateness of low-pitch timing superiority
   Haley Kragness
2. Can auditory rhythms help children with developmental coordination disorder (DCD)?
   Chantal Carrillo
3. The flow of language: Speech respiration as a rhythmical action
   Alexis Deighton MacIntyre
4. Rhythmic synchronization ability predicts performance on a melodic intonation therapy task and reading fluency
   Yi Wei
5. Does passive action improve rhythm perception? Use of electrical muscle stimulation for beat interval perception task
   Rei Konno
6. Neural mechanisms underlying sensorimotor synchronization with different forms of rhythms
   Ryan Meidinger
7. Does musical stimulation during slow-wave sleep potentiate slow oscillations and associated declarative memory performance?
   Justin Hopper
8. Synchronized musical performance and social bonding
   Nathan Oesch
9. A comparison of neural entrainment obtained with vibrotactile and auditory rhythms
   Sean A. Gilmore
10. TAMSIN and the separability of motoric and rhythmic sequencing and performance: A neural network model
    Omar Zeid
11. Use of electrical muscle stimulation for learning rapid drumming movements: An exploratory study
    Reo Anzai
12. Beat-based scoring systems of rhythmicity of different speaking styles from speech contexts belonging to stress and syllable-timed languages
    Bader Alotaibi
13. Examining the effects of synchronization to different extrinsic rhythms in people with aphasia
    Yina Quique
14. Glutamate levels in the caudate correlate with beat perception in patients with schizophrenia
    Shiori Honda
15. Does moderate syncopation increase groove? The answer depends on the syncopation pattern
    George Sioros
16. The interplay of interval and entrainment timing in duration perception

Tzu-Han Cheng

17. The influence of familiarity on beat perception and oscillatory entrainment
    Joshua Hoddinott

Poster Session 3, June 20th

1. A comparison of spontaneous motor tempo and variability when finger tapping, toe tapping and stepping on the spot in people with and without Parkinson's
   Dawn Rose
2. Do low-pitched rhythms facilitate beat detection?
   Haley Kragness
3. "Eye" Spy: Eye tracking evidence that eye-movements synchronize with visual and audio-visual rhythms
   Melissa Brandon
4. Rhythmic priming: A stimulus-brain coupling analysis in adults with dyslexia and matched controls
   Anna Fiveash
5. Effect of fractal music and metronome on gait in people with Parkinson's disease
   Vivien Marmelat
6. Timing is everything… or is it? Effects of timing style and timing reference on guitar and bass sound in groove performance
   Guilherme Schmidt Câmara
7. Analysis of the variability of the counting pace of stuttering people
   Simon Grondin
8. Does corticospinal excitability fluctuate when listening to isochronous rhythms?
   Syed Raza
9. Preference for simple ratios in the relative phase of bimanual rhythmic tapping
   Dobromir Dotov
10. Musical leadership: exploring the biopsychosocial sole of influence in facilitating socio-temporal synchrony during musical interactions
    Joshua Hargreaves
11. Timing and drummers' movement: A novel methodology for performance analysis
    George Sioros
12. Determining tempi: What compositional approaches to rhythm constrain performer interpretation?
    Michael Schutz
13. PP HH AA SS EE OR E P H A S: An observation of perceptibility of rhythmic manipulations in Steve Reich's phase and systemically rotated compositions
    Rebecca Carroll
14. Influences of cultural familiarity and metrical complexity on sensitivity to musical meter
    Jessica E. Nave-Blodgett
15. Investigating rhythm production and perception in traditional Scandinavian dance music in non-isochronous meter: A case study of Norwegian Telespringar

Mari Romarheim Haugen

16. Beat perception develops slowly and is reflected by steady-state evoked potentials during context-induced perception of musical beat

    Karli Nave

Keynote

Caroline Palmer

Thursday June 20, 10:50

Title: Working well together: Interpersonal synchrony in sound, mind, and body.

Caroline Palmer is a Professor of Psychology at McGill University. Internationally recognized for her interdisciplinary research in auditory cognition, Dr. Palmer holds the Canada Research Chair in Cognitive Neuroscience of Performance and she directs a national training network in Complex Dynamics of Brain and Behaviour. Her pioneering work uncovered temporal relationships among interpretation, emotion and meaning in music performance and speech prosody that have altered our understanding of how complex acoustics communicate information among musicians, speakers, and listeners. A Fellow of the Royal Society of Canada, Palmer's weapon of choice is the piano.

https://www.mcgill.ca/spl/palmer

Talk Abstracts

Tuesday June 18, 9:10

Computational analysis of tempo and metre: From signal processing to cognitive musicology

Olivier Lartillot[a]

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Computational models for the analysis of tempo, metre and the tracking of beats have made significant progress during the last decades. I first present a synthetic overview of the state of the art. Up to recently, classical approaches were based on signal processing, with the integration of heuristics based on assumptions related to music perception and cognition. The standard approach is to first detect percussive events through the establishment of an accentuation curve, followed by periodicity detection, and the construction and tracking of meter. Because rhythmic emphasis can develop on various metrical levels across time, it is necessary to track the metrical structure on multiple levels. I show the benefit of such detailed analysis with the use of a model I have developed, and which obtained one of the highest grades in the MIREX tempo estimation competition.

New approaches based on deep learning have achieved impressive progress and have largely surpassed signal-processing-based approached (including mine) in the recent yearly editions of MIREX. One limitation of these approaches, at least in their current stages, is that they appear as black boxes able to imitate a particular behaviour for which they were trained on particular examples. As such, they hardly offer insight on the cognitive mechanisms underlying the perception of metre.

I will discuss the limitations of signal processing approaches and highlight the complexity of the musical structure. Pulsation in music is not always expressed through a periodic repetition of percussive events, but may emerge from a subtle propagation of motivic or harmonic structures. I present an approach under development that models the different components of music analysis and combine them altogether, extending further Lerdahl and Jackendoff's vision. Motivic repetition, which plays a core role, is also one of the dimensions that is the most difficult to model and automate.

Tuesday June 18, 9:30

Motown, disco, and drumming: The effects of beat salience and song memory on tempo perception

Justin London[a*], Marc Thompson[b], Birgitta Burger[b], Johanna Wilson[b], Nick Schally[a], Petri Toiviainen[b]

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"Our tempo memory is highly accurate (Levitin & Cook 1996, Jakubowski, et al. 2015) as are absolute judgments for tempo in the range of 80-140 BPM (Madison & Paulin 2010, Gratton, et al. 2016). London, et al. (2016), found a conflict between remembered tempo and absolute tempo judgment, which they called the "tempo anchoring effect" (TAE).

Three experiments further probed the TAE. Exp1 (a replication of London 2016) used pairs of Motown songs at core tempos of 105, 115, and 125 BPM, which were then time-stretched to produce stimuli spanning the 100-130 BPM range in 5 BPM increments; time-stretching alters tempo without changing pitch. Exp2 used the same stimulus design but replaced the Motown stimuli with six disco songs, and Exp3 used looped drum patterns. Exps 2 and 3 systematically increased beat salience while reducing other cues (melody, harmony). Exp2 and Exp3 also included blocks of unaltered stimuli. Stimuli were presented in different random orders for each participant, and the task was to rate each stimulus on a 7-point scale (1=slowest; 7=fastest).

The TAE was replicated in Exp1, reduced in Exp2, and absent in Exp3. In Exp2 and Exp3 tempo judgments for unaltered stimuli corresponded to their BPM rates. Thus the TAE is negatively correlated with beat strength/clarity and with the presence of melodic and harmonic cues.

While BPM is usually regarded as the dominant cue for musical tempo (but see Drake, Gros, & Penel 1999; Boltz 2011; London 2011; Elowsson & Friberg 2013), the TAE shows that other musical parameters play into our judgments of musical tempo. The TAE also depends upon tempo memory for distinct musical performances, showing that real-world tempo judgments involve remembered and stimulus-driven components.

Tuesday June 18, 9:50

A neural mechanism for timing events and intervals

Darren Rhodes[a], Massimiliano Di Luca[b]

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Human beings can time when to move, control the rhythm of their speech, and estimate how long things take. Knowledge about time and statistical regularities are essential to cognitive and sensorimotor function, yet two fundamental aspects of everyday life, both how long something lasts, and when something occurs are investigated seemingly independent of one another. Here, we show that event and interval-timing are interdependent and reflect a unified cognitive mechanism. Here, we propose that duration is defined as a probabilistic model of the time between two events and, and that the prediction of a future time-point depends on the history of expected durations. Quantitative simulations match the results of a psychophysical study evidencing a phenomenon of cross-property interference in sequences of similar stimuli, where timing reliability can influence perceived interval duration. Such observations support a unified and physiologically plausible portrayal of the perception of these two temporal properties.

Tuesday June 18, 10:10

Assessing our assessment of timing: exploring the types of sounds used in examining auditory duration perception

Michael Schutz[a], Jessica Gillard[a]

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Our ability to perceive and produce musical rhythms is rooted in the auditory system's temporal acuity. This can be seen when pitting modalities against one another, as audition typically dominates vision in timing tasks. However, vision can significantly influence auditory perception of duration when listening to natural sounds (Schutz & Kubovy, 2009)—rather than the artificial beeps on which much psychophysical research is based. This raises important questions about the degree to which auditory research relies stimuli failing to capture important properties of natural sounds. To explore this issue, we surveyed the types of stimuli used in over 1000 experiments from four prominent journals: Journal of Experimental Psychology, Attention, Perception & Psychophysics, Journal of the Acoustical Society of America, and Hearing Research. Curiously, it researchers failed to define the temporal structure of over one third of stimuli from these prominent studies. More importantly, nearly 90% of the stimuli encountered in this wide range of experiments fail to exhibit temporal variation beyond simple ramped onsets and offsets.

Our talk will review the key findings from this novel survey, with a particular focus on implications for interpreting past research. For example, models and theories built on experiments using tone beeps fail to predict outcomes of experiments using sounds with natural amplitude envelopes in audio-visual contexts such as duration estimation (Schutz & Lipscomb, 2007) and temporal order judgments (Chuen & Schutz, as well as the underlying processes involved in duration assessment (Vallet, Shore, & Schutz, 2014). Together, these results suggest clear differences in the perception of timing when using the kinds of complex temporal structures structure of natural sounds. This raises crucial questions about the degree of reliance on tone beeps in developing our understanding of the auditory system.

Tuesday June 18, 11:00

The role of talker rhythm in understanding speech in difficult listening situations

J. Devin McAuley[a], Yi Shena[b], Sarah Dec[a], Gary Kidd[b]

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For both normal-hearing and hearing-impaired individuals, there are large individual differences in the ability to understand speech in difficult listening conditions (e.g., attending to a single talker in a crowded restaurant setting). Speech understanding in the presence of competing sounds also generally declines with increased age. Although hearing loss contributes to declines in understanding speech in difficult listening situations, other factors, such as cognitive ability, have also been shown to play an important role. Some recent work suggests that music training and/or rhythmic ability may enhance speech-in-noise (SIN) ability, but results on this topic have been far from unequivocal. Three experiments investigated the role of talker speech rhythm in understanding speech in multi-talker backgrounds using the Coordinate Response Measure (CRM) paradigm. Participants listened to spoken sentences of the form "Ready [call sign] go to [color] [number] now" and reported the color and number of a target sentence (cued by the call sign "Baron") spoken by a target talker. Across experiments, target sentences were presented amidst one-talker, two-talker, or six-talker background sentences of the same form. Talker rhythm for either or both the target and background talkers was varied by continuous modulation of rate by 0%, 25%, 50% or 75%. Results revealed that varying the rhythm of the background sentences, while keeping the target rhythm constant, improved listeners' ability to correctly report the color and number of the target talker; conversely, varying the rhythm of the target talker, while keeping the background rhythm constant reduced listeners ability to correctly report the color and number of the target talker. The latter result was not simply due to reduced intelligibility of the target sentence, as varying the rhythm of the target sentence presented in isolation had no impact on listeners' performance. Results are interpreted in the context of Dynamic Attending Theory (DAT).

Tuesday June 18, 11:20

Better phase-locking to song than speech

Christina Vanden Bosch der Nederlanden[a], Jessica A. Grahn[a], Marc Joanisse[a]

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Speech rhythms play an important role in the segmentation and perception of language as it unfolds rapidly in time. At the sentence level, an individual's ability to comprehend a spoken sentence is related to the degree of neural entrainment to the slow rhythms of speech. In this same vein, children who struggle to read and comprehend language also shown deficits in tracking the slow rhythms of spoken speech. In the current study, we examined whether we could boost neural entrainment to language when adults and children (8- 10-year-olds) listened to sentences put to song, with its greater rhythmic regularity and melodic cues to metrical structure, compared to the same sentences spoken. We found that adults (n=23) show greater cerebro-acoustic phase coherence to song compared to speech (3.7-5Hz) in our difficult listening condition when utterances were 50% time-compressed. We found the same pattern across for typically developing children (n=29), with greater phase locking to song than speech (3.3-4Hz). However, this effect was not observed for children with poor reading abilities (n=17). These results suggest that changing the salience of rhythmic information in speech can lead to better neural entrainment to the syllable rhythms of speech for typically developing adults, but children with poor reading abilities appear to have deficits neurally entraining to speech even when ample cues to syllable onsets are given in song.

Tuesday June 18, 11:40

Zebra finches learn vocal sequences within a rhythmic framework

Julia Hyland Bruno[a], Ofer Tchernichovski[b]

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The songs of zebra finches and other birds can be described as sequences of vocal gestures, and current research indicates that developmental song learning is a process of generating and linking together song elements, or "syllables." However, zebra finch song also sounds highly rhythmic, and song is often associated with courtship dancing. To test the biological significance of song rhythm, we trained juvenile zebra finches to alter their songs by incorporating a new syllable that either fit or deviated slightly from the prior rhythm. Contrary to a purely sequential account of song learning, birds more readily acquired the new sequence when it fit within a pre-established rhythm. This result suggests that temporal patterns are learned, in addition to and perhaps separately from constituent syllable sequences. We further investigated how song rhythms and tempos may be learned and reused. We found that tutored song rhythm (defined as ratios of syllable onset-to-onset intervals) was copied, but not tempo (the intervals themselves). Nevertheless, we found a strong tendency toward conservation of birds' own tempo across development, including in cases of incomplete sequence imitation. In other words, birds appear to learn new syllables within the 'framework' of their existing song tempo. Together, these findings raise the possibility that the developing songbird brain encodes song time structure independently of acoustic content.

Tuesday June 18, 1:30

Can you clap to the beat? Findings from the first large-scale genome-wide association study on rhythm

Maria Niarchou[a], J. Fah Sathirapongsasuti[b], Nori Jacoby[c], J. Devin McAuley[d]; Eamonn Bell[e], Miriam Mosing[f], Peter Straub[a], Nicole Creanza[a], Fredrik Ullén[f], Nancy Cox[a], David Hinds[b], Lea K. Davis[a], Reyna L. Gordon[a]

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Across musically trained and non-musically trained individuals, there is substantial variability in the ability to perceive and produce rhythms accurately. Individual differences in musical rhythm have been linked to a subcortico-cortical network of brain regions, involving primarily auditory, motor, and subcortical/basal ganglia circuitry. Family-based studies demonstrate a moderate genetic contribution to rhythmic ability. However, understanding the molecular basis of rhythm necessitates genome-wide interrogation in a large well-powered sample. Her we applied Genome-Wide Association Study (GWAS) methodology to identify common genetic variatns associated with musical rhythm, collected from N=606,825 research participants from the personal genetics company 23andMe. Individuals responsed to the question 'Can you clap in time with a musical beat?'. To validate this single question, we also conducted a separate (behavioral) study using Mechanical Turk in N=734, and showed that individuals who answered Yes (vs. No) to this self-report question also performed better on a musical rhythm perception task (p=0.0006). In the genetic cohort, preliminary GWAS revealed 68 independent loci that surpassed the threshold for genome-wide significance. We found two loci on chromosome 4 (4q34.2 and 4q22.1), replicating prior findings of linkage to musicality in this region, as well as new loci including 16p11.2 (a known locus of neurodevelopmental disorders), 2p16.1 (a region linked to mental health and sleep phenotypes) and 17q21.31 (previously associated with cortico-basal degeneration and intracranial volume). GWAS results held after conditioning the analyses on known markers of IQ, using mtcojo, revealing independence of genetic markers of rhythm and IQ. LD-score regression showed 5% observed SNP-heritability of the rhythm phenotype. Taken together, these findings provide promising evidence of genetic architecture that may be involved in rhythmic ability in humans.

Tuesday June 18, 1:50

Rhythmic priming improves grammatical skills

Eniko Ladanyi [a], Agnes Lukacs[b], Judit Gervain[c]

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According to recent evidence (Chern et al., 2018; Bedoin et al., 2016), performance on a grammaticality judgement task improves if children are presented with a regular vs. an irregular rhythm or environmental noise immediately before the linguistic stimuli. The phenomenon is referred to as rhythmic priming and was shown in English- and French-speaking children. The generality of rhythmic priming, however, is not well understood yet, neither across languages, nor across cognitive domains. Motivated by these results, our first aim was to test whether Hungarian-speaking children with and without Specific Language Impairment (SLI) show the same effect at 5-7 years of age. We also wanted to investigate whether the effect is specific to grammar or regular rhythm also improves performance on a) a picture naming task – a linguistic task which involves no grammar and b) a non-verbal Stroop task – a non-linguistic task. According to our results children showed a significantly better performance following an exposure to a regular rhythm vs. an irregular rhythm/silence in the grammaticality judgment task but rhythm did not have any effect in the case of the picture naming and non-verbal Stroop tasks. These results suggest that rhythmic priming improves grammar processing in Hungarian similarly to English and French supporting the generality of rhythmic priming across languages. The phenomenon was found to be specific to the grammaticality judgement task indicating shared mechanisms between rhythm and grammar processing.

References

Bedoin, N., Brisseau, L., Molinier, P., Roch, D., & Tillmann, B. (2016). Temporally Regular Musical Primes Facilitate Subsequent Syntax Processing in Children with Specific Language Impairment. Frontiers of Neuroscience, 10, 245.
Chern, A., Tillmann, B., Vaughan, C., Gordon, R.L. (2018). New evidence of a rhythmic priming effect that enhances grammaticality judgments in children. Journal of Experimental Child Psychology, 173, 371-379.

Tuesday June 18, 2:10

The role of endogenous rates in music and speech production

Emma Greenspon[a], Peter Pfordresher[a], Amy Friedman[b], Caroline Palmer[b]

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Recent evidence suggests that individuals are highly consistent in the spontaneous rate at which they produce music or engage in rhythmic tapping, and that these spontaneous tempos influence coordination across performers (e.g., Zamm, Wellman, & Palmer, 2016). Such results suggest that performance timing is driven by an endogenous oscillator characterized by a natural (spontaneous) frequency. We report two experiments that addressed whether speech production is also guided by endogenous oscillations, and the degree to which these oscillations vary across individuals and domains. In Experiment 1, monolingual English speaking pianists produced 13-syllable sentences organized into two phrases and performed 16-note melodies. In Experiment 2 English-French bilingual pianists produced 8-syllable English phrases and performed similar melodies to those in Experiment 1. Participants in both experiments produced all sequences at a self-selected comfortable rate. For both experiments, individuals were highly consistent in their spontaneous rates for different melodies, and different sentences. Thus, the timing of speech, like music, may be based in part on an endogenous oscillator. Individuals were also highly consistent with respect to timing variability within each domain. We also found that mean spontaneous rates in speech production were less variable across individuals than mean spontaneous rates in music production, suggesting that speech rates are more strongly constrained by task demands, such as communicative pressures, than piano performance. Consistent with this domain-specific difference, correlations of mean spontaneous rates across music and speech production were weak and did not reach statistical significance. As such, these results suggest that music and speech may rely on endogenous oscillators that are tuned to different natural frequencies.

Tuesday June 18, 4:00

The musical dwell time paradigm: A new method for investigating expressive timing

Haley E. Kragness[a], Laurel J. Trainor[b]

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Acquisition of time knowledge and temporal concepts, Expressive timing and performance modeling In performance, musicians deviate substantially from metronomically regular timing. Numerous studies have sought to characterize the origins of expressive deviations by analyzing excerpts produced by highly-trained musicians. However, this precludes opportunities to consider how development and experiential factors, such as formal training, might affect patterns observed in musical expression. We have introduced a new paradigm for eliciting musical production in non-expert participants, the musical dwell time paradigm. In its simplest version, participants repeatedly press a computer key to elicit the onset of each note or chord in a pre-determined sequence. The paradigm can also be adapted for use with a MIDI apparatus, allowing participants to control additional expressive aspects of their productions, such as loudness and articulation. Using the musical dwell time paradigm, we have demonstrated that musically-untrained undergraduates and children as young as 3 years old spontaneously lengthen phrase-final events in musical excerpts, suggesting non-communicative mechanisms may contribute to the well-documented effect of phrase-final lengthening. In another set of studies, we are investigating how adults with a variety of musical backgrounds and young children use expressive cues in communicating different musical emotions. We argue that studying musical production of non-experts, such as amateurs and children, adds an important dimension to the investigation of musical expression as a whole. The musical dwell time paradigm offers a new, highly flexible method for examining musical production in participants of different ages and with a wide variety of musical experiences, and directly comparing musical production across these different groups.

Tuesday June 18, 4:20

The development of rhythmic categories as revealed through a perception task and a production task

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The ability to speak with a native accent or play music depends on listeners' ability to perceive, reproduce and synchronize with rhythmic patterns. Previous research shows that listeners assimilate rhythmic patterns towards familiar structures or priors, and these assimilation patterns vary by culture. In this study, we investigate whether children also assimilate rhythms to culture-specific structures, as previously shown with adults. North American children ages 6-11 years completed a perception task (song rating game, Hannon et al., 2012) and a production task (interactive tapping game, Jacoby & McDermott 2017). In the perception task, children listened to a tiger play songs (simple: 4/4 meter or complex: 7/8 meter) and rated how well subsequent animals (variations on the original song) matched the tiger's song. All children performed above chance, and children over 7-years-old showed greater sensitivity to rhythmic disruptions of culturally familiar simple-meter than unfamiliar complex-meter songs (as expected from Hannon et al., 2012). In the production task, children helped an astronomer communicate with aliens by tapping in synchrony with rhythms sent to Earth from outer-space. On each iteration within a 5-iteration block, the child attempted to synchronize with a three-interval rhythm that they produced on the previous iteration. If children have culture-specific biases, we expected that over successive iterations, their tapping would converge on those ratios preferred by North American adults. Results to date suggest that children's iterated rhythmic categories are (nearly) integer ratios, The relative weights of the categories observed in US children are highly correlated with the ones observed in US adults ($r=0.82$ $p<0.001$). Categories with more complex ratios (e.g., 1:2:3) vary more with age than simple categories (e.g., 1:1:2). This suggests that rhythmic categories are represented accurately in children and are learned hierarchically based on culture-specific exposure at an early age.

Wednesday June 19, 9:00

A neuromechanistic model for keeping a simple rhythmic beat in the context of music

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When listening to music, we typically lock onto and move to a beat. Behavioral studies on such sensorimotor synchronization (Repp 2005) abound, yet the neural mechanisms remain poorly understood. Time processing has been widely studied in the context of decision making, language, memory and perception (Buonomano 2014). Beat perception may be a special case of interval timing, relying on fast perception and learning of time intervals from 100 to 2000 ms, but differs because of a beat's regularity. Some models of beat perception hypothesize that the brain contains an array of self-sustaining entrainable oscillators, which resonate when forced with periodic stimuli, i.e. musical rhythms (Large et al. 2010). In contrast, our approach, in the simplest case, assumes a single beat generator neuron (BG) which can adapt its frequency and phase to match that of an external rhythm. This represents a neuronal realization of Mates' dual-process algorithm, for adapting the period and phase (Mates 1994). In our formulation, the BG is a conductance-based neuron, with ionic currents such as INaP, ICaT and Ih. The model includes the novel use of naturally occurring gamma frequency oscillations to estimate time intervals. Based on these estimates, the BG's input drive is iteratively adjusted. This has the effect of changing the frequency of the BG and hence, alters the BG period and firing times. The model quickly learns new rhythms, within a few cycles as found in human behavior. When the stimulus is removed the BG continues to produce the learned rhythm in accordance with a synchronization continuation task. We extend this framework to include multiple BG neurons to track different salient feature in more complex sequences, for example combinations of loud and soft tones.

Wednesday June 19, 9:20

Pitting metrical structure against subjective accenting in a test of beat-perception ability

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Dynamic attending theory proposes that on-beat targets should be better perceived that off-beat targets because of heightened attentional energy at on-beat positions. However, the opposite might be true for targets that vary in intensity because of subjective accenting – if on-beat events are perceived as subjectively louder because of implied metrical structure, intensity increases might be masked in on-beat positions, thereby reversing the classical pattern of "on-beat is better" results. We conducted six behavioral experiments that varied in 1) how meter was communicated and disrupted (isochronous sequences with isochronous vs. jittered accents; isochronous vs. jittered sequences with accents at the same serial positions; strong-beat vs. weak-beat rhythms), 2) the acoustic dimension to be judged (intensity; pitch), and 3) the type of judgment to be performed (discrimination; detection). A single target event was always present in each rhythm and occurred either on or off the beat. Sequences comprised 500-Hz, 50-dB SL pure tones. For discrimination, intensity or pitch targets were presented at one of 8 levels (4 below and 4 above standard sequence tones). Participants judged whether the target was softer/louder or lower/higher, and slopes of fitted psychometric functions indexed perceptual sensitivity. For detection, intensity or pitch targets were presented at one of 4 levels (easy and difficult increments and decrements). Reaction times to the target were analyzed. We observed a consistent but small-effect-size pattern that performance was best for on-beat targets, and worst for targets presented in rhythms lacking a clear metrical structure (jittered and weak-beat). The notable exception was for intensity-target discriminations in strong- vs. weak-beat rhythms, where there was an advantage for off-beat targets. We propose that this paradigm, with refinements, will provide a sensitive test of beat-perception abilities that is divorced from musical expertise.

Wednesday June 19, 9:40

Effects of syncopation and repetition on beat clarity, liking, and urge to move

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Previous work indicates that some optimal amount of complexity is preferred in music. For rhythms, this is generally implemented through varying beat content or syncopation level. Although moderate syncopation appears to lead to increased liking and urge to move, repetition, shown to affect preference, is also relevant.
We assess repetition and syncopation using repeating syncopated patterns (RS), and randomized sequenced note durations, producing non-repeating syncopated patterns (NS). As control conditions, a minimally syncopated simple rock rhythm (S) and non-beat-based patterns (NB) were used. For each pattern type, beat clarity, preference and urge to move were assessed.
Thirty-eight participants (23 female, mean age=22, sd=6.8) tapped to rhythms of each pattern type and rated the beat clarity, their preference and urge to move. Additionally, the Goldsmith Musical Sophistication Index was administered. Each rating was compared between rhythmic categories; analyses of the tapping responses and syncopation index of each individual pattern are underway.
For preference and urge to move, S and RS patterns were rated equally, and significantly higher than NS or NB patterns (all p values <0.01). Beat clarity showed a different response pattern where all categories were significantly different (all p values <0.001), where S scored highest, then RS, NS, ending with NB patterns. No influence of musical background was found. Further analysis of individual patterns will clarify the homogeneity of syncopate level within these categories, and the impact of repetition on the syncopation index.
Repetition was shown as a more important influence on liking and urge to move than syncopation itself, which will be further clarified by forthcoming results on the syncopation indices of each pattern. Preference and urge to move were highly related, and dissociated from beat clarity for the simplest rhythm. These results promise to refine our understanding of the interaction of rhythmic aspects with pleasure and movement.

Wednesday June 19, 10:00

Anne Danielsen Noise in the click or click in the noise: Investigating probe-stimulus order in P-center estimation tasks

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Synchronization studies often involve a probe and a target sound, with the probe position manipulated until they are perceived as simultaneous. Probes are usually clicks, but instrumental sounds have been used.

In the present experiment four target stimuli were presented cyclically: a 1ms click, a 100ms narrow-band noise burst (50ms rise/50ms decay), and two variants of the noise probe. The click (CA) and noise (NA) were used as probes. Participants (n=15) aligned the probe with the target using the method of adjustment, and stimuli were blocked by probe sound.

Overall NA locations were 28 ms earlier than CA locations, indicating that perceptual centers and not acoustic onsets are used as temporal referents. Interestingly, while click-noise and noise-click tasks should have led to the same alignment, since manipulating the "probe" vs. "target" are perceptually equivalent, they did not. A 2x2 RM ANOVA (Task=CA vs. NA x Similarity= matched vs. mismatched) showed effects of Task ($F(1, 14) = 79.603$, $p = .000$; $\eta p2 = .850$), Similarity ($F(1, 14) = 30.382$, $p = .000$; $\eta p2 = .685$), and a Task x Stimuli interaction ($F(1, 12) = 41.953$, $p = .000$; $\eta p2 = .750$). Click probes were located 14ms after noise onset, while Noise probes were located 34 milliseconds before the click onset.

The order of manipulation—Click-Noise vs. Noise-Click—produces a 20ms difference in mean probe location. This may be related to the details of the alignment task—what participants understand as "probe" versus "target,"—and because the noise probe affords a larger "window" of possible synchronization points.

Wednesday June 19, 10:50

Case report of a dancing infant: Effect of song familiarity and tempo on rhythmic movement and joy

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The development of rhythm production is protracted, as reflected in children's failure to consistently align their movements with the musical beat until school age. Well before auditory-motor synchronization matures, however, infants are motivated to move to music. Little is known about the influence of song familiarity, acoustical features, and musical tempo on these early musical movements. I will present case report data of Vanessa, a 19-month-old infant. Across nine sessions, she was video-recorded in her home (by her mother) during the presentation of six 60-s song excerpts. Two of the songs (Dora the Explorer Theme and Metallica's Now That We're Dead) were highly familiar, and two (Backstreet Boy's Everybody and Franklin the Turtle Theme) were unfamiliar. The songs were presented at the original tempo and at faster and slower tempi. Vanessa exhibited musical movement in all recording sessions. She repeatedly displayed specific dance movements such as head-bobbing and arm-pumping. She danced most to Metallica's Now that We're Dead, a song high in beat salience and familiarity (her father's favorite song), but she requested Dora the Explorer Theme most frequently. She also moved faster to faster music, but only for unfamiliar songs. For familiar songs, she moved quickly regardless of tempo. In addition, Vanessa's rhythmic movement to music correlated positively with her displays of pleasure. We suggest a scaled-up version of the present study to test hypotheses about the development of musical movement, including effects of song familiarity, acoustic features, and mood on rhythmic movement in infancy.

Wednesday June 19, 11:10

Embodied entrainment in Parkinson's: Let the music make you move

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Objective

Parkinson's is a degenerative neurological condition resulting in motor and non-motor difficulties (e.g. irregular walking, loss of balance). Interventions such as Rhythmic Auditory Stimulation and other music and movement activities (such as dance for Parkinson's) have been successfully used to regulate well-being and walking in Parkinson's. However, as previous research has not studied specifically how music could impact motor control, this study compared how musical and non-musical auditory cues may affect entrainment in people with and without Parkinson's.

Methods

A synchronization/continuation task was used to assess timed motor production with and without external stimuli. In addition to the typical finger tapping task, we included foot tapping and a stepping 'on the spot' (as a proxy for dance) tasks for slow (81bpm), medium (116bpm) and fast (140bpm) stimuli. Participants (aged 18–78 years) included people with Parkinson's (PWP; n = 30, Hoehn & Yahr Mean = 1.78), age matched (n = 26), and young adult controls (n = 36).

Results

Analyses of mean errors in inter-response-intervals revealed that music supported entrainment more than metronome overall in the medium tempi, and specifically in fast tempi for PWP. Stepping supported entrainment better than tapping overall in all groups, and especially for PWP at the medium tempi. Qualitative data informed that the PWP perceived the tapping tasks as less effortful with music than with metronome beats maybe because they were able to sub-vocalize with the music but got 'lost' with metronomes, even when counting.

Conclusion

Understanding that whole-body movement (compared to tapping) and music (compared to metronome beeps) improves entrainment for people with Parkinson's has important implications methodologically, but also provides direction for therapeutic applications. Music should be used as exogenous stimuli to generate endogenous associations that may help PWP to use imagined music to facilitate and improve the control of body movements.

Thursday June 19, 9:00

A neurocomputational model of beat-based temporal processing

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Beat processing is a fundamental aspect of music cognition involving precise, periodic temporal predictions. When presented with a beat-based stimulus, humans can quickly entrain their movements to the beat and maintain this entrainment in the face of complex rhythms, omitted beats, and tempo changes. The basal ganglia and motor planning regions (including supplementary motor area (SMA)), which play a critical role in movement initiation, have been shown to be involved in beat-based processing. However, it is unclear what roles they play and how they interact. Building upon the basal ganglia and motor cortical modeling literature, the authors propose a "two-timer" model of sub-second beat-based temporal processing in which two distinct circuits connect SMA with basal ganglia. In the first, SMA (possibly in conjunction with cerebellum) measures absolute time between perceived beats and transmits tempo estimates to putamen by inducing persistent activity in frontal or prefrontal cortex. In the second, tempo signals from putamen set the speed of a relative timekeeper in SMA. When this timekeeper reaches a certain point, a beat is anticipated and/or imagined, which cues a timer reset and disinhibition of motor activity (facilitating synchronized movements) via the basal ganglia's hyper-direct pathway. The first circuit is responsible for period correction and the initial stages of synchronization, while the second is responsible for phase correction and beat continuation. A tonic dopaminergic signal is modulated by the accuracy of predictions and moderates competition between the two circuits. This model reproduces certain data on phase correction (Repp et al. 2012) and period correction (Repp & Keller 2004), and provides a possible mechanism for some timing-related aspects of Parkinson's disease, including the efficacy of a metronomic pulse in alleviating freezing of gait. This "two-timer model" represents a first step in building biologically-realistic models of beat-based temporal processing, and makes several testable predictions.

Thursday June 19, 9:20

Hysteresis in the selective synchronization of brain activity to perceived meter in musical rhythms

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Musical meter refers to the spontaneous ability of humans to perceive and move along with a periodic structure of embedded pulse-like beats when listening to music. Importantly, meter can be perceived in regular rhythms, but also in syncopated rhythms in which the meter periodicities are not prominent in the acoustic input. This might be particularly the case if a syncopated rhythm is preceded by a regular rhythm that supports meter induction. Here we show that this effect of context and invariance relative to the input may be supported by hysteresis in the selective synchronization of neural activity to the perceived meter. We recorded the EEG while non-musician and musician participants listened to nonrepeating rhythmic sequences where the prominence of meter frequencies in the input either gradually decreased (regular-to-syncopated rhythms) or increased (syncopated-to-regular rhythms). In sequences gradually transforming from regular to syncopated rhythms, non-musicians showed greater persistence of neural activity selectively synchronized to the meter frequencies when these frequencies became less prominent in the input, compared to sequences gradually changing from syncopated to regular rhythms. When asked to tap to similar sequences after the EEG recording, non-musicians also demonstrated overall better motor entrainment to the meter in sequences that started with prominent meter. In contrast, musicians did not show hysteresis in their neural responses, and were able to precisely synchronize their movements to the meter regardless of the prominence of the meter frequencies in the input, thus demonstrating overall greater invariance relative to the stimulus. Together, these results show that perceptual organization of rhythmic auditory input cannot be fully explained by physical stimulus features, but involves endogenous processes driven by short- and long-term neural plasticity. These results also provide additional evidence for an endogenous neural mechanism of frequency-selective coupling that could be the basis of rhythmic entrainment abilities in humans.

Thursday June 19, 9:40

Aesthetic appreciation of timing patterns in music: A comparative study across three cultures

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Musicologists have claimed that the aesthetic appeal of musical rhythm depends on micro-rhythmic deviations from isochronous metric grids. However, experimental studies have found little or no evidence for that claim, and a biological predisposition for isochrony is widely assumed in music cognition.

Here, we systematically study for the first time the influence of the stimulus' musical style, the listeners' cultural background, and their interaction, on the aesthetic evaluation of timing variations in music. We selected examples of three styles (Malian jembe, Uruguayan candombe, and Euro-American jazz music), analysed their timings, and manipulated in isolation the structure of, and the deviations from, the metric grid as found in the examples. Manipulations included the original and artificial, e.g., exaggerated, smoothened, random, and quantized variations. We presented all three stimuli sets to participants (N=200) in four countries (Mali, Uruguay, UK, USA) and asked them to rate their liking of the variations. Participant sub-groups involved performing musicians and university students (non-musicians) in each country.

Results on the one hand indicate cross-cultural similarities. For instance, we found a universal preference, across styles and groups, for minimizing the asynchronies between ensemble parts by quantization to a metric grid. On the other hands, we found effects of cultural background and degree of familiarity in the appreciation of different metric grids. For instance, the original non-isochronous subdivision structure was preferred over other patterns, including isochrony, in candombe music by candombe musicians from Uruguay and in jembe music by jembe musicians from Mali, but not in Uruguayan candombe by Malians nor in Malian jembe by Uruguayans. That is, both groups privileged the original non-isochronous grids in their own but not in foreign music. By contrast, jazz musicians from the UK and USA preferred isochronous grids in all styles.

The role of culture for rhythm perception will be discussed.

Thursday June 19, 10:00

Romantic interest is revealed by body sway and facilitated by groovy music in speed dating

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Romantic attraction is among the most basic forms of interpersonal interaction. However, it is unclear whether this interaction can be dynamically measured and facilitated in real-world situations. The current study used speed dating as a paradigm to investigate whether romantic attraction is reflected by interpersonal body sway coupling, and if it can be facilitated by groovy background music. These hypotheses were based on previous findings that (1) body sway coupling reflects interpersonal interaction in music performance, (2) groovy music increases the desire to move, and (3) moving together can facilitate interpersonal affiliation. Fifty-five participants experienced up to fifteen 4-minute dates while their body sway trajectories were motion captured by small markers on their heads. Across dates, songs with different levels of grooviness were played as background music. At the end of each date, participants confidentially indicated their interest in short- and long-term romantic relationships with their partner. Using a generalized linear mixed-effect model, the current results showed that song grooviness predicted romantic interest, but song enjoyment and familiarity did not. Furthermore, the Granger-coupling (degree of directional predictive power between a paired time series), but not the cross-correlation-coupling (degree of similarity between a paired time series), of the body sway between dating partners predicted their reported long-term but not short-term romantic interest, even after controlling for rated physical attractiveness of their partner. This work demonstrates that in a highly-controlled social environment such as speed dating, grooviness of the background music facilitates romantic affiliation. Overall, this work extends our understanding of how body sway coupling functions in nonverbal communication to the domain of romantic interest. While interest in a short-term relationship may mainly relate to perceived physical attractiveness of a social partner, body sway coupling may reflect the perceived quality of a social interaction, facilitating interest in a long-term relationship.

Thursday June 19, 1:30

Synchronizing in duet music performance through a bidirectional delay-coupled dynamical model

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In music performance, performers can remain synchronized by changing the degree to which they anticipate the timing of their partner's actions, allowing their partner more or less leadership in real time, and by changing their speed. To examine which of these parameters performers might use to remain synchronized, we applied a nonlinear bidirectional delay-coupled model to pairs of pianists performing duets during perturbation tasks. The model was a system of coupled differential equations with three free parameters (i.e., delay, coupling, rate change) for each individual in the duet. Model fits for each individual in the duet were compared between auditory feedback manipulation conditions in which sounded feedback was randomly removed and later returned from the parts performed by one or both partners, to force a change in leadership. In the Baseline conditions (with no feedback manipulations), the person playing the lower voice (accompaniment) of the music was more strongly coupled to and anticipated the person playing the upper voice (melody) more than that person coupled to and anticipated the accompaniment. When auditory feedback from the Melody was removed (only the accompaniment sounds), the person playing the accompaniment could not couple to the Melody and showed a significant decrease in coupling term and anticipation relative to Baseline, while the person playing the melody did not change from Baseline in coupling or anticipation. Results of the model fits were also compared to simulations of the model with different amounts of delay, coupling, and rate change, to further explore the importance of each parameter. These simulations compared favorably with the behavioral measures; the amount of anticipation by each partner corresponded to changes in the parameter values. These findings suggest that performers change their coupling, delay, and performance rate in order to maintain synchronization with their partner.

Thursday June 19, 1:50

Coordination dynamics in a quartet of synchronized drummers: Emergent properties are qualitatively different from those of dyads

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Music and other social interactions often involves group larger than dyads. From a mechanistic perspective the accumulation of variability, delays, and N-way "mirroring systems" from each member should hinder performance in larger groups but this is not the case. We examined 4-person drumming circles of non-professional musicians. From a mechanistic perspective the accumulation of variability, delays, and N-way "mirroring systems" should hinder performance in larger groups but this is not the case. Each participant played alone (Solo) and in a group of 4, from which we analyzed both individual performance (Individuals-in-Group) and performance of the group as a whole (Group). The task was to maintain a steady tempo and synchronize with each other in the group. Trials started at different initial tempos. Beat onset times were collected from each individual. Group-level beats were approximated as points of peak acoustic energy of the group. The time-series of inter-beat intervals for each condition were analyzed using lagged auto-correlations and a drift-diffusion model. As well, interactions among pairs of Individuals-in-Group were examined using lag-0 and lag-1 cross-correlations. The lag-1 auto-correlations of Solo, Group, and Individuals-in-Group time series were negative, suggestive of self-correction. Importantly, cross-correlations between pairs during group performances were positive at both lag-0 and lag-1, suggestive of a dynamic where individuals anticipated each other. This is in contrast with previous dyad studies which typically report positive lag-1 and negative lag-0 cross-correlations indicative of mutually reactive inter-personal dynamics. Furthermore, most group performances contained one participant with consistently positive (puller) and one with negative asynchronies (pusher) relative to the group. Finally, a four-beat periodicity was seen in the lag-N auto-correlation functions in all conditions. Thus, emergent 4-person dynamics differ qualitatively from 2-person. Arguably, central moment (Group timing) acts as stabilizing feedback and allows for mutual anticipation and consistent pushers and pullers to emerge.

Thursday June 19, 2:10

Evidence for a new synchronization strategy: leading/leading

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When two people engage in rhythmical interpersonal synchronization, we often see either a mutual adaptation or a leader/follower synchronization strategy. In mutual adaptation the participants constantly adapt to each other, whereas in the leading/following strategy one of the participants exhibit less adaptability than other and hence becomes a leader. These two strategies are found predominantly in joint finger-tapping studies, but also in experiments involving for instance imitative hand movements. Here, we report a third synchronization strategy – leading/leading. In a joint finger tapping experiment with bidirectional coupling, we found that a subset of our participants exhibited no clear directionality in their interaction, as measured with cross-correlation. This subset of participants did not differ from the rest in terms of synchronization measures, nor experience, but had a significantly higher occurrence of drummers. We propose that this synchronization strategy occurs when two highly skilled musicians choose to collectively disregard auditory feedback from the other, and instead rely solely on their own internal model of the task. Furthermore, we show that a Kuramoto-based coupled oscillator model confirms our prediction that the leading/leading strategy necessitates attributing less weight to external stimuli, and more weight on an internal representation of the task. As such, our study is one of the first to show that instrument-specific differences may impact synchronization strategies in interpersonal interaction.

Poster abstracts

Poster Session 1

A new test for measuring perception of dynamic pitch cues in fluctuating noise

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We know listeners can benefit from dynamic pitch cues (i.e., pitch variation in speech) for speech perception in noise. Many real-life noises, such as conversation and traffic, have amplitude fluctuation. Therefore, the ability to benefit from dynamic pitch, as a suprasegmental cue, in this type of noise would be particularly crucial for speech recognition under these realistic conditions. It is difficult, however, to test this hypothesis using the current perceptual tests, because these tests typically include dynamic pitch patterns that last less than a second and model after random or linear curves. The goal of the present study is to develop a new test that measures listeners' ability to perceive dynamic pitch in temporally modulated noise.
Dynamic pitch stimuli were created by extracting pitch trajectory in real speech and re-synthesizing to continuous pure tone glides. Two levels of dynamic pitch strength were generated while including the natural dynamic pitch strength as a baseline condition. The test used a two-interval force-choice (2IFC) task to measure individuals' ability to discriminate pitch contours that have different amount of dynamic pitch strength. Dynamic pitch glimpsing ability was quantified by the amount of difference between in-quiet and in-noise performances (i.e., percent correct difference).
Data from 20 young listeners with normal hearing showed inter-subject variability of approximately 30% in dynamic pitch glimpsing ability. Further work is being planned to use this test to measure dynamic pitch glimpsing ability in older listeners with hearing loss, which will be further connected to individuals' ability to benefit from dynamic pitch cues in speech perception in noise. [Work supported by NIH]"

Neural evidence of dynamic attending in Williams syndrome

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Williams Syndrome (WS) is a neurodevelopmental disorder characterized by hypersociability, heightened auditory sensitives, and strong musical interests despite variable musical skills. Individuals with WS exhibit variability in musical beat perception, and this is associated with individual differences in social communication (Lense & Dykens, 2016). We sought to investigate the neural basis of beat tracking (important for both musical and social interactions) in these individuals. Using EEG, we tested 28 individuals with WS and 15 age-matched controls in a dynamic attending paradigm in which participants passively listened to musical rhythms with accents on either the first (condition 1) or second (condition 2) tone of the pattern, leading to distinct beat percepts. Individuals with WS and controls showed strong evoked activity in the gamma (31-55 Hz) frequency band in response to physically accented beats – these responses were time-locked at similar latencies from beat onset in both conditions (condition 1:WS, 0-136ms, $p<0.001$; controls, 0-90ms, $p=0.003$; condition 2:WS, 190-316ms, $p=0.002$; controls, 204-298ms, $p=0.039$). Additionally, significant beta (13-30 Hz) activity was found for the WS and control groups in both conditions (condition 1: WS, 0-188ms, $p<0.00l$; controls, 0-142ms, $p=0.005$; condition 2: WS, 196-436ms, $p<0.001$; controls, 168-388ms, $p<0.001$). This is in line with previous research showing that meter perception driven by physical and perceived accents in tone sequences modulates beta and gamma activity in ERF brain responses in adults (Iversen et al., 2009). Individuals with WS additionally exhibited significant alpha (8-12 Hz) activity (condition 1: 0-228ms, $p<0.001$; condition 2: 258-514ms, $p=0.004$). Overall, brain activity was more widely distributed across the scalp for the WS group compared to controls, and results are consistent with increased attention to auditory stimuli in WS. Future analyses will explore individual differences in evoked brain activity in relation to IQ and social communication scores within WS.

A pilot study investigating the feasibility of a drum circle intervention for people with Parkinson's

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Background
Drum circles have been used as interventions to promote wellbeing in vulnerable populations. A drum circle involves a group of people (one leader) playing synchronized and syncopated rhythms using hand percussion. For people with Parkinson's, interventions utilising musical rhythms (such as Rhythmic Auditory Stimulation) have successfully helped ameliorate attendant symptoms, such as regulate movements, and improve mood.

Aims
This single session study explored the feasibility of a drum circle as a novel intervention for people with Parkinson's. The aim was to understand adaptations required to develop a specific protocol and capture measurable outcome data.

Methods
Quantitative methods included measures of affective states (Warwick-Edinburgh Mental Well-being Scale (WEMWBS; pre/post); Positive and Negative Affect Scales (PANAS; pre, during, post)), and upper-body motion capture. This utilises non-invasive reflective markers to track anatomical landmarks (e.g. hands, wrists, forearms and head) through a calibrated 3D coordinate volume. Participants included People with Parkinson's (PWP; n = 4, Mean Hoehn & Yahr = Stage 2), an age matched, a young healthy control, and a drum leader. Qualitative data reflecting the participants experience were captured using post activity questionnaires.

Results
An average increase of 2.2 points (3.6 points when including the drum leader) was revealed for the WEMWBS. For the PANAS, for PWP, though pre and post levels were stable, during the drum circle, positive affect scores increased by 3.5 points (average). Motion-capture data is being examined to consider quantitative changes in movement amplitude and to quantify levels of temporal synchronicity, both across and between individuals. Qualitative results suggested enthusiasm for the drumming, though more variety of instruments was recommended.

Conclusions
Measurement of affective states was successful, and early stages of motion capture analysis suggests this can be used to assess meaningful outcome measures. Furthermore, classes supporting the development of rhythmic skills would be welcomed by PWP.

Revisiting the bimanual advantage in synchronize-continue tapping

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Studies using synchronization-continuation tapping paradigms to investigate timing behavior have revealed a bimanual advantage (BA); within-hand variability of produced inter-tap-intervals (ITIs) is less when participants tap with two hands compared to when participants tap with a single hand (Helmuth & Ivry, 1996). The present study extends work on the BA by (1) using continuous motion tracking to provide a more fine-grained analysis of tapping dynamics and (2) considering the possibility that at least a portion of the BA is an artifact of Weber's Law. The later possibility arises due to some preliminary evidence that mean produced ITIs during continuation tapping may be reliably shorter in bimanual tapping than during unimanual tapping. Our first experiment replicated Helmuth and Ivry (1996; Experiment 1) using three target ITIs (400 ms, 550 ms, 700 ms). Results showed that participants produce shorter mean ITIs during bimanual tapping than during unimanual tapping, and there is no BA over and above the difference in variability accounted for by Weber's law. Continuous motion-tracking data revealed that tap amplitude is higher during unimanual (vs. bimanual) tapping and at slower tempi; similarly, dwell time (proportion of tap time spent with finger in contact with table) is longer during unimanual (vs. bimanual) tapping and at slower tempi. A second experiment considered the possibility of an inter-personal 'bimanual' advantage where participants either completed synchronize-continue tapping alone – a solo tapping condition – or with a partner who was seated directly across from them. Similar to experiment 1, results from this did not show an inter-personal BA, and we found that when people tap together, the mean produced ITI is shorter than when they tap alone. Experiment 2 results also showed a reduction in tap amplitude during interpersonal compared to solo tapping. Results will be discussed in the context of previous accounts of the BA.

Are you a 'dweller' or a 'bobber'?

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This study investigated how different tapping styles might affect an individual's ability to keep time with (and maintain) an isochronous rhythm. Participants engaged in a synchronization-continuation tapping task in which they synchronized finger taps with an isochronous auditory stimulus presented at four different target inter-tap-intervals (506 ms, 759 ms, 1139 ms, 1709 ms) and then continued tapping at the same rate once the stimulus stopped. A novel aspect of this study was that continuous movement data was recorded, allowing for a more in-depth analysis of tapping dynamic compared to traditional synchronize-continue tapping studies. Of particular interest were potentially different strategies people might use to synchronize with slow rhythms (i.e., rhythms that are outside the typical adult entrainment region and do not readily afford synchronization). Results reveal at least two distinct tapping styles (strategies) for slow rhythms. When synchronizing with slow rhythms, some participants tend to "dwell" on the table between taps – suggesting that they are using dwell time to sub-divide the long target inter-tap-interval into two shorter intervals. Other participants tended to let their finger "bob" in the air between taps. Differences in tapping dynamics and traditional measures of synchronize-continue tapping performance will be discussed for 'dwellers' and 'bobbers'.

Rhythmic organisation of spoken language: Insights from sensorimotor synchronisation

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Background: Language and music share similar structures in many ways though, unlike in music, rhythmic organisation in language has been a matter of controversial debates. The present study utilises sensorimotor synchronisation to shed light on the basic unit of rhythmic organisation in language, by observing motor entrainment to repetitive spoken sentences that are prone to evoke the speech-to-song transformation in listeners.
Hypotheses: (1) Listeners will entrain to the rhythmic structure of repetitive speech. (2) The target of entrainment will give insights into the basic unit of rhythmic organisation in language.
Method: Twenty-nine participants attended our experiment. During the experiment, six English sentences were displayed repetitively for 20 times in each trial. Participants were instructed to listen to each sentence for a period of time, and to start synchronising to its rhythm by tapping on a drum pad.
Analyses: Density estimation with Gaussian kernel was applied to the obtained tapping data. A synchronisation index was calculated by comparing asynchronies between density peaks and a pre-defined set of acoustic and linguistic events.
Results: First, Kolmogorov-Smirnov test confirmed that the obtained tapping patterns differed significantly from a uniform distribution. The best model of listeners' tapping behaviour was obtained for vowel onsets, in contrast to acoustic intensity maxima and linguistic structures like syllables or words.
Discussion: The results suggest that listeners were indeed entraining to the rhythmic structure of repetitive speech. Accordingly, intervocalic intervals are likely to constitute the basic unit of rhythm perception in spoken language. In contrast to p-centres which have been notoriously difficult to define, vowel onsets are relatively unambiguous points of reference in the acoustic signal. Ongoing research will extend the current dataset to include comparisons among rhythmically diverse languages."

A rhythm game for training speech comprehension in English as a foreign language

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Tapping, or engaging in a synchronised motor task while listening to an external stimulus, can be a means to entrainment with speech (Lidji et al 2011). In turn entrainment may produce improved performance in linguistic tasks (Quené & Port 2005). Wanat (2018) showed that tapping to the beat that is heard in speech helped Chinese learners of English as a Foreign Language to learn to comprehend fast conversational Glaswegian English speech. This presentation gives an overview of an app which aims to improve the users' comprehension of English connected speech, while collecting more data to explore the benefits of SMS training.

The app first of all offers users a brief introduction to basic concepts to do with rhythm, and illustrates tapping to various simple musical and speech rhythms. It also explains in simple terms how linguistic and musical rhythms can be connected. This is achieved through videos recorded with a community musician who specialises in rhythm.

The user is then able to play a game which trains them to tap to the beat in English speech, interleaved with testing sessions that assess their comprehension of fast connected speech. During the SMS training, participants use an interface which indicates visually when the tapping is to occur while they listen to rhythmically regular sentences. Their task is to tap their finger on the stressed syllables. The testing sessions focus on comprehension of reduced function words (the, her, a, their, our, etc) heard in sentences. The game is being currently developed in form of a web app, and a short demo version will be presented.

Universal constraints on rhythm revealed by large-scale cross-cultural comparisons of rhythm priors

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Music is present in every known culture, implying some biological basis. Yet the nature and extent of biological constraints have remained unclear, in part because cross-cultural comparisons have been limited. We measured a signature of mental representations of rhythm in over 500 participants from 13 countries on four continents, spanning modern societies and traditional indigenous populations belonging to 27 subgroups with varied musical expertise. Listeners were asked to reproduce random ''seed'' rhythms; their reproductions were fed back as the stimulus (as in the game of "telephone"), such that their biases (the prior) could be estimated from the distribution of reproductions (Jacoby and McDermott 2017). Every tested group showed priors with peaks. These peaks always overlapped with integer ratio rhythms, supporting the idea that rhythm "categories" at integer ratios are universal. However, the relative importance of different integer ratios varied considerably across cultures. Rhythmic prototypes in many cases reflected rhythms prevalent in the musical systems of a participant group's culture. However, university students in non-Western countries tended to resemble Western participants, underrepresenting the variability evident across indigenous participant groups and highlighting the problematic over-reliance on student participants in cognitive science (Henrich et al. 2010). The results illustrate consistency in rhythm perception amid cultural variation, demonstrating biological constraints and their interaction with culture-specific traditions.

The experience of speed when tapping to polyrhythms

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Different rhythmic patterns are hypothesized to be able to induce varying levels of subjective speed, irrespective of actual tempo. In an empirical study, subjects tapped to fragments of piano music in which polyrhythms were systematically varied between the pulse, played in the lower register, and a series of chords, played in a higher register. To standardize the actual tempo, they were instructed to tap with the lower pulse, and after each fragment they were asked to rate the fragment on several dimensions (i.e. subjective speed, ease of tapping, induced activation level, induced fatigue, and preference). Concurrently, heart rate was collected using an ECG measurement. Each polyrhythm is presented at three tempi, and the tonal structure is similar but different in each exemplar in terms of exact chord series and key. It was theorized that there are three classed of speed, relating to the ratio between the lower and higher register, based on whether the periodicity in the higher register was faster than the pulse, between 1 and 2 beats of the pulse, or 2 beats and longer. As the experiment is currently in progress, no results can yet be reported, but it is hypothesized that these three classes will be reflected as linearly decreasing in subjective speed. The other measures that are collected will be informative about measures of arousal, and effects of preference

Music-dance dissonance: A study on the effects of the soul calypso rhythm on flow in west-coast swing

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West Coast Swing (WCS) is a partner dance form that can be danced to many rhythms, genres, time signatures, and tempos. However, dancers within this community frequently observe some music to be less suited to the dance form. In particular, music featuring the soul-calypso ("soca") rhythm is commonly viewed as problematic. We hypothesize that the soca rhythm causes confusion due to a music-dance ""dissonance."

In this experiment, which we believe addresses a lacuna in the study of music and movement, groups of WCS dancers danced in pairs to musical selections representative of the variety of music heard at WCS dance events, and were asked to use a likert scale to rate the perceived "flow"(Csikszentmihalyi, 1990)---defined as how well the music feels like it aligns with the movements associated with the basic step patterns taught in WCS.

An experiment was carried out in an ecologically valid setting across five separate WCS group events. Dancers moved through their basic step patterns in pairs to several popular music excerpts. The dependent variable manipulated the genre of the song where each genre is defined by different characteristic rhythms (shuffle, rock, funk-rock, lyrical, and soca). We used two different stimuli for each genre. The study used a between-subjects design with subjects randomly assigned to dance to only one particular stimulus from each block for a total of five trials.

Data collection is still underway with our last experiment set to take place in March. An estimated 200 participants are expected in total. We will be using multiple regression analysis using the rhythmic categories to predict the perceived degree of flow. We plan to include as covariants the dancers' degree of expertise, and role (lead or follow). We will include the individual songs in each rhythmic category (or genre) as a random variable.

The production of the "pocket": Beats as domains in a corpus of drum grooves

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This paper takes a perceptually-informed, dynamic view of "the beat," arguing that beats are durations — or, more colloquially, "pockets" — which are elements within a flexible metric reference structure. Traditional theories of rhythm and meter tend to conceptualize the beat as a "durationless point in time" (Lerdahl & Jackendoff, 1983; citing Imbrie, 1973 and Komar, 1971) or an inaudible "timepoint that has no duration" (Kramer, 1988). The dynamic sense of how beat and meter are produced has been analyzed by Danielsen, drawing on Jones's Dynamic Attending Theory (e.g. Jones, 1976), to describe the experience of listening to and perceiving pulse, arguing that listeners have perceptual "beat-bins" or "extended beats" that have shape to them (2010; 2018); however these analyses are general and non-specific.

In this study I use the MIRtoolbox to analyze a corpus of 4/4 bars (N = 3,645) of recorded performances by four top session drummers using data from individually-miked drums to illustrate in detail how the beat-as-performed is not a durationless time point. In these performances there is a temporal location within the bar that is maximally likely to be performed as, for example, idealized beat 2; however there is spread to this data (across all the data, the mean location of beat two = beat 2.076, $\sigma = 0.331$) — onsets occur within a "pocket" that surrounds the idealized beat location. Furthermore, it may be observed how each individual drummer nuances their "pocket," having more or less variance to their onsets depending on the location within the bar (which idealized beat) as well as by drum type (hihat, snare, or bass drum). Overall, this corpus study examines the fundamental architect of the beat in most contemporary music styles — the drummer — and uses the analytical findings to challenge the notion of durationless beats.

Short-term adaptation and cultural influences in complex rhythm performance

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When performing or tapping along with complex rhythms composed of multiple intervals, listeners tend to systematically distort the timing of these rhythms. Distorted rhythms frequently appear to be 'normalized' in the direction of 'attractor' rhythms with simple integer interval ratios such as 1:1 or 1:2. However, two recent studies have found that the specific pattern of distortion varies partly with the music-cultural background of listeners. This variation invites the interpretation that complex rhythm processing relies on the long-term internalization of rhythms prevalent in a listener's native musical culture. However, group differences may also be the result of shorter-term adaptation in adulthood to regularly enforced cultural practices like dance. To understand the implications of both types of cultural influence, we present a framework for investigating culturally-mediated learning on rhythmic behavior across multiple timescales.

To demonstrate short-term adaptation and justify this framework, we conducted two tapping studies involving synchronization with two- and three- interval rhythms. In the first, participants significantly improve their average synchronization performance of a complex rhythm (3:2:2) after a twenty-minute practice session. Improvements are not seen for a simple rhythm alternative (2:1:1). In the second, participants tap along with one of four possible priming rhythms (1:1, 4:5, 4:7, 1:2) for 250 repetitions before being tested on five two-interval test rhythms (6:7, 3:4, 2:3, 3:5, 6:11) in two fifteen-minute test blocks. The priming rhythm significantly predicts the amount, and in some cases direction, that participants distort target rhythms in the first but not second test block. These results together provide evidence for the role of short-term adaptation in complex rhythm performance. Combined with cross-cultural data, these findings offer a richer understanding of possible sources of variation in sensorimotor processes. We will discuss future cross-cultural and longitudinal studies to investigate the extent of adult sensorimotor learning at multiple timescales.

Moving together to metal music: Metrical constructions as a plural model of entrainment

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The primary model for studies of musical entrainment has been isochronous synchrony, but a new paradigm based on “metrical constructions” (Zbikowski 2008) has greater explanatory power for both broader definitions of entrainment and cultural aspects of rhythm cognition. I define a metrical construction as any conventional association between specific sounding features, specific beat interpretations, and specific forms of movement. Here I consider two constructions common in metal, backbeats and phrase-ending 332s. Each has a distinct drumkit pattern, and a distinct performative beat interpretation realized through headbanging.

Metrical constructions and other movement practices form a “cognitive repertoire"" of ways of moving, a culturally-specific “mindscape” which shapes how we experience rhythm (Zerubavel 1997). Each individual’s visceral head movements must be felt beats or “focal impulses” (Ito 2004) around which they coordinate their own movements. Headbanging beats are also a “referential rhythm” against which musical sound is perceived as syncopated (or not). Heavy metal fans participate in a “thought/movement community” of genre-specific movement practices and metrical constructions like headbanging and backbeats, practices which afford “heavy” ways of experiencing rhythm.

I argue that metrical constructions are not objective structures in sound or notation, but subjective strategies for /actively construing/ one's own metrical interpretation (as in Butler 2006). Music is often thought to “communicate a meter,” but several studies have suggested that listeners entrain in more diverse ways. I show how backbeat and 332 apparently underlie a plurality of motion visible in performance video of Metallica’s “Master of Puppets,” including moments where some musicians embody periodic 4/4 simultaneous to others’ non-isochronous 332 headbanging. This framework models a broader sense of musical entrainment as /moving together/, the cooperative and intentional movements of individuals (Tomasello 2008, Tomlinson 2015), rather than passive metronomical resonance.

Do children prefer musical rhythms with syncopation?

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Listeners tend to move along to music and most enjoy moving to music. Pleasure and groove—the sense of wanting to move with music—both have an inverted-U relationship with syncopation in musical rhythms; adults rate drumming excerpts with a medium degree of syncopation more highly in pleasure and groove compared to excerpts with low or high degrees of syncopation (Witek et al., 2014). Although infants have been shown to move more to music and rhythms than to speech, and show positive affect associated with this movement (Zentner & Eerola, 2010), we do not know how the relationship between groove, pleasure, and syncopation develops with age. Here, we used a novel touchscreen task to test whether 3-year-old children have preferences for syncopation or its absence. Children were presented with a touchscreen tablet with three visible circles, each of which was associated with drumming excerpts with Low, Medium, or High degrees of syncopation (a subset of stimuli used by Witek and colleagues (2014)). Children were encouraged to freely press the circles, listen to the drumming music, and to move to the music if they wanted to. We recorded video of the sessions to be used for (blind) ratings by adults of how much children moved while listening to different levels of syncopation in the drumming music. We hypothesize children will prefer medium levels of syncopation as shown by their listening duration and amount of movement. We will also report on relationships to children's music and listening experience as reported by parents, with the expectation that children exposed to more music, and particularly to jazz, will prefer higher levels of syncopation.

Perceived interpersonal synchrony in argentine tango

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Background: Argentine tango is a social dance that is closely tied to tango music, with its popularity rising around the world. The dance has been primarily studied in terms of dynamic coordination (Kimmel & Preuschl, 2016), interpersonal synchrony (Sevdalis & Keller, 2011), and neural activities during body movement (Brown, Martinez, & Parsons, 2005; Karpati, Giacosa, Foster, Penhune, & Hyde, 2015), giving little attention to the role of music in the dance. Two experiments explored how auditory cues are processed behaviorally and perceptually in Argentine tango.
Method: Experiment 1 motion-captured 9 pairs of dancers from Finland using the silent disco paradigm in four auditory conditions (leader-follower): Music-Music, Music-Beat, Music-Silence, and Beat-Music. Experiment 2 presented the silent point-light videos from each auditory condition in Experiment 1 to 30 individual dancers from the U.S., who rank ordered the videos based on the physical synchrony between the Finnish dancers.
Results: Mixed-model analysis revealed that in Experiment 1, the condition where the leader heard only beats resulted in less physical and perceived synchrony compared to conditions where the leader heard the music. When the leader heard the music, the follower' audio affected perceived synchrony for both the leader and the follower, but not their physical synchrony. In Experiment 2, the viewer's rank ordering, which was solely based on the dancers' physical movements, corresponded to the leader's auditory conditions but not the followers'.
Conclusions: The findings suggest that the leader and the follower jointly dance to the leaders' auditory cues while inhibiting moving to the followers' cues. This mechanism contributes to the interpersonal synchrony between tango dancers and their feeling of being in sync with each other. In addition, the reverse process is also valid in that the viewers were able to identify the corresponding auditory conditions of the leader based on observed interpersonal synchrony."

Effects of pitch characteristics on perceived musical tempo

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Two experiments examined the relation between tempo determination (decisions about the 'best' tempo for a musical excerpt) and tempo perception (whether a musical excerpt is perceived to be relatively fast or slow). In Experiment 1, fifty-nine participants listened to thirty-one isochronous melodies and used a spin-wheel to make continuous tempo adjustments until they arrived at a perceived 'correct' final tempo. Musical excerpts with more contour changes had slower chosen tempos than musical excerpts with fewer contour changes (M = 462 ms; 423 – 502 ms). One explanation for this relationship is an assimilation hypothesis whereby listeners perceive the tempo of melodies with more contour changes to be faster, but regress to a mean average tempo, thus setting a slower tempo for melodies with more contour changes and a faster tempo for melodies with fewer contour changes. An alternative, contrast hypothesis, is that listeners perceive melodies with more contour changes to be slower than melodies with fewer contour changes, setting the tempos of the melodies to reflect their contrasting relative tempo perceptions. To distinguish between these two hypotheses, a second experiment selected eight melodies from Experiment 1 to create pairs of melodies with relatively few or relatively more contour changes for a standard-comparison task. Comparison excerpts were presented at either the same, slower, or faster tempo than the standard. In Experiment 2, thirty-one participants listened to these pairs and judged whether the comparison melody was faster or slower than the standard. Results revealed that comparison melodies were perceived to be slower (faster) than the standard when there were more (fewer) contour changes than the standard. Consistent with the contrast hypothesis, the magnitude of over and underestimation of tempo in Experiment 2 predicted the tempo that listeners felt was 'correct' for those melodies in Experiment 1.

All about that bass? Testing the innateness of low-pitch timing superiority

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In music, melodic information is often assigned to high voices and timing information assigned to low voices. These compositional tendencies might be attributable to human processing biases. Specifically, melodic information is better processed when it is carried in high compared to low pitches and the reverse pattern is observed for rhythmic information. Evidence that these biases reflect innate predispositions comes from modeling cochlear dynamics, as well as from developmental work showing very young infants' brains respond more to pitch deviants in high-pitch contexts than low-pitch contexts. However, no such developmental evidence has been reported for low-pitch timing superiority. In the present study, we use a preferential looking paradigm to investigate the effect of pitch height on infants' perception of audiovisual synchrony. Eight- to 12-month-old infants are seated facing a single screen with two videos displayed side by side. Each video depicts a finger tapping on a surface of a table, one at a rate of 430ms and the other at 600ms. Simultaneously, a series of sine tones plays at either a 430ms or 600ms inter-onset interval, with the auditory stream phase-aligned (synchronous) with the tempo-matched finger. Across trials, the sine tones play at either 1236.8 Hz (high pitch) or 130 Hz (low pitch). Infants' gaze to the synchronous and asynchronous videos across a trial is recorded using an eye tracker. We expect infants to preferentially gaze at the synchronous video, especially at the beginning of each trial. We hypothesize that this preference will be enhanced in the low-pitch versus high-pitch conditions. Results will offer insight into the developmental origins of auditory scene analysis, as well as implications for early audiovisual time perception.

Can auditory rhythms help children with developmental coordination disorder (DCD)?

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DCD is a neurodevelopmental disorder involving deficits in motor coordination, affecting 5-6% of children. Children show deficits in visual-motor and motor timing, but auditory timing has not been well studied despite its importance for speech and music. Given previous research showing motor areas are involved in auditory time perception, we hypothesized children with DCD would have impaired auditory time perception.

Our first study measured discrimination thresholds for duration timing, rhythm timing, and pitch (control task). We found that children with DCD aged 6-7 ($n = 20$) have larger discrimination thresholds for duration ($p = 0.009$) and rhythm-based timing ($p = 0.012$), but not for pitch, compared to typically developing (TD) children ($n = 27$).

Our second study explores whether auditory rhythmic stimuli can help children (6-7 years) with DCD to execute rhythmic motor movements. We are testing tapping consistency when: tapping alone; with a metronome (400, 600 ms IOI), continuation tapping (after metronome stops); and tapping to the beat of musical dance excerpts. We hypothesize, compared to TD children, tapping in children with DCD will be more variable both in phase and tempo with no auditory stimulus (tapping alone or continuation), but the differences between groups will be diminished when an auditory stimulus is present (metronome or dance music). Pilot data from 7-year-old TD children ($n = 24$) showed tapping consistency was higher in the metronome (beat-present) compared to continuation (beat-absent) tapping condition ($p < 0.0001$), and at 600 ms than 400 ms ($p < 0.0001$). An interaction between beat presence and tempo ($p = 0.011$) revealed greater benefit of the metronome at 600 than 400 ms IOI. Data collection with DCD children is ongoing. The study is important for informing whether auditory-motor training may confer additional benefit for children with DCD compared to conventional interventions based on motor function.

The flow of language: Speech respiration as a rhythmical action

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Speech rhythm can be described as the temporal patterning by which sequences of vocalic and gestural actions unfold, both within and between interlocutors. Quantification of speech rhythm is important, but has thus far been unsuccessful for a number of reasons. For example, the primary means to quantify speech rhythm has been based on an analysis of the acoustic signal itself. However, speech is multimodal and motoric. Thus, we propose that investigations of speech rhythm will benefit from a greater range of complementary measures, including physiological recordings. The current project explores respiratory effort as a contributing factor in determining speech rhythm. Participants underwent simultaneous inductive plethysmography and acoustic recording while producing speech spontaneously or by reading texts aloud in single and dyadic (joint) conditions. Speech-associated breathing patterns were analysed in conjunction with traditional linguistic annotative approaches to speech rhythm using neighbourhood component analysis and generalized linear mixed models. The data indicate that both the duration of inhalations and the temporal boundaries between inhalations and subsequent vocalisations are flexible and responsive to structural timing constraints, such that the interval between the end of an inhalation and the following stressed vowel onset (but not between a stressed vowel and its subsequent inhalation onset) lengthens in the presence of a quasi-regular beat, which was experimentally introduced via reading rhyming poetry and counting aloud. Moreover, the extent to which partners coordinate their breathing and vocalisations during joint speech also appears to vary according to rhythmic context, with performance in both domains improving during beat-based speech in comparison with reading prosaic, non-beat-based texts or producing spontaneous speech. These preliminary results are interpreted with a focus on the temporal relationship between inhalation events and previously proposed rhythmic units (e.g., inter-stress interval, p-centre, syllable), underscoring breathing as a necessary, yet often overlooked, component in speech rhythm planning and production.

Rhythmic synchronization ability predicts performance on a melodic intonation therapy task 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 synchronization in many clinical populations with language related deficits, such as aphasics and dyslexics. In this study, we explored the relationship between rhythmic synchronization ability, performance on the MIT task, and reading fluency and comprehension in healthy English- and Mandarin-speaking adults. We assessed rhythmic synchronization by asking subjects to synchronize taps with a metronome that exhibited occasional tempo and phase perturbations. We used three different base tempi (2 Hz, 2.5 Hz, and 3 Hz), and manipulated direction (negative and positive) and size (8%, 15% and 25%) in the phase and tempo perturbation conditions. Subjects were instructed to synchronize taps to every tone in the rhythmic stimuli as accurately as possible. Rhythmic synchronization performance was assessed by phase variability immediately following the perturbation. 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' ability to synchronize with a perturbed metronome correlates strongly with performance on the MIT task, and synchronization performance 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.

Does passive action improve rhythm perception? Use of electrical muscle stimulation for beat interval perception task

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Moving to the beat"" has been shown to improve rhythm perception, such as tapping to the beat improves the perception of timing [Manning & Schultz, 2013], and moving bodies affects how we perceive the meter [Phillips-Silver, Trainor, 2005; 2007; 2008]. While the previous studies have focused on the effect of voluntary movement on rhythm perception, the effect of non-voluntary passive movement on rhythm perception has not been clarified. In this study, we used the electrical muscle stimulation (EMS) to investigate whether a non-voluntary passive body movement improves our rhythm perception.

Nine individuals (five male, age = 21~29) participated in this study. The Beat Interval Test in the Harvard Beat Assessment Test [Fujii & Schlaug, 2013] was used to assess the perception threshold of beat interval changes. We electrically stimulated the finger flexor muscles of the participants and they were asked to discriminate whether the inter-stimulus interval is getting faster or slower in the test. To compare if passive body movements affect the beat interval perception, we used the EMS in two conditions; one elicited the finger movements with the EMS (i.e., passive movement condition) and the other stimulated the muscles while constraining the finger-joint movement (i.e., non-movement condition).

We performed Wilcoxon Signed Rank test to compare the perception thresholds between the two conditions. As a result, we found that the participants showed better beat interval discrimination in the passive movement condition compared to the non-movement condition ($p = 0.018$). This result suggests that not only voluntary movement but also non-voluntary passive body movement may improve rhythm perception.

Neural mechanisms underlying sensorimotor synchronization with different forms of rhythms

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Neuronal activity, like behavior, synchronizes with periodic rhythms, reflecting beat perception. Regular auditory beats elicit a periodic neural response at the exact frequency of the beat, which is hypothesized to reflect the neural entrainment underlying beat perception. However, neural activity exhibits a form of non-periodic rhythm known as fractal fluctuations. According to the complexity matching hypothesis, during sensorimotor synchronization with fractal rhythms, fluctuations in neuronal activity should match the stimuli's fluctuations but remains untested. This project will address this question by using an innovative approach based on nonlinear dynamics and complex systems to tackle neural and motor properties of entrainment to auditory rhythms presenting fractal fluctuations. Our central hypothesis is that the amplitude envelope (AE) from electroencephalography (EEG), interbeat intervals (IBIs), and intertap intervals (ITIs) from a pressure sensor will match to varying degrees during sensorimotor synchronization with non-periodic metronomes. We expect complexity matching to be maximal with the fractal metronome because it presents biologically relevant fluctuations. Data for the present study is currently being collected and processed. We plan to collect behavioral (finger tapping ITI, pressure sensor) and cortical (EEG) data from 20 healthy young adults. Each participant will undergo the following conditions: resting state, self-paced tapping, and tapping in synchronization with periodic, random and fractal metronomes. Each condition will last 5 minutes, with as much rest as needed between conditions. Electroencephalography data are recorded using a 128-channel Geodesic Sensor Net placed on the scalp sampled at 1000 Hz (128-channel high-speed amplifier, EGI Net Amps 400), and tap events are recorded using a pressure sensor. Complexity of ITIs, IBIs and AEs will be assessed using detrended fluctuation analysis (DFA). This research will answer important questions about the relationship between the perception of and synchronization with scale-free (biologically relevant) stimuli, which must be addressed by theories of sensorimotor timing.

Does musical stimulation during slow-wave sleep potentiate slow oscillations and associated declarative memory performance?

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Slow oscillations (SOs), the hallmark of slow-wave sleep, are known to play an important role in memory consolidation. Appearing as high-amplitude, low-frequency electroencephalographic activity, SOs contribute to memory consolidation by synchronizing neural activity between brain regions, including the hippocampus and neocortex. Boosting SOs through methods such as non-invasive brain stimulation and closed-loop rhythmic auditory stimulation has been shown to improve declarative memory consolidation. Exposure to music during sleep may also improve sleep quality, as measured by self-report. However, few studies have used quantitative measures to explore the impact of music processing on sleep quality. Our hypothesis is that the boost in SO power induced by rhythmic auditory stimulation will also be observed when sleepers process musical stimuli with a strong 0.8 Hz beat (corresponding to the peak frequency of SOs). In turn, this boost in SO power is predicted to improve declarative memory performance, consistent with the documented relationship between declarative memory and SO power. To test this hypothesis, participants took two 90-minute naps while exposed to either a piece of music at ~48 BPM (corresponding to 0.8 Hz), or a constant white-noise control stimulus. Brain activity during sleep was measured through polysomnography. Stimulation began at the onset of stable stage 2 sleep, presented in short periodic blocks, with silent intervals included to evaluate endogenous persistence of SO entrainment. Declarative memory was assessed using a paired word association task, during which participants learned and subsequently recalled ~50 associated word pairs, with unique counterbalanced lists across sessions. Polysomnographic data is being analyzed to measure slow oscillation amplification, and memory task performance between sessions will be compared. Overall, the findings will indicate whether music is an effective stimulus for memory consolidation.

Synchronized musical performance and social bonding

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Rhythm and synchronization, Ensemble or group performance "Music is found universally in all known human cultures including both primitive and industrial societies. Music is also a form of social communication that is often synchronized (e.g. playing at the same time) with another participant or to an external time-piece. In large groups, synchronized drumming (Dunbar et al. 2012) and singing (Weinstein et al. 2016) have been shown to be socially bonding. Yet, it is unknown if other forms of synchronized music may also promote social bonding, potentially recruiting endorphin reward systems in the brain (Tarr et al. 2014). Thus, we investigated whether alternative kinds of music-making promoted social bonding, such as synchronized piano playing among trained pianists.
Here, in accordance with Boiteau et al. (2014), pairs of skilled pianists (i.e. > 5 years of experience) were instructed to improvise on “chopsticks” with another participant. Pairs performed four 10-minute experimental conditions: synchronous playing (i.e. two subjects playing music at the same time), asynchronous playing (i.e. one playing subject and one listening subject), a synchronous non-musical control condition (i.e. playing the cooperative game ‘Jenga’ together), and an asynchronous non-musical control condition (i.e. playing ‘Jenga’ separately). Subjects were pre- and post-tested using a standard battery of pain-threshold measures (i.e. blood pressure cuff inflation, as a proxy for endorphin activation) and self-reported relationship closeness measures (Tarr et al. 2016). As predicted, subjects experienced greater social bonding and endorphin activation in the synchronous musical condition compared to the asynchronous musical condition. In summary, this finding suggests that synchronized instrumental music can facilitate social cohesion among pairs of strangers.

References

Boiteau et al. (2014). J Exp Psychol Gen 143(1), 295-311. Dunbar et al. (2012). Evol Psychol, 10(4), 688-702. Tarr et al. (2016). Evol Hum Behav 37(5), 343-49. Tarr et al. (2014). Fron Psychol 5(1096), 1-10. Weinstein et al. (2016). Evol Hum Behav 37, 152-158.

A comparison of neural entrainment obtained with vibrotactile and auditory rhythms

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Perceiving the beat is an integral part of our experience with music. A proposed mechanism for this ability in the temporal structure of low-frequency neuronal oscillations which have been shown to entrain to the frequency of the beat. Research has demonstrated that temporal processing of a beat is superior in auditory compared to visual modalities. However, vibrotactile rhythms may serve as another important point of comparison. A small number of recent studies have found that performance in sensorimotor synchronization (SMS) tasks is equivalent for vibrotactile and auditory rhythms given the right conditions. No research to date has examined neural oscillations in the context of vibrotactile rhythms.

In the current study neural entrainment and SMS were assessed for rhythms presented in auditory, vibrotactile and multimodal conditions. The rhythms varied in their complexity: metronomic (i.e., isochronous beats) or simple (i.e., isochronous beats with metrical subdivisions). SMS was assessed using a tapping task and indexed by tapping variability, neural entrainment was observed using electroencephalography (EEG) in a passive listening task. Behavioral and neural data were assessed using multi-level modeling and a priori planned contrasts.

Behavioral results revealed that multimodal SMS was superior to auditory SMS and vibrotactile SMS. These modality effects were moderated by rhythmic complexity. For metronomic rhythms, auditory SMS was comparable to vibrotactile SMS, but for simple rhythms, auditory SMS was superior to vibrotactile SMS. EEG results showed that multimodal neural entrainment was marginally better than auditory neural entrainment, which was in turn marginally better that vibrotactile neural entrainment. These results replicate prior behavioral work and provide new electrophysiological evidence for the auditory advantage in beat perception. Moreover, they also suggest that multimodal rhythms may enhance the temporal acuity of beat

TAMSIN and the separability of motoric and rhythmic sequencing and performance: A neural network model

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Many complex actions (e.g. writing and speaking) are precomposed, by sequencing simpler motor actions. For such an action to be executed accurately, those simpler actions must be planned in the desired order, held in working memory, and then enacted one-by-one until the sequence is complete. In addition, humans learn and perform rhythm-based motor sequences regularly, where both a motoric and a temporal sequence plan must be enacted simultaneously.
It has been shown that people can learn motoric and time interval sequences separately and then combine them or learn a combined sequence and then separate the disparate sequences with little trouble (Ullén & Bengtsson 2003). Also, functional MRI data suggest that there are distinct sets of neural regions responsible for processing the two different sequence types (Bengtsson et al. 2004). Since few computational models exist to extend and inform our understanding of the neural bases of these phenomena, we introduce the TAMSIN (Timing And Motor System Integration Network) model, a systems-level neural network model designed to replicate rhythm-based motor sequence performance. TAMSIN utilizes separate Competitive Queuing (CQ) modules for motoric and temporal sequencing, as well as modules designed to coordinate these sequence types into a cogent output performance consistent with a perceived beat and tempo. The separate CQ modules – in addition to task-dependent competitive gating mechanisms – allow the model to perform a sequence with only temporal variations, only motoric variations, both, or neither.
Here, we shall detail the structures in the TAMSIN model that allow for tempo and task invariance in performance, present the results under those conditions, and then compare those results to behavioral and imaging data from the literature. Lastly, we discuss future modifications that could be made to TAMSIN to simulate aspects of rhythm learning, rhythm perception, and disordered productions such as those seen in Parkinson's disease."

Use of electrical muscle stimulation for learning rapid drumming movements: An exploratory study

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Expert drummers can produce extremely rapid rhythmic movements. For example, the winner of a world's fastest drummer contest achieved a record of 1208 beats per minute, which is the equivalent to maintaining 10-Hz rhythmic movement with each hand over the 60 sec. Acquiring this skill is incredibly difficult for untrained individuals. Here, we investigate whether training using electrical muscle stimulation (EMS) can assist untrained individuals to learn these rapid rhythmic movements. As an exploratory study, we trained four participants that were new to drumming. Half of them were trained using an EMS system we developed, and the other half were trained without the EMS. They were trained 3 days, performing 48 trials in a day. In a single trial, participants were asked to tap as quickly as possible for 10 sec with one hand. The participants who used the EMS received the stimulation in half of the trials. One of the EMS-trained participants was provided with a constant 10 Hz stimulation across 3 days, while the other received a 6 Hz EMS stimulation on the first day and gradually increased up to 10 Hz stimulation on the last day. We calculated the number of beats in each trial. To assess the learning rate over the complete study duration, we fit a line over each participant's trials.

We found out that the participant trained by means of gradual EMS showed the higher rate of increase of number of taps (the slope of the fit was 0.5575) compared with the participant who trained with the constant 10-Hz EMS (slope was -0.0535). The without EMS had lesser of a learning effect (slopes were 0.1194 and 0.3839). These results suggest that gradually increased EMS may help to acquire the rapid drumming skill efficiently.

Beat-based scoring systems of rhythmicity of different speaking styles from speech contexts belonging to stress and syllable-timed languages

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Vocal rhythm is defined as groups of beats which include the suprasegmental properties of speech signals (such as stress, pitch and intensity). Tracking such beats is often done in Music Information Retrieval, analysis of audio performance and detecting tempo of rhythm. Most existing studies attempt to automate beat induction - timing human movement in accordance with musical beats during listening. However, automating beat induction of some speech contexts (i.e. poetry and oratory) uttered in particular speaking styles (melodic chanting of joint speech and tonal recitation) has not yet been fully explored. Therefore, this study investigates the use of an onset detection approach (finding the peak of pulses using spectral flux) to track rhythmic pulses (i.e. beats) in such contexts in five languages (Arabic, Farsi, Spanish, English and Chinese) that are categorized into three rhythmic classes of world languages (syllable-timed, stress-timed and mora). The direct objective of this study is to use a beat-based scale to assign a score to determine the range of rhythmicity of each speech context (normal recitation of poetry, melodic chanting of joint recitation and oratory recitation). This scale varies from (1) isochrony (a rhythmic pattern where all intervals have roughly equal duration) to (2) semi-isochrony to (3) anisocronous (not isochronous). Scores are assigned across two stages: human scoring, automatic scoring and a comparison between human and automatic scoring. Automatic scoring is divided into four elements: detecting onset times; estimating periodicity (inter onset interval (IOI)), tempo (beats per second); and matching beat locations with the metrical structure of each context (i.e. timing and duration of poetic feet). Results of this study shows that joint recitation of poetry scores the highest rhythmicity (isochrony). Individual recitation of poetry is rated as semi-isochronous, and oratory is rated as anisocronous. Results of this study are expected to be a starting point for improving measurements of rhythmic entrainment of poetry using different speaking styles such as joint recitations. It is hoped that these results can be generalized to different speaking styles such as synchronous speech (i.e. turn-taking conversation).

Examining the effects of synchronization to different extrinsic rhythms in people with aphasia

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Aphasia is a language disorder that negatively affects communication abilities creating barriers to participation and quality of life (Cruice et al., 2006). An improvement in sentence-level linguistic output can help people with aphasia (PWA) to sustain functional communicative interactions critically contributing to PWA's well-being. Script training is a treatment method that can promote sentence-level functional communication by training sentences in either monologues or dialogs via intense rehearsal (Goldberg et al., 2012). Script training's mechanism of action is limited, as well is the understanding of the aphasia candidates that benefit most from it. Script training involves speech entrainment, or simultaneous mimicking of fluent speech. One key component of this entrainment is mimicking speech rhythmicity, evident in word stress, as to entrain it is necessary to detect, integrate and produce rhythmic signals (Phillips-Silver et al., 2010). Alternatively, synchronization to extrinsic rhythms, such as beats produced by a metronome, can also promote language recovery in PWA (Stahl et al., 2011, 2013) Distinct attentional mechanisms may be behind the positive effects of entrainment to those rhythm types: attention supports/enhances the perception of strong syllables (Pitt & Samuel, 1990), and strong predictable beats also receive more attention (Large & Jones, 1999). However, the benefits of these two types of rhythm have not been directly compared to date, and it is unknown whether extrinsic rhythms create greater benefits when they are aligned with speech rhythmicity or when they are steady. The current work therefore will seek to: (a) identify the effects of entrainment to extrinsic rhythms, both speech-aligned and steady and (b) determine language and cognitive measures are correlated with success in learning scripted sentences in PWA. This proposal will inform both mechanistic models and clinical practice about the effects of extrinsic rhythms in sentence-production in people with aphasia.

Glutamate levels in the caudate correlate with beat perception in patients with schizophrenia

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【Background】
Basal ganglia (BG) plays an important role in beat perception. Patients with schizophrenia have abnormal glutamate levels in the BG, which results in difficulty in beat perception. Higher glutamate levels in the BG could also explain poor response to antipsychotics in this population. However, it still remains unclear whether glutamate levels in the BG are related to the beat processing ability. Here, we investigated this relationship in patients with schizophrenia, stratified into treatment-resistant schizophrenia (TRS) and non-TRS based on antipsychotic response, and healthy controls (HC).
【Methods】
Fifty-eight patients with schizophrenia (27 TRS and 31 non-TRS) and 30 HC participated in this study. Glutamate levels in the right caudate were assessed with 3T proton magnetic resonance spectroscopy (PRESS, TE=35ms). Beat perception ability was assessed by the Harvard Beat Assessment Test (H-BAT). First, we compared the H-BAT scores among the three groups by one-way ANOVA and Bonferroni's post-hoc tests. Second, we conducted partial correlation analyses to examine the relationships between the H-BAT scores and glutamate levels controlling for severity of extrapyramidal symptoms, chlorpromazine equivalent dose, disease duration, and Negative Symptom subscale score of the Positive and Negative Syndrome Scale.
【Results】
There were significant differences in the beat perception ability among the three groups ($F(2,69)=7.85$, $p=0.001$). Compared with HC, TRS group had lower beat interval perception ability ($p=0.006$). In contrast, there were no significant differences in other comparisons. Further, the beat interval perception score in the H-BAT was correlated with glutamate levels in the caudate in patients with non-TRS ($r=-0.57$, $p=0.01$) while such a correlation was not found in patients with TRS or in HC.
【Conclusions】
Together with the previous literature, our findings suggest that abnormal glutamate levels in the BG may be involved in the pathophysiology of antipsychotic response and beat processing impairment in patients with schizophrenia."

Does moderate syncopation increase groove? The answer depends on the syncopation pattern

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Recent research points towards a relation between syncopation and groove (Witek et al., 2014; Madison and Sioros, 2014), i.e. the pleasurable sensation of wanting to move to music (Janata et al., 2012). We aimed at confirming the inverted-U shape relation found in previous research, using more controlled music examples (MEs). To this end, we asked twenty-seven participants to listen to and rate variations of MEs that only differ in their syncopation.

Ten short funk and rock loops consisting of drums, bass and keyboards were algorithmically transformed (Sioros and Guedes, 2014) to 1) remove the original syncopation, and 2) introduce various amounts of new syncopation: 25% (roughly equal amount to the original), 50%, and 70%. The MEs were produced using professional sound samples.

The participants rated the groove of the original versions higher than all the transformed versions, including the version with a similar amount of algorithmic syncopation, while the 50% and 70% versions had the lowest scores. Statistically significant differences were observed between 1) the original and the rest, and 2) the 25% and the 50% and 70%, but not between the 25% and the deadpan.

To understand this result, we compared the original and algorithmic syncopation. Our findings include: 1) The algorithmic syncopation is relatively uniformly distributed. In contrast, the original versions have less syncopated drums with almost no syncopated hi-hats. Certain metrical positions in the drums are never syncopated, e.g. the back-beat snare. 2) The original syncopation forms more and longer cross-rhythmic or metrically shifted patterns, as often encountered in the funk style (Danielsen, 2006). 3) The micro-timing alignment of sounds differs between versions.

This experiment concludes that groove is increased by syncopation, however, not every pattern will do. Our analysis calls attention to the complex nature of syncopation and its possible dependence on structural factors.

The interplay of interval and entrainment timing in duration perception

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Entrainment has been proposed to be essential to listeners' estimates of short time durations and prediction of onset timings. One of the most influential proposals is McAuley and Jones' framework (2003). They demonstrated that listeners' duration estimates were shifted from reality in opposite directions when to-be-judged durations occurred earlier than an entrained beat vs. later than an entrained beat, which is predicted by their entrainment models. Presumably, the entrainment effect built from the repetitive tones' influence on how subjects perceive durations afterward. However, their model did not specify how long the entrainment persists after the cessation of external stimulation. Here, we investigated the persistence of the entrainment effect in a duration estimation task. On each trial, participants first heard a series of six context tones with an inter-onset interval of 600 ms. After a short silent period, a pair of tones defining a standard interval were presented on beat and the other pair of tones defining a comparison interval were presented either early, on-time or late. After each sequence (context + standard + comparison), the participant judged if the comparison interval was shorter than or longer than the standard interval. We varied the delay length between the standards and comparisons as short delay (2 beats) and long delay (4 beats) to compare the magnitude of entrainment effects on subjects' response patterns. With a short delay, we found a response pattern similar to the prediction of the entrainment models, which replicated McAuley and Jones' finding. On the other hand, when there was a long delay, this pattern mostly disappeared. Our data suggest that the entrainment effect decreases somewhere between 2 to 4 beats delay, and thus, suggests the importance of adding a "decay parameter" to make entrainment models more complete to predict human duration estimation performance.

The influence of familiarity on beat perception and oscillatory entrainment

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Humans often spontaneously synchronize movements to a perceived underlying pulse, or beat, in music. Beat perception may be indexed by the synchronization of neural oscillations to the beat, marked by increases in electrical amplitude at the same frequency as the beat in electroencephalography (EEG) signals (Nozardan, Peretz, & Mouraux, 2012). Neural synchronization to the beat appears stronger for strong-beat than non-beat rhythms (Tal, et al., 2017), and has been hypothesized to underlie the generation of an internal representation of the beat. However, because we are exposed disproportionately to strong-beat rhythms (e.g., in most music) in the daily environment, comparisons of neural responses to strong-beat and non-beat rhythms may be confounded by relative differences in familiarity. Thus, in this study we disentangled beat-related and familiarity-related effects by comparing EEG responses during the perception of strong-beat and non-beat rhythms that were either novel or familiar. First, we recorded EEG to a set of strong-beat and non-beat rhythms. Then, subjects were familiarized with half of the rhythms over 4 behavioural sessions by listening to and tapping along with the stimuli. Finally, EEG to the full set of rhythms (half now familiar, half still unfamiliar) was recorded post-familiarization. Preliminary data show changes in EEG amplitude at beat-related frequencies between pre- and post-familiarization, suggesting that oscillatory entrainment is influenced by stimulus familiarity. Further analyses will characterize whether the contributions of familiarity are similar for strong-beat and non-beat rhythms.

A comparison of spontaneous motor tempo and variability when finger tapping, toe tapping and stepping on the spot in people with and without Parkinson's

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"Objective
Investigation of human Spontaneous Motor Tempo (SMT) has focused on either perceptual studies or motor activities to provide insight into endogenous timing mechanisms, whether cognitive or embodied. Parkinson's is a neurological condition in which timing is disturbed due to the depletion of dopamine producing cells in the basal ganglia. Attendant symptoms of Parkinson's include motor and non-motor activities. SMT has been most commonly studied using a finger tapping paradigm. However, this is not necessarily ergonomically or methodologically appropriate for people with Parkinson's (PWP).

Methods
This study compares finger tapping (FT), toe tapping (TT) and marching 'on the spot' (MS) as three distinct types of movement in PWP (n = 30), age matched controls (AMC; n = 24) and Young Healthy Controls (YHC; n = 36). A Stomp Box was used to collect tapping data, and two BioPac gait sensors collected heel strike data for comparable analyses for marching. Two trials of 40 secs were collected; the central 30 secs of both averaged for analyses. Coefficient of Variation (CoV) was used to compare within subject variability.

Results
All movement modalities were correlated. Between-groups differences were found in all movement modalities. FT, $F(2, 89) = 7.915$, $p = .001$ (PWP faster than YHC); TT, $F(2, 87) = 4.829$, $p = .010$ (PWP faster than AMC); MS, $F(2, 82) = 3.487$, $p = .035$ (PWP faster than AMC). Analyses of CoV a group difference for FT only, $F(2, 87) = 4.096$, $p = .020$. PWP were more variable than AMC ($p = .017$).

Conclusion
This study provides the first direct comparison of SMT between different types of movement modality in people with Parkinson's and two control groups. Results suggest SMT is generally faster in Parkinson's, and that finger tapping is less stable than other measures of SMT for people with Parkinson's.

Do low-pitched rhythms facilitate beat detection?

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In music, timing information is often assigned to low voices, such as the bass drum or bass guitar. Recent studies have suggested that this compositional tendency might be attributable to human processing biases. Specifically, compared to high pitch, rhythms presented in a low pitch elicit stronger neural entrainment, more phase correction in a tapping task, and greater spontaneous behavioral entrainment. However, conflicting reports in this area have raised questions about the task contexts within which this low pitch advantage emerges (e.g. Lenc et al., 2018). Low-pitch timing superiority may arise only when sensorimotor processes are recruited, such as in beat and metrical tracking, as opposed to all contexts that require temporal encoding. To date, behavioural advantages have only been documented using tasks involving moving to the beat. Here we investigate whether low-pitch timing superiority extends to performance on a rhythm perception task that does not involve movement. The present study uses the beat detection task developed by Manning and Schutz (2013), in which participants hear a beat-establishing context, followed by a period of silence, followed by one final beat on each trial. The final beat is either presented on time or offset by 15 or 30 percent (early or late). Across 96 trials, the stimuli are presented at either a low or high pitch (130 and 1236.8 Hz, respectively) loudness-adjusted to be perceptually equal to pilot listeners when presented through the experimental apparatus. We expect that participants will perform the best in the low-pitch context, which will provide further support for the low-pitch timing superiority hypothesis in tasks that recruit beat-based processing.

“Eye” Spy: Eye tracking evidence that eye-movements synchronize with visual and audio-visual rhythms

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The field of entrainment to environmental rhythms demonstrates vision’s role in action coordination. Visual tracking increases the coherence between participants’ movements and environmental stimuli for both intentional and unintentional coordination. Interestingly, eye-movements in response to visual rhythms have not been studied for signs of rhythmic planning or synchrony of the eyes to environmental rhythms. In a series of eye tracking experiments, eye-responses to apparent-motion characters presented either with rhythmic or random timing (between-subjects), but with the same predictable 6-location spatial pattern, were explored. The studies all consisted of 12 blocks of trials with 4 repetitions of the pattern per block. The first look to each location was classified as either anticipatory or reactive relative to the image’s appearance. In Experiment 1 (N=32), adults’ anticipatory-looks were closer to the onset of the silent characters in the rhythmic condition (M= -200.26ms) compared to the random condition (M= -249.12ms) ($F(1,30)=7.55$, $p=0.01$), when a distracting object was present. Adults used the visual rhythm to decide when to disengage from the distracting object to anticipate the next character’s appearance. Experiment 2 used a tweeting bird with the audio-visual stimuli presented synchronously, again the stimuli’s timing were either rhythmic or random (between-subjects) and a distracting object was present. When examining the timing of the anticipatory-first-looks relative to the bird’s appearance, the results, thus far (N=31), indicate the rhythmic condition (M= -56.76ms) produced looks closer in time to the onset of the bird compared to the jittered condition (M = -123.91ms) ($F(1,29)= 9.73$, $p=0.04$). The audio-visual experiment’s anticipatory looks are closer to the image onsets than in the visual only experiment. The findings across experiments indicate adults’ use rhythmic timing above and beyond spatial regularities to accurately plan eye-movements when tracking rhythmic stimuli. Future directions for this line of eye tracking research will also be discussed.

Rhythmic priming: A stimulus-brain coupling analysis in adults with dyslexia and matched controls

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Music and language contain rhythmic regularities that allow for temporal prediction. The regularity of music rhythm makes it an ideal stimulus to entrain neural oscillations, and research has shown that the brain oscillates to frequencies present in the stimulus. The dynamic attending theory (DAT) predicts that entrained oscillations persist after the external stimulus has stopped, suggesting that entrainment to rhythmic stimuli can influence subsequent perception. Indeed, research has shown that speech perception can be influenced by a previous rhythm, via increased stimulus brain-coupling. Research has also shown that neural rhythmic entrainment to the beat is atypical in individuals with dyslexia. In the present rhythmic priming study, electroencephalography was recorded to investigate whether (1) the brain responds in a non-linear way to the beat level of a rhythmic stimulus; (2) regular compared to irregular rhythmic primes influence subsequent speech perception in a grammaticality judgement task; and (3) these results differ for control and dyslexic adults. Controls (n = 12) and dyslexics (n = 13) showed enhanced stimulus-brain coherence to regular compared to irregular rhythms, and a non-linear transformation was observed between stimulus and neural representation wherein the beat level was overrepresented in the brain compared to the acoustic signal. There were no differences between groups in stimulus-brain coherence. However, an FFT analysis of the EEG data revealed that while the boosting of the beat level (2Hz) in the neural representation was visible for controls, dyslexics showed a more linear transformation of the sound acoustic features, with a greater response to the 4Hz acoustic information. For the target sentences presented after the rhythmic primes, preliminary data suggest that stimulus-brain coherence was enhanced at the 2Hz, stressed syllable rate after regular compared to irregular primes for dyslexics. These results will be discussed in relation to DAT and observed rhythmic processing deficits in dyslexia.

Effect of fractal music and metronome on gait in people with Parkinson's disease

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Rhythmic entrainment can guide gait in people with Parkinson's disease (PD), who are impaired in their ability to produce internal rhythms. Traditional rhythmic auditory stimulus (RAS) signals are periodically structured, which do not account for the fractal fluctuations of healthy human movement. We used two novel auditory stimuli 1) Fractal On-Step (FOS) which was fractally structured with cues for each step and 2) Fractal On & Between Step (FOBS) which was fractally structured with cues for each steps and between-steps. Fifteen people with PD (67.9 +/- 9.2 years old), and 15 older adults (69.5 +/- 11.2 years old) walked around a 200m indoor track with footswitches in their shoes to record stride times. Participants walked under 3 conditions for 15-min each: first, baseline without auditory stimuli, then FOS walking and FOBS walking in a randomized order. Participants were instructed to match their steps with each beat in the FOS condition, and to every other beat in the FOBS condition. Participants filled out a questionnaire at the end to assess self-reported difficulty and enjoyment in synchronizing to the stimuli. DFA was applied to stride intervals, and a two-way ANOVA (groups x conditions) was conducted. There were no significant differences between groups, but DFA was significantly higher in the FOS condition compared to baseline ($t(27) = 2.309$, $p = 0.029$). Self-reported enjoyment was significantly higher in the FOS condition, as compared to FOBS, and difficulty was significantly higher in the FOBS condition, as compared to the FOS condition. FOS (i.e., metronome-like auditory stimulation) seems more beneficial to improve fractal dynamics in people with PD. Self-reported enjoyment also favors the FOS stimulus, probably because FOS presented a stronger beat. Future studies should evaluate the efficacy of a FOS-based training program to improve gait stability and gait adaptability in people with PD.

Timing is everything… or is it? Effects of timing style and timing reference on guitar and bass sound in groove performance

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In addition to tempo, rhythmic pattern, and expressive timing, sound parameters such as timbre, intensity, and duration are fundamental to the production and perception of timing styles in groove-based music.
21 professional guitarists and 21 bassists performed a simple groove pattern in three different timing styles: a) Laid-back, b) Pushed, and c) On-beat relative to an isochronous timing reference (96bpm) presented with: i) woodblock (metronome), and ii) drum-kit sounds (instrumental backing-track). Onset location and three descriptors – duration, sound-pressure level (SPL), spectral centroid (SC) – previously shown to affect perceived timing (Danielsen et al., 2019; Villing, 2010) were extracted from the recorded audio of each instrument.
RM ANOVAs were conducted with Style (Laid-back, On-beat, Pushed) and Reference (Metronome, Instrumental) as independent, and Onset, Duration, SC and SPL as dependent, variables. For onset, significant main effects of Style and Reference were found for both instruments. Regarding the sound descriptors, significant main effects of Style were found on duration and SC for guitar, and on SPL for bass. For Reference, there was a main effect on duration and RMS for guitar, and on SC for bass. Interaction between Style and Reference was found on onset and SC (guitar only).
The results showed systematic differences in duration, SPL and/or SC between timing styles for both guitarists and bassists. Such a finding is in accord with previous research on drum instrument sound (Danielsen et al., 2015) and further supports the hypothesis that sound parameters are important in signaling the intended timing of an event in groove performance. The difference in mean onset location between the metronome and the instrumental backing-track can be related to the phenomenon of ""negative mean asynchrony"" from the tapping literature (Repp, 2005).
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References:
Danielsen, A., Waadeland, C. H., Sundt, H. G., & Witek, M. A. G. (2015). “Effects of instructed timing and tempo on snare drum sound in drum kit performance,” in Journal of the Acoustical Society of America. 138(4), 2301-2316
Danielsen, A., Nymoen, K., Anderson, E., Câmara, G.S., Langerød, M.T., Thompson, M., and London, J. (2019). “Where is the beat in that note? Effects of attack, duration and frequency on the perceived timing of musical and quasi-musical sounds.” In Journal ofExperimental Psychology: Human Perception and Performance (in press).
Villing, R.C. (2010). Hearing the Moment: Measures and Models of the Perceptual Centre. Phd Thesis, Department of Electronic Engineering, National University of Ireland Maynooth.
Repp, B. H. (2005). “Sensorimotor synchronization: A review of the tapping literature,” in Psychonomic Bulletin & Review, 12(6), 969–992."

Analysis of the variability of the counting pace of stuttering people

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This study assesses the effect of a speech disorder, namely stuttering, on the ability to maintain a steady rhythm. The performance of a group of adult stutterers (n = 21) is compared to that of a group of adult non-stutterers (n = 24) during explicit counting activities. There are three counting paces (every 800 ms, 1200 ms or 1600 ms) and three experimental conditions (count silently, count orally and count orally in the presence of an assistant).
The results for temporal variability show lower performance (higher Weber ratio) when participants count silently and when they have to deal with very long intervals (1600 ms). There is no main effect of group, but the interaction between the experimental condition, the counting pace and the group is significant. Adult non-stutterers are better than adult stutterers in the silent and long time-interval condition (1600 ms). This finding could be interpreted as an indication of a greater limitation in memory for temporal information in stuttering people.
Finally, the experiment shows that adult stutterers have a significantly higher situational anxiety score than adult non-stutterers. This result is consistent with the scientific literature indicating the high level of anxiety experienced by stutterer people.

Does corticospinal excitability fluctuate when listening to isochronous rhythms?

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Perception of rhythmic auditory stimuli, such as musical beat, activate motor areas of the brain. Neuroimaging studies show greater activation of areas such as the basal ganglia, supplementary motor area, premotor cortex, and cerebellum while listening to rhythms compared to rest, in the absence of movement. Additionally, magnetoencephalography has shown that isochronous stimuli induce oscillations in excitability (the readiness of neurons to fire) that are similar in motor and auditory areas. However, the role of the motor system in perceiving rhythmic stimuli remains unclear. One hypothesis is that oscillations in motor (corticospinal) excitability may be involved in the spontaneous internal generation of the beat that arises when hearing beat-inducing rhythms. Here we investigate whether corticospinal excitability fluctuates in response to an isochronous rhythm, and whether that fluctuation is greater during internal generation. Participants listened to a 10-tone isochronous stimulus without moving. When the sequence finished, participants imagined a further 3 tones, then a fourth tone ended the sequence. To measure excitability, motor evoked potentials (MEPs) were collected using transcranial magnetic stimulation (TMS) over primary motor cortex. TMS pulses were delivered at various time points during each trial and the amplitude of the MEPs across time points was concatenated to assess excitability changes over several intervals. These MEP amplitudes were fit to a cosine wave to quantify oscillations in excitability during intervals marked by external tones versus internally generated tones. We predicted that excitability would fluctuate in phase with the tones, with higher excitability at tone onsets and lower excitability between onsets, and that this would persist during imagined tones. Our findings clarify the role of the motor system in auditory sequence processing, and its relationship to beat perception in rhythm.

Preference for simple ratios in the relative phase of bimanual rhythmic tapping

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The provenance of musical structures such as pitch, harmony and evenly spaced metric subdivisions is an oft-debated question. With respect to rhythm and meter, dynamic accounts based on the formal constraints or geometry involved in synchronizing periodic movements predict that not all phases are born equal. For example, coordination is more difficult for anti-phase than in-phase. Anti-phase is where one effector completes a cycle when the other is at its half way point (1/2) of its cycle. Music typically has richer structures than simple in- and anti-phase relations. Here we investigated the dynamic properties of bimanual synchronization at other phases, such as one hand tapping at the quarter (1/4) of the cycle of the other hand, or the third (1/3), to two fifths (2/5), etc. We instructed participants (N=12) to maintain different phase relations of bimanual tapping while performing a synchronization-continuation task. Each trial started with phased auditory cues for each hand. After cuing discontinued, participants' task was to maintain the same phase while increasing the tapping rate. Thus, we probed the stability of different initial phases because, as expected, increasing the rate of tapping leads to increased variability and eventually to a transition to in-phase tapping. Importantly, the instructed phases were sampled from a theoretic hierarchy of ratio complexity, the Stern-Brocot tree, generating ratios in the range from 0/1 (in-phase) to 1/2 (anti-phase). We found that coordination stability across trials was accounted for by the hierarchical model of ratio complexity better than by the absolute distance to in- and anti-phase or by the asynchrony. Thus, the ease with which people can maintain a bimanual pattern of tapping can be explained by the theoretical complexity of the temporal relationship, providing further insight in how rhythm and meter in music are constrained by synchronization dynamics.

Musical leadership: exploring the biopsychosocial sole of influence in facilitating socio-temporal synchrony during musical interactions

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The purpose of this research is to better understand the influential behaviours and mechanisms that give rise to sensorimotor and interbrain synchrony during musical joint action, as well as how these behaviours manifest as socialised perceptions of leadership. Unlike the leader-follower dichotomy commonly associated with most musical scenarios (conductors, soloists, front-men/women), it is hypothesised here that the underlying mechanisms responsible are far more complex and interdependent. Musicality provides a particularly striking form of joint action, as it requires the transfer, prediction of, and adaptation to sensory (auditory, physical, visual) information between independently acting entities. Furthermore, this information flow necessitates a shared perception of temporality and intentionality, and therefore collective consciousness – namely, an awareness of 'self' and 'other'.

The first stage of this research has been to design a baseline experimental model, which applies the well-documented finger tapping study paradigm, to observe the transfer and prediction of non-verbal, rhythmic information flow between dyads, as well as observe how they adapt their rhythms to maintain synchrony. This baseline model is intended to test the efficacy and replicability of both the approach's methodology and analysis, in order to be expanded upon for more dynamic musical behaviours, alongside data recorded from EEG or motion capture. Couples will first have to entrain to a metronome stimulus, which will eventually fade out, leaving the participants to attend only to each other's taps. All input/output channels and musical/auditory parameters will be manipulated and recorded using a specially designed code in Supercollider (IDE for audio synthesis and algorithmic composition). The data collected from the participants taps will be recorded both as audio data and time series data, the latter of which can then be analysed using a MatLab toolbox called Multivariate Granger Causality, to make predictions about the direction and influence of information flow between participants' time series.

Timing and drummers' movement: A novel methodology for performance analysis

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Timing is an important aspect of groove music. The relationship between musicians' body motion in performance and timing is, however, as yet not well understood **Timing and drummers' movement: A novel methodology for performance analysis**. In the present study we recorded movement of 20 drummers performing the same rhythmic pattern under four different timing instructions: natural, on-the-beat, laid-back and pushed. Motion capture data synchronized to audio recordings of their performances were collected as part of a larger experimental project. This presentation focuses on our method for analyzing motion capture data. The aim of the analysis is a) to identify common movement strategies for sub-groups of drummers, and b) to identify strategies for achieving the four different timing conditions across drummers.

In this presentation we focus on the movement of the left arm, and particularly on the preparation and rebound phase of the snare strokes. To explore and analyze the data without statistically testing a priori hypotheses about specific performance techniques, we combined existing practices from different disciplines into a novel methodology. First, we reduce the data into motion templates (Müller and Röder 2006). We design a set of 22 binary features to describe the movement of the arm. Second, we perform a phylogenetic analysis of the motion templates, in which we identify clusters within each timing condition. A comparison between clusters reveals differences in the coordination of the participants' movements that correspond to the different performance strategies. Preliminary analysis has shown distinct clusters within all timing conditions that differ in specific features. For instance, we observe three groups of participants within the "natural" condition that differ in the flexion of the wrist and elbow.

Besides our findings we will present the details of the methodology, which can be applied in the study of music-related movements beyond the scope of this project.

Determining tempi: What compositional approaches to rhythm constrain performer interpretation?

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The selection of a tempo is a crucial decision, particularly when playing music written before widespread adoption of the metronome. Why do some compositions "feel right" at specific tempi, whereas others afford a wide range of interpretations? J.S. Bach's Well Tempered Clavier provides a particularly interesting case study in this issue, for although it has been reprinted numerous times and recorded extensively, his "indented tempi" remain elusive. In his liner notes András Schiff (2011) openly confesses to wondering "what is the right tempo . . . and how do we find it?" Renowned artists have disagreed strikingly on interpretation—Glenn Gould recorded the E minor Fugue at twice the tempo of Rosalyn Tureck, and Anthony Newman the B minor Prelude at three times that of Fredric Gulda. Willard Palmer's landmark survey of tempi used for these pieces affords a novel opportunity to explore this intriguing issue.

Palmer's study covers 20 authoritative interpretations –13 albums, 5 notated editions, and 2 commentaries. This offers a fascinating glimpse into the complex relationship between compositional structure and performance interpretation. To contribute to this important topic, we calculated rhythmic variability using the normalized Pair-wise Variability Index (nPVI), and compared it with performer agreement regarding tempo—as defined by the standard deviation of tempo choices. Our analysis revealed that pieces with high rhythmic variability led to strong tempo agreement and pieces with low rhythmic variability (i.e. isochronous) led to low tempo agreement. Our talk will discuss how this intriguing data set sheds light on how listeners' emotional responses are governed by a complex interaction between a composer's choices of rhythms in conjunction with performer's decisions around tempi. An interactive visualization is now available online at www.maplelab.net/bachTempi.

PP HH AA SS EE OR E P H A S: An observation of perceptibility of rhythmic manipulations in Steve Reich's phase and systemically rotated compositions

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This project will observe the rhythmic manipulations in Steve Reich's early compositions, especially "Come Out," and "Clapping Music." Clapping Music (1972) employs ambiguous compositional techniques, reminiscent of Reich's early phase pieces, which enable listeners to perceive rhythmic interaction as a shift or rotation of one rhythmic unit—exploring how many ways additive patterns can be heard, the propensity for individual interpretation. In Reich's music, the manipulation that moves the patterns out of alignment varies depending on the work and tempo and affects how the listener perceives it. Could one who was exposed to the theories of phase rhythm acknowledge a different pattern in these works than one who encounters them with no prior knowledge?

A more distinct separation between these two types of techniques—phase-shifting and deliberate rhythmic rotation—is necessary. It should be acknowledged that while utilizing the same directional manipulation, whether during a shift of the two (or more) parts or a systematic choice to factor in different permutations of the relationship that can occur when rotating one rhythm against itself, there needs to be a fine distinction. Manipulations, including a phase-shift and a systemic-rotation, though their direction and form are identical will be strictly categorized as separate because of the speed at which they occur. Highlighting the similarities and differences between the manipulations in both pieces, examples will be used to demonstrate the amount of time required for a manipulation to be perceivable by the listener.

Guidelines for further research are suggested based on a review of terms involved with rhythm perception. Because organizational perception defines these pieces, to truly understand the compositions the musical perception of them must be more clear. To confirm whether such a fine perceptual difference exists between phase shifting and rotating, a self-report survey of classically trained musicians could help determine if there is a consistent split in how these patterns are perceived. A pilot of this self-report survey was run, and further data will be collected.

Influences of cultural familiarity and metrical complexity on sensitivity to musical meter

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In Western cultures, musical meter is thought to be hierarchical, with recurring isochronous patterns of stronger (downbeat) and weaker (upbeat) events. Rhythms that conform to isochronous meters tend to be made up of intervals having simple-integer ratios such as 1:1 and 2:1. By contrast, many non-Western musical cultures have both isochronous and non-isochronous beats and metrical structures, and rhythmic ratios such as 3:2 are more common. Previous evidence suggests that non-Western listeners have difficulty finding the beat and synchronizing to non-isochronous, non-Western music and rhythms. We examined whether this difficulty arises from a lack of familiarity with the musical style, or from a lack of familiarity with complex meter and ratios.

We presented English-speaking U.S. university students with clips of familiar (U.S./British) and unfamiliar (Turkish) pop music with simple (isochronous) and complex (non-isochronous) patterns, paired with auditory metronomes that matched or mismatched the music at two metrical levels (beat and measure). Participants gave goodness-of-fit ratings. For the familiar isochronous music, participants gave the highest ratings of fit to metronomes that matched the music at both levels. For the unfamiliar isochronous music, participants gave higher ratings to beat-matching metronomes, but they did not exhibit sensitivity to measure-level matching.

For the non-isochronous music, participants again were sensitive to matching at the beat level but not at the measure level. This pattern held for both culturally familiar and unfamiliar music, suggesting listeners did not perceive multiple levels of meter in any non-isochronous music. Thus, listeners had difficulty perceiving multiple levels of meter in stylistically familiar but metrically unfamiliar music as well as in stylistically unfamiliar but metrically familiar music. These findings suggest that both stylistic and metrical familiarity influence listeners' ability to perceive multiple levels of musical metrical structure."

Investigating rhythm production and perception in traditional scandinavian dance music in non-isochronous meter: A case study of norwegian telespringar

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Certain traditional Scandinavian dance tunes are referred to as being in so-called asymmetrical meter– that is, the beats in the measure are of uneven duration. This study focuses on Norwegian telespringar, which is recognized for a type of asymmetrical triple meter featuring a systematic long–medium–short duration pattern at beat level (tactus). Telespringar is normally played on a Hardanger fiddle. The sound can be characterized as “flowing,” often with smooth transitions from one beat to the next. People familiar with the style of telespringar can nevertheless readily determine the temporal positions of the beats.
This study aims to get a better understanding of the rhythm in telespringar by investigating the relationship between the sound and performers’ body motion in a telespringar performance.
We report from a motion capture study where a fiddler playing telespringar on Hardanger fiddle and a couple dancing telespringar participated. Participants’ body motions were recorded using an advanced optical infrared motion capture system.
The motion analysis of the fiddler’s foot stamping – showing acceleration peaks corresponding to the points in time when the feet hit the floor – revealed a stable long–medium–short beat duration pattern. The dancers’ vertical hip motion showed the same consistent pattern. The analysis of bowing patterns – showing acceleration peaks corresponding to directional changes in the bow motion – revealed patterns related to the phrasing of melodic segments. The majority of the directional changes and their associated sonic events coincide with foot stamps and corresponding beat-positions. Remaining beat-positions were associated with melodic or ornamental onsets.
The results demonstrate the compound nature of the telespringar rhythm, which features a combination of several interacting forms of motion and corresponding sonic events. The results also support the view that rhythm perception is a fusion of auditory and motor sensations."

Beat perception develops slowly and is reflected by steady-state evoked potentials during context-induced perception of musical beat

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Entrainment Synchronous movement to music is often effortless, yet relatively little is understood about the mechanisms that underlie this ability. It is assumed that listeners perceive musical beat from regularly occurring events in the musical surface and sustain this percept once inferred. However, it is difficult to disentangle stimulus-driven processing of the music from internal perception of the beat, and no studies have done this with children to our knowledge. In one experiment, children (4-11 years), adolescents (12-17 years), and adults (18+ years) listened to a musical excerpt that strongly supported a particular beat pattern (context phase), followed by an ambiguous rhythm consistent with either beat pattern (ambiguous phase). During the final probe phase, listeners indicated whether a superimposed drum matched the beat of the ambiguous rhythm. Accurate performance required that participants perceive the beat in the musical excerpt and maintain that percept throughout the ambiguous rhythm, despite having no surface evidence to reinforce that percept exclusively. While younger children (4-7 years) did not perform above chance, older children (8-11 years) gave higher match ratings to probes that matched the beat of the context than to probes that did not match the beat of the context. Performance did not reach adult-like levels until 12-14 years, suggesting the ability to maintain a beat continues to develop through adolescence. In another experiment, we used electroencephalography to investigate whether steady-state evoked potentials (SSEPs, electrocortical activity at the frequency of a periodic stimulus) reflect beat perception. SSEPs during the ambiguous phase had higher amplitudes at frequencies corresponding to the beat of the preceding context, and the amplitude of the beat-related SSEPs was predictive of whether or not participants correctly perceived the beat. These findings suggest that SSEPs reflect perception of musical rhythm and not just stimulus encoding of temporal features.