Society for Music Perception and Cognition
2009 Biennial Conference

August 3-6, 2009

Indiana University – Purdue University Indianapolis

Indianapolis, Indiana, USA

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Objectives of the Society (http://www.musicperception.org/)
The Society for Music Perception and Cognition is a not-for-profit organization for researchers and others interested in music perception and cognition. The objectives of SMPC are:

- to further the scientific and scholarly understanding of music from a broad range of disciplines, including music theory, psychology, psychophysics, linguistics, neurology, neurophysiology, ethology, ethnomusicology, artificial intelligence, computer technology, physics and engineering;
- to facilitate cooperation among scholars and scientists who are engaged in research in this interdisciplinary field; and
- to advance education and public understanding of knowledge gained.

*Sponsored by the **Society for Music Perception and Cognition***
*and the **IUPUI Department of Music and Arts Technology**.*
Additional support provided by the Department of Otolaryngology, Indiana University School of Medicine.

Keynote Speakers

Sandra Trehub

Dr. Sandra Trehub, Professor Emeritus at the University of Toronto and Director of the Auditory Lab at the Infant and Child Studies Centre in Mississauga, Ontario, has conducted many ground-breaking studies on the development of music, speech, and language in infants and young children. Dr. Trehub has published over 100 articles and book chapters on her research, which ranges from infants' sound detection and melody discrimination abilities to cross-linguistic and cross-cultural comparisons of maternal singing to infants. Her work has also been featured in many articles in the popular press.

Infancy: A musical history tour

The talk provides a glimpse of questions, findings, and conceptions of infant musicality over the past 35 years. The tour begins in the 1970s with the onset of systematic empirical research in this domain and ends with recent findings and work in progress. It also touches upon some of the big questions such as musical predispositions, early learning, and relations between music and language.

Elaine Chew

Dr. Elaine Chew, Associate Professor at the University of Southern California and Director of the Music Computation and Cognition Lab at the USC Viterbi School of Engineering, conducts research on music and computing. An operations researcher and pianist by training, her goal is to explain and de-mystify the phenomenon of music and performance using formal scientific methods. Her research centers on the mathematical and computational modeling of music; as a performer, she collaborates with composers to present eclectic post-tonal music. She received the NSF Career/PECASE Awards in 2004-05 for research and education activities at the intersection of music and engineering, and co-led a research cluster on analytical listening through interactive visualization at the Radcliffe Institute for Advanced Study in 2007-08. Dr. Chew co-chaired the program committees for the 2008 International Conference on Music Information Retrieval and the 2009 International Conference on Mathematics and Computation in Music, and was a Visiting Scholar at Harvard's School for Engineering and Applied Sciences and Music Department in 2008-09.

Music Computation and Cognition

This talk explores how mathematical and computational techniques can assist in the understanding, explaining, and modeling of music and music making. Mathematical formalisms express and communicate musical ideas in a culturally agnostic way for systematic study. Computation turns these formalisms into computer processes to automate the mimicking and examining of the musical products of the human mind. Examples featured include methods for analyses of music compositions and their expressive performance, and systems for improvising music and musical interpretations in partnership with computers.

Event	Time	Location (IUPUI Campus Center, unless otherwise noted)
Monday, August 3rd		
Registration	8:00 – 5:00	4th Floor Lobby
Welcome: Dr. Tonya Bergeson	10:00 – 10:10	450C
President's Address: Dr. Aniruddh Patel	10:10 – 11:00	450C
Session 1A: Performance I	11:10 – 12:30	450A
Session 1B: Genre	11:10 – 12:30	450B
Lunch		
Session 2A: Performance II	2:00 – 3:00	450A
Session 2B: Memory and Cognition I	2:20 – 3:20	450B
Break		
Session 3A: Music and Language I	3:40 – 4:40	450A
Session 3B: Memory and Cognition II	3:40 – 5:00	450B
Reception	5:30 – 7:30	4th Floor Lobby & Terrace
Tuesday, August 4th		
Registration	8:00 – 5:00	4th Floor Lobby
Keynote I: Dr. Sandra Trehub, University of Toronto	9:00 – 10:00	450C
Break		
Session 4A: Music and Language II	10:20 – 11:40	450A
Session 4B: Rhythm and Meter I	10:20 – 11:40	450B
Lunch		
Session 5A: Music and Language III	1:30 – 2:30	450A
Session 5B: Rhythm and Meter II	1:30 – 2:50	450B
Break		
Poster Session I (available for viewing all day)	3:00 – 5:00	405 & 409
Wednesday, August 5th		
Graduate Student Breakfast	7:30 – 9:00	305
Session 6A: Symposium on Pulse, Meter & Groove I	9:00 – 10:00	450A
Session 6B: Cross-Modal Interactions	9:00 – 10:00	450B
Break		
Session 7A: Symposium on Pulse, Meter & Groove II	10:20 – 11:40	450A
Session 7B: Timbre	10:20 – 11:40	450B
Lunch		
Session 8A: Pitch	1:30 – 2:50	450A
Session 8B: Evolution of Music	1:30 – 2:30	450B
Break		
Poster Session II (available for viewing all day)	3:00 – 5:00	405 & 409
SMPC Business Meeting (open to all SMPC members)	5:10 – 6:00	305
Thursday, August 6th		
Keynote II: Dr. Elaine Chew, USC	9:00 – 10:00	450C
Break		
Session 9A: Models and Theories	10:20 – 11:40	450A
Session 9B: Emotion I	10:20 – 11:40	450B
Lunch		
Session 10A: Harmony	1:30 – 2:30	450A
Session 10B: Emotion II	1:30 – 2:50	450B
Break		
Poster Session III (available for viewing all day)	3:00 – 5:00	405 & 409
Banquet	6:30 – 10:00	Eiteljorg Museum, Sky City Café

Monday, August 3rd

Welcome
10:00 – 10:10 Dr. Tonya Bergeson, Indiana University School of Medicine

President's Address
10:10 – 11:00 Dr. Aniruddh Patel, The Neurosciences Institute

Session 1A Performance I (*Chair: Roger Chaffin*)

1A) 11:10 – 11:30

Evaluating expressive performance: How performance individuality and structural complexity affect the preferences of experienced listeners

Stacey Davis
University of Texas, San Antonio

Purpose
Many empirical studies have investigated the relationship between expressive performance and musical structure, but fewer have examined how expression affects judgments of performance creativity and opinions about preference. Some research suggests that the relationship between originality and preference could be depicted with an inverted-U shape (just as with complexity and arousal). In this case, experienced listeners would prefer more idiosyncratic performances, with the unpredictable expressive deviations providing novelty that captures attention and generates liking. Other research highlights the interaction between performance originality and structural complexity, with simple music requiring more "structurally ambiguous" performances to engage interest and elicit preference. Given these suggestions, what occurs when experienced listeners encounter music that is both familiar and complex? Does familiarity create a preference for performance novelty or does an awareness of complexity engender preference for more conservative interpretations?
Methods
Two excerpts from Bach's unaccompanied violin pieces were chosen, along with commercial recordings of both excerpts by ten expert violinists. For each performance, participants provided ratings for perceived tempo, technical goodness, amount of performance expression, and overall preference. Ratings of perceived tempo were compared to measurements of actual tempo, while ratings for technical goodness, expression, and preference were compared with perceived complexity and amount of musical training and/or familiarity with this repertoire.
Results
As predicted, results indicate a significant, positive correlation between perceived tempo and actual tempo and between perceived technical goodness and overall preference. For the less complex excerpt, participants preferred performances judged to have a greater amount of expressive individuality. As perceived complexity increased, participants preferred the performers that adopted a more conservative expressive approach. These results were more pronounced as overall experience and familiarity increased.
Conclusion
Overall, the evaluations of expression and preference were affected more by complexity than by familiarity. Although strength of correlation varied with experience, participants generally preferred less exaggerated performances of the more complex excerpt. This suggests that sufficient structural complexity engages listener attention, even when the music is familiar and the performances are expressively conservative (or even strict).
Research and/or Educational/Clinical Implications
Although musical expression is subjective and individual, a greater awareness of the relationship between complexity, familiarity, and preference can help performers make more informed expressive choices. The results of this study therefore have implications for how we teach musicians to understand musical structure and produce expressive performances that are positively evaluated and generally enjoyed.

1A) 11:30 – 11:50

Brain science to performance: the view from a pianist's bench

Lois Svard
Bucknell University

Purpose
How can a performing musician make practical use of the information gained from the myriad studies in the neuroscience of music, or for that matter, from recent non-music-based neuroscience research? This question serves as the impetus for the presentation here of research findings that have great potential for practical application in the study of music. During the past two decades, the brain basis of almost every aspect of music has been studied, often with corresponding brain scans, from the basic musical building blocks of melody, harmony, and rhythm, to more complex issues such as emotion in music, sight-reading, motivation, performance anxiety, improvisation and memory. But few attempts have been made to translate these research findings into practical applications for those of us who actually perform and teach music. One area of particular interest to any performer and teacher is the learning of a new piece of music. In considering the Western European tradition of music, the learning of a score is basic to the entire process of making music, whether one plays at an elementary or at a concert level. How can one be most effective, not just in learning quickly and accurately but more importantly, in playing musically as well?
Methods
This presentation reviews some diverse studies that can offer new insights into the process of learning music. I begin by reviewing selected literature concerning mental motor practice, mirror neurons, and the effect of different teaching methods on specific brain activation patterns.
Results
In some cases, these studies confirm conventional wisdom about the teaching of music. In others, they suggest exciting new ways to approach practice that may ultimately make us stronger musicians.
Conclusion
There is no question that, over the past two decades, research in the neuroscience of music has uncovered tremendous knowledge about the complex art of making music. Performers are vitally interested in learning how to translate that knowledge into practical applications for the study and performance of music.
Research and/or Educational Implications
Experimental teaching applications in my own studio based on the research cited in this presentation suggest that musicians can benefit a great deal from teaching practices derived from neuroscience research. This is an ideal time for researchers and practicing musicians to work together to define possible research directions that may contribute to promising educational practices in the musician's studio. This presentation is an attempt to promote that collaboration.

1A) 11:50 – 12:10

Individual differences in muscle tension and air support during trumpet performance

Jonathan Kruger[1], James McLean[2], and Mark Kruger[3]
Rochester Institute of Technology[1], SUNY-Geneseo[2], Gustavus Adolphus College[3]

Purpose
Research done on muscle tension in brass performance has focussed on the embouchure (e.g., White and Basmajiian, 1973), on remedying embouchure problems using biofeedback (Hauser and McNitt-Gray, 1991), or selective control of individual muscles within the face and embouchure (Lapatki, Stegeman, & Jonas, 2002). For string players, a larger body of literature has examined the relationship between muscle tension, perceived exertion and fatigue, or reduction of muscle strain (c.f. Chan et. al., 2000; Berque and Gray, 2002; Fjellman-Wiklund et. al., 2003; Shan et. al. 2004) Although Henderson (1979) demonstrated tension in the throat of trumpet players changes with pitch, much less work has been done on general body tension in brass performers. Our study examines changes in muscle tension in the shoulder and lower back in the context of changes in mouthpiece pressure applied to the embouchure, intra-oral air pressure used to energize the embouchure, and breathing patterns during a musical task and as a function of expertise. We hope to identify strategies that performers use to create air pressure which are counter-productive because they lead to extraneous muscle tension and/or mouthpeice pressure on the embouchure.
Method
Thirteen trumpet players played a concert Bb scale, arpeggios differing in articulation and dynamics, and excerpts from the Haydn Trumpet Concerto. Extraneous muscle tension was measured electromygraphically at the left trapezius (shoulder) and the lower back. Measures were also made of expansion and contraction of the upper chest and abdomen, air pressure inside the mouth measured by placing a fine tube (attached to a gas pressure sensor) inside the performer's mouth, and mouthpiece pressure on the embouchure recorded by placing a force sensor in a

sleeve between the mouthpiece and the instrument. A trumpet mounted camera recorded embouchure movement during performance.

Results

Successful performers demonstrated selective control of extraneous muscle activity and created the highest levels of air pressure at the embouchure. This control was most apparent in high ranges of the arpeggios and during difficult passages of the Haydn concerto.

Conclusions

By observing muscle tension, internal air compression, breathing patterns, mouthpiece pressure, and sound simultaneously it is possible to see differences in physical approaches to wind instrument playing as a function of both individual expertise and musical task.

Educational/Clinical Implications

These observations support pedagogical approaches to brass teaching that make students aware of the effect of excess muscle activation at either the embouchure or in other muscle systems on performance.

Acknowledgement of Research Funding

Rochester Institute of Technology and Gustavus Adolphus College

1A) 12:10 – 12:30

Temporal patterns and formal structures in the performance of an unmeasured prelude for harpsichord

Meghan Goodchild, Bruno Gingras, Pierre-Yves Asselin, and Stephen McAdams
McGill University

Purpose

Several studies have recently renewed interest in the relationship between music-theoretical analysis and performance by advocating a collaborative view between analyst and performer (Lester 1995; Rink 1995). Gingras, McAdams and Schubert (2009) investigated the connection between the performer's concept of a piece as an analyst and performer to circumvent the apparent disconnect between the language and goals of music theory and performance. They observed that organists used a strategy of "phrase-final lengthening," the degree of which corresponds to the hierarchical importance of major subdivisions in their written analyses. However, individual organists' analyses did not correspond unequivocally to their tempo profiles. The present study continues this research by examining the analyses and performances of an unmeasured prelude for harpsichord. This genre, which allows considerable interpretative freedom regarding its temporal structure, provides an ideal context for further analysis of the link between temporal patterns and formal structure.

Methods

Twelve professional harpsichordists were invited to perform the *Prélude non mesuré No. 7* by Louis Couperin on a MIDI harpsichord, which allows precise measurement of performance parameters. Immediately following their performances, the harpsichordists were invited to submit their own analyses of the piece, indicating its main formal subdivisions. Performances were matched to the score using an algorithm developed by Gingras (2008).

Results

A comparison of the written analyses shows that, despite a fair amount of individual variation, the harpsichordists generally agreed on the main structural boundaries. Their performances, however, displayed considerable variation in acceleration and/or deceleration patterns. Through detailed analyses of performance parameters such as tempo fluctuation, articulation, and velocity, we show how harpsichordists conveyed their structural interpretation of the piece, assess whether these interpretations correspond to their written analyses, and compare structural readings of the piece offered by different performances.

Conclusion

Although the unmeasured prelude is a genre characteristic of the Baroque era, no empirical research has been conducted on it or on harpsichord performance in general. By showing that performances of unmeasured preludes display a wide range of possible structural realizations which is more varied than what is found in measured music, this study constitutes a first step in characterizing this neglected genre which stands between strictly-notated music and improvisation.

Research Implications

This study will contribute new insights into the complex relationship between performance and analysis by focusing on the actualized music rather than score-based analytical readings, thus proposing a reevaluation of the performer's role in music analysis.

Acknowledgement of Research Funding

CIRMMT, NSERC and a Canada Research Chair to Stephen McAdams.

Session 1B Genre (*Chair: Alexander Rozin*)

1B) 11:10 – 11:30

Music genre schema construct accessibility in evaluation of a charity

Mark Shevy
Northern Michigan University

Purpose
The present study explores the cognitive influence of country music and hip-hop music genres in a persuasive message. In doing so, it works to further define genre as a cognitive schema; a definition that has been suggested (e.g., Bordwell, 1989; Shevy, 2008; Zillmann & Bhatia, 1989) but been barely researched empirically. Prior schema research in other contexts has shown that a primed schema activates associated concepts, making those concepts more accessible for use in evaluation (e.g., Iyengar & Kinder, 1987). The present study continues this line of research by examining the effect that primed music-genre schemas might have on the evaluation of a charity presented in an appeal presented in association with a piece of music.
Methods
An online experiment presented participants (n=182) at a large Midwestern university with an ostensibly live audio recording of a music performer making a charity appeal between songs at a concert. Participants were randomly assigned to a country music, hip-hop music, or no-music condition. In the music conditions, a few seconds of either country or hip-hop music preceded the appeal, and a few seconds of the respective music followed it. The appeal itself (approximately 100 seconds long) was the same recording across all three conditions. After hearing the recording, participants answered questions regarding their attitude toward the charity, how much money they would probably give to it, and their perception of the performer.
Results
Results showed that brief exposure to country music caused perceived performer friendliness and political ideology to become positively correlated with charity evaluation, whereas exposure to hip-hop music caused perceived performer expertise to become correlated with attitude toward the charity. Also in the hip-hop condition, perceived liberal ideology of the performer correlated with positive evaluation for liberal participants. Trustworthiness was significantly correlated with evaluation in the country condition and in the no-music control; the correlation was marginally significant in the hip-hop condition.
Conclusion
Exposure to a music genre does not necessarily make audiences more or less favorable toward the charity, but it causes them to consider different characteristics when making their decision.
Research and/or Educational/Clinical Implications
The present research supports the definition of music genre as a type of cognitive schema. Future research should further investigate the nature of these schemas in various contexts.

1B) 11:30 – 11:50

The effect of musical and visual components on genre classification and plot continuation in the opening credits of Hollywood feature films

John Hajda
University of California, Santa Barbara

Purpose
Music can substantially change the interpretation of a visual scene. Vitouch (2001) found that, for the opening segments of a film, musical underscoring was a salient feature for plot continuation. This study is the first to systematically investigate opening segments of films of different genres. Specifically, this research investigates the effect of musical underscoring on expectations about genre and plot.
Methods
Stimuli: 32 stimuli were generated from opening credit segments of Hollywood feature films. Altogether there were 8 original clips—two from each of the following genres: *adventure*, *comedy*, *horror* and *romance*—and 24 "fake" clips, in which the visual elements from a film of one genre (e.g. comedy) were combined with the musical underscoring from a film of a different genre (e.g. horror). Each stimulus contained visual scenes, credits and titles with names matted out, and musical underscoring.

Experimental Task
Each subject was presented with four stimuli; no subject saw the same visual scene or heard the same musical underscoring twice. After each stimulus presentation, a subject (1) gave the genre to which the film likely belonged and (2) wrote a story (plot continuation) about what might happen immediately following the presented clip.
Results
Results show that, overall, music is more salient than visual features in determining genre classification and whether a plot outcome is positive or negative. This is likely due to the absence of characters or plot. One notable exception for genre classification was generated by the opening images from the romance film *Emma* (1994), during which a planet rotates quickly against a starry background. This scene elicited genres and plots related to science fiction themes regardless of underscoring.
Conclusion
This study, conducted in light of Cohen's (2005) Congruence-Associationist Model, stands in contrast to existing theories on multimedia cognition. Many Hollywood films begin with opening credits, and this research indicates that music, not visual scenes and text, is more salient in communicating genre and general plot expectations. Future research will attempt to determine conditions under which music or visual saliency predominates.
Research Implications
The larger goal of this research is to increase understanding of the processes by which meaning and interpretation occur in multimedia contexts. Therefore, this research impacts the fields of film theory, music theory and psychology (multimedia cognition).
Acknowledgment of Research Funding
Hellman Family Faculty Fund Fellowship, UC Santa Barbara

1B) 11:50 – 12:10

Participatory discrepancies and the perception of beats in jazz

Matthew Butterfield
Franklin and Marshall College

Purpose
What generates "swing" in a jazz rhythm section? Charles Keil proposed that swing stems specifically from asynchronous timing between bass and drums in their shared articulation of the beat, a phenomenon he dubbed "participatory discrepancies," or PDs. The "push and pull" between these instruments purportedly generates a "productive tension" thought to drive the groove with energy, prompting listeners to tap their feet and bob their heads along with the beat. No one, however, has proven that PDs are actually available to human perception, much less that they do in fact produce swing. This paper presents the results of two experiments on the perception of PDs and their purported effects.
Methods
Experiment 1 employed synthetic recordings of a conventional swing groove in which the onset asynchronies between bass and drums were varied between 10, 20, and 30 ms at three different tempos. Participants used three different listening strategies in an effort to perceive the asynchrony and its purported effects. Experiment 2 employed recordings of professional jazz musicians and tested for the effects of learning in the perception of PDs.
Results
Average scores on both experiments did not exceed chance levels, indicating that most listeners are unable to perceive PDs or their purported effects as predicted in the PD framework. Participants had marginally more success in perceiving drum leads than bass at higher tempos. Widening the asynchrony modestly facilitated perception of bass leads, though it had no significant effect on the perception of drum leads. Repeated listening did not help, but a few individuals (14-18%) could perceive the discrepancy fairly effectively with one particular listening strategy. Neither formal musical training nor a stylistic preference for jazz distinguished these individuals, however; they appear simply to have a greater perceptual acuity for temporal discrimination than others.
Conclusion
These experiments failed to confirm that most ordinary listeners are able to discern the discrepancy between bass and drums with any consistency across a range of tempos and timing values. The expressive effects of PDs, though not negligible, are quite modest, minimally salient, and thus not likely the driving force behind the production of swing.
Research and/or Educational/Clinical Implications
Though not inconsequential, the expressive effects of PDs must be understood as more limited and local than previously thought. The driving force behind the swing groove probably stems from aspects of syntactical pattern, and not subsyntactical timing processes. PDs may temper or condition the motional energy of this groove, but they do not likely generate it.

1B) 12:10 – 12:30

Genre identification of very brief musical excerpts

Sandra Mace, Cynthia Wagoner, and Donald Hodges
University of North Carolina at Greensboro

Purpose
The purpose of this study was to examine how well individuals are able to identify different musical genres from very brief excerpts and whether or not musical training, gender, and musical preference play a role in genre identification.
Methods
Listeners were asked to identify the genre of classical, jazz, country, metal, and rap/hip-hop excerpts that were 125 ms, 250 ms, 500, or 1000 ms in length. Participants were 219 students recruited from two universities in the southeast region of the United States.
Results
The results indicated that participants were very successful at identifying genres of very brief excerpts. Overall, they were correct 75% of the time. At 1000 ms, accuracy reached 89% for all genres combined and 93% and 91% for Classical and Jazz, respectively. Even at 125 ms, listeners performed well above chance: Classical (71%), Jazz (38%), Country (56%), Metal (51%), and Rap (38%). Clearly, these participants were able to make fairly accurate judgments on the basis of extremely limited information.
In general, the length of excerpt made a significant difference in performance, with longer time lengths leading to greater accuracy. No significant differences were found between those with musical training and those without. Generally, there were no significant differences between males and females and expressed preference did not play a significant role in listener's ability to identify genres of different lengths.
Conclusion
These findings support a primary conclusion that people are very adept at identifying particular musical styles when presented with excerpts that are one second in length or less.
Research and/or Educational/Clinical Implications
Previous research has indicated that listeners can make emotional judgments very rapidly and the current results extend this ability to the identification of specific genres. Based on Ashley's (2008) findings that listeners can make judgments of valence (happy/sad) and mode as rapidly as 100 ms (and in some cases in 50 ms), it is tempting to speculate that genre identification takes slightly longer. It is also possible that valence judgments and genre identifications are made by different cortical pathways. However, further studies are needed to test these hypotheses. Numerous additional studies could be designed to explore this fascinating and quite extraordinary ability to make rapid musical judgments based on extremely brief snippets of sound.

Session 2A Performance II (*Chair: Bruno Repp*)

2A) 2:00 – 2:20

After-effects of alterations to the timing and pitch of auditory feedback during sequence production at the keyboard

Peter Q. Pfordresher and John David Kulpa
University at Buffalo, SUNY

Purpose
Understood is the tendency for pitch alterations and asynchronous feedback to affect, respectively, error rate and timing in the performance of musical sequences. The following three experiments were designed to investigate the effects of these alterations on performance both during their application and after their withdrawal. Of interest was to determine if feedback alterations of pitch and/or synchrony would exert their effects immediately or gradually and whether the effects would be persistent or transient.
Methods
In all experiments, each trial consisted of three segments and began with a 500ms metronome. First, participants synchronized with the metronome and heard normal feedback. Second, participants heard altered auditory feedback while attempting to maintain the metronome rate. Third, altered feedback either reverted to normal or was removed while participants continued to attempt maintaining the same rate.
Participants either tapped (experiment 1) or played an eight-note melody from memory (experiments 2 and 3). Feedback alterations as well as the number of keystrokes in segment 2 varied across experiments. In experiments 1 and 2, participants' feedback was asynchronous relative to their keystrokes. The number of keystrokes was 1, 2, 4, 8,

or 16. In experiment 3, participants' feedback was the note which corresponded to the immediately preceding keystroke. The number of keystrokes was 1, 8, 16, or 32.

Results

Experiment 1 showed that participants' production slows significantly when feedback is asynchronous. Furthermore, this effect did not depend on the number of asynchronous events. Time-series analyses indicated that slowing was effected immediately and that recovery upon termination of the alteration was rapid. That these results generalize to more typically musical behaviors was shown by the largely equivalent findings of experiment 2.

Experiment 3 found that, during segment 2, error rates increased as the number of pitch alterations increased, suggesting that their effect takes place gradually over time. Importantly, pitch alterations continued to exert their effect on error rate even in segment 3 when these alterations were no longer being applied.

Conclusion

These results indicate that alterations to the timing of a person's productions have effects which are immediate, but do not persist. Conversely, alterations to pitch have effects which persist, but take time to build up.

Research and/or Educational/Clinical Implications

The studies herein described suggest the existence of separate timing and sequencing mechanisms for tasks in which perception and action are dynamically interrelated.

Acknowledgement of Research Funding

NSF Grant 06042592

2A) 2:20 – 2:40

Analyzing expressive timing data in music performance: A multi-tiered time-scale sensitive approach

Panayotis Mavromatis
New York University

Purpose

We develop a method for analyzing expressive timing data, aiming to uncover rules which explain a performer's systematic timing manipulations in terms of the music's structural features.

Methods

We adopt a multi-tiered approach. We first identify a continuous *tempo curve* by applying non-linear regression analysis to inter-onset durations extracted from an audio recording. Our non-parametric regression employs radial basis functions, thus avoiding rigid a priori assumptions about which specific factors contribute to the tempo fluctuations (e.g. grouping structure) or what the functional form of that contribution is (e.g. parabolic segments). Once the effect of tempo is factored out, subsequent tiers of analysis examine how the performed subdivision of each metric layer (e.g. quarter note) deviates from an even rendering of the next lowest layer (e.g. two equal eighth notes) as a function of time. The contribution from each metric layer is factored out before the next one is analyzed.

Results

We analyzed harpsichord performances of Bach preludes from commercially available recordings. The most salient factors shaping the tempo curve (Fig. 1) are • an initial small *accelerando* and a pronounced final *ritardando*; • less pronounced, but consistent *ritardandi* leading to important cadences, with magnitude reflecting the cadence's depth in the tonal hierarchy; • small but measurable contrasts in tempo to differentiate sections marked off by distinctive texture or tonal function. The metric layer analysis begins by examining the timing of individual measures in response to specific features of the music (Fig. 2). Variations of this type include lengthening a measure that • begins a hypermetric pair; • effects tonal arrival or resolution of a dissonant chord; • contains unexpected material. In subsequent metric layers, the nature of the deviations from exact subdivisions varies with metric depth. Systematic variations include a lengthening of the metrically strongest member of the subdivision (agogic accent). It is perhaps most remarkable that, even though deviation from exact subdivision is free to vary on a point-by-point basis, the observed deviations sometimes vary smoothly over extended time spans, typically corresponding to formal units such as phrases (Figs. 3-4). This phenomenon typically occurs on specific metric layers that perhaps bear some special relation to the *tactus*.

Conclusion

Our analysis confirms that expert performers systematically manipulate timing to communicate musical structure. Manipulations are typically linked to specific structural features of the music, and are manifested differently at different time scales.

Research Implications

The data-analytic technique proposed here can be used to quantitatively model the mapping of musical structure to expressive timing patterns. Consistently executed timing deviations can shed light on mental representation of the music in the performer's long-term memory, offering indirect evidence that complements results established through controlled laboratory experiments.

2A) 2:40 – 3:00

Emotional and neural response dynamics depend on performance expression and listener experience

Heather L. Chapin[1], Kelly J Jantzen[2], JAS Kelso[1], Fred Steinberg[3], and Edward W. Large[1]
Florida Atlantic University[1], Western Washington University[2], University MRI of Boca Raton[3]

Purpose
The goal of this study was to link dynamic emotional and neural responses of listeners with time-varying music performance parameters, and to investigate the role of musical experience in modulating these responses.
Methods
Emotional responses and neural activity were observed as they evolved over several minutes in response to changing stimulus parameters. Our experimental stimulus was a skilled music performance that included natural fluctuations in timing and sound intensity that musicians use to evoke affective responses. A mechanical performance of the same piece served as a control. Participants reported emotional responses in real-time on a 2-dimensional rating scale (arousal and valence), before and after fMRI scanning. During fMRI scanning, participants listened without reporting emotional responses.
Results
Stimulus changes predicted real-time ratings of emotional arousal and real-time changes in neural activity. Limbic areas responded to the expressive dynamics of music performance and activity in areas related to emotion processing and reward were dependent upon the musical experience of listeners. Dynamic changes in activation levels of the mirror neuron system, insula, anterior cingulate and basal ganglia were found to correlate with expressive timing fluctuations in performed music.
Conclusions
These findings are consistent with the hypothesis that music influences emotional responding through an empathic motor resonance mediated by the mirror neuron system. We also showed that music's affective impact on neural activity depends on the musical experience of listeners.
Research Implications
Apart from its natural relevance to cognition, music is shown to provide a window into the intimate relationships between production, perception, experience, and emotion.
Acknowledgements
This work was supported by NSF grant BCS-0094229 and a Fulbright Visiting Research Chair awarded to EWL, and NIMH grant MH80038 and the Pierre de Fermat Chair to JASK.

Session 2B Memory and Cognition I (*Chair: Judy Plantinga*)

2B) 2:20 – 2:40

Associating sounds: Tone envelope, timbre, and associative memory

Michael Schutz[1], Jeanine Stefanucci[2], and Sarah Baum[2]
University of Virginia[1], College of William and Mary[2]

Purpose Associating sounds and images is important in everyday tasks such as pairing faces with voices and identifying unseen events. Although tone envelope is known to play a key role in the perception of timbre, its effect on cognitive tasks such as associative memory is less thoroughly researched. As recent research shows that ethologically relevant sounds facilitate associative memory in young chicks (Field et al., 2007), here we ask whether sounds with ecologically familiar exponentially decaying envelopes (regularly produced by the collision of solid objects) are easier to associate with target objects than sounds with artificial flat envelopes. These results have relevance for psychological research on audition and music perception, as well as our understanding of timbre and associative memory.
Methods
In the first experiment, participants were asked to associate various household objects (e.g., cell phone, key, credit card) with 4-note melodies made of tones using one of two amplitude envelopes: "flat" (off-on-off) or "percussive" (exponential decay). In the second experiment we crossed training and testing conditions such that some participants were trained on percussive sequences but tested on flat sequences, and vice versa. Both experiments were designed using a modified version of the old-new paradigm (Mandler, 1980; Tulving, 1985). We presented 10 sequences during training and 20 during testing, allow for separate evaluation of sequence recognition (old/new judgments) and recall of associated objects.

Results
Neither of the experiments showed any difference in recognition sensitivity to sequences between tone conditions. However, participants hearing percussive sequences in the first experiment correctly recalled 62% more of the sequence-object pairs. In the second experiment, this advantage was found only for those both training and testing on percussive sequences, who showed a 45% advantage in the number of items recalled over the other three conditions.
Conclusions
Although sequences with percussive envelopes were no more memorable (as assessed by the recognition task), they were significantly more easily associated with targets, as long as they were heard both at training and at test.
Implications
Although tone onsets are generally regarded as more important than offsets, these findings demonstrate offsets in fact play a crucial role in forming associations between sounds and objects. Among other implications, they suggest that human-computer-interfaces requiring users to associate sounds with messages may be improved with the use of percussive envelopes.

2B) 2:40 – 3:00

The effect of musicality and scale type on memory for tone sequences

Charles Barousse and Michael Kalish
University of Louisiana at Lafayette

Purpose
Music researchers have hypothesized that unequally spaced intervals provide more tonal orientation and psychologically distinct information for listeners than equally spaced intervals, making it easier to remember tone sequences based on unequal step scales. Experimental results have provided support for this hypothesis. There is also research that demonstrates better memory performance for tonal sequences. These tonal sequences, in addition to being based on unequal step diatonic scales, typically exhibit a high degree of musicality (the quality of sounding musical). However, there has been no research that has investigated the separate contributions of scale and musicality to memory for tone sequences. Three experiments examined these contributions.
Methods
In each trial, participants heard a tone sequence followed by two transpositions. Participants chose which transposition contained a mistuned note. In Experiment 1, scale step spacing and musicality were investigated using random tone sequences (low degree of musicality). The sequences for Experiment 2 were pre-selected randomized tone sequences rated as being 'equally musical' in a ratings study. In Experiment 3, tone sequences were written to cross scale type and musicality.
Results
In Experiments 1 and 2, participants performed better with tone sequences that were based on the major scale when compared to a seven pitch equal step scale (Experiment 1) or a whole tone scale (Experiment 2). In results for Experiment 3, a 4x1 ANOVA showed that four different tone sequence categories were significant. Performance was best to worst in the following order: Major scale musical sequences, whole tone scale musical sequences, major scale unmusical sequences and whole tone scale unmusical sequences. A separate rating study of these sequences showed mean musicality ratings followed the same trend. A 2 way ANOVA showed significance for musicality only, with no significant interaction between musicality and scale. In linear regression analyses, in which three factors were tested as predictors of participants' scores, scale was insignificant while musicality and rating were significant.
Conclusion
There are many characteristics of tone sequences that may contribute to our remembrance of them. Specific scales have an effect on memory in both musical and unmusical tone sequences. Though scales still contribute to tone sequence memory when crossed with musicality, they are less of a contributor to tone sequence memory than musicality.
Research Implications
In future research involving tone sequence memory, researchers should consider musicality as either an experimental variable or a possible untested explanatory contribution to results for experiments that do not vary or control for musicality.

2B) 3:00 – 3:20

The relationship between music perception and self-reported memory in breast cancer survivors

Debra Burns, Tonya Bergeson, Bryan Schneider, Fred Unverzagt, and Victoria Champion
Indiana University–Purdue University Indianapolis

Purpose
A variety of chemotherapy agents have ototoxic effects that can decrease both high and low frequency hearing. Several studies have shown that chemotherapy may also induce cognitive impairments such as decreased information processing speed, motor function, verbal memory, visuospatial skill, and visual memory. It is unclear whether reports of qualitatively different and negative musical listening experiences in cancer patients who have received chemotherapy are due specifically to the ototoxic effects (i.e., hearing loss) or to more general neurotoxic effects (e.g., decreased cognitive function). Finally, it is also unclear whether such changes in music perception are domain-specific (i.e., limited to music) or domain-general (i.e. cognition). The purpose of this study is to describe the relationships between the results of auditory-based perception tests and self-reported memory in breast cancer survivors who have received adjuvant cancer treatment and age-matched healthy controls.
Methods
Breast Cancer Survivors (BCS) and age-matched Healthy Controls (HC) completed audiometric testing and the Montreal Battery of Evaluation of Amusia to determine hearing thresholds, pitch perception, rhythm perception, and melodic memory. Participants also completed the Squire Memory Self-report Scale.
Results
The groups (BCS & HC) were similar in years of education, hearing PTA, race/ethnicity, and marital status. There was a moderate, negative correlation between hearing and the scores on the auditory perception tests. There were no significant differences in self-reported memory or perception tests between the two groups, although effect sizes were moderate. Correlations between scores on working memory and music perception (Overall score, Scale, Interval, Meter, Melodic Memory) were significant for HC, but not for BCS.
Conclusions
Although BCS and HC received very similar scores on tests of working memory and music perception, their processing of such information differs dramatically, as revealed by significant correlations between the two tasks for healthy controls but not for breast cancer survivors.

Session 3A Music and Language I (*Chair: Steven Livingstone*)

3A) 3:40 – 4:00

Production of vocal prosody and song in children with cochlear implants

Tonya R. Bergeson, Matthew Kuhns, Steven B. Chin, and Annabelle Simpson
Indiana University School of Medicine

Purpose
The goal of this study was to explore spoken prosody and music production in children with cochlear implants (CIs).
Methods
Four 8- to 15-year-old children with 5-8 years of CI experience completed three tasks: 1) Production of sentences in happy, sad, questioning, and neutral manners of speaking; 2) Production of a variety of pitch contours; and 3) Production of the familiar song “Happy Birthday.” Recordings from the first task were presented to a listener panel of three normal-hearing adults, who completed two additional tasks: *identification*, a closed-set task in which listeners listened to low-pass filtered (400 Hz) versions of the recordings and identified the emotion, and *rating*, a task in which listeners were given the “correct” emotion and rated the quality of the child’s representation of that emotion on a 7-point scale.
Results
Sentence Prosody: The listener panel correctly identified the children’s sentence emotion 36.8% (s.d. = 17.1) of the time, which did not significantly exceed chance values. The children’s prosody productions received lower quality ratings (*question* = 3.48, *sad* = 4.23, *happy* = 4.60, *neutral* = 4.65) than the model’s productions (range = 6.00-7.00).
Pitch Contour: In general, we found smooth pitch progressions in the examiner’s model but not for the children with CIs. Across children’s productions, pitch direction was relatively preserved, but pitch range was smaller than that of the model. The timing of the pitch contour glides was similar across the model and children’s productions.
Song: The model produced “Happy Birthday” with stable pitch on each syllable, whereas the children with cochlear implants produced significantly more pitch fluctuations. As expected, the children’s pitch production was generally

worse than their rhythm production. In the best song production, the child included a good singing tone and pitch variation, but pitch changes were not in the right direction or the right interval size. Unexpectedly, the children's rhythm production was also inaccurate. Although global rhythmic patterns were largely maintained, the temporal patterns did not fall into a periodic hierarchical framework (i.e., a "beat").

Conclusion

In summary, although cochlear implantation has significantly improved the communication abilities of many deaf children, these findings suggest that pediatric CI users still have difficulty producing prosody in a variety of contexts.

Clinical Implications

Because prosody also influences the intelligibility of spoken language, it will be important to develop therapeutic interventions that address the prosody production difficulties in deaf children who use cochlear implants.

Acknowledgement of Research Funding

NIH-NIDCD Training Grant T32DC00012

3A) 4:00 – 4:20

Vocal imitation of speech and song: Effects of phonetic information and temporal regularity

James Mantell and Peter Q. Pfordresher
University at Buffalo, SUNY

Purpose

Four experiments addressed the accuracy with which people imitate pitch-time trajectories from spoken sentences and sung melodies. Experiments 1 and 2 were designed to address the role of phonetic information in imitation while experiments 3 and 4 were designed to address temporal regularity of syllables in the target sequence.

Methods

Participants imitated sentences and melodies that were presented in their original form and as phonetically neutral sequences (each syllable synthesized to a 'hum'). Melodies were created based on the pitch-time contour of sentences but were diatonic and isochronous.

The original stimulus set was imitated as heard in Experiment 1. In Experiment 2, participants ignored phonetic information and imitated using the syllable "ah." Experiments 3 and 4 manipulated temporal structure so that sequence timing always matched speech (Experiment 3) or was isochronous like melodies (Experiment 4).

We analyzed accuracy of pitch imitation by comparing the pitch trace during imitations with the pitch trace of the original stimulus, after adjusting for differences in production rate. These adjustments were used to measured accuracy of timing.

Results

Three primary results emerged. First, imitation of speech may rely on phonetic information more so than song. Though both domains benefit from phonetic information, imitation of speech was disrupted when phonetic information was irrelevant to imitation (Experiment 2). Second, a general singing advantage emerged with respect to pitch matching (imitation of absolute pitch information). This advantage may be due in part to timing characteristics of music (Experiments 3 and 4). Third, overall ability of individuals to imitate song correlated with imitation of speech.

Conclusion

Results are consistent with the idea that music and language use common resources but different representations (Patel, 2008). Correlated imitation abilities across individuals may reflect a domain-general capacity for linking perception with action. At the same time, domain-specific sensitivity to the integration of articulation (phonetics) and phonation (pitch) suggests the presence of distinct representations. Finally, contrary to common belief, we find no evidence of an advantage for speaking over singing. In fact we find the opposite, though we interpret our musical advantage in light of stimulus structure, rather than domain specificity.

Research Implications

Recent work on speech imitation suggests that certain speech sounds are imitated automatically. Further work utilizing the current imitation paradigm, with an emphasis on the pitch-time contour, could provide insight into the dynamics of speech perception and production while providing clues about the role of indexical information in the signal.

Acknowledgement of Research Funding

NSF Grant 06042592

3A) 4:20 – 4:40

Does pitch processing in English have a musical basis?

Laura C. Dilley[1], Louis Vinke[1], Elina Banzina[1], and Aniruddh Patel[2]
Bowling Green State University[1], The Neurosciences Institute[2]

Purpose
A variety of meaningful distinctions are conveyed by pitch variations in speech, which linguists have characterized in terms of abstract phonological categories based on primitives like H (high) and L (low) and combinations of these. What is the relationship between pitch processing in music and in language, and do fundamentally "musical" processes or abstractions underlie linguistic distinctions based on pitch?
Methods
We tested the hypothesis that differences of contour (e.g., up-down pitch pattern) underlie contrasts in linguistic phonological categories (e.g., H* vs. H+L*) pegged to widely-described distinctive fundamental frequency (F0) timing properties across languages. In particular, the timing of F0 maxima and minima relative to speech phonemes, which is widely claimed to distinguish meanings and phonological categories across languages, was manipulated using speech resynthesis techniques for short English phrases in several experiments. These experiments assessed: (1) how participants perceptually classified F0 patterns in speech on the basis of the timing differences, (2) whether participants' classifications were based on differences in the relative pitch levels of syllables, and (3) the role of these timing differences in linguistic communication. A variety of tasks were used, including AX discrimination (Experiment 1), AXB categorization (Experiment 2), speech imitation (Experiment 3), judgment of the relative prominence of syllables (Experiment 4), and judgment of the relative pitch of syllables using participants who were musicians (Experiment 5a) or nonmusicians (Experiment 5b). Moreover, pitch perception for the speech stimuli on the basis of F0 was modeled using the Prosogram algorithm (Mertens, 2004).
Results
Results show converging evidence that listeners form distinct perceptual categories on the basis of timing differences in F0 maxima and minima in speech. Moreover, crossover points from one category to another in speech-based categorization and discrimination tasks in Experiments 1-4 were in good agreement with those derived from judgments of relative pitch in Experiments 5a and 5b. Large individual differences in ability to process pitch differences in speech were also observed.
Conclusions & Research Implications
These results support the hypothesis that differences of up-down contour underlie contrasts in at least some linguistic phonological categories, suggesting that similar or overlapping cognitive mechanisms are engaged in processing music and language.

Session 3B Memory and Cognition II (*Chair: Stacey Davis)*

3B) 3:40 – 4:00

Modeling a melody recognition task for musicians, nonmusicians, and amusics using a cohort network

Naresh N. Vempala and Anthony S. Maida
University of Louisiana at Lafayette

Purpose
Dalla Bella, et al. (2003) studied effects of musical familiarity on melody recognition by comparing performance between musicians and nonmusicians in a melody gated-presentation (MGP) task. They identified three events in this task: (1) familiarity emergence point (FEP), (2) isolation point (IP), and (3) recognition point (RP). The FEP was the point at which the listener correctly judged the presented melody as `familiar.' The IP was the point where the listener identified the melody. The RP was the point where the listener identified the melody with maximum confidence. The qualitative results of the MGP task are the following. The FEP occurred earlier in musicians than nonmusicians, but the IP occurred earlier in nonmusicians. Finally, the RP occurred slightly earlier in musicians. Our aim was to simulate the MGP results using a connectionist simulation of the cognitive processes underlying the emergence of the FEP, IP, and RP in musicians versus nonmusicians. We call this a *melody cohort network* (MCN) which is based on analogy to cohort models of word recognition. We also used the simulation to predict the effect of acquired amusia on the MGP task.
Methods
We built an MCN for this task. Its core consisted of a sequence recognition neural network. This network consisted of sequence recognition (SR) neurons interconnected in a winner-take-all competitive network. SR neurons were activated by notes in a melodic sequence connected to temporal delay filters. SR neurons, with associated input

weights, represented stored melodies. Separate neural networks modeled musicians and nonmusicians. The musician network represented a larger corpus of stored melodies than the nonmusician network. The core network modeled the IP. Meta-level networks modeled the FEP and RP. These networks used the core network as input. By lowering pitch perception thresholds, two states of acquired amusia were simulated in the musician network. The states were: (1) a minimum of two semitones for detecting pitch changes, and (2) a minimum of three semitones for detecting pitch changes Memories, as represented by the melody-specific SR neurons, remained unaffected.

Results

Our MCN captured the qualitative results of the MGP task in musicians versus nonmusicians. It also makes predictions about performance of acquired amusics for the MGP task.

Conclusions and Research Implications

Our model shows how stored memory size may affect the recognition process as indicated by the differential IP phenomena, and how meta-level processes monitoring the status of the recognition process may explain contrasting FEP and RP phenomena for musicians and nonmusicians.

3B) 4:00 – 4:20

The influence of time and memory constraints on the cognition of hierarchical tonal structures

Morwaread Farbood
New York University

Purpose

The presence of tonal hierarchical structures in music has long been observed by theorists and experimental psychologists. While there is general agreement as well as supporting empirical data indicating that these structures exist, the extent to which listeners perceive them is still under investigation. The goal of this research is to examine the issue in more detail and offer a perspective that incorporates models of short and long-term memory. Within this context, it proposes some modifications to Lerdahl's tonal tension model (2001) in order to better explain certain experimental data.

Methods

Data was gathered in an experiment measuring continuous listener responses to tension in musical excerpts from the classical repertoire. Thirty-five subjects from the MIT community took part in the study and were asked to move a slider on a computer interface in response to how they felt tension was changing in a given musical excerpt.

The primary musical excerpt chosen for the purposes of this investigation was analyzed and quantified according to its salient musical features (harmonic tension, pitch height of the bass and soprano lines, and onset frequency). The harmonic tension values were obtained using Lerdahl's tonal tension model excluding the melodic attraction component. In addition, mathematical derivatives were calculated for each musical feature—that is, a description of how each feature was changing in time, where the difference in time ranged from 0.25 to 20 seconds. All of the feature descriptions and their derivatives were used as input to regression analysis in order to identify the best predictors of the mean tension curve.

Results

The results showed that for every feature except harmony, the derivatives that were most effective were those that described changes taking place under 3 seconds. Harmony, on the other hand, best fit the tension data when the time differential was 10-12 seconds in length.

Conclusion

This 10-12s window suggests that a decay factor imposed on inherited hierarchical value in Lerdahl's prolongational reduction should be applied after a minimum of 10 seconds of elapsed time. Furthermore, the decay factor should taper the value to zero at around 17 seconds in time, where the mean square error flattens out at a maximum.

Research and/or Educational/Clinical Implications

Given these preliminary results, it appears that the cognition of tonal hierarchies goes beyond the regular limits of short-term memory and is processed in a different manner than other structures such as pitch contour and rhythm. More data will be gathered to verify these findings.

3B) 4:20 – 4:40

A procedural take on the Deutsch/Feroe formalism: Cognitive motivation and computational realization

Craig Graci
State University of New York at Oswego

Purpose
In previous talks (Graci, 2008a, 2008b) I have discussed the computational modeling of grouping structure within a symbolic framework that features tools of analysis based on grouping preference rules (Lerdahl & Jackendoff, 1983). In this talk I will present a computational realization of a procedural variant of the Deutsch/Feroe formalism for representing reductional structure in tonal music (Deutsch & Feroe, 1981). A simple symbolic language called Clay which possesses a large measure of structural generality (Wiggins & Smaill, 2000) serves as the medium in which computational constructs for both grouping structure and reductional structure have been shaped. Elements of Clay which are particularly relevant to the implementation of alphabets, sequences, and reduction operators will be discussed.
Method
The work is grounded in simple but powerful concepts found within the field of computer science. For example, stacks are used to conveniently scope Deutsch/Feroe alphabets, and Post productions (Post, 1943) serve as the conceptual basis for my interpretation of the Deutsch/Feroe "prime" operator. In short, a spectrum of ideas associated with the theory and practice of symbolic computation constitutes the core methodology employed in this particular investigation of the internal representation of tonal melody.
Results
Generally speaking, the results of this effort take the form of a computational framework called MxM (Music Exploration Machine) and an executable music knowledge representation language (Clay) within which reductional structure, grouping structure, and the interaction between these two forms of structure may be studied. Investigation of melodic structure is facilitated by a collection of graphical tools and a collection of analytical tools. More specifically, an alternative inscription language (Pea, 1996) to that proposed by Deutsch and Feroe for representing the internal structure of tonal melody is defined. One notable aspect of this inscription language is that, unlike the Deutsch/Feroe formalism, it accommodates durational variablility. Another characteristic is that it fairly naturally supports the incremental modeling of reductional structure from both the top-down and the bottom-up perspectives.
Conclusions
Sloboda (2005) aptly observes that making sense of music has often been equated with the process of discovering and representing its structure. Writing expressions for melodic fragments in the elegant notation defined by Deutsch and Feroe is a worthwhile, albeit challenging, exercise in making sense of music. The computational system described in this talk changes the nature of the reductional inscription process, and can be viewed as a form of cognitive scaffolding (Wood, Bruner, & Ross, 1976) for tasks which require insight into melodic structure.
Research and/or Educational/Clinical Implications
MxM/Clay has, in fact, been deployed both as an educational microworld (Papert, 1980) and as a cognitive artifact (Norman, 1991) in classroom situations (Graci, 2000, 2008b). Based on these experiences the system appears to hold considerable potential for a range of educational applications involving the distributed cognition of melodic knowledge.

3B) 4:40 – 5:00

Serial position effects in a singer's long term recall identify landmarks and lacunae in memory

Roger Chaffin[1], Jane Ginsborg[2], and James Dixon[1]
University of Connecticut[1], Royal Northern College of Music[2]

Purpose
When a piece of music is first learned, memory for what comes next is activated by *serial cuing* as the current passage cues motor and auditory memory for what comes next. During memorization, serial memory is overlaid with more explicit *performance cues* that provide *content addressable* access, where the musician can recall a passage by simply thinking of it, e.g., "G section". We expected content addressable access and serial cuing to produce negative serial position effects in free recall: Recall would be best at cues and decline progressively in succeeding bars.
Method
An experienced singer memorized Stravinsky's *Ricercar I*. She reported features of the music that she attended to in practice and performance cues where she thought about during performance, e.g., where she needed to attend to an upcoming entry or to the other musicians (*Prepare-PC's*). Later, she wrote out the melody line and words from memory six times, after 0, 18, 32, 42, 47, and 59 months. We used mixed hierarchical regression analysis to identify relationships between the singer's reports and her practice and recall.

Results

The singer used beginnings of sections and phrases as starting places during practice. There were corresponding effects on recall, which declined from 100% accuracy at 0 months to just over 50% after 4 years. Recall was *better* at beginnings of sections and phrases and declined linearly in successive bars *after* the cue (negative serial position effects). In contrast, recall was *worse* at Prepare-PC's, and improved as distance from the cue increased in bars both *before* and *after* the cue (a negative curvilinear effect). Other performance cues produced positive curvilinear effects.

Conclusions

Starts of sections and phrases became *landmarks,* providing the singer with content addressable access to her memory for the piece. Prepare-PC's became *lacunae* where the music was forgotten, probably because the singer paid less attention to it during practice.

Research Implications

Content addressable access to serially cued memory was reflected in negative serial position effects, i.e., linear declines in recall in bars *after* retrieval cues. Serial position effects that extended symmetrically both before and after retrieval cues are more plausibly attributed to effects of attention.

Tuesday, August 4th

Keynote I **Infancy: A Musical History Tour**
9:00 – 10:00 Dr. Sandra Trehub, *University of Toronto*

Session 4A **Music and Language II** **(*Chair: Joy Ollen)***

4A) 10:20 – 10:40

Resolving conflicting linguistic and musical cues in the perception of metric accentuation in song

Jieun Oh
Stanford University

Purpose
This study explores the interplay of prosodic and musical accentuation by examining situations in which implicit accents in a song's melody conflict with stress patterns in the lyrics. While previous studies offer examples in which the musical accentuation dominates over text, the opposite phenomenon has only been artificially generated. This study examines an instance in which the Korean translation of the song "Happy Birthday" renders its implicit musical accentuation subordinate to the conflicting linguistic features, resulting in a perceptual alteration of the intended metric structure of the song.
Methods
Twelve native English speakers with no knowledge of Korean (Group I) and eighteen Korean-English bilinguals (Group II) participated in the study. Subjects were asked to sing "Happy Birthday" in English (Group I and II) and in Korean (Group II only) while finger tapping along to the song's rhythm. An acoustic drum trigger, affixed to the bottom surface of a table, was used to record the finger taps, and the amplitude data were extracted for analysis. A final survey collected information about the subjects' musical and language background.
Results
Our analysis focused on the change in the tapping intensity over the musical anacrusis. Across-group comparison of the tapping patterns over the syllables "happy" and "birth", sung in English, showed a tendency for speakers less fluent in English to de-emphasize "birth", which corresponds to the music's downbeat. Moreover, a within-subject comparison over the syllable "to" and "you" showed that relative beat-strength perception reversed depending on the language used to sing the song: "you" was emphasized over "to" when sung in English, but de-emphasized when sung in Korean.
Conclusion
The across-group data suggest that offline effects of one's native language can be manifested when singing in a second language, and that language fluency may affect the extent to which linguistic stress patterns play a role in the overall beat-strength perception of songs. Furthermore, the within-subject data imply strong online effects of language, demonstrating that beat-strength perception of songs can be altered based on the lyrics' stress patterns.
Research Implications
Our findings imply that linguistic cues can play a significant role in the inference of beat accentuation (and by extension, the metric perception) of songs.
Acknowledgment of Research Funding
Major Grant, awarded by the Stanford University Undergraduate Research Program

4A) 10:40 – 11:00

The costs and benefits of background music for processing written and spoken verbal materials

William F. Thompson[1], E. Glenn Schellenberg[2], and Jana Letnic[1]
Macquarie University[1], University of Toronto[2]

Purpose
The success of MP3 players illustrates the widespread use of music as accompaniment for other activities. Although background music is often irrelevant to task performance, it demands cognitive resources. Kahneman's (1973) capacity model maintains that a limited pool of resources is distributed over cognitive processes. The arousal-mood hypothesis posits that background music affects task performance through its mediating influence on arousal and mood (Thompson, Schellenberg & Husain, 2001). Two experiments addressed the hypothesis that the use of background music involves a trade-off between cognitive capacity limitations and arousal-mood benefits. We examined the effects of tempo and intensity of background music on comprehension of written (Experiment 1) and spoken (Experiment 2) verbal materials.
Methods
Mozart's *Sonata for Two Pianos in D major* was presented through headphones to 25 listeners following manipulations of tempo (150 bpm / 110 bmp) and intensity (60 dB / 72 dB). Tempo and intensity changes were matched for psychological magnitude. Reading passages (GMAT papers, Martinson & Ellis, 1996) were presented as written (Experiment 1) or spoken (Experiment 2) stimuli. Comprehension was assessed by multiple-choice questions.
Results
Baseline comprehension (no music) was 46%. Manipulations of intensity and tempo influenced comprehension of both written and spoken materials. For written materials there was an interaction between intensity and tempo. For slow tempo music, comprehension scores did not differ for loud and soft conditions (~40% accuracy). For fast tempo music, comprehension ranged from 49% (soft) to 32% (loud).
Conclusion
Music is a source of distraction for comprehension of verbal materials but the degree of distraction is dependent on attributes of the music. Loud music is generally more distracting, especially if the musical tempo is relatively fast.
Research and/or Educational/Clinical Implications
Background music while reading or listening to verbal material is a fact of life and widespread in educational contexts (studying, libraries). Understanding how to minimize musical distraction effects may have educational benefits.
Acknowledgement of Research Funding
Supported by the Australian Research Council (WFT), the MQRES Fund (WFT), and NSERC (EGS).

4A) 11:00 – 11:20

Affective and cognitive changes following prolonged exposure to Music and Speech

Gabriela Ilie[1] and William F. Thompson[2]
University of Toronto[1], Macquarie University[2]

Purpose
We examined the affective and cognitive consequences of listening to music (Experiment 1) or speech (Experiment 2) for prolonged periods of time. We also examined the effects of manipulating pitch height, rate and intensity in the two domains.
Methods
In Experiment 1 a classical piece of music was manipulated in pitch (high/low), rate (fast/slow) and intensity (soft/loud). Manipulations yielded eight conditions (2 pitches x 2 tempi x 2 intensities). For each, participants listened to music for seven minutes and reported their affective experiences based on ratings of valence (pleasant-unpleasant) and two types of arousal: energy (awake-tired) and tension (tense-relaxed). Creativity and routine task performance was also examined after each condition.
Experiment 2 reproduced the condition Experiment 1 using a male and a female speech about sea turtles (samples were longer versions of stimuli used by Ilie & Thompson, 2006).
Results
Manipulations induced changes in experiences of valence, energy arousal, and tension arousal in music (Experiment 1) and speech (Experiment 2). Manipulations of intensity and rate had identical effects in music and speech. Intensity manipulations affected ratings of tension arousal but not valence or energy arousal. Rate manipulations affected judgements of energy and tension arousal but not valence. Manipulations of pitch height had similar effects on valence ratings for music and speech, but different effects for ratings of experienced energy arousal. Manipulations of pitch height influenced energy arousal for speech, but not music.

Conclusion
Affective consequences of manipulating pitch height, rate and intensity were observed for both music and speech stimuli. Music and speech were not associated with identical effects, however, indicating that their connections with affective experience are partially domain specific. We discuss the relationship between perceived and felt affect by comparing the results obtained with Ilie & Thompson (2006). We also discuss a psychological framework for conceptualizing the affective and cognitive implications of the human auditory affective code.
Acknowledgement of Research Funding
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4A) 11:20 – 11:40

Parallel acoustic cues in sad music and sad speech

David Huron, Olaf Post, Gary Yim, and Kelly Jakubowski
The Ohio State University

Purpose
Linguistic research has established that "sad speech" is characterized by six prosodic cues: (1) quiet voice, (2) slow speaking rate, (3) low pitch, (4) small pitch movement, (5) slurred articulation, and (6) dark timbre (Fairbanks & Pronovost, 1939; Eldred & Price, 1958; Davitz, 1964; Siegman & Boyle, 1993; Banse & Scherer, 1996; Sobin & Alpert, 1999; Breitenstein, van Lancker & Daum, 2001). Listeners make use of all six cues in assessing the sad mood state of speakers. In this presentation, we review a series of published and unpublished analytic studies showing that Western music in the minor mode commonly exhibits these same six features.
Methods
The studies described in this presentation focus on aspects of musical organization and test hypotheses using correlational rather than experimental approaches. The studies involve large-scale analyses of several musical corpora, including Beethoven piano sonatas, Germanic folksongs, twentieth-century percussion music, the Barlow & Morgenstern dictionary of musical themes, and random samples of music from the Baroque, Classical, and Romantic periods. Both score-based and recording-based analyses are described.
Results
Music in the minor mode tends to exhibit lower dynamic markings, has slower notated and performed tempos, is lower in overall pitch, involves smaller pitch intervals, and shows greater use of slurring and pedaling. In addition, when musical repertoires are compared for similar instruments with darker (marimba) and brighter (xylophone) timbres, there is a marked tendency for the brighter instrument repertoire to favor major-key works.
Conclusion
In general, these corpora studies show a broad agreement between sadness cues in speech prosody and features in Western music (Juslin & Laukka, 2003).
Research Implications
The biological role of sadness is discussed and a theory proposed as to why "sad" sounds exhibit the six aforementioned cues. Grief (high arousal) is distinguished from sadness (low arousal). Low epinephrine levels are linked to weak muscle tone and slow muscle movement which produces low subglottal air pressure and slow movement of lips and tongue. It is proposed that, rather than being innate, the acoustic cues for sadness are learned associations or mirrored affects that are artifacts of low arousal. Evidence consistent with this interpretation is found in the difficulty listeners have in distinguishing "sad" voice from "sleepy" voice.

Session 4B Rhythm and Meter I (*Chair: Petr Janata)*

4B) 10:20 – 10:40

Sustained sound in a rhythmic context does not cause a filled duration illusion

Bruno H. Repp and Rachel Marcus
Haskins Laboratories

Purpose
Filling intervals between short “beat” tones with subdivision tones makes the beat interonset intervals (IOIs) seem longer and the sequence tempo slower—a kind of “filled duration illusion” (FDI) in music (Repp, 2008; Repp & Bruttomesso, submitted). Another kind of FDI has been obtained in psychophysical studies: An interval marked by onset and offset of continuous sound seems longer than a silent interval of the same duration. Two explanations for

this type of FDI have been proposed: acceleration of an internal pacemaker by continuous sound (Wearden et al., 2007), and slower perception of sound offsets than of sound onsets (Burghardt, 1972; Fastl & Zwicker, 2007). Two experiments tested whether this latter type of FDI might play a role in music.

Methods

Experiment 1 tested the pacemaker hypothesis in a rhythmic context by asking musicians to compare or reproduce short isochronous sequences of low-pitched piano tones played legato or staccato at different tempi. If there is a FDI, legato sequences should be perceived as slower than staccato sequences. Experiment 2 tested the offset perception hypothesis by asking musicians to judge the timing of tone offsets relative to the IOI midpoints of short isochronous sequences of low-pitched piano tones (gradual offsets) or artificial tones (abrupt offsets), played at three different tempi. If there is a FDI, tone offsets should be judged as late when they occur at the IOI midpoint, and would have to occur early to be judged as occurring at the midpoint.

Results

Results of Experiment 1 gave no indication that legato sequences were perceived as slower than staccato sequences. Results of Experiment 2 indicated that tone offset timing was judged quite accurately with both types of tone. There was no evidence of delayed perception of offsets, although piano tone offsets had to occur about 10 ms earlier for their timing to be judged like that of abrupt offsets.

Conclusions

These results show that a FDI with sustained sound is not obtained in a quasi-musical rhythmic context, in contrast to the reliable FDI obtained when additional sound events are inserted into an interval. The results raise questions about the explanations proposed for the first type of FDI in psychophysical experiments.

4B) 10:40 – 11:00

Differences in metrical structure confound tempo judgments

Justin London
Carleton College

Purpose

Musical tempo is usually regarded as simply the rate of the *tactus* or beat, yet most rhythms involve multiple, concurrent periodicities. Two experiments were conducted to investigate relations between the absolute rate of the tactus versus a more global sense of speed via a tempo discrimination task involving typical rhythmic patterns.

Method

Stimulus rhythms in 4/4 meter were presented at two tempos (component periodicities of 2400, 1200, 600, and 300ms vs. 2000, 1000, 500, and 250ms). Seven patterns using all combinations of the longest periodicity with one, two, or all three other components were employed. Trials consisted of a standard followed by a comparison, a 3AFC design (comparison = slower, same, or faster). In Exp1 participants simply judged relative speed. In Exp2 participants focused on the tactus rate. In both participants were told to refrain from tapping or making other synchronization movements.

Results

In both experiments when standard and comparison used the same pattern responses were accurate (97% correct for same absolute tempo; 85% when the comparison was slower or faster). This did not hold when standard and comparison involved different patterns: The presence of beat subdivisions (SDs) seems key. In both experiments, when Std and Comp both had SDs accuracy remained high. If SDs are lacking in either the standard or the comparison, performance was poor, as the presence/absence of SDs largely determined the response. In Exp. 2, focusing on the beat level improved performance where it was poor in Exp. 1, but degraded performance where it was good.

Conclusion

Periodicities in the 200-400ms range are highly salient in creating a sense of speed, even though these periodicities lie well outside the region of maximal pulse salience (Parncutt 1994). Beat subdivisions, while beneficial in rhythmic production, may not always enhance tempo perception (Repp 2003).

Research and/or Educational/Clinical Implications

This work provides a baseline for future studies of tempo perception involving more ecologically valid stimuli and/or a motor behavior component.

4B) 11:00 – 11:20

Temporal stability in rhythmic continuations by drummers and dancers

Christine Beckett
Concordia University

Purpose
To explore rhythmic capability across two time-based arts, music and dance; to explore whether an implicative paradigm could be applied to rhythm and dance.
Method
Participants—drummers (13, 2F) and dancers (11, 8F)—improvised continuations of 2 Slow, 2 Medium, and 2 Fast drum opening gestures. (Opening dance stimuli of similar nature were also improvised upon, but are not the main focus here.) Opening drum stimuli, each containing two time intervals delineated by 3 strikes of the right hand on a conga drumhead, were taped for uniformity. Each stimulus started with a one bar count-in to establish the beat and tempo. Participants saw/heard each opener twice (drummers) or 3 times (dancers). They counted in at the given tempo for one full bar and performed seated at the same drum. They were free to use both hands, and were videotaped. Two null hypotheses were adopted: that there would be no difference of temporal stability between dancers and drummers; and that there would be no difference in temporal stability between slow, medium and fast stimuli. The initial 20s of each improvisation was evaluated by 3 independent judges for temporal stability, as defined by the regularity of the beat and conformity to original tempo.
Results
Overall, drummers were significantly more temporally stable than dancers. Fast openers elicited improvisations of significantly more stable temporality than medium and slow openers. There was no significant difference of stability comparing improvisations elicited by medium compared to slow openers.
Conclusion
That fast openers led to more stable continuations may be a result of beat proximity (more beats in a given time span) and/or related to preferred tapping/tempo rates. Musicians' clear superiority at maintaining temporal stability was somewhat surprising given that dance is rhythmic, dancers often work to a drum, and the conga used was not technically challenging.
Research/Educational Implications
Whether this was a musical training effect, or whether these musicians were more accustomed to improvising than were the dancers, could be tested through use of highly over-learned materials in drumming and dance. Such materials could be used, further, to explore MMN and CPS, etc., in a standard/deviant ERP paradigm. Given that musicians and dancers frequently coordinate their arts, specific musico-rhythmic training for dancers might be warranted.

4C) 11:20 – 11:40

Fractal structure of tempo fluctuations in skilled piano performance

Summer K. Rankin[1], Edward W. Large[1], and Craig Sapp[2]
Florida Atlantic University[1],Stanford University[2]

Purpose
In previous work the performances of one skilled pianist revealed 1/f type serial correlations and fractal scaling (Rankin, et al., 2009). In order to investigate whether and how this finding generalizes we conducted fractal analyses on 2 databases of piano performances.
Methods
Database 1 (http://mazurka.org.uk) included commercial audio recordings of 5 pieces of music (Chopin Mazurkas) performed by professional pianists. The beat times were manually coded and inter-beat intervals were extracted for the analyses. Database 2 (http://www.piano-e-competition.com) consisted of performances from the top 5 pianists at the Minnesota International Piano-e-competition 2008 & 2004. Performances were recorded on a Yamaha CFIIIS Disklavier Pro concert grand piano. Each performance was matched to its score using a custom dynamic programming algorithm (Large & Rankin, 2007), to extract inter-beat intervals (IBIs) for analysis.
Results
Power Spectral Density (b) and Rescaled Range (*H*) analyses of the IBI time-series at multiple metrical levels, showed that the majority of performances in both databases revealed fractal scaling and long-range (1/*f* type) serial correlations.
Conclusion
Our results show that piece and style of music were better predictors of *H* and b values than pianist. Fractal scaling

implies that fluctuations at lower levels of metrical structure (e.g., $\frac{1}{16}$-note) provide information about fluctuations at higher levels of metrical structure (e.g., ¼-note). Long-range correlation implies that fluctuations early in the time series provide information about fluctuations later in the time-series.

Research Implications

Researchers have suggested a deep relationship between musical and other biological rhythms. Fractal stimulus fluctuations may facilitate perception-action coordination, such that endogenous processes are better able to perceive structure, dynamically engage, and adapt to changes. Such processes may enable more successful interaction with the environment and between individuals.

Acknowledgement

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Session 5A Music and Language III (*Chair: Tonya Bergeson)*

5A) 1:30 – 1:50

Congenital amusia is not a music-specific disorder: Evidence from speech perception

Fang Liu[1], Aniruddh D. Patel[2], and Lauren Stewart[1]
University College London[1], The Neurosciences Institute[2]

Purpose

The domain-specificity of congenital amusia is a topic of active research. This paper investigates whether individuals with amusia have intonation perception deficits in speech when the pitch contrasts are subtle, and considers the relationship between performance on intonation tasks and sensitivity to changes in pitch.

Methods

Ten British amusics participated in a set of intonation tasks and pitch threshold tasks. The intonation tasks involved three same-different discrimination tasks: statements versus questions in 1) natural speech, 2) gliding-tone analogs, and 3) nonsense-speech analogs. A statement/question identification task was also included. The pitch threshold tasks involved the use of adaptive-tracking, forced choice procedures to determine the threshold for a) detection of a pitch change, and b) discrimination of pitch direction.

Results

In the intonation tasks, discrimination accuracy was not equivalent across the three conditions, even though the pitch patterns were identical. 7/10 of amusics performed worse on discrimination of speech stimuli (mean percentage correct: 75%) than tone analogs (91%). Furthermore, 7/10 of amusics performed better on discrimination of speech stimuli (88%) than nonsense-speech analogs (79%). Accuracy rates for identification of statements and questions were relatively low (71%) across amusics. Regression analyses revealed a significant negative association between both pitch threshold tasks and performance on the gliding-tone analog condition ($F(1,7) = 16.7$, $p = 0.0047$; $F(1,7) = 38.8$, $p = 0.0004$). A similar relationship was also found between pitch direction threshold and performance on the nonsense-speech analog condition ($F(1,7) = 11.3$, $p = 0.0121$). In contrast, performance on the speech discrimination/identification tasks was not predicted by either of the pitch threshold tasks.

Conclusions

The above results extend those of Patel et al., 2008 (*Music Perception,* 25: 357-368), where 30% of amusics had difficulties in distinguishing between statements and questions that differ only in the direction of their final pitch glides. The present paper, which used more subtle pitch contrasts and gliding-tone analogs, reveals that the majority (7/10) of individuals with amusia show worse performance for discrimination of speech-intonation versus tonal-analogs.

Research implications

The findings point to the non domain-specificity of amusia, and constrain theories of the underlying neural mechanisms associated with this deficit.

Acknowledgement of Research Funding

Supported by Neurosciences Research Foundation and the Economic and Social Research Council

5A) 1:50 – 2:10

Illusory conjunctions in memory for phonemes and melodic intervals: Vowels sing but consonants swing

Pascale Lidji[1], Régine Kolinsky[3], Isabelle Peretz[2], Hélène Lafontaine[3] and José Morais[3]
McGill University[1], University of Montreal[2], Université Libre de Bruxelles[3]

Purpose
The lyrics and the tune of songs are known to leave associated memory traces (e.g., Peretz, Radeau & Arguin, 2004; Crowder, Serafine, & Repp, 1990). The nature of these connections between text and melody are, however, still unknown. The present study investigates whether the phonetic properties of the lyrics influence the strength of the tune-lyrics connections. Indeed, a recent study in song perception (Kolinsky et al., in press) revealed that consonants are less integrated to melodic information than are vowels. Based on these results, we expect to find similar differences between consonants and vowels in song memory. The occurrence of illusory conjunctions of lyrics and tune was taken as an index of the strength of association between these song components (Thompson, Hall, & Pressing, 2001).
Methods
After the learning of bisyllabic nonwords sung on two-tone intervals, the participants had to recognize these "old stimuli" among four types of foils. These foils were (1) completely new stimuli (new interval and new nonword), (2) a new interval combined with an old nonword, (3) a new nonword combined with an old interval, or (4) mismatch stimuli. The mismatch stimuli were new combinations of familiar components, namely, the interval and the nonword of two stimuli presented separately in the learning phase. Twelve participants were presented with stimuli in which the nonwords differed on one consonant, and twelve other participants were presented with stimuli in which the nonwords differed on one vowel. False alarms to mismatch stimuli, i.e. erroneous recognitions of these mismatch stimuli as old stimuli, reflected to occurrence of illusory conjunctions.
Results
The participants produced more false alarms for mismatch stimuli than for any other kind of foils, suggesting that they made illusory conjunctions of nonwords and intervals. The illusory conjunction rate was significantly higher for stimuli in which nonwords varied on consonants than for stimuli in which nonwords varied on vowels.
Conclusion
The results confirm that the phonetic properties of the lyrics modulate the lyrics-tunes interactions: consonants are less strongly associated with the melody than are vowels. In other words, vowels sing but consonants swing, hence leading to more numerous illusory conjunctions. These results will be discussed in the light of the different evolutionary origins and linguistic functions of consonants and vowels.

5A) 2:10 – 2:30

Using a rhythm-based pedagogical technique to improve reading fluency

Scott D. Lipscomb[1], Dee Lundell[2], and Larry Scripp[3]
University of Minnesota[1], Minneapolis Public Schools[2], New England Conservatory[3]

Purpose
Past research has revealed that music can serve as a useful means of facilitating learning in other academic areas (Burnaford, 2007; Catterall, 2005; Deasy, 2002 & 2003; Peterson, 2005), including benefit specifically to reading ability (Andrew & Sink, 2002; Butzlaff, 2002). For the past five years, the present authors have been collaborating with classroom teachers and music specialists to integrate music across K-12 curriculum. In the Fall of 2007, a reading program was established in a highly diverse northside Minneapolis school. The Purpose of this investigation is to determine to what extent the use of musical rhythm can facilitate the acquisition of reading fluency with high frequency sight words by third graders.
Methods
During the 2007-08 academic year, a Rhythm & Reading Group (RRG) was established in each of three third grade classrooms. The pedagogical method involves establishment of a steady rhythm to which students read lists of 25 words. Four lists of words were used during the testing period, with two- to three- week practice periods per list, resulting in a total duration of 12 weeks for empirical investigation. The RRG sessions were led by a teaching artist twice a week for 20 minutes in each classroom. A variety of tempos and word orders were used to continuously engage the students. A carefully designed assessment schedule was established to measure reading ability at two- to three-week intervals throughout the testing period.

Results
Results revealed a significant level of improvement for both student below grade-level reading ability and for those at or above grade-level reading, as determined at the beginning of the academic year. Students improved dramatically in their reading fluency on the list of 25 words they had practiced during the weeks preceding each test, as measured by the number of words read correctly (increased significantly) and the time required to read the list of words (decreased significantly). Results revealed significant transfer of reading fluency, as both the accuracy and reading time improved significantly for the lists of words not seen since the initial pre-test as well.
Conclusions & Educational Implication
Integration of the Rhythm & Reading Group appears to significantly improve student reading fluency within a very short period of time. This example of music integration may benefit students and teachers across the glove. Future research needs will be explicated.
Acknowledgement of Research Funding
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Session 5B Rhythm and Meter II (*Chair: Jon Prince)*

5B) 1:30 – 1:50

Turn that noise up: How Rock Band© helps youth develop rhythmic intuitions

Michael P. Downton, Kylie A. Peppler, and Ken Hay
Indiana University

Purpose
With the growing popularity of rhythmic videogames (e.g., Rock Band), youth are spending large amounts of time playing music in the context of games although we know little about the efficacy of such environments for musical learning. As such, videogames present a novel opportunity to examine rhythmic games as an alternative pathway into music education. In this study, we investigate the following research questions: 1) Through game play, do youth improve their abilities to perform rhythms accurately and in tempo? 2) In what ways does Rock Band teach youth to understand how rhythms and patterns are a part of music?
Methods
The study took place in a local after-school program. A total of 30 participants took part in the study over a three-month period. At the start of the study, 44% of participants were unfamiliar with the game. A quantitative performance analysis that logged the number of hits, misses, near hits, extra hits, and non-synched hits during game play was used to measure *Rhythmic Perception* (i.e., rhythm that can be attended to immediately), *Rhythmic Accuracy* (i.e., the number of correct hits made during game play), and *Rhythmic Estimation* (i.e., the reconstruction of rhythmic information from stored memory).
Results
Researchers chose six case studies that represented the larger trends amongst the participants. The results show that youth do improve their abilities to perform rhythms accurately and in tempo. One case, Karen, is shown for the purposes of this abstract. In Figure 1, observations 1 and 5 are compared and demonstrate that Karen's rhythmic intuition was becoming more developed (i.e., her perception, estimation, and accuracy all improved). In Figure 2, the graph shows that the margin for error decreased for Karen and accounted for more accurate hits overall, demonstrating some understanding of the rhythm in the song.
Conclusion
The nature of the Rock Band experience provides the benefits of simultaneous music-making as commonly realized in the classroom setting, while also framing the learning within an activity that leads youth to make connections at their own speed. Findings demonstrate that rhythmic intuitions develop during game play as evidence by the improvement of rhythmic perception, accuracy, and estimation.
Educational Implication
This research builds a foundation for the use of new technologies, and particularly videogames, in the classroom. In addition, this study holds implications for capitalizing on informal, out-of-school music experiences for musical learning.

5B) 1:50 – 2:10

A perception-action model for similarities in perceived musical tempo and the kinematics of physical action

Aysu Erdemir, Erdem Erdemir, and John J. Rieser
Vanderbilt University

Purpose
Many pieces of music slow down at the end, and the "final ritardandi", signals that the end of the piece is near. Controlled locomotion ends with a "ritardandi" as well, as runners slow down to stop. The main thesis of this paper is that the ritardandi that listeners prefer in music have commonalities with the ritardandi in physical actions. We propose a 2nd order homogenous differential equation modeling approach, which is used to model a variety of real world systems such as diffusion processes, control of electrical/mechanical devices and human arm/hand/leg movements, to capture the similarities of musical ritardandi and stopping from running. Our model consists of (1) a goal/attraction point, xref (2) an internal driving factor, _ coefficient, which moves the system towards the final goal (3) a viscous damping factor, _ coefficient, which provides dissipation of energy and a controlled trajectory and (4) an energy-storage element, _coefficient. The equation of motion for such system is **__+ __+ _x=0**, where x is displacement as a function of time.
Methods
The model parameters were changed iteratively to simulate several 2nd order systems until we find the system output that was closest to the observed data profile. These data include 16 individual velocity patterns of runners' deceleration as well as 20 individual tempo patterns of ritardandi, generously shared by Friberg & Sundberg (1999) and Sundberg & Verillo (1980).
Results
Our model not only matched the velocity and tempo patterns of 12 stopping and 12 ritardandi samples as well as the kinematic model proposed by Friberg & Sundberg (1999), but also produced a higher mean correlation (p<0.02) for the additional 4 velocity and 8 tempo profiles which have been discarded from the calculations due to worries about low aesthetic rating and tempo fluctuations.
Conclusion
Based on the idea of a unifying mechanical formula, our findings suggest that expressive timing in music can be explained by parameters of physical/mechanical motion that deal with force, mass and velocity; and provide further support with regard to the common analogy between "music" and "movement".
Research and/or Clinical or Educational Implication
We aim to assess the generalizability of the model as well as its potential to account for individual differences by analyzing the kinematics of various actions such as playing ritardandi, stopping from running, grasping and hand shaking by both within and between subjects designs; and accordingly we plan to develop a personal visuomotor training method primarily for use in sports and musical education.

5B) 2:10 – 2:30

Temporal context and choice reaction time

Robert J. Ellis and Mari Riess Jones
The Ohio State University

Purpose
The majority of influential models of choice reaction time (RT) do not consider the temporal context in which a to-be-decided event appears. In this study, we manipulated the temporal context ("Rhythmic" vs. "Scrambled") of a sequence of clicks that preceded a final target tone to determine how temporal context contributes to choice RT.
Methods
Listeners heard a sequence of 6 or 7 clicks (10 ms tones, F#5) that preceded a final tone (25 ms, C5 or C6), and made a speeded judgment whether that tone was "low" or "high." The timing of the click sequence was either "Rhythmic" (in which inter-onset intervals [IOIs] between tones corresponded to a strong 4/4 metrical grid) or "Scrambled" (permutations of the rhythmic sequences that were designed to hinder the percept of meter). All sequences were exactly 4 s from the onset of the first tone to the onset of the target tone. The final IOI (the "foreperiod") before the target was, equally often, 250, 500, or 1000 ms; we included this variable to uncover whether the classic foreperiod effect (i.e., RT decreases as foreperiod increases when multiple foreperiods vary randomly within a session) holds when a foreperiod is part of a larger sequence. Listeners heard either a block of Rhythmic trials or a block of Scrambled trials first (72 each).

Results
Four effects were noteworthy. (1) Listeners were faster overall during the rhythmic block. (2) Those listeners with a faster overall RT showed the first effect more strongly than those listeners with a slower mean RT. (3) Those listeners who heard the Scrambled block first showed the first effect more strongly than those listeners who heard the Rhythmic block first. (4) RTs in the Rhythmic block were faster when the foreperiod was 500 ms (vs. 250 or 1000 ms), suggesting that a subdivision of the 1000-ms "beat" prior to the target tone facilitated performance; no significant foreperiod effects were present in the Scrambled condition.
Conclusion
The rhythmic structure of the temporal context preceding a target tone judgment significantly affects RTs, despite the fact that the temporal context contains no information about the *what* of the decision, only the *when*.
Implications
These findings are consistent with entrainment approaches to temporal sequencing (e.g., Large & Jones, 1999; McAuley & Jones, 2003). They also have implications for models of choice RT (e.g., Ratcliff, 1978; Luce, 1986) which are currently tacit with regards to how temporal structure influences decision making.
Acknowledgement
This research was supported by The Caroline B. Monahan Fund for Experimental Research Support within the Department of Psychology at Ohio State University.

5B) 2:30 – 2:50

Comparing synchronization to auditory and visual rhythms in hearing and deaf individuals

John Iversen[1], Aniruddh Patel[1], Brenda Nicodemus[2], and Karen Emmorey[2]
The Neurosciences Institute[1], San Diego State University[2]

Purpose
The ease with which humans synchronize their movements with sound suggests a tight coupling between auditory and motor systems. Is this a special relationship, or can other sensory modalities drive motor synchronization? In previous studies, synchronization with flashing lights was far worse than to equivalent auditory rhythms. Flashing lights may however not be optimal for a visual system often concerned with detecting motion. We ask if synchronization accuracy to moving visual stimuli approaches that for auditory stimuli. The role of experience in shaping sensory-motor synchronization is also examined by comparing the performance of hearing participants and deaf signers with extensive visuo-motor experience through sign language.
Methods
Deaf and hearing participants (n=22 each) tapped to isochronous (600 ms period) visual and auditory (hearing participants only) stimuli. Visual stimuli included a flashing light, and an animated bouncing ball. Participants were instructed to synchronize with the moment of contact of the ball with a surface. The auditory stimulus was a metronomic series of beeps. Tap times were collected using a drum pad, and inter-tap intervals and asynchronies were computed.
Results
The substantial difficulty of synchronizing to a flashing light was confirmed in both groups. In contrast, for hearing participants synchronization with the bouncing ball was just as good as with the auditory metronome (mean standard deviation of asynchrony (sd. async) 35 ms vs. 36 ms; $p = 0.59$). Deaf participants synchronized with the bouncing ball as well as did hearing participants (sd. async 38 ms; $p = 0.98$).
Conclusion
The results suggest that synchronization with a moving visual stimulus can be as accurate as synchronization with auditory stimuli. Deaf signers performed the same with visual synchrony as hearing non-signers, suggesting visuo-motor synchronization is not modified by experience, at least for these simple stimuli. Future experiments will examine more ecologically relevant stimuli.
Research Implications
Both auditory and visual systems appear capable of driving accurate synchronization. A question for future cross-modal comparisons is whether synchronization to the beat of metrical patterns (multiple time-scales of temporal structure) is as good for visual as for auditory stimuli.
Acknowledgement of Funding
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Poster Session I

3:00 – 5:00

1. Implicit and explicit memory for melodies in aging and cognitive impairment

Ashley D.Vanstone, Lola L.Cuddy, Angeles Garcia, Rosalind G.Sham, and Leila Tangness
Queen's University

Purpose

We sought to clarify the effects of aging and cognitive impairment on explicit and implicit memory for melodies. Previous results are conflicting. In studies of aging and explicit memory, older participants performed as well as (Blanchet, Belleville, & Peretz, 2006), or, alternatively, more poorly than (Bartlett, Halpern, & Dowling, 1995) younger controls. Further, Alzheimer participants performed similarly to older controls on recognition (explicit) tests and were impaired on preference (implicit) tests (Halpern & O'Connor, 2000), but the reverse pattern has also been reported (Quoniam et al. 2003).

Methods

Both young (N = 30, ages 19-25) and elderly (N= 40, ages 68-88) adults were recruited. Older adults included both cognitively healthy individuals and those who had been diagnosed as cognitively impaired (with or without dementia). Eight unfamiliar melodies were presented, in random order, on each of three study trials and participants were given intentional learning instructions. Study trials were followed by a recognition trial containing 16 melodies. Eight of the 16 were the study melodies; eight were novel. Study melodies and novel melodies were counterbalanced across participants. Participants were asked both to indicate the pleasantness of each melody on the test trial—a test of implicit memory, or mere exposure effect—and also to respond yes/no to each melody whether it had appeared in the study trials—a test of explicit memory.

Results

On both explicit and implicit tasks, melody retention scores were, in order, young adults highest, followed by healthy older adults, followed by impaired adults. Young and older adults scored well above chance, but impaired older adults were at chance.

Conclusions

Our experimental method was sensitive to both the effects of aging and the effects of impairment. Retention of unfamiliar melodies is subject to aging, but the effects of healthy aging are not necessarily severe. The effects of cognitive impairment are additive to the effects of aging and, in contrast to healthy aging, may be severe.

Research/clinical implications

A major challenge for future theory and research, with implications for music therapy, is to reconcile the evident loss of retention of unfamiliar tunes in aging and impairment with the well documented sparing of long-term musical memories.

Acknowledgments

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2. The obsessive song phenomenon: Induction, memory and emotions

Andréane McNally-Gagnon, Sylvie Hébert, and Isabelle Peretz
University of Montreal

Purpose

Earworms, or songs that get "stuck" in one's head, are a common experience and yet, we know very little about this strange mental phenomenon. The goal of this study was to 1) obtain descriptive as well as production data of obsessive songs, and 2) examine whether they could be induced experimentally.

Methods

One group of musicians and one group of non-musicians who self-reported having obsessive songs frequently were recruited and given a personal recording device. They had to reproduce their obsessive songs when they appeared, by singing them as accurately as possible, over two non-consecutive 3-day periods. They also had to fill out questionnaires describing the songs and associated emotions. Before each 3-day period, half of each group was exposed to an "induction" condition where they were presented with five catchy songs and had to reproduce them. The other halves were exposed to a control condition.

Results

Induction was deemed successful when one or more of the "induced" songs were recorded by the participant during the subsequent 3-day period. It was successful in 47.22% of the participants in the induction group. Songs that were induced were very or moderately familiar in 84.6% of the cases, which makes familiarity a necessary but not sufficient factor for induction to be successful. Also, musicians had longer episodes and their reproductions were more accurate than the ones of non-musicians, that is, they were closer in pitch and time to the original versions. Musicians also recorded more classical and invented songs, which indicates that the phenomenon is closely related to exposure and musical habits. Lastly, our data show that emotions preceding the earworm episodes were mostly positive, and only

rarely neutral (3,16%). In addition, the emotional states described after (or during) the earworms were more often neutral (32,27%) and less strongly positive or negative.

Conclusion

Our findings suggest that like voluntary musical imagery, earworms are closely related to the absolute memory representations of music in the mind. Moreover, they suggest that one of the earworm's function could be related to emotional regulation. Finally, although our induction condition was not optimal, the fact that it was partly successful is encouraging and warrants further investigation.

Research and/or Educational/Clinical Implications

This study enables a view of the phenomenology and physical attributes of involuntary mental imagery and furthers our knowledge about musical memory and the role of music in emotional regulation.

Acknowledgement of Research Funding

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3. Speaking, singing and observing: A TMS Study

B. Stahl, F. Lessard, Pascale Lidji[1], H. Theoret[2], and Isabelle Peretz[2]
McGill University[1], University of Montreal[2]

Purpose

During the past decade, neurophysiological studies in primates have identified a population of neurons that respond not only to executed actions but also to the observation of these actions. This neurophysiological phenomenon has become well-known under the label of “mirror neurons” (Fadiga et al., 1995). In humans, a similar mirror neuron system seems to be involved in speech perception (e.g. Watkins et al., 2003). However, it remains unclear whether such a system also exists for singing. The aim of this study was to assess the contribution of mirror neurons in speech and music.

Methods

Professional singers performed speech and singing tasks while single pulse transcranial magnetic stimulation was applied over the right and left motor cortices. Cortical excitability changes were measured by motor-evoked potentials in the contralateral hand. We compared the motor-cortical excitability during production tasks (i.e., speaking and singing) and perceptual tasks (i.e. judging accuracy of verbal and sung productions). The stimuli in the perceptual tasks were auditory, visual (lip-reading for speech, facial expression for singing; Thompson & Russo, 2007) or audio-visual.

In the speech tasks, subjects were instructed to explain French proverbs (production) or were observing someone else explaining French proverbs (perception). Subjects had to rate whether the explanation of proverbs was correct in the auditory and audio-visual condition, or whether distinct words could be read on the lips in the visual condition. In the singing tasks, subjects were instructed to sing intervals (production) or to observe someone else singing intervals (perception). Subjects had to rate whether the sung intervals were correct based on auditory information or on facial expression. Control condition included meaningless figures which had to be classified as closed or open. Speech and singing conditions were tested in two different sessions involving production and perception trials. Meaningless figures were presented separately before or after each session.

Results

Speech production and perception equally increase the excitability of the left motor cortex whereas song production and perception increase the excitability of the right motor cortex.

Conclusion

The results are in line with prior studies in showing increased motor-cortical excitability during speech perception (Watkins et al., 2003) as well as during speech and music production (Sparing et al., 2007). Our data further suggest the involvement of mirror neurons that are differently lateralized in speech and music.

Acknowledgement of Research Funding

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4. Relative influence of musical and linguistic experience on the subcortical encoding of pitch

Gavin M. Bidelman, Jackson T. Gandour, and Ananthanarayan Krishnan
Purdue University

Purpose:

Neural encoding of pitch in the auditory brainstem is known to be shaped by long-term experience with language or music, implying that early sensory processing is subject to experience-dependent neural plasticity. In language, pitch patterns consist of sequences of continuous, curvilinear contours whereas in music, pitch patterns consist of discrete, stair-stepped sequences of notes. The aim of this study was to examine how domain specific experience (language vs. music) influences the pre-attentive encoding of pitch within the human brainstem.

Methods:
Brainstem frequency-following responses (FFRs) were recorded from native Chinese, English amateur musicians, and English non-musicians in response to iterated rippled noise (IRN) homologues of a musical interval (major third; M3) and a lexical tone (Mandarin tone 2; T2). Pitch strength (50 ms sections) and pitch-tracking accuracy (whole contour) were computed from the FFRs using autocorrelation algorithms. In addition, narrow-band spectrograms were used to evaluate their spectral composition.
Results:
Chinese and musicians showed higher pitch-tracking accuracy than the non-musicians regardless of the domain. Relative to non-musicians, musicians showed more robust pitch strength across all sections whereas Chinese did so only in those sections containing the most rapid changes in pitch. Interestingly, musicians exhibited greater pitch strength than Chinese in one section of M3, corresponding to the onset of the 2nd musical note, and two sections within T2, corresponding to a note along the diatonic musical scale.
Conclusion:
Despite the striking differences in the nature of their pitch experience, both Chinese and musicians, relative to non-musicians, show positive transfer across domains in terms of pitch encoding. Musicians have a more robust representation of pitch than Chinese, but only in subparts of the stimulus which can be related to perceptually salient features found in music. As such, we infer that brainstem neurons are differentially tuned to extract specific acoustic features relevant to a listener's domain of expertise. Cross-domain enhancement of pitch representation appears to be greater from music to language than the reverse at the level of the brainstem.
Research Implications:
Our results imply that the auditory brainstem is not simply a passive way station, but rather, is shaped by long-term experience. As in the cortex, this early, pre-attentive sensory processing is subject to experience-dependent neural plasticity. More importantly, processing relevant to music and speech perception may begin as early as the level of the brainstem.
Acknowledgement of Research Funding:
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5. Musicians display enhanced auditory event-related potentials to both music and voice

Natalya Kaganovich and Christine Weber-Fox
Purdue University

Purpose
Musical training has a pervasive influence on auditory processing and appears to enhance early sensory encoding of not only music but also pure tones and speech. Because speech is necessarily carried by voice, reports of greater phonological abilities in musically trained individuals raise the question of whether musicians have an enhanced processing of the human voice. Chartrand and Belin (2006) showed that musicians were more accurate in discriminating both musical and vocal timbres; however, the cognitive mechanisms underlying such enhancement remained uninvestigated. Therefore, the first goal of our project was to compare auditory encoding of musical and vocal sounds in musicians and non-musicians. Voices are often described as "auditory faces." In the visual domain, faces have a powerful ability to capture attention. We asked if voices may have a similar power in the auditory domain and investigated whether rare changes in musical and vocal sounds were equally distracting for musicians and non-musicians.
Methods
Ten musicians and 10 non-musicians participated in the study. We combined a version of an auditory distraction paradigm (Schröger and Wolff, 1998) with event-related potential (ERP) recordings. During each block, participants identified sounds as either short (300 ms) or long (500 ms) by pressing response buttons. In half of the blocks, musical sounds (cello or French horn playing a G4 note) were present on 80% of trials while voices (male and female saying neutral "a") were present on 20% of trials (deviants). In the other half, the reverse was true. A change in the type of sound (from music to voice or the reverse) was irrelevant for the duration judgment task. We collected RT, accuracy, and ERPs in response to all sounds.
Results
Preliminary analysis of ERP data shows that both music and voice deviants elicited a larger fronto-central negativity between 100 and 400 ms post-stimulus onset in musicians compared to non-musicians, with a greater group difference for music deviants. Inspection of group averages suggested a greater re-orienting negativity component in musicians to both types of deviants.
Conclusion
Early exposure to musical timbres may enhance perception of other spectrally complex sounds, such as the human voice.
Research Implications
This study extends research into the relationship between music and speech perception by suggesting that one reason for the beneficial effect of musical training on linguistic skills may be the enhanced sensory encoding of complex spectral information present in the voice.

Acknowledgement of Research Funding
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6. Inferring rules from sound: The role of domain-specific knowledge in speech and music perception

Aaronell Matta and Erin E. Hannon
University of Nevada, Las Vegas

Purpose
Speech and music are two forms of complex auditory structure that both play fundamental roles in everyday human experience and require certain basic perceptual and cognitive abilities. Nevertheless, human listeners may process the same information differently depending on whether a sound is heard in a linguistic vs. musical context. The goal of these studies is to examine the role of domain-specific knowledge in auditory pattern perception. Specifically, the study examines the inference of "rules" in novel sequences containing patterns of both spectral structure (i.e., changes in speech or instrument timbre) and fundamental frequency (i.e., changes in pitch).
Methods
In Experiment 1, participants were familiarized with sequences containing contrasting rules, where speech syllables followed one sequential rule (e.g., ABA) and pitch (of the voice) followed another (e.g., ABB). In a test phase, participants rated the similarity of novel stimuli that were consistent or inconsistent with one or all of the rules established during familiarization. In Experiment 2, participants will be again be familiarized with sequences containing contrasting rules (ABA vs. ABB), however instrument timbre will replace speech syllables. Pitch stimuli will follow one consistent instrument timbre. The test phase will also follow the same procedure as Experiment 1.
Results
Results of Experiment 1 indicate that listeners respond primarily to violations of syllable structure and largely ignore changes in pitch, presumably because of domain-specific knowledge within a speech context. In a control condition where the same stimuli are presented but syllables are held constant, listeners show no difficulty picking up on pitch patterns, suggesting that they are capable of detecting pitch patterns in music but ignore them when contrasting speech information is available. Conversely, in Experiment 2 we expect domain-specific musical knowledge to lead listeners to attend to patterns of pitch change and ignore changes in instrumental timbre.
Conclusions
These results support the notion that adults are capable of learning patterns in a number of domains, but that they attend to different cues depending on the context, essentially "filtering" information according to domain-specific knowledge.
Research Implications
These findings will contribute to research and knowledge in the area of auditory cognition, particularly music and speech perception, offering insight into populations including infants, children, and adults.

7. Song prosody: Electrophysiological correlates of temporal alignment and metrical regularity in textsetting

Reyna L. Gordon[1], Cyrille L. Magne[2], and Edward W. Large[1]
Florida Atlantic University1, Middle Tennessee State University2

Purpose
The aim of this study is to test the hypothesis that good textsetting helps listeners better understand sung language by focusing attention on stressed syllables. Using behavioral and electrophysiological measures, we investigate how the proportion of well-aligned syllables (stressed syllables on strong beats) in sung sentences affects intelligibility. We also compare the effects of metrical regularity (regular vs. irregular patterns of stressed and unstressed syllables) in song.
Methods
We created a corpus of sentences, comprised of regular (iambic and trochaic) and irregular linguistic stress patterns. Each sentence was sung on an isochronous melody. For regular sentences, good and bad textsettings were generated by pairing the sentences with a metronome beat that was either well-aligned (in-phase) or misaligned (anti-phase) with the linguistic stress pattern. Irregular textsettings were created by pairing irregular sentences with a metronome beat on alternating syllables, such that some of the syllables were well-aligned and some were misaligned. We used a cross-modal priming protocol to assess how sung prime sentences facilitate or hinder semantic processing of visual target words. Participants performed a lexical decision task in which they listened to the sung prime sentence and then decided whether a target word was a real word or pseudoword.
Results
Our preliminary findings indicate that Event-Related brain Potentials related to semantic integration are adversely affected by sentences with irregular and misaligned textsettings. Furthermore, induced (non-timelocked) gamma-band activity was enhanced for well-aligned versus misaligned syllables.

Conclusion
These findings fit with previous studies showing that attention is preferentially allocated to stressed syllables in speech and strong beats in music. The present observations add to our understanding of the neurophysiological basis of metrical expectancy, providing a viable explanation for the human tendency to unify linguistic and musical stress patterns in song.
Research and/or Educational/Clinical Implications
This research addresses the ongoing debate regarding the extent to which language and music share cognitive and neural resources. Our results may improve therapeutic interventions that incorporate singing in rehabilitation programs.
Acknowledgement of Research Funding
The first author was supported by the American Association of University Women Doctoral Dissertation Fellowship and the Newell Doctoral Fellowship.

8. Musical experience results in better speech-in-noise perception: behavioral and neurophysiological evidence

Alexandra Parbery-Clark, Erika Skoe, and Nina Kraus
Northwestern University

Purpose:
Musicians have life long experience with attentively listening to and manipulating musical sounds. Not surprisingly, musical experts demonstrate enhanced basic auditory perceptual skills as well as functional adaptations for the processing of acoustic features such as pitch, timbre and timing at both cortical and subcortical levels. These acoustic cues contribute to the parsing of multi-source sounds and it would appear that musicians use their heightened perceptual skills to better segregate concurrently presented sounds. Here we investigate whether musical expertise results in enhanced speech-in-noise perception. To this aim, we examined the effects of musical experience on both behavioural speech-in-noise tests and the brainstem representation of speech sounds with and without competing noise.
Methods:
To investigate the effect of musical experience on speech-in-noise perception we compared behavioural and neurophysiological responses in adult musicians and nonmusicians. We administered clinically relevant speech-in-noise tests (QuickSIN and HINT) and recorded auditory evoked brainstem responses to speech sounds in both a quiet and competing background noise condition.
Results:
Musicians outperformed the control group on the measures of speech-in-noise perception with years of musical practice positively correlating to speech-in-noise performance. Musicians were also found to have more robust subcortical representations of the acoustic stimulus in the presence of background noise suggesting that musical experience limits the degradative effects of background noise on subcortical representation of speech sounds.
Conclusion:
Musical experience appears to enhance the ability to hear speech in challenging listening environments and the underlying subcortical representation. Clinically, these findings highlight the importance of taking musical training into consideration when evaluating a person's speech-in-noise ability and suggest that musical training may be a useful rehabilitative tool for populations with known speech-in-noise deficits such as children with learning disorders and people with hearing impairments.
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9. The intentional nature of perception-action coupling as a basis for musical interaction

J. Scott Jordan
Illinois State University

Purpose
Recent research indicates (1) actions are planned in terms of the distal effects they are to produce, and (2) planning and perception share common neural resources. As a result, perceiving the effects of an action (e.g., hearing the tones produced by striking a piano key) activates the pre-motor cortical centers one would use while *planning* to produce such effects oneself. In short, perception takes place within an intentional, planning context that emerges out of the action-effect contingencies one learns over the life course. Given this intentional, *effect*-relative context for perception, the present talk will present research that (1) supports the assertion that perception is altered in a forward-looking manner as one learns the action-effect contingencies that underlie intentional contexts, (2) examines the conditions that allow one to develop intentional contexts, (3) examines how one's own perceptions are altered as one learns to cooperatively generate a distal effect with another (e.g., play a duet).

Methods and Results
The experiments to be presented examine intentional contexts in spatial perception. Specifically, research indicates participants perceive the vanishing point of a moving stimulus beyond the actual vanishing point. Jordan and Hunsinger (2008) found that those who have experience controlling the stimulus' movements, perceive the stimulus to vanish further ahead than those who do not. Also, one can learn the action-effect contingencies that give rise to such forward displacements (FD) by simply observing another control the stimulus. However, larger FD only occurs if one perceives the effects of the model's actions, as well as the actions themselves. Finally, Jordan and Knoblich (2004) found that FD increases as one attempts to control the movements of the stimulus co-operatively with another participant.
Conclusions and Implications
These data support the assertion that perception entails forward-looking, intentional content derived from planning. They further imply that as agents continuously generate distal effects together (e.g., a choir sings together), the resultant group effect (i.e., the sound of the choir) become part of one's own action-effect contingencies (i.e., one's own intentional context). One's planning therefore, transforms from being about oneself, to being about one's own effects in relation to the overall group-effect. Perceptions, likewise, become more group-relative.
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10. When amusics sing in unison: another perspective of poor-pitch singing

A. Tremblay-Champoux[1], I. Peretz[1], S. Dalla Bella[2], and M-A. Lebrun[1]
University of Montreal[1], University of Finance and Management, Warsaw[2]

Purpose:
Poor-pitch singing is often seen as a consequence of a poor perception. However, new research has shown that a poor production may result from factors other than the perception. Indeed, Pfordresher and Brown found poor-pitch singers in a sample of individuals who do not exhibit any difficulties in pitch discrimination (1). Moreover, people who cannot perceive music, namely amusics, are able to produce two notes in the good direction even though they cannot tell if the second note was higher or lower than the first (2). Similarly, some of them are able to produce a well-known song with the right contour when they sing with lyrics, while they are unable to do so when singing on the syllable /la/ (3). The authors suggest that this dissociation might be due to memory problems for the melody when it is not supported by lyrics. The purpose of this study was to examine if singing along with a model could help amusics to improve their performance, by reducing memory load. More specifically, the objective was to evaluate if singing with a model could help amusics to increase pitch accuracy without the help of the song lyrics.
Method:
One group of amusics (n=10) and their controls (n=10) sang a well-known song with lyrics and on the neutral syllable /la/. They first sang alone and then with a pre-recorded model in which a student (one male and one female) sang the song. Each production was recorded using Adobe Audition and then analyzed acoustically with Pratt and Matlab (using the method of Dalla Bella, Giguère & Peretz (3,4)).
Results:
The analysis showed that, for melodies sung on lyrics, unison singing did not improve performance of amusics as compared to when they sang alone. In contrast, amusics' performance on the syllable /la/ was improved by singing with the model as compared to singing alone.
Conclusions:
The results of this study suggest that choir singing can be useful to recover the melody of a well-known song. Unison singing can be seen as a potential solution for the production problems of amusics, mitigating their deficit in musical memory. However, the positive effect of the choir singing could also be due to motor entrainment. More research will be done to evaluate this possibility.
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11. Neural stratification of sequencing and timing in auditory feedback? An fMRI study

Peter Q. Pfordresher, Jennifer L. Cox, Michelle Andrews, James Mantell, and Robert Zivadinov
University at Buffalo, SUNY

Purpose
Behavioral research has demonstrated different effects on music performance of altered feedback that results in asynchronies between perception and actions (e.g. delayed auditory feedback) and altered feedback that influenced pitch contents (e.g., serial shifts). Based on these results, Pfordresher (2006) speculated that links between perception and action are stratified according to levels of timing (synchrony) and sequencing (serial order). We tested whether these behavioral dissociations are also found in brain activity.
Methods
Eleven pianists performed simple melodies while being scanned in a 3-Tesla MRI. In different conditions they experienced normal auditory feedback, altered auditory feedback (asynchronous delays or altered pitches), or control conditions that excluded movement or sound. Performances were recorded via MIDI in order to compare behavioral with neuroimaging data.
Results
Behavioral results replicated past findings: Asynchronous delays slowed produced timing but did not increase errors whereas altered pitch increased errors but did not increase timing.
With respect to neuroimaging data, reliable effects emerged when contrasting conditions with auditory feedback (normal or altered) against control conditions that involved listening (which reveals motor activity) or that involves playing without feedback (which reveals auditory activity). While playing with normal feedback, primary centers of activity were in the motor cortex (hand area) and auditory cortices. By contrast, performances with asynchronous delays reduced activity in these areas. The effect of pitch shifts was more complex. On average, pitch alterations led to similar activity as found for normal feedback. Closer inspection suggested that pitch alterations led to more variability across individuals in brain activity than other conditions.
Conclusion
Results suggest that altered feedback disrupts the way in which the brain links perception and action. Though not fully consistent with the stratification suggested by Pfordresher (2006) the results nevertheless point to distinct effects of asynchronous delays versus alterations to pitches.
Research and Educational Implications
Results point to the importance of considering the role of both activation and de-activations in neuroimaging analyses.
Acknowledgement of Research Funding
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12. Violations of expectancy: Eyetracking while sightreading

Kimberly A. Leiken
University of Rochester

Purpose
To what extent are processing mechanisms similar in language and music? Patel (1998) found that expectation violations of language (namely complex vs. ungrammatical sentences) differ by a similar degree in the P600 as those in music (i.e. phrases containing an out-of-key chord in a nearby key on the circle of fifths vs. a distant key). Thus in music and language, as incongruity increases, the P600 increases. Moreover, there are qualitative differences between complex and ungrammatical sentences (as there are between nearby and distant keys). Eye-tracking during reading provides fine-grained measures of complexity and expectation violation. Data is reported from an eye-tracking study examining the effect of these qualitative differences on processing patterns.
Methods
We monitored musicians' eye movements during sight-reading and piano-playing. Five original phrases were manipulated by expectancy violation type; No Surprise, Melodic Leap (a large pitch gap between notes), or Chromatic Pitch (a pitch that lies outside of the diatonic scale). We defined 5 regions: *Beginning* (before critical measure), *Pre-Critical* (within critical measure before Critical note), *Critical*, *Post-Critical* (following Critical note within critical measure), and *Spillover*.
Results
Although the interaction between conditions and regions was not significant ($p<.71$), both experimental conditions show much time spent on second pass readings in the Critical region, with Melodic Leap showing slightly shorter second pass fixation times than Chromatic Pitch ($p<.02$). There were significantly more regressions ($p<.001$) and second pass ($p<.014$) fixations in the Chromatic Pitch condition in the Post-Critical region. (Subjects "skipped ahead" to this region, regressed to the Critical region, and returned to the Post-Critical region to complete the score naturally). While there are regressions from the Critical regions of both Chromatic Pitch and Melodic Leap conditions, significantly more occurred ($p<.001$) in that of the Melodic Leap condition. Here, subjects reach the Critical region, then regress to the Pre-Critical region or even more to the Beginning- where there are indeed more second pass

readings than in the Chromatic Pitch condition. In summary, when subjects encounter a melodic leap they look backward in the score, and with a chromatic pitch, subjects jump ahead.

Research and/or Educational/Clinical Implications

These results demonstrate that eye-tracking during sight-reading provides insights into music-reading processes. The results suggest that processing of the above expectation violations might be analogous to the local coherence effects reported by Tabor, Galantucci, & Richardson (2002); melodic leaps resembling ambiguous reduced types and chromatic pitches resembling the unambiguous reduced version. Ongoing experiments address these hypotheses.

13. Encoding of musical notation by violinists and pianists

Elizabeth Wieland and Andrea R. Halpern
Bucknell University

Purpose

For musicians, reading the musical notation of a phrase may appear to be as simple a process as non-musicians reading a sentence of literature, but in fact much is still unknown about how musicians encode musical notation. Music readers are assumed to mentally process musical notation the same way regardless of their instrument, but it is possible that they in fact differ due to different production routines. In general, we predicted that pianists would be more affected than violinists by pitch interference, and vice versa for temporal interference. We also predicted violinists will demonstrate initial processing in the right hemisphere, whereas pianists would be more symmetrical.

Methods

The *interference* task tested if different aspects of musical notation (rhythm and pitch) are processed independently or interdependently. The participants were asked to recall a ten note musical phrase while an interference melody was played. If pitch and rhythm are independent processes, a rhythmic distractor should only disrupt rhythmic processing whereas a pitch distractor should only interfere with the processing of pitch. The *concurrent* task tested the locus of the initial processing of musical information by creating hemispheric competition. The participants were asked to tap their index finger on one hand while identifying musical intervals presented visually. This task occupied the contralateral hemisphere with the tapping task, and depending on the hemisphere used for initial processing of the musical notation, hemispheric competition would create a decrement in the tapping rate.

Results

In the interference task, pianists were better than violinists in both pitch and rhythm recall, but a main effect of Interference was found only in pitch recall. Pitch interference reduced pitch accuracy the most with a trend toward pianists being more affected than violinists. Temporal accuracy was not affected by any interference. Pilot testing of the concurrent study suggests the expected asymmetry in violinists, with a larger decrement in tapping rates of the left hand than pianists.

Conclusion

Although performance seemed to be better for pianists than violinists overall, a significant interaction was not found (although data collection is ongoing). This implies that musicians do encode musical notation similarly.

Research and/or Educational/Clinical Implications

Examining these differences in processing may show how musical notation is encoded by both types of musicians as well as possible differences between them. This is a fairly unexplored direction, and would give additional information about encoding musical notation to the field of psychology and music as well as to areas of music education.

14. Intonation tendencies in solo a cappella vocal performances

Johanna Devaney, Jonathan Wild and Ichiro Fujinaga
McGill University

Purpose

The intonation practices of the singing voice are a complex phenomenon that has received only limited attention in the literature to date. Previous studies have observed that singers do not conform to either equal temperament or any other fixed-intonation system, however none of these studies has explored whether singers' intonation practices are systematic. This research project examines the ways in which melodic interval tuning in solo *a cappella* singing relates to harmonic context.

Methods

The first part of this ongoing experiment considers a set of performances of Schubert's "Ave Maria". These performances are being recorded explicitly for this study by a group of female vocalists. This group is made up of two sub-groups, the first comprised of undergraduate vocal majors and the second comprised of professional singers. The second part of the experiment uses a composed melody, designed to have strong harmonic implications. The melody repeats several semitone patterns in different harmonic contexts, so as to provide a more controlled evaluation environment than the "Ave Maria". The purpose of the first part of the experiment is to explore the commonalities that exist in intonation tendencies in the performance of a well-known piece, while the second provides the opportunity to examine the role of implied harmonic context more precisely.

Results
This research builds on a pilot study that related the intonation tendencies in a single performance to Fred Lerdahl's theory of melodic attraction and Steve Larson's theory of musical forces. Lerdahl's theory models melodic attraction and harmonic stability, while Larson's theory defines the forces of gravity, magnetism, and inertia. In this earlier study there was no correlation found between any of the components of these theories. The current study aims to evaluate the validity of these results on a larger data set. With this larger data set it will be possible to explore which components of these theories are applicable and what, if anything, is missing.
Conclusion
The experiment is ongoing.
Research and/or Educational/Clinical Implications
Empirical studies of recorded performances are a valuable complement to perceptual studies of performance. Not only does this type of "experiment" provide new data with which to test the proposed models, it also provides ecologically valid data, as it is acquired from a situation that is more familiar to the participant, i.e., the recording studio.
Acknowledgement of Research Funding
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15. Listeners' sensitivity to performers' expressive intentions

Kristen T. Begosh and Roger Chaffin
University of Connecticut

Purpose
Previously, researchers collected self-reports from musicians to determine what musical feelings they intend to convey to the audience. Additionally, examinations of bar to bar fluctuations in tempo and volume demonstrated that musicians' expressivity can change both within a given performance and between performances of the same piece. The current study examines whether audience members can perceive these variations in the performers' intended musical feelings.
Methods
A professional cellist and pianist reported their expressive intentions when playing the Prelude from Suite No. 6 for solo cello by J.S. Bach and the Piano Sonata No.2 in F Sharp Minor, Allegro non troppo ma energico by Johannes Brahms respectively. They recorded their pieces at three levels of expressive intensity – exaggerated, normal, and minimal. As participants listened to recordings of each of the six performances, they provided continuous ratings of the music's expressive intensity and emotional arousal that they experienced. Their evaluations were recorded by tracking the position of the mouse cursor as they moved it around the computer screen to indicate the intensity and arousal levels they felt at each given moment.
Results
Differences in intensity ratings were due to the cello being less intense than the piano. Exaggerated performances were less intense than normal ones, which were less intense than minimally expressive performances. Differences in arousal ratings were due to the piano being more calming than the cello. The interaction between the piece and performers' expressive intentions on arousal was due to participants rating the piano piece at the same arousal level regardless of the musician's intentions while arousal ratings for the cello piece increased from the minimally expressive performance to the normal and exaggerated performances.
Conclusion
Listeners' perceptions were affected by the musicians' expressive intentions and the piece of music to which they were listening. Analyses completed thus far show this for comparisons between performances. We expect further analyses to show that listeners perceived differences in the musicians' reported expressive intentions within a given performance.
Research Implications
Our study shows that musicians can deliberately vary the expressive effect of a highly prepared performance on listener's experience. To do so, they have several techniques and tools at their disposal including selection of the piece itself as well as their intentions to convey musical feelings to their listeners during any give performance of the composition.
Acknowledgement of Research Funding
This research was supported by Research and Teaching Assistantships to the first author from the Department of Psychology, University of Connecticut.

16. Good vocal mimics are also good entrainers: Individual differences suggest a shared mechanism for entrainment and vocal mimicry

Adena Schachner, Timothy F. Brady, and Marc D. Hauser
Harvard University

Purpose
It has been proposed that the ability to entrain to an auditory pulse evolved as a byproduct of selection for vocal mimicry (Patel, 2008), and cross-species comparative data has provided support for this theory (e.g. Schachner et al. 2008). We sought to test the theory that vocal imitation and entrainment depend on a shared mechanism by asking if there is a specific correlation between skill at entrainment and skill at vocal imitation in human adults.
Methods
Observers completed tasks designed to test their accuracy of entrainment and vocal imitation, as well as a control task. In the vocal imitation task, observers heard brief single pitches (13 semitones from a single octave, three times each in random order). The differences between the mean pitches of the observers' imitations and the true pitches were then calculated. In the entrained tapping task, subjects heard isochronous drumbeats and were instructed to tap the spacebar in synchrony with the timing of each sound as accurately as they could. Tempi ranged from 30 to 200 beats per minute, with 30-second blocks of each tempo, for a total length of seven minutes. The control tapping task was identical except the beats were spaced pseudo-randomly, creating unpredictable inter-onset-intervals. This task was intended to resemble the entrained tapping task, but without the possibility of entrainment. To analyze the tapping data, we used a previously published algorithm to establish correspondence between the beats and the observers' taps (Elliott et al. 2008), then calculated the errors between the IOI of the beats and the ITI of the observer.
Results
N=16. There was a strong correlation between skill at entrainment and skill at pitch imitation (Spearman's rank-order correlation, rho=0.64, $p<0.01$). No significant correlation was seen between skill at the control task and pitch imitation, suggesting that the effect was specific to entrainment and not a result of general motivation or motor skill (rho=0.04, $p=0.87$). In addition, the percentage of times observers skipped a beat or tapped more than once per beat was not significantly correlated with performance in the pitch task (all $p>0.1$), providing further evidence against a general motivational account.
Conclusion
Our results suggest that a persons' skill at entrainment is strongly correlated with their skill at vocal imitation of pitch, and that this correlation is not due to general motivational factors or general motor system ability.
Research Implications
This supports the theory that vocal imitation and entrainment rely on a shared mechanism.
Acknowledgement of Research Funding
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17. The effect of metre on accuracy and consistency of auditory-motor synchronization

Benjamin Rich Zendel, Takako Fujioka, Bernhard Ross
Rotman Research Institute

Purpose
Accuracy and consistency of finger tapping to an isochronous auditory stimulus is influenced by metric structure (i.e., the number of tones between taps), the rate of the stimuli (i.e., tempo), and the rate of the tapping target (i.e., the time between each tone to be tapped to). We investigated how these three factors interact with each other within the upper and lower temporal limits of sensori-motor synchronization.
Methods
Eight participants were presented with an auditory stimulus resembling a metronome click and were asked to tap their finger to different metric divisions (tap to every single [tap1], second [tap2], third [tap3], or fourth [tap4] click). We manipulated the stimulus rate so that in experiment 1 the tapping target rate (inter-beat interval: IBI) varied across three levels (780, 1170 & 1560 ms). In experiment 2 the tempo (inter-stimulus interval: ISI) was manipulated across three levels (260, 390 & 780 ms). Mean and standard deviation (SD) of timing differences between tap and click onset and were used to measure accuracy and consistency.
Results
In experiment 1, accuracy was significantly influenced by metre ($p<0.01$). That is, the larger metric division, the greater the accuracy. For consistency, the interaction between metre and IBI was significant ($p<0.01$). This interaction was caused by an increase in consistency for larger metric divisions, especially in the larger IBI conditions. In experiment 2, accuracy was significantly influenced by both metre and ISI ($p < 0.05$), but the factors did not interact. Accuracy was lowest in the tap3 condition, and accuracy increased as ISI decreased. Metre and ISI also significantly affected consistency ($p<0.01$), but did not interact. Consistency increased as ISI decreased, and consistency was highest in the tap1 condition.

Conclusion
Metric division improved synchronization when the tap interval was constant and shorter than 1.5sec. In addition, a decrease in accuracy observed for tap3 condition suggests a binary metre advantage over trinary metre, in line with previous findings. Consistency of tapping increased with greater number of intervening tones, especially at longer tap intervals. However, this advantage is reduced as the tap intervals approach the upper (longer) limit of synchronization.
Research Applications
Auditory-motor synchronization tasks such as dance may be useful for rehabilitation. Understanding the systematic relationship between metre and time perception is helpful for future research on the underlying neural mechanisms of auditory motor synchronization.
Funding
National Science and Engineering Research Council of Canada (NSERC) & Canadian Institute for Health Research (CIHR).

18. The heart of the music: Musical tempo and cardiac response

Robert J. Ellis, John J. Sollers III, Bradley M. Havelka, and Julian F. Thayer
The Ohio State University

Purpose
Empirical investigations of subjective and cardiac responses to music date back over 125 years. However, the literature has been plagued by two methodological/interpretive pitfalls. First, most investigations do not "recompose" music along a particular dimension (e.g., tempo), but rather use unique pieces of music that vary along a number of dimensions (genre, instrumentation, dynamics), adding potential confounds. Second, the utility of measuring *mean* heart rate (HR) changes to music is not particularly strong: for as many studies that report significant effects of music on HR, nearly an equal number report a null effect. However, two less-frequently-investigated indices of cardiac activity — HR variability and phasic HR — may provide better windows into cardiac response to music. HR variability (calculated from frequency-domain analyses of underlying periodicities in HR) is a sensitive measure of parasympathetic (restorative) nervous system activity; higher resting levels of HR variability have been consistently linked with greater health and emotional well-being, and increased cognitive flexibility. Phasic HR refers to beat-by-beat changes in HR, and indexes adjustments in attention and emotional processing.
Method and Results
We varied the tempo (60, 90, 120 beats per minute) of computer-generated (MIDI) performances of ragtime piano music. Experiment 1 examined HR variability to extended excerpts (2.5-m) of music, and revealed that HR variability decreased as tempo increased, indicating greater parasympathetic withdrawal to faster music. This pattern of response was more pronounced in subjects with higher resting levels of HR variability. Importantly, no significant relationship was found between tempo and *mean* HR. Experiment 2 examined phasic HR responses to shorter excerpts (12–16-s) of music, and revealed that phasic responses increase in magnitude as tempo increases, suggesting that tempo differentially affects the heart within a few moments of music onset. Similar to Experiment 1, differences in phasic responses as a function of tempo were more pronounced in subjects with higher resting levels of HR variability. Experiment 3 used even shorter excerpts (6–8-s) of this music to explore how tempo influences simple reaction times (RTs). RTs decreased as tempo increased. This novel finding indicates a role for a previously-unexplored stimulus property (tempo) on cognitive performance. We also found that the inverse relationship between tempo and RT was more pronounced in subjects with higher resting levels of HR variability.
Conclusion
The present results attest to both the value of the "recomposition" method and the utility of the physiological analysis, as well as the importance of individual differences in physiological activity and cognitive performance.
Implications
Taken together, these data help clarify our understanding of how music impacts the autonomic nervous system. Noticeable differences in cardiac response and RTs between individuals with high (versus low) resting levels of HR variability indicate that the parasympathetic nervous system mediates physiological and cognitive responses to music.
Acknowledgement
This research was supported by The Caroline B. Monahan Fund for Experimental Research Support within the Department of Psychology at Ohio State University.

19. The effects of cultural experience and subdivision on tapping to slow tempi

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

Purpose
The present study explores the role of cultural exposure as a means of more fully understanding the nature and underlying mechanisms of temporal processing constraints. Subdivision can improve synchronization at slow tempi, but the ability to utilize subdivisions is constrained by the nature of component interval ratios. Unlike Western music,

Indian music contains very slow tempi and complex interval ratios. Therefore Indian listeners may provide a unique opportunity to examine the effects of culture on sensorimotor synchronization.

Methods

American and Indian participants were asked to perform synchronous tapping to a stimulus with a slow tempo (i.e., inter-event intervals of 3 s), which was accompanied by silence or by an unattended rhythmic pattern subdividing target intervals into groups of two (simple), groups of three (simple), or alternating units of two and three (complex). On a subset of trials, the pattern of subdivision switched halfway through the trial, from a simple to simple, simple to complex, or complex to simple.

Results

Indians listeners performed comparably across all subdivision patters, but showed an increase in error whenever there was a switch of subdivision pattern, regardless of the nature of the switch. By contrast, Western listeners showed higher overall error for the complex subdivisions, and an increase in error any time there was a switch away from simple subdivision.

Conclusions

Cultural exposure seems to influence the extent to which subdivision structures improve performance in general and dependent on the type of subdivision structure.

Research Implications

This study highlights the nature of the temporal processing constraints, by examining the role of cultural exposure to music that violates these constraints.

20. Rocking in synch: Effects of music on interpersonal coordination

Alexander Demos, Roger Chaffin, Alexandra Lewis, Kristen Begosh, Jennifer Daniels and Kerry Marsh
University of Connecticut

Purpose

Music is often used to help individuals intentionally synchronize with one another. Soldiers, for example, use the beat of the music to help keep them marching in step. Music may also provide a means for two people to unintentionally synchronize in a task. The current study measures unintentional synchronization through rocking chairs. While previous research using rocking chairs has shown the importance of visual information (Richardson et. al, 2007), this research highlights the importance of auditory information to unintentional synchronization.

Methods

Forty-six participants were paired and sat in identical wooden rocking chairs positioned 0.5m apart and were asked to rock at a comfortable pace. The experiment contained three counterbalanced conditions, repeated once. Condition one contained no auditory stimuli. Condition two had participants rock their chairs over sandpaper. This allowed them to hear their own and their partners' rocking. Condition three contained Greek music played in common time with a steady tempo of about 64 BPM. Each condition contained three partially counterbalanced back-to-back trials. First participants looked forward for 30 seconds at an image and then looked directly at their partners chair or away from each other for 70 seconds.

Results

Visual Information: When the pairs had direct or peripheral visual information, they averaged more unintentional synchronization than when looking away [$F(2,38)=17.0$, $p<.001$].

Auditory Information: Overall, participants synchronized most with the sound of the other rocker [$F(2,38)=3.25$, $p=.05$]. Preliminary results show that when musician pairs (n=3) could not see each other, they synchronized more with each other in the second exposure to the music over the other conditions [$F(4,40)=2.625$, $p=.049$]. Regardless of visual information, mixed pairs of musicians and non-musicians and non-musician pairs did not improve on synchronization between the first and second exposure to the music, while musician pairs did [$F(2,20)=4.757$, $p<.001$].

Conclusion

The initial expectation was that music would create the strongest synchronization between pairs. However, the strongest effect was the sound of the other rocker as the other rocker may have acted like a metronome. Only musician pairs synchronized in the condition with music and no visual information. Musicians may have the ability more quickly sort through the complexities of novel music.

Research Implications

The current findings suggest that musicians are more unconsciously attuned to auditory information than non-musicians. Ongoing research is investigating whether the type and familiarity of the music and/or the size of the difference between the tempo of the music and the natural tempo of the rocker affect unintentional synchronization.

21. The effect of melodic complexity and rhythm on working memory as measured by digit recall performance

Michael J. Silverman
University of Minnesota

Purpose

The purpose of the present study was to isolate the effects of melodic complexity (three versus five versus seven pitches) with and without rhythm on working memory as measured by sequential digit recall performance.

Methods

The recall of information paired with six different melodies was tested on 60 university students (30 music majors and 30 non music majors). Melodies were composed using three, five, and seven pitches, both with and without a rhythmic component. The texts were randomly determined monosyllabic digits. A CD was created with a female voice singing the melodies. Participants listened to all six melodies and then were asked to recall the digits immediately after each melody was sung. A Latin Square Design was used in an attempt to control for learning and order effects.

Results

Results indicated that there was no significant difference between recall of music majors and nonmusic majors, although music majors outperformed nonmusic majors. There was a significant difference in the within subject variable of rhythm: the mean recall of information paired with a rhythmic component was higher than recall of information not paired with a rhythmic component. Recall of information paired with melodies built upon three notes was poorest while recall of information paired with melodies built upon seven notes was highest. Participants recalled information in serial positions of primacy and recency most accurately while information in the middle positions was poorest.

Conclusion

Congruent with previous research, music majors outperformed nonmusic majors and rhythm served as the dominant factor in facilitating recall. Also congruent with the literature, participants' recall was greatest during primacy and recency positions. However, from the results of this study, it seems that recall is greater when information is paired with melodies that are built upon seven pitches as opposed to three pitches.

Educational & Clinical Implications

In composing original music to facilitate academic and social objectives, a simple rhythmic component should be used. This rhythm serves to "chunk" (organize) the information and thus facilitates its recall. From the results of the current study, if educators or therapists are composing melodies to teach social and/or academic material, melodies should be built from seven pitches as opposed to three pitches and incorporate a rhythmic aspect. Future research could evaluate how timbre and other musical aspects of melodies facilitate recall.

Wednesday, August 5th

Session 6A **Symposium: Pulse, Meter and Groove I (Chairs: *Mike Brady & Edward W. Large)***

6A) 9:00 – 9:20

Filtering discordant onsets from complex temporal patterns

Michael Brady
Indiana University

Purpose
Many approaches to temporal structure analysis presume that an input pattern will have some underlying pulse that an oscillator may entrain to. The oscillator synchronizes with this pulse in the face of local temporal noise and broader-scale rate fluctuation. How the oscillator aligns with the elements of a pattern can be charted for comparative analysis. With some types of complex temporal sequences however, such as the timing of vowel onsets in the casual stream of speech, an underlying pulse is often not readily apparent. In analyzing such patterns, is it folly to seek to entrain an oscillator to a possibly nonexistent underlying pulse?
Method
The method first asks: "what is the opposite of an isochronous pulse?" If a pattern that exhibits maximal temporal haphazardness may be successfully entrained to, the assumption of an underlying or cognitive pulse is reinforced. Work begins by establishing a definition for the maximally haphazard temporal sequence. An adaptive oscillator is then made to systematically synchronize with a variety of patterns that approach maximal haphazardness by essentially filtering out the pattern's discordant onsets. Filtering involves the use of a bank of resonators. Each resonator is tuned to resonate with a slightly different natural period and the sum of 'expectancies' from the bank provides a measure of how periodic an onset is in relation to preceding onsets. The 'cognitive pulse' adaptive oscillator entrains to onsets that have stronger periodicity scores, while onsets receiving weaker periodicity scores are filtered from the entrainment function.
Results
By initializing the cognitive oscillator from different phase angles and watching how it consistently aligns itself with patterns that approach maximal temporal haphazardness, the model is shown to be successful. Furthermore, higher periodicity scores from the resonator bank tend to correspond to the events of rhythms that people typically synchronize with when asked to tap along to various experimental rhythms as reported in the literature. Thus, entrainment by the model reflects human performance.
Conclusion
It is not folly to seek to entrain an oscillator to temporal patterns that do not exhibit an obvious underlying pulse.
Research Implications
The cognitive oscillator may be applied to the analysis of complex temporal patterns using circular statistics. In languages like Japanese for instance, where timing cues serve as the basis for phonological distinctions, such an analysis may allow a speech parser to distinguish what was said based on temporal relationships.
Research Funding This work was partially supported by an NSF EAPSI fellowship.

6A) 9:20 – 9:40

A probabilistic model of downbeat identification

Leigh M. Smith
IRCAM

Purpose
A number of computational models of musical rhythm and beat induction have been previously presented. Those successful approaches using oscillator entrainment, resonant comb filterbanks, Fourier, autocorrelation or wavelet methods identify quasi-periodic frequencies contained in the rhythm being analysed. In several of these systems, identification of the metrical period, as well as the beat period (tactus), is possible. This success in determining meter and beat period does, however, raise the question as to how a listener infers the phase of the meter. That is, how is the position of the downbeat determined? Meter is considered to arise from the interaction between rhythmic frequencies (strata), yet it is not yet clear how that interaction leads to an unambiguous interpretation of metrical

phase that rapidly arises in the minds of listeners. It is clear this is not entirely a top down process, illustrated by the ability to experience and resolve changes of meter and syncopation.

Methods

A model of the bottom-up component of the identification of downbeat is proposed and is currently under evaluation. This probabilistic model estimates the most likely choice of beat, within the metrical period, that functions as the downbeat. A number of feature observations provide evidence for this estimation. Such observations are performed on a continuous measure of onset detection salience from the spectral flux of the audio signal. These observations are amassed using Bayesian maximum likelihood estimation to determine the likely downbeat location.

Results

The observations being evaluated include: a number of onset detection salience profiles derived from the currently perceived metrical structure; metrical locations of perceptually longer local intervals; locations of intervals exceeding the beat period; and characterisations of rhythmic phase derived from continuous wavelet representations of the rhythm. The model is currently being evaluated against a dataset of 250 annotated recordings of a variety of Western popular music.

Conclusion

While intensity and duration in experimental stimuli function as accents, in recorded music, these cues are not as clear and often contradictory. The proposed model suggests that a combined set of feature observations is necessary to successfully estimate the downbeat.

Research Implications

This research studies listeners' ability to identify downbeat from contradicting cues. It represents that capability as a weighted likelihood estimation from evidence from the temporal structure of the audio energy. This attributes the contribution of each form of accent to the perception of rhythmic structure.

Acknowledgement of Research Funding

This research is performed in the context of the Quaero project (http://www.quaero.org).

6A) 9:40 – 10:00

A damped oscillator model for relating the temporal structures of bimanual tapping responses and complex musical stimuli

Petr Janata and Stefan Tomic
University of California, Davis

Purpose

We describe a model based on reson filters (damped oscillators) that serves as a common framework for the analysis of the temporal structure in both musical and behavioral data. We illustrate its use in the analysis of data from an experiment in which 34 subjects tapped along with excerpts of recorded music.

Methods

We collected bimanual tapping responses to 48 30-s excerpts of music that varied in genre and the degree of perceived "groove," with the objective of determining whether there was any systematic variation in the model output as a function of how much a person felt "in the groove" while tapping, how much they enjoyed the task, and how difficult they found the task. The prominence of periodicities at metric and non-metric levels was assessed with mean periodicity profiles (MPPs; distributions of energy across the bank of reson filters). The number of peaks in the MPPs was compared across tapping conditions (isochronous and freeform) and music conditions (high groove, mid groove, low groove, silence).

Results

On average, high groove stimulus MPPs had fewer peaks than mid or low groove MPPs. With few exceptions, the major peaks in the MPPs from isochronous and freeform tapping conditions coincided with the major peaks in the MPPs of the stimuli. Release of the isochronous tapping constraint resulted in freeform tapping MPPs having more peaks, many of which coincided with other peaks in the stimulus MPPs, indicating that subjects spontaneously synchronized with more complex aspects of the metric structure. However, additional peaks were also observed that did not correspond to the stimulus MPPs, hinting at synchronization failures. Subjective ratings obtained following each trial were correlated with the number of peaks in the MPPs such that higher experienced difficulty led to more peaks, and higher experienced groove and enjoyment led to fewer peaks. With the exception of experienced difficulty, these relationships were observed only in the isochronous tapping condition and primarily for mid and low groove stimuli.

Conclusion

The pleasure experienced when "finding the beat" in music is related to properties of the metric structure in the music and the metric structure of the participant's actions as assessed by a damped oscillator model.

Research Implications

Many further metrics can be derived from the model output to better understand the coupling of music, behavior, and affect.

Acknowledgement of Research Funding
This research was supported by a Templeton Advanced Research Program grant from the Metanexus Institute.

Session 6B Cross-Modal Interactions (*Chair: Scott Lipscomb)*

6B) 9:00 – 9:20

The effects of sensori-motor learning on melody processing

Elizabeth Wakefield and Karin Harman James
Indiana University

Purpose
To investigate how motor systems interact with, and/or contribute to the learning of sung melodies, using functional Magnetic Resonance Imaging (fMRI).
Method
Nine university students underwent a training session, followed the next day by an fMRI scan. During training, participants learned 12 melodies under 3 conditions using a recall procedure adapted from Racette and Peretz (2007). In an auditory condition, participants heard melodies sung on nonsense syllables (analogous to solfège syllables) and repeated them. In a motor condition, in addition to hearing melodies, participants learned hand signs corresponding to notes in the melody (analogous to Curwen hand signs). In a visual condition, in addition to hearing melodies, the syllables being sung were presented visually. Training was complete when participants had sung each melody accurately without help from the experimenter. During the fMRI session, participants listened to learned or novel melodies in a random order. Participants indicated whether they remembered learning each melody via button-presses on a hand paddle.
Results
Behavioral results: The addition of motor or visual components during training may be detrimental to melody learning. Participants performed better than chance on recognition of learned melodies in the auditory condition only, indicating that the melodies in the motor and visual conditions were not as well committed to memory.
Functional MRI results: Reactivation of brain regions corresponding to the modality specific to each learning condition (motor, auditory, visual) were seen subsequent to learning in auditory and visual conditions, but not in the motor condition. After auditory learning, activation occurred in auditory cortex, some frontal regions, and Broca's area bilaterally. After visual learning, middle occipital gyrus activation occurred bilaterally. Although motor cortex activation was seen in four participants after motor learning, it was sub threshold overall.
Conclusion
Learning melodies using different modalities results in some reactivation of brain regions associated with these modalities during later presentations of the melodies. Additionally, although learning with multiple modalities may be beneficial over long-term learning, short-term melody learning is most successful when individuals learn though audition alone. Perhaps individuals concentrate less on the melodies if they are visually represented, or cannot learn as easily if their attention is divided between melodies and motor patterns.
Research & Educational Implications
The present study adds to the understanding of multisensory integration in the brain. It also has implications for music education, as it demonstrates that incorporating motor movements into learning, like Curwen hand signs, may not be beneficial to music learning in the short term.
References
Racette, A. & Peretz, I. (2007). Learning lyrics: To sing or not to sing. *Memory & Cognition, 35,* 242-253.

6B) 9:20 – 9:40

Visual fixation patterns and the contribution of visual dynamics in perception of vocal music

Frank A. Russo, Michael Maksimowski and Gillian Sandstrom
Ryerson University

Purpose
Numerous studies have highlighted the importance of visual information in perception of music. Thompson & Russo (2007) demonstrated that in the context of vocal music, relative size of intervals can be discerned on the basis of visual information alone. Video-based motion tracking revealed a strong correlation between interval size and maximal displacement of the head, eyebrows, and mouth.

In the current study, we utilize two complementary methodologies (eye tracking and point-light animation) in order to better understand the key determinants of visual influence in perception of vocal music.

Methods

Experiment 1: Participants viewed audio-visual recordings of sung intervals under 3 signal-to-noise conditions (high, medium, low). Participants made judgments of interval size while gaze fixations were tracked using a Tobii x50 eye tracker.

Experiment 2: Participants viewed visual-only recordings of sung intervals under full-light (original) or point-light conditions. In each trial, participants were required to judge which of two intervals presented in sequence was larger (forced choice).

Results

Experiment 1: Frequency and duration of gaze fixations increased as the signal-to-noise ratio decreased (i.e., more fixation as listening conditions worsened). Fixation points were distributed across the face with highest concentration on the mouth followed by the eyes, and biased overall to the right side (viewer's perspective).

Experiment 2: In both full-light and point-light conditions, accuracy increased as a function of interval size difference, with accuracy surpassing chance for intervals differing by 4 semitones or more. Overall accuracy was highest in the full-light condition.

Conclusion

Perhaps not surprisingly, we found that in making judgments of interval size, viewers tend to track those visual features that previous research has shown to be well correlated with interval size, and the extent of tracking intensifies as listening conditions worsen. Critically however, the eye tracking allowed us to determine that the mouth is the key feature of visual interest. The overall right-side bias is likely task dependent, arising from an analytic strategy that favors the left-hemisphere (i.e., contralateral to bias of fixation).

The above-chance accuracy of discriminations in the point-light condition suggests that dynamic visual information contributes to judgments of interval size.

Research and/or Educational/Clinical Implications

The current study corroborates the view that individuals may use visual information to support judgments of structural information in vocal music. This insight suggests opportunities for enhancing the experience of music in deaf and hard of hearing listeners.

Acknowledgement of Research Funding

This study was supported by a grant from the Natural Sciences and Engineering Research Council of Canada awarded to FA Russo.

6B) 9:40 – 10:00

The color of music: Cross-modal sensory perceptions in musicians

Matthew McCabe, David Biun and Jamie Reilly
University of Florida

Purpose

Recent research has discovered cross-modal, possibly synaesthetic associations in healthy, normal adults. Our experiments apply concepts from previous research to musicians, with the purpose of understanding rapid cross-modal associations and their role in music perception as well as clarifying understanding of human musical capacities in both trained and untrained subjects. Further, the adaptations acquired with musical training can give insight into neural plasticity, the nature of learning, and the origins of music and language.

Methods

Sixty age and gender-matched right-handed native English speakers were divided into two groups: musicians and non-musicians. A third group, individuals with absolute pitch, were also tested for the purposes of contrast. All participants were screened with color blindness and hearing acuity measures and were administered Gordon's AMMA prior to testing. In a series of 4 experiments, participants made matching pairs of sounds and colors while viewing auditory and visual stimuli by turning dials that controlled pure tone frequency, piano tone height, color hue, and color luminance. When the presented stimulus was auditory, the participant was asked to make a visual match, and vice-versa.

Results

Previous studies have indicated that healthy adults behave like synaesthetes in associating tones with colors and phonetic features to physical forms. Musicians, due to training in the auditory sensory realm, show stronger cross-modal associative consistency and decreased search time in finding matching pairs.

Conclusion

Healthy adults are consistently sensitive to the relationship of pitch height to both hue and luminance, indicating that cross-modal associations are a normal perceptual process. Musicians, with specific auditory training, show a greater intersensory affinity, demonstrating that the processes involved in cross-modal associations utilize parts of the brain also utilized during the perception and production of music.

Implications
Since the cortical areas responsible for cross-modal relationships play an important role in musical processing, our results have implications for deeper understanding of neural plasticity and musical training effects. Specific understanding of cross-modal relationships also offers insight into the evolution, production, and reception of music and language. Potential applications include novel means of testing the integrity of association cortexes, cross-modal Stroop paradigms, the facilitation of auditory training, and a deepening of the techniques used in art, music, and language-based education and therapies.
Acknowledgement of Research Funding
All costs were covered by the startup funds of Dr. Jamie Reilly, Departments of Communicative Disorders and Psychology, University of Florida.

Session 7A Symposium: Pulse, Meter & Groove II (Chairs: *Mike Brady & Edward W. Large)*

7A) 10:20 – 10:40

Modeling of pulse and meter as neural oscillation

Edward W. Large and Marc J. Velasco
Florida Atlantic University

Purpose
In rhythm perception the experience of periodicity, namely pulse and meter, can arise from stimuli that are not periodic. One possible function of such a transformation is to enable attentional and behavioral synchrony among individuals through perception of a common abstract temporal structure. Thus, understanding the brain processes that underlie rhythm is fundamental to explaining musical behavior. Here, we ask whether a model of neural resonance can account for important aspects of human rhythm perception, rhythmic attending and perception-action coordination.
Methods
We derived a canonical model of neural oscillation and used it to define a gradient frequency neural oscillator network (GFNN). A GFNN is a one dimensional network of neural oscillators, tuned to different natural frequencies, and arrayed along a frequency gradient. Such networks are conceptually similar to banks of bandpass filters, except that the resonating units are nonlinear rather than linear. We stimulated the networks with a variety of rhythms from simple isochronous sequences to complex rhythmic patterns. We asked how well the behavior of the network matched certain well-known features of human behavior, and also compared the predictions of the nonlinear model with those of a linear filterbank.
Results
The GFNN reproduces several effects observed in perception, attention and coordination. These include persistence of pulse in the absence of stimulus events, entrainment with rhythmic stimuli, tendency of pulses to precede auditory events in some circumstances, and a form of metrical accent in which active endogenous processes contribute to perceived stress patterns. Some of these properties are observed in linear systems, others are not.
Conclusion
Neural resonance provides an explanation for many of the basic results associated with human responses to musical rhythm. In addition, we discuss several new predictions that have no correlate in music-theoretic models of pulse and meter.
Research Implications
This approach has the potential to link neurophysiology directly with behavior, an important goal of cognitive neuroscience. It also makes novel predictions about the perception of rhythm in music.
Acknowledgement of Research Funding
AFOSR FA9550-07-C0095

7A) 10:40 – 11:00

Using cross-entropy to test models of common-practice rhythm

David Temperley
Eastman School of Music

Purpose
This study explores ways of modeling the compositional processes involved in common-practice rhythm (as represented by European classical music and folk music). I consider a series of probabilistic models of rhythm and

evaluate them using the method of cross-entropy: the best model is the one that assigns highest probability to the data.

Methods

Six models were evaluated. The uniform position model decides at each beat (metrical position) whether or not to generate a note there, with notes equally likely on all beats. The zeroth-order duration model chooses time-points for a series of notes, assigning different probabilities for different inter-onset intervals (time intervals to the previous note). The metrical position model decides whether to generate a note on each beat, dependent on the strength of the beat at that point. The fine-grained position model is similar to the metrical position model but distinguishes between different metrical positions of the same strength (for example, the second and fourth quarter-note of a 4/4 measure). The hierarchical model decides at each beat whether or not to generate a note there, conditional on the note status of neighboring strong beats (i.e. whether or not they contain notes). The first-order duration model chooses time-points for a series of notes, dependent both on the metrical position of the note and that of the previous note. Each of the models above can be formulated to assign a probability to a rhythmic pattern. The parameters of the models were set from a corpus of melodies in 4/4 time from the Essen folksong corpus; the models were then evaluated by the probability they assigned to a different set of melodies (also Essen melodies in 4/4 time).

Results

The model achieving lowest cross-entropy was the first-order duration model; the hierarchical model was a close second. When simplicity (number of parameters) is also considered, it is argued that the hierarchical model is preferable overall.

Conclusion

When both cross-entropy and simplicity are taken into account, a hierarchical model is the most plausible model (among those considered) of the process of common-practice rhythmic composition.

Research Implications

This study demonstrates the feasibility and value of the cross-entropy approach as a method of evaluating models of compositional processes.

7A) 11:00 – 11:20

Analytical and computational modeling of musical groove

Peter Martens[1], Petr Janata[2], and Stefan Tomic[2]
Texas Tech University, University of California, Davis

Purpose

This presentation will demonstrate a necessary linkage between the psychological/computational investigation of musical groove and the traditional music-theoretical tools of transcription and analysis. Janata, Tomic, and Haberman (2007) asked subjects to assess groove in 48 excerpts of commercially-available music while engaged in either isochronous or freeform tapping, and classified each excerpt as high-, medium-, or low-groove based on these assessments. Subjects' tapped periodicities were compared with a computer model's assessment of the excerpts' meter. Some aspects of subjects' tapping were found to be correlated with groove judgments, but no linkage between the computer model's determination of meter and subjects' groove ratings were made, nor could be made. The sophisticated computer model correctly identified the primary meter in most excerpts, but could only suggest cross-rhythms in excerpts by identifying periodicities in the signal that were weaker than those in the primary meter. While some groove patterns exhibit this type of consistent cross-accentuation in the form of conflicting pulse streams, most grooves are enlivened with local events, short-term groupings that contradict the primary meter, and inconsistent interactions between timbral layers, all of which can be conceived as syncopation, broadly construed. The goal of this presentation is to bring this level of information into contact with subjects' tapping-influenced judgments of groove, and to suggest possible refinements to existing computer models.

Methods

Ten 30-second excerpts from Janata et al. (2007) were transcribed by hand; four were drawn from their high and low groove categories, and two from their medium groove category. Syncopation in a representative four-bar phrase in each of these excerpts was calculated using a quantitative analytical model based on the syncopation definitions of Huron & Ommen (2006).

Results

Results indicate that the analytical model's output matches listeners' judgments of groove in Janata et al. (2007), and thus could be predictive of similar judgments in future studies.

Conclusions & Research Implications

Computer-based analysis of rhythm and meter in audio signals benefits greatly from either 1) comparison with music-theoretical analyses, or from 2) building into future computer models such analytical judgments, as well as the generic and timbral knowledge on which they are based. For assessments of musical groove to move beyond observation and classification, analytical attention must be paid to the complex rhythms and multi-layered texture that creates groove.

11:20 – 11:40 Discussion

Session 7B Timbre (*Chair: John Hajda)*

7B) 10:20 – 10:40

Roughness ratings for just- and micro-tuned dyads from expert and nonexpert listeners

Susan E. Rogers[1] and Stephen McAdams[2]
Berklee College of Music[1], McGill University[2]

Purpose
The assumption that expert and nonexpert listeners assess the perceptual qualities of isolated musical sounds similarly has been challenged by recent neurophysiological findings. Outside of a tonal context, musical intervals evaluated for their sensory properties are under the influence of top-down, cognitive-based processing that affects judgments of the magnitude, variety, and relevance of auditory properties. Thus the evaluated sensory dissonance of dyads (two simultaneous tones) is not immune to extra-stimulus factors such as how an interval functions in a given musical culture.
Method
To explore the extent to which musical experts and nonexperts agreed, listeners rated dyads for auditory roughness – a primary component of sensory dissonance. The variability of internal roughness standards and the influence of musical training on roughness evaluation were compared with objective ratings from two auditory roughness analyzers. Stimulus sets included dyads in familiar, just-tuned frequency-ratio relationships as well as microtuned dyads – mistuned from the familiar Western standard by a quartertone.
Results
Roughness ratings by nonexperts showed greater instability (more variance) than those of experts and less influence of the frequency-ratio relationship between tones. Nonexperts' pure-tone dyad ratings provided a closer match than experts' to previously published sensory dissonance data (Plomp & Levelt, 1965). Experts' complex-tone (just-tuned) ratings provided a closer match than nonexperts' to earlier work describing the role of harmonic relationships in Western consonance perception (Hutchinson & Knopoff, 1978). The highest agreement between expert and nonexpert listeners was seen in the microtuned dyad assessment. Roughness analyzers showed strong correlations with listeners' just-tuned dyad ratings but correlated weakly with microtuned dyad ratings.
Conclusion
Assessment of the perceptual attributes of chords in isolation is mediated by top-down, knowledge-based processing. Sources of error or intrasubject variability in psychophysical scaling judgments can be reduced through experimental design accounting for the listener's experience with the attribute under evaluation.
Research Implications
Accounting for sources of listener variability in the perception of musical qualities assists in the development of audio analyzers and experimental protocols, and aids in the interpretation of sensory dissonance findings.

7B) 10:40 – 11:00

Vibrotactile discrimination of musical timbre

Frank A. Russo, Michael Maksimowski, Maria Karam, and Deborah Fels
Ryerson University

Purpose
Research concerning music and vibration has primarily focused on the role of feedback in music performance. Spurred by rapid developments in tactile displays and multimodal integration, we have been investigating the potential for vibration to influence auditory judgments and as sensory substitution for the deaf and hard of hearing (Karam, Russo, & Fels, under review, IEEE Transactions on Haptics). The goal of the present study was to investigate the use of vibrotactile information for discrimination of musical timbre.
Methods
Experiment 1: Complex vibrotactile waveforms generated from an acoustic signal were presented to the back via voice coils embedded in a conforming chair. Participants made same-different judgments based on timbre (piano, cello, trombone). Stimuli were presented at each of 3 levels of fundamental frequency (110, 220, 440Hz). All stimuli were equated for vibration intensity. Continuous white noise was presented over headphones to mask residual sound created by chair vibration.

Experiment 2: The method was identical to that used in Experiment 1 except that additional precaution was taken to mask sound that may have resulted from bone conduction (i.e., not airborne sound). In addition to presenting the white noise as sound over headphones, it was also presented as vibration on the cheekbones via Tactaid skin stimulators.
Experiment 3: The method was identical to Experiment 2 except that participants made same-different judgments in steady-state tones that varied only with regard to spectral centroid (dull vs. bright). All stimuli were presented at 220 Hz.

Results

Experiment 1 and 2: Results in both experiments indicated that participants were able to discriminate timbre (piano, cello, trombone) significantly better than chance. Optimal discrimination performance occurred at 220 Hz.
Experiment 3: Results indicated that participants were able to discriminate timbre significantly better than chance on the basis of spectral centroid alone.

Conclusion

Participants were able to make reliable discriminations of complex vibrotactile waveforms. This ability does not depend on overall intensity or the amplitude envelope, which is suggestive of some type of Fourier transform. Performance was optimal at 220 Hz (A3), which approximates the peak sensitivity of the Pacinian corpuscles.

Research and/or Educational/Clinical Implications

The findings suggest that vibration is an important candidate modality for the development of sensory substitution systems that may enable better access to music for deaf and hard of hearing populations.

Acknowledgement of Research Funding

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7B) 11:00 – 11:20

The spectra of average orchestral instrument tones

Joseph Plazak, David Huron, and Benjamin Williams
The Ohio State University

Purpose:

The spectrum for an average orchestral instrument tone is presented based on timbre data from the Sandell Harmonic Archive (SHARC). This database contains static (time invariant) spectral analyses for 1,338 recorded instrument tones from 23 Western instruments ranging from contrabassoon to piccolo. Although several caveats apply, music perception researchers might find the calculated “average tone” and “average instrument” more ecologically appropriate than other common technical waveforms, such as sine tones or pulse trains.

Methods:

An average of all 1,338 spectral analyses in the SHARC database was calculated, yielding what might be considered an “average orchestral instrument tone.” Additionally, average spectra were calculated individually for 81 pitches ranging from B0 to G7. Each of these tones represents the average of all instruments in the SHARC database capable of producing that pitch. These latter tones reveal common spectral changes with respect to pitch register, and taken collectively, might be regarded as an “average orchestral instrument.”

Results:

Synthesized versions of both the “average orchestral tone” and the “average orchestral instrument” are permanently archived at the Knowledge Bank website (https://kb.osu.edu/).

Research Implications:

Average orchestral tones may prove useful in a variety of research applications where representative, yet highly controlled stimuli, are needed.

7B) 11:20 – 11:40

Predicting perceptual differences between musical sounds: A comparison of Mel-Band and MFCC based metric results to previous harmonic-based results

James W. Beauchamp[1], Hiroko Terasawa[2,] and Andrew B. Horner[3]
University of Illinois[1], Stanford University[2], Hong Kong Univ. of Sci. and Tech.[3]

Purpose

In order to arrive at an objective measure of “perceptual distance” between similar musical sounds, listeners were tested for their ability to discriminate between eight original sustained musical instrument sounds and modified

versions of these sounds. Results for metrics based on harmonic amplitudes measured from the musical sounds were reported by Horner et al., in J. Audio Eng. Soc., Vol. 54, No. 3, 2006. It was found that a metric based on relative Cartesian distance between harmonic spectra performed best of the metrics tested with a maximum R2 correspondence of 91%. This paper's objective is to compare the harmonic-based results with more recently obtained results based on mel-bands and mel-frequency cepstral coefficients (MFCCs). MFCCs have had much success for categorization of speech sounds in speech recognition programs and show promise for compact representation of sound spectra in general and musical sounds in particular.

Methods

Eight 2-s Eb4 instrumental sounds (bassoon, clarinet, flute, horn, oboe, saxophone, trumpet, and violin) were spectrally modified. Each sound's time-varying sound spectrum was randomly altered under constraints that preserve the sound's spectral centroid and loudness. Modification was done by filtering the original spectrum by a fixed function of frequency, which randomly varies around unity in the range [1 - 2ε to 1 + 2ε], so that the relative standard deviation error was approximately ε. Spectral alterations were applied at 50 levels of ε (0.01 to 0.50), resulting in one original sound and 50 modified sounds for each instrument. Discrimination between each original sound and each of the corresponding spectrally altered sounds was tested with a 2AFC procedure, with 20 participants (10 musicians, 10 non-musicians), resulting in eight plots of percentage correct discrimination vs. epsilon. Perceptual trends were analyzed using a 4th-order regression model employing various spectral representations as explanatory variables. The spectral representations include variations of mel-band-based and MFCC-based metrics. In addition to these representations, exponents were varied in distance calculations from 0 to 3, where 2 is the standard Euclidean distance exponent.

Results

Preliminary results indicate that mel-band measurements give R2 correspondences of up to 90% while MFCCs give correspondences up to 89%.

Conclusion

Mel-band and MFCC results almost exactly match the results obtained from harmonic-based metrics.

Acknowledgement of Research Funding

This work is supported in part by Hong Kong Research Grant Council's Projects 613806 and 613508.

Session 8A Pitch (*Chair: Frank Russo)*

8A) 1:30 – 1:50

Are pitch-class profiles really 'key for key'?

Ian Quinn
Yale University

Purpose

Most current approaches to key-finding, either from symbolic data such as MIDI or from digital audio data, rely on pitch-class profiles. I will present an alternative approach for a specific repertoire (four-part chorales) that is based on two ideas: first, that chord progressions, understood rather loosely as pairs of neighboring harmonic states demarcated by note onsets, are sufficient as windows for key-finding, at least in the chorale context; and second, that the encapsulated identity of a chord progression (modulo pitch-class transposition and revoicing) is sufficient to do key finding – even without enabling the algorithm to reduce progressions to their constituent pitch-class distributions. The system has no access to explicit information about a chord progression other than its transpositional distribution in the training corpus, yet it is able to reach a remarkable degree of subtlety in its harmonic analysis of chorales it's never heard before. This suggests that pitch-class reductionism might not be necessary for a principled account of key.

Methods

We asked ten upperclass music majors at Yale University to analyze five randomly-selected chorales, identifying keys and locating key changes. We compared our algorithm's key-finding judgments, and the results of several other key-finding algorithms, against these experts' judgments.

Results and Conclusion

While all algorithms proved equally good at identifying the overall key of the chorales, our algorithm outperformed the others at identifying and localizing modulations (localized key changes). Part of this is due to the fact that our algorithm is designed to operate with a window of just two chords, enabling it to make quick key judgments and to localize a key change at a single chord. We also establish that the algorithm's privileging of the bass line is a key component of its high performance, and that a version of the algorithm that treats the bass line as structurally equivalent to the other voices fails to perform as well.

Research Implications

While the success of this algorithm has obvious implications for research in key-finding – which has generally been based on an architecture involving pitch-class profiles – it is not obvious how this algorithm could be generalized to

styles of music that are not as rhythmically and harmonically regular as homophonic chorales. Some suggestions for future research along these lines will be given.

Acknowledgement of Research Funding
This research was made possible by a fellowship from the Center for Advanced Study in the Behavioral Sciences at Stanford University.

8A) 1:50 – 2:10

Hearing Interval Patterns in Atonal Melodies

Jenine Lawson
Eastman School of Music

Purpose
This study focuses on implicit learning of interval patterns in an atonal musical language. It investigates whether listeners can abstract interval patterns into trichords (three-note groups).

Methods and Results
Pilot subjects (n=21) were freshmen music majors at Ithaca College. In experiment 1, listeners (n=11) heard a familiarization phase consisting of the 48 versions of a derived 12-tone row. The row, <014_985_632_7te>, has four consecutive trichords, all of which are set-type [014]. Each [014] contains adjacent-intervals (AIs) 1 and 3. The nonadjacent-interval (NAI) between first and third notes of each [014] spans 4 semitones. During each trial phase (randomly ordered), listeners heard an [014] and some other trichord and were asked to identify which trichord was more idiomatic of the familiarization phase. Stimuli were synthesized piano tones between F2-A5, and each note lasted .33 seconds. Performance on correct discrimination between [014] and other trichords heard within the row ([037], [013], and [015] that occur half as often) is 72.7% (SE=.12). This is significantly higher than listeners' ability to correctly discriminate between [014] and lures constructed with AIs 1 and 3 but arranged such that the NAI≠4 (M=34.1%, SE=.19). The procedure in experiment 2 was the same as experiment 1, but listeners (n=10) heard a different row during the familiarization phase. The row <014_958_632_7et> contains four [014] trichords, each illustrating the three possible ways to order a trichord:

<014>,<632>	AIs=1,3; NAI=4
<958>	AIs=4,3; NAI=1
<7et>	AIs=4,1; NAI=3

Performance on correct discrimination between [014] and lures never heard in the row is 90.0% (SE=.04). These lures (e.g.<t01> and <037>) contain two of [014]'s intervals (1, 3, or 4). This is significantly higher than listeners' ability to correctly discriminate between [014] and lures containing two AIs heard within the row such as <586> and <327> (M=74.3%, SE=.04).

Conclusions
Experiment 1: When listeners hear a row consisting of repeated interval patterns, they extract adjacent-intervals patterns but not the set-type. Experiment 2: When listeners hear a row consisting of a set-type arranged with different NAI patterns, they learn the set-type itself, an initial step in hearing structure in trichordal array music.

Research Implications
Each of these experiments attempts to create a simplified "atonal language" similar to the artificial languages in J.R. Saffran's (2003) research, except that transitional probabilities are based on interval patterns rather than note or syllable patterns. In addition to Kuusi (2003), this study is one of the first to demonstrate that listeners have an ability to hear set-types.

References
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Saffran, J. R. (2003). Musical learning and language development. *Annals New York Academy of Sciences, 999*, 1-5.

8A) 2:10 – 2:30

Temporal pitch perception – An ERP study of iterated rippled noise

Blake E. Butler
McMaster University

Purpose
Pitch processing is essential for understanding music. Pitch is derived in the auditory system through complex spectrotemporal processing. There is considerable evidence that a temporal code is particularly important for the perception of pitch. The purpose of this study was to isolate the mechanism of temporal pitch perception using EEG and iterated rippled noise (IRN) stimuli.

Methods
The stimuli for this study were 485ms iterated rippled noise samples consisting of a segment of frozen white noise, repeated in 5 and 6 ms intervals to create sounds with either 200 Hz or 167 Hz pitch sensations, respectively. The stimuli were then high pass filtered at 2600 Hz to remove the resolvable harmonics of the fundamental frequency, and low pass filtered at 4500 Hz to remove noisy areas of the spectrum that failed to contribute to the sensation of pitch. The 167 Hz sound was presented on 85% of trials (standards), while the remaining 15% (deviants) consisted of the 200 Hz sound. EEG was collected from adult participants using an EGI system with 128 channel HydroCel GSN nets. Following data collection, EEG trials were averaged within each individual to create difference waves representing the difference between the deviant and the standard stimuli. We expected a mismatch negativity (MMN) component in response to occasional changes in the perceived pitch of the IRN. MMN reflects processing in secondary auditory cortex and is typically seen in response to a change in a repeating sound; it is thought to reflect the updating of auditory sensory memory traces.
Results
The difference waves showed a mismatch negativity response peaking at 250ms after onset of the deviant tones. The MMN had a right, frontal focus on the surface of the head with a left posterior reversal.
Conclusion
Although the shift in perceived pitch in this experiment was relatively difficult to hear, it succeeded in eliciting a mismatch negativity response. Furthermore, since both stimuli contained information in the same spectral range, with no cues at resolvable harmonics of the frequency of the perceived pitch, it is apparent that the temporal information coded within the IRN stimuli is responsible for the pitch sensation.
Research and/or Educational/Clinical Implications
EEG measures do not require a response from subjects, so we can now investigate the development of the temporal mechanism for pitch perception in children and infants.
Acknowledgement of Research Funding
This research was funded by a grant to LJT from the Canadian Institutes of Health Research.

8A) 2:30 – 2:50

The effect of task and pitch structure on pitch-time interactions in music

Jon Prince[1], Mark Schmuckler[1], and Bill Thompson[2]
University of Toronto[1], Macquarie University[2]

Purpose
Musical pitch-time relations were explored by investigating the effect of temporal variation on pitch perception (Prince, Schmuckler, & Thompson, in press). Previous research (Prince, Thompson, & Schmuckler, 2008) demonstrated an asymmetric effect of pitch structure (tonality) on temporal judgments, but not vice versa. These findings conflict with dynamic attending theory research that demonstrates effects of temporal variation on pitch perception. The goal of the present research was to reconcile the aforementioned research and explore the factors that affect pitch-time integration.
Methods
In Experiment 1, musicians heard a standard tone followed by a tonal context and then a comparison tone. The participants then performed one of two tasks. In the cognitive task, they indicated whether the comparison tone was in the key of the context. In the perceptual task, they judged whether the comparison tone was higher or lower than the standard tone. For both tasks, the comparison tone occurred early, on time, or late with respect to temporal expectancies established by the context. Experiment 2 used the perceptual task, and varied the pitch structure by employing either a tonal or an atonal context. Experiment 3 replicated the results of Experiment 2, controlled potential confounds and added a very early and very late comparison tone timing.
Results
In Experiment 1, temporal variation did not affect accuracy for either the cognitive or perceptual task. In Experiment 2, temporal variation did not affect accuracy for tonal contexts, but did for atonal contexts. The findings of Experiment 3 replicated those of Experiment 2 and also showed evidence of the metric hierarchy (Palmer & Krumhansl, 1990) influencing accuracy in atonal contexts.
Conclusion
The presence versus absence of a tonal framework, and not the task type (cognitive or perceptual), drove the appearance of pitch-time interactions in the form of temporal expectancies. We argue that tonal contexts bias attention toward pitch and eliminate effects of temporal variation, whereas atonal contexts do not, thus fostering pitch-time interactions.
Research Implications
The present study supports the notion of an inherent focus on pitch variation in Western musical contexts. Previous work (Prince et al., 2008) demonstrated asymmetric pitch influences on temporal judgments in typical musical contexts; the present study demonstrated that systematic manipulation of the tonality of the stimuli affected the role of

temporal expectancies on pitch judgments. The pitch structure of typical Western musical contexts appears to involuntarily invoke greater attention to pitch than time, obscuring otherwise observable interactions between pitch and time.

Acknowledgment of Research Funding
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Session 8B Evolution of Music (*Chair: David Huron)*

8B) 1:30 – 1:50

Experimental evidence for synchronization to a musical beat in a nonhuman animal

Aniruddh D. Patel[1], John R. Iversen[1], Micah R. Bregman[2], and Irena Schulz[3]
The Neurosciences Institute[1], Univ. of California, San Diego[2], Bird Lovers Only Rescue Service[3]

Purpose
Synchronization to a musical beat is a universal of human music, but is not commonly observed in other species. Does this ability reflect a brain specialization for music, or is it an outgrowth of some non-musical brain function? This question is relevant to debates over the evolutionary status of music, and can be addressed by asking whether other species are capable of musical beat perception and synchronization (BPS). According to the "vocal learning and rhythmic synchronization hypothesis" (Patel, 2006), BPS builds on the neural circuitry for complex vocal learning, because vocal learning requires a tight auditory-motor interface in the nervous system. This hypothesis predicts that only vocal-learning species (such as humans, parrots, and dolphins, but not nonhuman primates) are capable of BPS.
Methods
We studied a sulphur-crested cockatoo (Cacatua galerita eleonora) named "Snowball" who moves rhythmically in response to human music. A ~78 second excerpt of a song was computer-manipulated to create versions at 11 different tempi (original, +/- 2.5%, 5%, 10%, 15%, and 20%), without changing the pitch. These versions were presented multiple times across several sessions, and movements were videotaped for analysis. During taping, we ensured that no humans were dancing (in order to rule out imitation of human movement). Analysis focused on the timing of head bobs in the vertical plane. These head bob times were compared to musical beat times in order to determine if there were periods of sustained synchrony to the beat ("synchronized bouts").
Results
Snowball showed synchronized bouts at 9 of the 11 different tempi. In trials with synchronized bouts, the bouts accounted for ~25% of the head bobs, meaning that Snowball was not able to maintain synchrony for long periods of time (i.e., there were long stretches where his dance tempo did not match the musical tempo). Even though Snowball showed sporadic synchronization, a Monte Carlo test indicated that his degree of synchrony was unlikely to have occurred by chance ($p = .002$).
Conclusion
A nonhuman animal is capable of genuine synchronization to a musical beat, though his abilities are not comparable to a human adult, who can sustain synchrony to music for long stretches of time (Snowball's ability may be more comparable to a human child).
Research Implications
Complex vocal learning may provide the neural and evolutionary foundations for synchronization to a musical beat. Further comparative work with other species can help test this hypothesis.
Acknowledgement of research funding
Supported by Neurosciences Research Foundation.

8B) 1:50 – 2:10

Statistical regularities of human melodies reflect perceptual-motor constraints: evidence from comparisons with bird song

Adam T. Tierney[1], Frank A. Russo[2], and Aniruddh D. Patel[3]
Univ. of California San Diego[1], Ryerson University[2], The Neurosciences Institute[3]

Purpose
Researchers have discovered statistical regularities in a wide range of vocal music, including 1) lengthening of the last note of a phrase, 2) arch-like melodic contours, and 3) post-skip reversals: the tendency for jumps in pitch ("skips") to be followed by a change in direction. These patterns may be due to basic perceptual and motor constraints on the vocal production of pitch sequences. To test this hypothesis we examined whether these patterns also occur in bird

song. We also examined whether these patterns occur in the pitch patterns of speech intonation and in instrumental musical themes.

Methods

We encoded 56 bird songs (from a wide range of bird species), 81 sentences, and 718 musical themes as sequences of discrete pitches. For bird song, each note's mean pitch was computed. For speech, intonation patterns were converted to pitch sequences using the prosogram model of intonation perception. For music, pitches were encoded relative to A440.

Results

Final lengthening and post-skip reversals were found in bird song, speech, and instrumental music. Arch-shaped contours were found in speech and instrumental music, but not bird song (where pitch contours were generally descending). However, we found that the individual notes of bird songs tended to have an arch-shaped contour. Unlike singing humans, singing birds tend to breathe between the individual notes of a melody, suggesting that the arch shape may be a motor consequence of breath patterns, which occur at the phrase level in human song but at the note level in bird song.

Conclusion

Some widespread features of human vocal melody also occur in bird song and speech intonation patterns, and hence may be due to basic perceptual and motor constraints on pitch sequence production. For example, final lengthening may reflect a motor tendency to slow down before stopping at a phrase boundary. Post-skip reversals may reflect the fact that pitch ranges are bounded, and skips that approach the edge of the range must be followed by reversals (as suggested by Von Hippel & Huron [2000]). Arch-shaped contours may reflect the breath cycle during song. Final lengthening and post-skip reversals in instrumental music may also have a perceptual-motor origin, but the arch shaped contours may be a case of instrumental music reflecting vocal music.

Research Implications

This research suggests that comparisons of human and avian singing can help uncover the bases for certain widespread features of melody.

Acknowledgement of research funding

Supported by Neurosciences Research Foundation.

8B) 2:10 – 2:30

Rhythmic structure in humpback whale (Megaptera novaeangliae) songs: Preliminary implications for song production and perception

Stephen Handel[1], Sean K. Todd[2], and Ann M. Zoidis[2]
University of Tennessee[1], College of the Atlantic[2], Cetos Research Organization[3]

Purpose

Roughly 40 years ago, Payne and McVay (1971) described the hierarchical repetitive "songs" produced by male humpback whales (Megaptera novaeangliae) on their mating grounds. The basic sounds are grouped into phrases, the phrases are grouped into themes and the themes are organized into a repetitious pattern that recycles in rigid order. One complete cycle has been termed a song and the song may be repeated several times in a session. However, it is unknown how singers keep these intricate songs intact over multiple repetitions or how they learn variations that occur sequentially within each mating season. Here we investigated whether the rhythmic structure defined by the durations of individual sounds and the duration of the silent intervals among the sounds can expose some production constraints, and/or reveal how the whale organizes the sounds into phrases and themes.

Method

The humpback whale songs analyzed here were recorded in 1994 and 2001 off the island of Kauai, Hawaii by Cetos Research Organization. Each recording was collected from a different individual whale. The program Praat was used to construct spectrograms and determine the start- and end-time for every sound. The sounds were classified aurally and visually.

Results

In all songs, nearly every sound occurs in more than one phrase. The role of rhythm in structuring the song into phrases was determined by analysis of the timing of the same sounds in different phrases. In every song, the silent interval between two sounds changed as a function of the other sounds within the phrase, although the duration of the sounds did not change consistently. In a phrase, two or three sounds are heard together as a rhythmic unit, separated from other sounds that are heard individually. There was no evidence that the silent intervals at the transition between themes were any longer than the intervals within a phrase.

Conclusions

These results demonstrate that the sounds are not produced independently; the following sound influences the temporal properties of the present sound. The rhythmic timing is local. Individual sounds are grouped into rhythmic units that make the production and perception of the lengthy complex songs tractable by yielding a set of simple units that, although arranged in rigid order, can be repeated multiple times to generate the entire song.

Research and/or Clinical Implications
The rhythmic structure, an invariant cue in the ocean environment, may identify pod membership, provide a way to identify changes in the mating song, and yield a measure of reproductive fitness.

Poster Session II
3:00 – 5:00

22. Mental rotation in visual and musical space: Comparing pattern recognition in different modalities

Marina Korsakova-Kreyn and W. Jay Dowling
University of Texas, Dallas

It is plausible that spatial abilities—such as mental rotation of shapes—are related to certain kinds of musical abilities—such as the mental manipulation of musical "shapes" in the virtual space of pitch and time. Cupchik, Phillips, and Hill (2001) had found such a correlation between spatial mental rotation and recognition of inverted and retrograde transformations of melodies. Here we replicated their results, including less extreme melodic transformations than the mirror images they used, obtaining a correlation of r = .37 between the spatial and musical tasks. Participants performed 122 trials of a Shepard-type task, judging the congruency of rotations of three-dimensional objects. In this music perception task, the participants judged the congruency of 27 melodic contours in their standard and transformed versions, namely, tonal answer, inversion, and an incomplete inversion. The musical transformations were collected from keyboard compositions by J. S. Bach. Unlike Cupchik et al., we included a non-spatial musical control task involving timbre judgments, which correlated almost as strongly with mental rotation (r = .33). Hence we doubt that the correlation between mental rotation and melodic transformation tasks should be attributed to underlying spatial abilities common to both domains, but rather to more general processing abilities.

23. Music videos: Effects of visual information on music perception and remembering

Marilyn Boltz
Haverford College

Purpose
Although a substantial amount of research has revealed ways in which music can influence the film-viewing experience, relatively few studies have examined the reverse relationship. The purpose of the present research was to investigate whether the affect and structure of visual information influence the way a tune is heard (Experiment 1) and remembered (Experiment 2).
Methods
In both studies, listeners were presented with a set of five ambiguous tunes (i.e. with a neutral affect and moderate activity level) paired with four visual displays that varied in their affect (positive vs. negative) and format (video of scenes that smoothly transitioned from one to another vs. a montage (i.e. slideshow) of still images), or as a control condition, no visual information at all. Immediately after each, participants rated different characteristics of the melody (i.e. affect, activity, tempo, rhythm, flow, tonality, harmony, and loudness) on a set of 7 pt. scales. In Experiment 2, S's viewed and listened to the 5 stimuli and immediately afterwards, were given a surprise recognition memory task. On a given trial, they were required to discriminate an old melody from a new version that had been systematically transformed along one of three structural dimensions. In particular, each tune was increased or decreased by 15% in either tempo, pitch, or both together to reflect a more positive or negative mood, respectively. The main measure of interest was the false alarm data ("old"/new) which is predicted to reflect biases from visual affect.
Results
In Experiment 1, the most important finding was a 3-way interaction between the different musical dimensions, visual affect, and format $F(7, 295) = 10.32$, $p < .001$. In general, visual affect influenced music perception in a mood-congruent fashion. Melodies pre-rated as neutral in overall affect were judged to have a positive affect in the presence of positive scenes but a negative affect in the presence of negative scenes. More interestingly, the perceived acoustical qualities were influenced in a corresponding manner. In the presence of positive (negative) scenes, tunes were perceived as louder (softer), faster (slower), more (less) rhythmic, and more (less) active than these same tunes presented in the absence of visual information. Although the effect of visual affect applied to all audiovisual pairs, visual format also had an impact on perceptual ratings. In contrast to the videos which were judged smoother and more passive, visual montages were rated "choppier" and more staccato in nature.
In Experiment 2, there was a significant interaction between visual affect and distracter melody affect, $F(2, 57) = 11.72$, $p < .001$. Within each transformation condition, mood congruency effects were once again observed in that relative to the control melodies, false alarms for positive (vs. negative) distracters were higher in the positive visual affect condition, while the reverse was observed in the negative condition. Hence, memory was distorted by visual information, an effect that generalized across both the video and montage formats.

Conclusions and Implications
The present set of results parallel the demonstrated effects of musical soundtracks on the cognitive processing of film. In both cases the mood of film or music provides an interpretative framework that then biases the nature of perception and memory. Consistent with the Congruence-Associationist Model (Cohen, 1999), one can argue that the effects of visual affect and format on music cognition reflect a type of stimulus overgeneralization effect in order to achieve structural congruity. For format, melodies were perceived to have the same qualities as an accompanying montage or video, namely, a rapid, rhythmic, and staccato flow of information vs. a slower and smoother presentation of material, respectively. Visual affect exerted a similar influence: the perception and remembering of certain acoustical qualities were altered to reflect the mood of the visual display. As this relatively unexplored area of research continues to develop, its finding may better illuminate the mediational mechanisms of cross-modal perception, and better inform performing artists how to construct a music video for its desired effects.

24. Effects of background music and built-in audio on performance in a role-playing video game

Siu-Lan Tan[1], John Baxa[1], and Matthew P. Spackman[2]
Kalamazoo College[1] and Brigham Young University[2]

Purpose
Few studies have examined the role of sound in video games (Hébert et al., 2005; Tafalla, 2007). Further, as some studies have used built-in sound provided by the game and others have supplied an external soundtrack, it is difficult to synthesize findings. Our aims were a) to examine the effects of various sound conditions on performance in a role-playing video game, and b) to determine whether sound must be contingent on player's actions, or whether unrelated background music can also enhance performance.
Methods
Twenty-one undergraduates played 'Twilight Princess' on a Wii console in individual sessions on four consecutive days, in the following conditions (randomized between participants): Full Sound (Screen and Wiimote), Partial-Sound (Wiimote only), No Sound, and Non-Contingent Music (unrelated background music). Performance measures included number of tasks completed, amount of time to complete tasks, and use of 'continues' (which extends play when the gamer has run out of power).
Results
A series of one-way repeated measures ANOVAs revealed no significant effects for sound condition on most performance measures. However, significant differences were found for the effect of sound condition on the use of 'continues,' $F(3, 57) = 3.34$, $p < .026$. Most 'continues' were requested in the no-sound condition ($M = 2.6$, $SD = 2.21$), followed by partial-sound ($M = 2.1$, $SD = 1.41$), full-sound ($M = 1.45$, $SD = 1.67$), and non-contingent music ($M = 1.0$, $SD = 1.52$) conditions. Follow-up repeated measures ANOVAs based on the performance scores participants had earned up to the first 'continue' also revealed a main effect of sound condition on the number of completed tasks, $F(3, 57) = 3.166$, $p < .05$, and length of play, $F(3, 57) = 3.696$, $p < .05$. Specifically, participants completed more clusters ($M = 2.6$) and played longest ($M = 33.3$ minutes) in the non-contingent music condition, followed by full-sound condition ($M = 2.05$ clusters, $M = 30.3$ minutes). The lowest scores were obtained in the partial-sound ($M = 1.64$ clusters, 19.41 minutes) and no sound ($M = 1.36$ clusters, 20.5 minutes) conditions.
Conclusion and Research Implications
Participants' use of 'continues' and performance scores before the use of the first 'continue' varied with sound condition, with background music and full-sound leading to higher scores than partial-sound and no-sound. Full sound (i.e., contingent audio cues from screen and remote) seemed to facilitate top-scoring players' performance. However, the highest performance scores on most measures were yielded in the non-contingent music condition, regardless of proficiency. While the best players may successfully integrate audio and visual cues during play, background music may enhance performance through more general mechanisms (e.g., modulation of mood or arousal), and may therefore be demonstrated across proficiency levels. Our study reconciles mixed findings in this area, contributes to research on positive effects of background music on gamers' performance (e.g., Cassidy & MacDonald, 2008), and links more generally to the literature on the facilitative effects of music.
Acknowledgment of Research Funding
Funding provided by the Psychology Departments at Brigham Young University and Kalamazoo College.

25. Evaluating the impact of music video games on musical skill development

Patrick Richardson and Youngmoo Kim
Drexel University

Purpose:
This research project seeks to track and quantify any effect by which routine exposure and play with popular music and rhythm-based video games may inspire or bolster the development of music-specific skills (tonal/rhythm memory, aural skills, sight-reading/singing, etc). This one-year longitudinal research study provides an evaluation of the impact of musical video games that specifically investigates the following questions:

1. Does game proficiency have a positive impact on musical skill development?
2. Does avid game play lead to the pursuit of other music making outlets?
3. Does interest and regular participation in the playing of music video games affect whether a student seeks additional formal music education?

Methods:

For this longitudinal study, both control and experimental groups complete a computer-based battery of musical skills and -sensitivity tests. Each of 20 subjects in the experimental group attends 6 months of weekly after-school game play sessions. All 15 Control group participants abstain from play of these games for the study's duration. After the duration, both groups repeat the full music test battery. Games score and test score are evaluated for learning effects and training advantages.

Results:

As of 10/1/08, this study is under active funding, following the approved research calendar. As of 1/1/09, the research team is has established the web-based test battery and targeted recruitment populations. We plan to end the gaming sessions in late May of 2009, and have experimental results available within June of 2009.

Conclusion:

This project's Results, Discussion, and Conclusion will be available for presentation at the June 2009 SMPC conference.

Research and/or Educational/Clinical Implications:

In recent years, a variety of video games have been developed based on the premise of simulated music play. These games have become extremely popular, and are indicative of a strong demand within society for some form of musical experience and expression. At the same time, particularly in at-risk communities, traditional music education has been a lesser priority within the public school curriculum. For students within school districts that provide little or no funding for fine arts programs, music video games may represent the foremost form of musical interaction to which these students are exposed. Consequently, it is crucial to understand the impact and the potential for these music games to serve as a tool for learning musical skills and stimulating music appreciation.

Acknowledgement of Research Funding:

We would like to thank the NAMM Foundation for their support.

26. Segmentation of music and film and the nature of their interaction and integration

Cindy Hamon-Hill[1], Annabel J. Cohen[2], and Ray Klein[1]
Dalhousie University[1], University of Prince Edward Island[2]

Purpose

In a previous study, Hamon-Hill and Barresi (2008) showed that social and emotional interpretations of an animated visual stimulus varied with different accompanying music. Viewers were exposed to simple line-drawn animated objects (Heider & Simmel, 1944) without music or with one of three musical excerpts and rated each of the objects on a social-characteristics scale. Ratings of characteristics, such as "lonely" or "threatening", differed between objects and the intensity of ratings varied under different music backgrounds. To explain how the music influences the meanings assigned to the visual objects, we are focusing on the parsing or segmentation of the visual and musical stimuli when processed individually and together. Segmentation studies reveal how people organize and parse stimuli from different modalities into meaningful events or units of information (Zacks, 2004). Krumhansl and Schenck (1997) revealed similar patterns of segmentation for music and dance, each contributing additively to the experience of tension and expression of emotion. An investigation of visual and auditory information representing clarinet performance revealed that information from each modality was processed structurally similarly yet the visual information could both augment and dampen the emotional interpretation of tension in the performance (Vines, Krumhansl, Wanderley & Levitin, 2006).

Methods

In the current study, participants segment 1) the Heider and Simmel animation, 2) a music excerpt of the same duration as the animation, and 3) the animation and music combined, by marking breakpoints between meaningful units of information (Newtson, 1977). Frequency and temporal patterns of breakpoints are collected from each participant for all three experimental conditions.

Results

The data will show the segmentation patterns for the visual and musical information when experienced independently, and how their joint encoding modifies the pattern. A primary question of interest is the relative strength of the segmentation from the two modalities, as the results of Krumhansl and Schenck (1997) for dance showed less visual dominance than did the results of Vines et al. (2006) for music performance.

Conclusion & Research Implications.

To the best of our knowledge, this is the first study of parsing of music and film animation and their interaction. The study should further our understanding of how music and film interact at a structural level so as to influence interpretations when making cognitive and emotional judgments. As such the research will help to inform the lower (sensory analysis) level of Cohen's (2008) Congruence-Association Model of the role of music in media which proposes a matching process between sensory-based analysis at a low level and generation of semantic

interpretations at a higher level. Such knowledge and theory may ultimately aid the film industry or educational multimedia sector in having greater control over the impact of music scores on audiences.

Acknowledgement of Research Funding
Social Sciences and Humanities Research Council awarded to A. J. Cohen.

27. An experimental investigation into the effects of stereo versus surround sound presentation in the cinematic and music listening experiences

Mark Kerins[1] and Scott D. Lipscomb[2]
Southern Methodist University[1], University of Minnesota[2]

Purpose
5.1-channel surround sound presentation is ubiquitous in theatrical releases and DVDs; most television programs and video games also utilize soundtracks mixed for this sonic environment. This broad deployment demonstrates the media industries' implicit assumption that changing sound presentation mode significantly alters the experience of audience members. There has been, however, little experimental investigation into this relationship. This study is part of an ongoing series of experiments designed to fill this void.
Methods
In previous studies (Kerins & Lipscomb, 2003; Lipscomb & Kerins, 2004), the present authors studied the influence of the sound systems used in motion picture exhibition (monophonic, 4-channel surround, and 5.1-channel surround) and music listening (stereo and 5.1 surround) on audience judgments of the films/songs themselves. In the present study, the authors reexamined the effect of presentation mode using a method similar to, but with important differences from, that of the previous studies.Seventy participants rated each excerpt on a series of 11 verbal scales, including the scales employed in the previous studies and additional scales designed to highlight the "immersion" factor of the experience. Most importantly, presentation mode was incorporated into the experimental design as a within-subjects variable within a block-design paradigm so that all participants were exposed to excerpts representing two presentation modes (stereo and 5.1 surround).
Results
In a preliminary analysis of this data (Kerins & Lipscomb, 2007), responses to each verbal scale were subjected to analyses of variance, consisting of two between-subjects variables (musical training and visual training) and two within-subjects variables (cinematic/musical genre and presentation mode). After much consideration of the results, alternative means of statistical analysis have been pursued to clarify the outcomes observed, revealing important findings that were not apparent in the initial interpretation. Details concerning statistically significant differences that emerged will be provided during the presentation.
Conclusion
The present study reveals that 5.1-channel surround sound's effects are not the same for every genre or media form, and suggests specific elements whose influence on the cinematic or music listening experience with respect to sound presentation mode warrant further study.
Research and/or Educational/Clinical Implications
Relationships between audience responses and sound presentation mode emerge for some genres of music/cinema but not for others, suggesting the significance of stereo versus 5.1-channel presentation varies. Further research based on the present results and designed to isolate the specific elements that determine whether the 5.1-channel experience differs significantly from the stereo experience is suggested.

28. Intersensory attention

Matt Rosenthal and Erin Hannon
University of Nevada, Las Vegas

Purpose:
This study investigates the applicability of an internal oscillator model of attending to multimodal rhythms.
Method:
Participants were presented with either an auditory or visual context rhythm. A cross was then briefly presented that either conformed to or violated the temporal expectation created by the context rhythm and was oriented to the left, right, or center. Participants were instructed to indicate whether the orientation of the cross changed from an initial viewing at the beginning of the trial. Accuracy in this task was the dependent variable.
Results:
We expect participants exposed to auditory context rhythm will be more accurate in the visual attention task at expected locations than participants exposed to the visual context rhythm and that both conditions will be more accurate than a baseline condition of no rhythmic context. If this hypothesis is supported, this would support the internal oscillation model for attending to external rhythms but with the constraint that rhythms in the visual modality do not entrain as readily as auditory rhythms. If accuracy scores for both rhythmic context conditions are not different from each other but higher than the baseline condition, this would suggest that visual context rhythms are just as

effective as auditory context rhythms at inducing temporal expectancies or that there is a cost of switching attention between the auditory and visual modalities even when the rhythmic pattern of the context is preserved. In the case where one or both accuracy scores from the rhythmic context conditions are not different than baseline, this would suggest that auditory rhythm patterns do not create temporal expectancies for visual events; visual rhythms do not create temporal expectancies for visual events or both.

Research Implications: The internal oscillation model may provide the mechanism for attending to external rhythms. Although this model predicts oscillatory entrainment to visual rhythms, the visual modality's shortcoming in temporal processing suggests attenuation of entrainment to visual rhythms relative to auditory rhythms. If oscillatory entrainment is the mechanism by which attending and the creation of temporal expectancies occur, then the temporal expectancies created by an auditory rhythm should modulate accuracy in a visual task based on the degree to which the timing of the visual task conforms to the temporal expectancy created by the auditory rhythm. This effect should be reduced when the temporal expectancy is created by a visual rhythm. This study should make clear the extent to which the internal oscillator model applies to multimodal events.

29. Aural versus visual cues in communicating tactus

Peter Martens[1], Stefan Tomic[2], and Petr Janata[2]
Texas Tech University[1], University of California, Davis[2]

Purpose

The purpose of this study was to investigate whether or not performers' intended metrical interpretation of a piece of music can be communicated to an audience in the form of a main beat or tactus, and to what extent this communication depends independently on a performance's aural and visual components.

Methods

A student string quartet was coached to perform a set of seven musical excerpts twice, keeping the same tempo in each performance but feeling and attempting to express a different main beat (tactus) in each. These two beat levels were adjacent in the metric hierarchy, and related by either a duple or triple ratio. The initial group of study participants viewed these videorecorded performances and were asked to tap their dominant hand along with the main beat of the music. A second group completed the same tapping task in response to either audio-only or video-only versions of the same performances. Finally, the audio and video of these performances were analyzed separately using the meter-finding computer model of Janata & Tomic (2008) and ImageJ video analysis software, respectively. The three human response conditions and the two computer analysis conditions were compared in a 3x2 matrix.

Results

Overall, the quartet's intended tactus significantly influenced listeners' choice of tactus under the A/V condition, but much less so under the audio- or video-only conditions.

In some excerpts, the computer analysis matched the human responses closely; in others, the computer "heard" or "saw" differences in the quartet's intention that human listeners seemed not to notice, and vice versa.

Conclusions

Communicating a specific metrical interpretation of music to an audience is a multi-sensory act. The quartet's success with its intended tactus was significantly greater when video was present, but "objective" visual and aural cues uncovered by computer analysis were not relevant to human listeners in all cases.

Educational/research implications

Performers in training should be made more aware of their physical presence onstage, and should practice and be evaluated on whether or not the gestural components of their performances contribute to their desired effect. In order to model meter perception more ecologically, tapping studies should involve performance visuals.

Acknowledgement of research funding

Metanexus Institute grant (UC-Davis), Texas Tech University Growing Graduate Programs grant (Texas Tech University Music Research Lab)

30. A comparison of auditory and visual perception via a novel auditory search task

Kat Agres[1], Spencer Topel[1], Stephen Moseson[1], Sarah Victoria Brown[1] and Michael J. Spivey[2]
Cornell University[1], University of California, Merced[2]

Purpose

Visual search tasks have elucidated fundamental properties of visual perception, such as attention and efficiency of processing. Until this time, few studies have utilized the search task paradigm to test whether auditory perception shares certain phenomena (e.g. the "pop-out effect") in common with visual perception. The present experiment sought to address the following question: Do the auditory and visual systems exhibit similar constraints of attention on perception?

Methods

A new ambisonics-based technology was developed to assess this question. This interactive technology, which features a headphone-mounted magnetometer, enabled listeners to actively direct and influence their auditory

environment. In the experimental task, listeners were given a target tone at the beginning of every trial. The target tone consisted of a particular timbre (the instrument playing) and pitch. After hearing the target, either two, three, or four tones were presented in distinct auditory locations within the front hemisphere of space. The listeners' task was to locate the target among distractors that could feature either the same pitch or timbre as the target. Analogous to some visual search tasks, the search type could either be simple or complex. In simple searches, the distractor(s) did not have either feature (timbre or pitch) in common with the target. In complex searches, one of the distractors exhibited either the same timbre or pitch as the target.

Results

The results provide evidence that listeners do require more time for complex searches than for simple searches. A 2 X 3 ANOVA of Search Type X Set Size (the number of sounds per trial) yielded a significant main effect of Search Type ($p < .05$), with complex search eliciting longer reaction times than simple search, and a significant main effect of Set Size ($p < .01$), with reaction times increasing with the number of distractors. The interaction of Search Type and Set Size was not significant. In separate analyses, simple search exhibited only a mild (marginally significant) effect of Set Size on reaction time ($p < .1$), whereas complex search showed a robust and highly significant effect of Set Size ($p < .01$).

Conclusion

These data provide evidence that simultaneous musical tones compete with one another for attentional resources as a function of their degree of perceptual similarity. The results thereby support the stance that attention in the auditory domain is akin to visual processing, because attention acts as a major constraint to efficient processing.

Research Implications

This research approach provides a novel way to test seminal work from visual perception in the auditory domain. More research is needed to investigate the degree to which attention within the auditory domain shares common mechanisms to attention within the visual domain.

Acknowledgement of Research Funding

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31. Musical familiarity and early social preferences

Gaye Soley and Elizabeth Spelke
Harvard University

Purpose:

Native structures play a significant role in guiding attention (Moon et al., 1993; Kelly et al., 2005) and social preferences (Kinzler et al., 2007) early in life. Music is a ubiquitous, culture-specific stimulus; yet the role of shared culture-specific musical experiences in cementing social bonds early in life are largely unexplored. We investigated whether preferences for familiar music guide children's social preferences.

Methods:

Seventy-two children in Boston participated in three experiments (mean age= 56.8 months, SD=6 months). Subjects were shown photographs of two 5-year-old children. Photographs were matched based on adult ratings on attractiveness and friendliness. After hearing two songs identified as "the photographed child's favorite song", participants were asked, whom they would like to be friends with. The order and lateral positions of photographs, and photograph-song pairings were counterbalanced. In Experiment 1, half of the songs were popular American children's songs (e.g., Mary Had a Little Lamb), and the other half consisted of unfamiliar Balkan folk songs. In Experiment 2, half of the songs were unfamiliar American folk songs from the 18th century, with similar rhythmic and melodic structures as the familiar songs from the first experiment and the other half were unfamiliar Balkan folk songs. In Experiment 3, musical excerpts were consonant or dissonant versions of unfamiliar American folk songs. All songs were created as MIDI files using the same instruments and were matched for length and tempo.

Results:

Two-tailed one-sample-t-tests revealed that subjects tended to choose children whose favorite songs were a familiar children's songs ($t(23) = 3.102$, $p < .01$) (Experiment 1); children did not show a preference when songs were familiar at a culture-specific level ($t(23) = .569$, $p > .5$) (Experiment 2); and subjects chose children who were associated with the consonant songs ($t(23) = 32.498$, $p < .05$) (Experiment 3).

Conclusions:

These results suggest that musical preferences can serve as a social cue among children. These preferences seem to be modulated by familiarity and universal rules governing music. Yet, when the songs exhibit a more abstract level of familiarity by conforming to a culture-specific style of music, children do not appear to transfer this information to the social domain, despite their sensitivity, since infancy, to such information (Soley & Hannon, under revision).

Research and/or Educational/Clinical Implication:

These studies may begin to shed light on the origins of music's social functions and of the role music plays in forming one's ethnic and social identity.

Acknowledgement of Research Funding:

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32. Auditory and visual attention networks in musicians and non-musicians

Kathleen A. Corrigall and Laurel J. Trainor
McMaster University

Purpose:
Attention research is largely focused on the visual modality. For example, the Attention Network Test (ANT; Fan et al., 2002) is a visual reaction time/accuracy task that measures three different aspects of attention concurrently. Our first goal was to create an auditory ANT to test whether attentional networks differ across modality. Our second goal was to test whether adult and child musicians differ from non-musicians on each aspect of attention, and whether such differences are modality-specific.
Methods:
In the original ANT, each trial consists of a fixation point, a visual-spatial cue, and then a target. The ANT measures reaction time and accuracy to the target and can assess three attention networks: alerting, orienting, and executive control. Alerting, or maintaining an alert state, occurs when the cue prepares participants for the target, but does not predict where or when that target will occur. Orienting, or shifting attention, occurs when the cue does predict where or when the target will occur. Executive control involves selectively attending to one aspect of a target (central arrow) while ignoring conflicting information (flanking arrows). In our auditory ANT, (1) all stimuli are auditory, (2) the task is to judge whether the word "day", "loud" or "soft" is said loudly or softly, (3) alerting is measured by comparing performance between trials with and without a warning sound, (4) orienting is measured by comparing performance between trials where the target occurs at an expected or unexpected time following a cue, and (5) executive control is measured by comparing performance on trials where the semantics ("loud", "soft") and physical features (spoken loudly or softly) are congruent or incongruent.
Results:
Preliminary results with 8 participants on the auditory ANT revealed significant effects of alerting [$t(7) = 3.12$, $p = .02$], orienting [$t(7) = 2.94$, $p = .02$], and executive control [$t(7) = 3.63$, $p = .01$]. We are currently testing musicians and non-musicians on the visual and auditory ANT.
Conclusion:
Our results suggest that alerting, temporal orienting, and executive control can be measured in the auditory modality. We expect that musicians will exhibit attentional processing advantages, especially in the auditory modality.
Research and/or Educational/Clinical Implications:
Since temporal orienting involves attending to a particular point in time, our auditory ANT has implications for musical rhythm and meter processing. Furthermore, if musical training leads to attentional benefits, this research has significant educational and clinical implications.
Acknowledgement of Research Funding:
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33. A method for studying music practice: SYMP (Study Your Music Practice)

Topher Logan, Alexander Demos and Roger Chaffin
University of Connecticut

Purpose
Music practice provides a natural laboratory for studying the development of complex mental and motor skills. Musicians can provide insightful reports about their practice and memorization strategies. Musicians' starts, stops and hesitations also provide a detailed behavioral record of the complex problem solving involved in learning a new piece. Together, these different perspectives provide a rich source of information about learning, problem solving, and memorization strategies (Chaffin & Logan, 2006). Here we describe procedures for obtaining reports from musicians and a new software tool for summarizing recorded music practice. These easily adaptable methods provide musicians and psychologists with tools for studying effective practice strategies and the learning/memorization process.
Method
We describe a new tool we have created, SYMP (Study Your Music Practice) for relating music practice to musicians' decisions about technique, interpretation, and performance. SYMP provides a format for recording both music practice and musicians' reports of their decisions during practice and their understanding of the music. Practice is first recorded on audio or videotape. The researcher then transcribes the location of starts and stops. Musicians provide reports about their decisions regarding technique and interpretation. They also report the locations that they try to attend to during performance—the performance cues they need to direct their attention in order for the performance to unfold as planned. The researcher enters the reports into the data base. SYMP provides graphical summaries of both practice and reports and the relationships between them. The program outputs data files for analysis of these relationships using standard statistical packages such as SPSS. SYMP is written in Microsoft Excel 2007 and its use requires a basic knowledge of this program.

Results
Examples will be provided of musicians' self-reports, of how the data are entered into the program, and of the graphical summaries that SYMP auto-generates. The graphs visually summarize the pattern of starts and stops in each practice session and show their relationship to the musical structure of the piece and to the musicians' decisions about technique, interpretation, and performance.
Conclusion
The described methods provide new ways for researchers and musicians alike to view the learning and memorization process.
Research and/or Educational/Clinical Implications
By helping musicians to study themselves, as well as other musicians, we can learn more about what musicians actually do when they practice. We expect that empirical study of practice will lead to strategies for making practice more effective and rewarding, and less frustrating and time consuming.

34. Impact of musical experience on measures of top-down auditory processing

Dana L. Strait, Richard Ashley, Alexandra Parbery-Clark, and Nina Kraus
Northwestern University

Purpose
Long-term musical experience is known to significantly modulate lower-level auditory function, although mechanisms by which this occurs remain uncertain. By reinforcing top-down mechanisms, music could selectively benefit perceptual abilities subject to cognitive control. In light of the extensive perceptual acuity and cognitive demands that musical activity requires, we investigated the impact of musical experience on auditory perceptual performance—especially for tasks linked to cognitive abilities like auditory attention and backward masking.
Methods
We administered a standard battery of perceptual and cognitive tests to I.Q.- and hearing-matched adult musicians (N=18) and non-musicians (N=15), including tasks more vs. less susceptible to cognitive control (e.g., backward vs. simultaneous masking). Measures were administered individually via an animated computer game developed by the Hearing Research Center of the Medical Research Council. Tasks addressed auditory attention, visual attention, frequency discrimination, frequency selectivity (simultaneous masking with and without notched filters), and temporal resolution (backward masking with and without a temporal gap between the target and masker).
Results
Overall, musicians performed a subset of tasks with greater proficiency than non-musicians. Enhanced musician performance was observed for frequency discrimination (FD), auditory attention and both backward masking measures (BM and BMgap). Musicians demonstrated lower thresholds than non-musicians for the frequency discrimination and backward masking measures (FD $F=14.03$, $P<0.001$; BM: $F=9.52$, $P<0.005$; BMgap: $F=5.60$, $P<0.03$) and faster reaction times to targets in the auditory attention paradigm ($F=4.67$, $P<0.04$). These enhancements in musicians were observed in the absence of between-group differences for the simultaneous masking and visual attention tasks.
Conclusions
Our data indicate that long-term musical practice specifically strengthens auditory-related perceptual abilities by bolstering cognitive mechanisms that, when impaired, relate to language and learning deficits. Thus, musical training may serve to lessen the impacts of a variety of cognitive deficits by strengthening the corticofugal system for hearing.

35. Advancing interdisciplinary research in singing through a short test battery: Progress update

Marsha Lannan, Jenna D. Coady, Emily Gallant, and Annabel Cohen
University of Prince Edward Island

Purpose
Although much research has been directed to the acquisition of language, little attention has been directed to the acquisition of singing. Yet both abilities develop universally early in life. Several researchers have conducted case studies of singing acquisition of their children (e.g., Dowling, 1984; Papoušek & Papoušek, 1981). Davidson, McKernon and Gardner (1981) studied groups of children in Boston, and Kreutzer (2001) studied Zimbabwean children. Stadler Elmer (2001) emphasized that children link singing with motor activity and play, de-emphasizing the significance of pitch accuracy. Together the studies are equivocal in regard to the early significance of scale segments, major triad, intervals, and tonality.
Methods
In consultation with Simone Dalla Bella and Stefanie Stadler Elmer, a test battery was developed having 11 components. Components 1 and 11 engaged conversation to assess language unobtrusively. The remaining components assess (2) pitch range; (3) minor third call-back; (4) musical interval, triad, and scale; (5) singing the familiar melody "Are you sleeping" in segments; (6) singing a favourite song; (7) improvising the ending to an unknown song; (8) composing a song to a picture prompt; (9) repeating an unknown song; and (10) singing from memory "Are

you sleeping". Experiment 1 tested 20 participants --two females and two males of ages 3, 5, and 7 years and young adults having no or considerable voice training-- at five monthly intervals resulting in 100 examples of each component. Analysis was directed to memory of "Are you sleeping" (10) and free composition (8). Renditions of "Are you sleeping" were analyzed with Stadler Elmer's (2001) pitch extraction technique. For free composition, the structure and content of the transcribed prose was analyzed. Experiment 2, in progress, refined the protocol and is being administered to young and older adults and persons with Alzheimer's disease.

Results

Systematic improvement in pitch accuracy was observed across the children of age 5 and 7 years, and across the young adults with and without training in singing. Representing the hierarchical structure of "Are you sleeping" was apparent as early as five years from the pitch timing and frequency analysis. Composition skills were evident in young children and showed similarity across all age groups.

Conclusion

The test battery provides a wealth of information. The results encourage longitudinal studies over a longer course. The enjoyment of the session found for children is reflected in preliminary observations with senior participants, however, in contrast to the children and young adults, persons with Alzheimer's disease are challenged in regard to composing a new song.

Educational and Clinical Implications

The battery may assist in defining natural singing skills and help in the teaching of singing and the maintenance of musical creativity. It may help in defining preserved musical ability in Alzheimers Disease and retention of singing skills with normal aging. It may also benefit crosscultural studies and comparisons of music and language skills and interactions.

Support

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36. Modeling meter and key implication

Eric Nichols[1] and Elton Joe[2]
Indiana University[1], Hampshire College[2]

Purpose

Music cognition researchers have previously considered both key determination and meter determination in the context of listening to a monophonic melody. Our research takes into account both problems at once, based on the intuition that in listening to the beginning of a melody, listeners quickly make judgments about both the key and meter of the melody. Specifically, we investigate the hypothesis that the initial interval in a melody has significant implications for both perceived meter and key, and that these two perceived musical features are not independent.

Methods

We recruited 14 music students and recorded their improvised, sung responses to two-note melodic fragments. For each of 24 initial intervals (both ascending and descending), each participant was instructed to sing a short response beginning with the given interval and continuing to a point of repose. We transcribed the resulting melodies and extracted the meter and tonal function of the initial notes.

Results

We studied the effect of the initial interval on the implied key, meter, and metric placement of the first notes, and noted that while there is a preference for duple meter in general (only 21% of responses are in triple meter), certain intervals such as an ascending half-step, ascending perfect fourth, or descending perfect fifth result in more triple-meter responses (32% triple for the ascending half step, 26% triple for the other two). Additionally, we identify several factors which complicate key and meter induction, including the direction and quality of initial intervals, the natural preference for duple meter, and a preference to hear the first note as a tonic.

Conclusion

The data suggest certain links between implied tonal functions and meter of an initial pair of notes; for example, we can infer the rule that if the second note sounds like a tonic, it also sounds more like a downbeat. Our results build on prior work such as Carlsen's (1981) expectation study, but the metric results are novel.

Research Implications

The computer model Musicat simulates the process of inferring metric structures, tonal functions, and motives while listening to a sequence of notes. Musicat already has mechanisms for incorporating multiple conflicting factors in perception such as those identified above; we suggest that our findings should be used to validate the results of the existing model when given two-note melodic beginnings as input; discrepancies will indicate opportunities for improving Musicat.

Acknowledgement of Research Funding

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37. Prevalence of congenital amusia

Mélanie A. Provost[1], Isabelle Peretz[1], Benoit A. Bacon[2], and Nathalie Gosselin[1]
University of Montreal[1], Bishop's University[2]

Purpose:
Congenital amusia is a disorder in musical pitch perception in the absence of more general deficits in audition, language and cognition (Peretz & Hyde, 2003). Its prevalence has been estimated at 4% (Kalmus & Fry, 1980) using the Distorted Tunes Test (DTT). However, because the DTT uses familiar melodies, congenitally amusic participants are a priori disadvantaged compared to normal subjects, since their knowledge of the familiar melodies might be limited. Furthermore, there is evidence of a ceiling effect in the results at the DTT. These limitations motivate a re-examination of the prevalence of congenital amusia using a better adapted test. Towards this aim, we used the Amusia on-line test (Peretz et al., 2008) as this test uses unfamiliar melodies, is sensitive and includes a control (rhythm) condition.
Methods:
Participants aged between 18 and 40, not preselected for their musical abilities, and for whom education level was controlled, were asked to fill out the online Amusia test, which includes three subtests. The «Scale» and «Out-of-Key» subtests measure the participant's ability to detect out-of-key notes, whereas the «Out-of-Time» test evaluates their ability to detect rhythmic deviations. The rhythmic test also serves as a control condition, since it detects whether the participant's difficulties are the result of a more generalized music problem or of another deficit (ex: ADHD). The criteria used to determine a problematic result is a score on the «Scale» subtest that falls two standard deviations below the mean (Peretz et al., 2003). Furthermore, amusic participants should show a distinct pattern of performance. That is, their performance on both the melodic subtests should be impaired, whereas their scores on the rhythmic component should be relatively normal, since congenital amusia is primarily a pitch deficit. The prevalence is determined by the proportion of participants that scores below this cutoff.
Results and conclusion:
To date, 977 participants have completed the online test, and a prevalence rate of 4.5% has been determined. Recruitment of participants is ongoing, and we are aiming for at least 1000 participants. A prevalence rate between 4% and 5% can be expected.
Research Implications:
The re-evaluation of the prevalence of congenital amusia is crucial for the genetic study of this disorder. In fact, heritability estimates rely on the prevalence rate.
Acknowledgement of funding:
Isabelle Peretz: Canadian Institutes of Health Research.
Mélanie Provost: Natural Sciences and Engineering Research Council of Canada.
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38. Subcortical correlates of consonance, dissonance, and musical pitch hierarchy in the human brainstem

Gavin M. Bidelman and Ananthanarayan Krishnan
Purdue University

Purpose:
Psychophysical data has revealed that listeners rank musical intervals along a hierarchical scale, judging some as more consonant (pleasant) than others (dissonant). The aim of this study was to determine if there are electrophysiological correlates of consonance and dissonance as reflected by the pre-attentive, subcortical processing in the human brainstem.
Methods:
Frequency-following responses (FFRs), reflecting sustained phase-locked neural activity in the brainstem, were recorded from 10 nonmusicians in response to the dichotic presentation of 9 musical intervals with varying degrees of consonance and dissonance. For each FFR, the autocorrelation function (ACF) was computed to understand the dominant periodicities present in the response. The relative strengths of all pitch related periodicities were then calculated by sliding a series of harmonic pitch sieves across the ACF and recording the output for each sieve template. This procedure essentially implements a time-domain analogue of the classic "pattern recognition" model of pitch perception. The template with maximal output was taken as the heard pitch and its output value was taken as the neural pitch salience for that musical interval. A "neural consonance ranking" was then constructed by comparing the

pitch saliences across all intervals. In a perceptual task, individuals were asked to judge the same stimuli according to their degree of consonance (i.e. pleasantness) in order to obtain a behavioral consonance ranking for each musical interval. Consonance estimates based on the neural data were then compared to those obtained behaviorally to assess the relationship between the perceptual and neurophysiologic responses.

Results:

Neural responses to consonant intervals were generally more robust than those to dissonant intervals. Moreover, FFRs showed differential encoding such that the neural pitch salience across musical intervals followed the pitch hierarchy stipulated by Western music theory. Finally, neural pitch salience showed a high degree of correspondence to behavioral consonance judgments.

Conclusion:

We conclude that brainstem mechanisms underlying pitch encoding preserve information regarding the perceptual attributes of consonance and dissonance. Furthermore, our results suggest that innate, subcortical mechanisms subserving pitch are geared toward processing consonant musical relationships over dissonant ones. This may be one reason why such intervals are preferred behaviorally.

Research Implications:

Our results demonstrate that the extraction of pitch information relevant to music processing may begin as early as the brainstem. Moreover, the basic pitch relationships governing music are encoded even in individuals without music training.

Acknowledgement of Research Funding:

NIH/NIDCD predoctoral traineeship to G.B.

39. Quantitative viewpoints on orchestration

Randolph Johnson
The Ohio State University

Purpose

Orchestration treatises largely discuss the first-order properties of individual instruments (e.g. range, tone color, and dynamic characteristics); higher-order concerns are given little consideration (e.g. instrumental combinations and pitch distribution among ensemble units). Timbre perception research suggests that instrument family classification (e.g. woodwinds) does not necessarily reflect acoustic similarities between instruments or begin to describe how instruments are functionally combined (Grey, 1977). The present study supplements data concerning instruments' acoustic similarities with analyses of instrumental behavior in actual musical works.

Methods

Chords from randomly selected nineteenth-century symphonies comprise the sample. Multidimensional scaling of instrument pair correlations yields a three-dimensional space that shows instruments' proximity according to their frequency of combination. Elucidation of the geometric model comes from a hierarchical clustering analysis that identifies three instrumental deployment groups: the groups can be interpreted as Standard, Power, and Color instruments (hereafter, the SPC model). Examples of these three groups include violin (Standard), tuba (Power), and harp (Color). The specific attributes of each of the three groups are uncovered via hypothesis testing through the lens of the SPC model.

Results

Five SPC model predictions are tested to examine its robustness and musical significance. Two experimental hypotheses fail in significance tests; therefore the following null hypotheses are retained: 1) Color and non-color instruments have equal numbers of solo occurrences; and 2) When power instruments are present in the musical texture, the pitch range spanned by the entire orchestra does not become more extreme. Three SPC model predictions are supported through hypothesis tests: 1) Color instruments are included less often in symphonic works; 2) When color instruments are included, they perform less often than the average instrument; and 3) Power instruments are positively associated with louder dynamic levels.

Conclusion

Instruments cluster together according to criteria other than instrumental family or even apparent acoustic similarity. The SPC model encapsulates some of these functional causes; it accounts for patterns of nineteenth-century orchestration; and it generates predictions concerning instruments' deployment.

Research Implications

The present study's method shows how instrumental function can be examined using a hybrid artistic-empirical approach. It has broad applications for the development of new musical analysis techniques and also to the construction of orchestration theory. Although the method of the present study defines a model of instrumental combination in orchestration, this approach is descriptive and should not be interpreted as prescribing fixed patterns of orchestration.

40. Neural processing of pitch as revealed by magnetoencephalography (MEG)

Roger Dumas, AC Leuthold, Scott Lipscomb and AP Georgopoulos
University of Minnesota

Purpose

We used MEG to investigate the dynamic brain mechanisms underlying pitch processing.

Methods

Ten human subjects listened to 24 randomized permutations of a sequence of the 24 pitches between C3 (Middle C on a piano) and B4 (approx. 2 octaves higher), for a total of 576 pure tones. Each of these tones was presented for 500 ms, inclusive of 20 ms amplitude ramps up (fade in) and down (fade out). We recorded brain activity using 248 axial gradiometers (Magnes 3600WH, 4-D Neuroimaging, San Diego, CA) at a sampling rate of 1017 Hz (bandpass: DC-400 Hz) . We then computed the means for each of the 24 notes (across subjects and repetitions) to obtain a stimulus-response curve, or pitch-processing vector (PPV), for each of the 248 MEG sensors. Finally, we calculated all pairwise correlation coefficients (N = 30628) between sensor PPVs: positive correlations would indicate similar PPVs, i.e. a similar way of processing pitch information, and vice versa for negative correlations.

Results

We found the following: (a) Highly significant positive and negative correlations were found. (b) Positive correlations occurred ~4x more frequently than negative correlations. (c) Pairs of sensors with positive correlations were clustered in the frontal (bilateral) and left temporo-occipital regions. Finally, (d) pairs of sensors with negative correlations were typically in opposite hemispheres; these negative correlations occurred more frequently in frontal regions than in posterior regions.

Research Implications

Results indicate that pitch is being processed by segregated neural networks with intricate interrelations that are currently being further analyzed.

41. Approaches to research in electroacoustic music perception

Lonce Wyse
National University of Singapore

Purpose

Much music written today is of the electroacoustic (“EA”) variety, and draws on the entire domain of sound. Since the art is generally accepted as music, it is likely to share some perceptual mechanisms with tonal music such as those involved with expectation. Other mechanisms are probably shared with the processing of everyday sounds. One of the distinguishing features of EA music is the perceptual presence of sound sources. Whether they correspond to real world objects such as dogs or trains, or are entirely abstract, perceived sources play an important role in the organization of sound environments. Research into “auditory object” formation is thus directly relevant. One goal of this presentation is to identify research already being conducted in related areas which are relevant to the understanding of electroacoustic music perception. This includes priming, distributed neural processing of objects and events, ecological acoustics, language, tonal music, sound processing, activation patterns derived from ERP, fMRI and other imaging studies, and particularly “auditory object” formation. The ultimate goal is to identify directions for research that can more directly address electroacoustic music perception.

Methods

To see how sound sources can play a musical role in electroacoustic music, we consider two key aspects of music restated here in note-free form. The first is that music involves understanding the relationship between sounds. In traditional music it is harmonic and intervallic contexts that constitute these relationships. The second is that music involves the perceptual dynamics of expectation. Far from being musical distractions, sound sources may, through qualities such as structural and transformational invariances and object permanence, be the key to understanding how the relationships between sounds and the dynamics of expectation can still function musically when tonality is no longer the medium of support.

Conclusion

There is already a wide variety of research with important implications for understanding electroacoustic music perception, very little of which has been considered, let alone conducted in this context.

Research and Educational/Implications

An agenda for research into EA music perception should include studying the relationship between auditory object formation and musical experience. Among the music educational implications is the need for a new kind of ear training, analogous to Hindemith’s (1946) classic Elementary Training For Musicians, which incorporates the basic skills important for EA creation and appreciation.

Acknowledgement of Research Funding

This work is supported by a grant from the Academic Research Fund, National University of Singapore for a project entitled, “Listening Strategies for New Media; Experience and Expectation” (T208A4105).

42. Differential perception of pitch-ambiguous stimuli in Filipino and American listeners: The Tritone Paradox with new methods of data analysis

Michael Maquilan and Barbara Luka
Bard College

Purpose
Previous studies used complex tones that belong to one of the pitch classes in the musical scale (e.g., C, C-sharp, D), but are ambiguous as to pitch height. Individual listeners show preferences to judge some tones as higher than others despite their equivalent log frequencies – the "Tritone Paradox". Deutsch has suggested that an individual's "peak pitch" is determined by early language experience, but speakers of only three languages have been examined in published work, with mixed results. Other investigators suggest that stimulus construction methods have a large influence on peak pitch effects. We develop and apply improved methods of statistical analyses for pitch judgments on ambiguous tritones.
Methods
Participants were three groups of 15 college students defined by native language and geographic region (Cebuano, Cebu City, the Philippines; American English of mixed geographic origin, or American English of local geographic origin all currently living in the northeastern U.S.). Following audiometric screening and a pure tone test, participants listened to and rated pairs of ambiguous tritones as ascending or descending in pitch. The octave-related complex tones were taken from a CD for public use published by Deutsch (1995). Each participant completed a second session, administered approximately 48 hours after the first.
Results
The experiment yielded four principal results. We observed 1) geographic differences in judgments of pitch-ambiguous stimuli that 2) were stable across repeated testing. We also observed two influences of the spectral envelopes used to generate the tones: 3) weaker differences among the pitch classes and between the geographic groups when the tones were higher in overall frequency (centered on the fifth octave rather than the fourth), and 4) a reduction in the tendency to consider a tone high in pitch when it is near the center of the spectral envelope. The influences of geographic group and stimulus construction methods proved to be dissociable and roughly equal in their impact on relative pitch judgments.
Conclusion
Our finding of additive effects of a geographic peak pitch and spectral characteristics of the auditory stimuli clarifies a relationship that might otherwise obscure group comparisons. We believe that stronger statistical tools for defining group differences, developed here, will contribute to stronger tests of the relationship between peak pitch effects in ambiguous tritone perception and early influences of speech community.
Implications
Our study offers a statistical analysis that permits the comparison of magnitude of peak pitch differences across individuals. The new analysis permits an investigation of axial symmetry in pitch class perception.
Acknowledgement of funding
This research was supported by a grant from the Bard Research Fund.

43. Measurement of music intelligibility under hearing-loss and aided-hearing-loss conditions

Martin F. McKinney
Starkey Laboratories

Purpose
The perception of music is adversely affected by hearing impairment, e.g., sensorineural hearing loss, as well as by some audio amplification strategies intended to improve speech perception. In order to improve music transmission through hearing aids, we need to develop a quantitative objective measure of music transmission. There exist such measures for speech intelligibility (along with associated methods for predicting them from the acoustical signal), but there are no standard methods for quantitatively measuring the transmission of music information under the conditions of a corrupted music signal. The purpose of this study is to develop a method for measuring perceptual music intelligibility under conditions where the audio signal or its perception is degraded, either through detrimental audio processing or hearing impairment.
Methods
We first examine related measures, including test batteries for amusia, measures of general audio quality, and measures of music perception for cochlear implantees. The measures include tests for melodic and rhythmic perception, timbre perception, memory, and subjective audio quality. It is expected that some or parts of these measures may be sensitive to the degradation in music intelligibility caused by hearing impairment and non-optimal audio processing, but other aspects of the measures will not be appropriate. In addition to compiling relevant parts of current related measures and protocols, we will add specific tests to make the music intelligibility test battery sensitive to a wide range of perceptual deficits incurred through audio processing and hearing impairment. The test battery will be verified through a set of experiments to systematically investigate scores across a range of degradations, both due to hearing impairment and audio amplification and processing.

Results
The most common forms of perceptual degradation in music due to hearing impairment and processing in hearing aids occur in timbral aspects. Severe degradations can also affect tonal and melodic aspects of music as well as rhythmic aspects in the most severe cases. From the current set of related perceptual tests, the methods for measuring music perception through cochlear implants are the most relevant to our case (e.g., Looi et al. Ear Hear, 2008, V29, 421-434). Other types of tests are less relevant: tests for amusia focus primarily on melodic, rhythmic and memory deficiencies and are sensitive to only the most severe degradations in our case; measures of general audio quality tend to be too vague and not specific enough to be useful in determining specific deficits in music perception. With work still in progress, the final complete form of the test battery along with validation results will be presented at the conference.
Conclusion
There are currently no existing methods to test for music intelligibility under conditions of degraded perception due to hearing loss or suboptimal audio amplification strategies. Methods for measuring music perception in cochlear implant wearers offer a good starting point and can be extended, particularly in the area of timbre perception, to become sensitive to perceptual degradations associated with moderate and severe hearing loss and processing through hearing aids.
Research and/or Educational/Clinical Implications
A standardized method for quantitatively and objectively measuring music intelligibility enables a systematic approach to developing audio amplification strategies aimed specifically at improving music perception for those with hearing loss.

SMPC Business Meeting
5:10 – 6:00 (*all SMPC members are invited to attend*)

Thursday, August 6th

Keynote II
9:00 – 10:00 Dr. Elaine Chew, Univ. of Southern California

Session 9A Models and Theories (*Chair: Christopher Bartlette)*

9A) 10:20 – 10:40

A unified probabilistic model of polyphonic music analysis

David Temperley
Eastman School of Music

Purpose
This paper presents a probabilistic model of polyphonic music analysis. Taking a polyphonic note pattern (midifile) as input, the model identifies the metrical structure, harmonic structure, and stream structure (grouping the notes into melodic lines). The model also yields an estimate of the probability of the note pattern itself. The model is "unified" in two senses. First of all, it integrates three aspects of music analysis—metrical analysis, harmonic analysis, and stream segregation—that in previous work have only been addressed individually. This allows the model to capture the complex interactions between these structures: for example, the effect of metrical structure on harmony. Secondly, the model unifies the general problem of structural analysis with the problem of estimating the probabilities of note patterns—a problem that, in turn, has implications for the modeling of "surface" processes such as transcription (pitch identification) and expectation. Here, a Bayesian probabilistic framework is particularly helpful. In considering the probabilities of different note patterns, it stands to reason that we bring to bear structural considerations: roughly speaking, a probable note pattern is one that implies and adheres to a clear metrical structure, harmonic structure, and stream structure. The Bayesian approach provides a natural way of capturing these dependencies.
Methods
We assume a generative model in which a metrical structure is generated first; a harmonic structure and stream structure are then generated, where the stream structure is simply a set of streams that span certain portions of the piece. (The stream structure and harmonic structure are dependent on the metrical structure, but not on each other.) A note pattern is then generated, dependent on all three structures. In the analytical process, the model is given a note pattern and must recover the metrical, harmonic and stream structures; this is done using a complex search process which relies heavily on dynamic programming.
Results
The model has been tested on harmonic and metrical analysis, and performs competitively with other models in these domains. Work is also ongoing to integrate the model into a transcription system, which can identify pitches in a polyphonic audio signal.
Conclusion and Research Implications
This project shows the viability of a unified approach to music analysis which combines structural processes and surface processes into a single integrated system.

9A) 10:40 – 11:00

Bayesian inference of musical grammars using hidden markov models

Panayotis Mavromatis
New York University

Purpose
The problem of algorithmic grammatical inference is addressed using Hidden Markov Models (HMMs) (Rabiner & Juang 1986, Manning & Schütze 1999). The HMM training algorithm receives as input a sample representative of a musical corpus, whose features of interest are encoded as symbolic sequences. The output is a probabilistic Finite State grammar that models stylistic constraints among the values of musical variables.

Methods
We have adapted a HMM training algorithm whose goal is two-fold: (i) determination of the HMM topology (i.e., number of states and how they are connected by transitions); and (ii) for a given topology, determination of the HMM parameters (i.e., transition and output probabilities). The first goal is achieved by systematic search over topology space using state merging (Stolcke & Omohundro 1993), state splitting (Ostendorf & Singer 1997), or a combination of both. The second goal is accomplished by the Baum-Welch algorithm (Rabiner & Juang 1986, Manning & Schütze 1999). We perform the above HMM training in the framework of Bayesian model selection, using a model complexity prior. This prior is derived using the Minimum Description Length principle (Rissanen 1989, Grünwald 2007); it achieves optimal balance between goodness-of-fit and model simplicity, thereby preventing over-fitting.
Results
We present two applications that successfully tackle two classic problems in music computation, namely (a) algorithmic statistical segmentation, and (b) meter induction from a sequence of durational patterns. Application (a): A HMM was able to identify grouping boundaries in various samples of symbolic sequences based solely on the patterns of occurrences of symbol combinations. No explicit cues or annotations were present in the sequences. Among the test samples used was the one employed in the study by Saffran et al. (1999). In all cases, grouping boundaries were identified as specific states in the HMM graph. Application (b): A sample of melodies taken from Palestrina's vocal music were encoded as sequences of note durations alone, without any annotations as to their metric placement. A HMM was able to recover the metric structure of these melodies, with each metric position represented by a particular HMM state.
Conclusion
Our HMM training algorithm offers a powerful and flexible tool for algorithmic inference of musical grammars. Moreover, a HMM can go beyond expressing relations among explicitly encoded variables; the technique is also capable of uncovering significant latent variables (in our examples, grouping boundaries, metric placement), whenever the latter are implicitly manifested in statistical regularities of the explicitly represented variables, and are crucial in shaping their syntactical constraints.
Research Implications
HMM-based grammatical inference can be used to (i) refine and quantify our understanding of well-explored musical styles: (ii) model unexplored repertories, such as non-Western music (Mavromatis 2005). Moreover, HMMs are a powerful generalization of fixed-order Markov models, and as such are amenable to entropy-based analysis of musical style.
Acknowledgement of Research Funding
New York University Research Challenge Fund, 2007-08.
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9A) 11:00 – 11:20

An expansion of music theory through perceptual analysis in 'Pictures at an Exhibition'

Tim Bass
University of California, Santa Barbara

Purpose
This study attempts to increase ecological validity in perception and music theory research by using real musical excerpts for comparing timbral similarity and blend. The goal of this is to provide the music theorist with a new set of tools for analyzing timbre and orchestration.

Methods
The perceptual study consisted of three parts that measured two separate timbral characteristics. The first part gathered similarity ratings of the eleven primary instruments used in Ravel's orchestration of Pictures at an Exhibition by Modeste Mussorgsky in order to establish a basic timbral palette. These instrument sounds were taken from Finale 2008 using the Garritan Orchestral Library. Following work by Kendall (2004), the second part of the study gathered similarity and blend ratings of six contrived triadic harmonizations of the initial three-note motive from the opening of Pictures, orchestrated using bassoon, clarinet, and oboe. The third part of the study obtained blend and similarity ratings for musical excerpts taken from Ravel's orchestration.
Results
The single instrument similarity ratings were subjected to multidimensional scaling. As in previous research, the primary dimension of the two-dimensional configuration correlated strongly with spectral centroid. Groupings of the triadic configurations from the second part of the study were based on the position of the oboe with respect to the other two instruments. This expands on Kendall's study (2004) that found that the top voice shifted the triads along a "nasality" dimension in the MDS representation, but which did not address the clustering of triads based specifically on the position of the highly nasal oboe within the triad. The blend ratings of the second and third part of the study agreed with Kendall and Carterette (1990) and Sandell (1995) that single instrument similarities are a good predictor of blend.
Conclusion
The data gathered can be used in the analysis of Pictures at an Exhibition to more precisely define and describe the perceptual effect of Ravel's orchestration. Ravel's orchestration takes the trumpet, one of the more salient instruments, and uses it as a timbral tonic, relating all other instruments to it. Ongoing research is addressing the blend of the trumpet specifically with other instruments used by Ravel.
Research Implications
This research has the potential to expand the scope of music theory by basing analysis on empirical perception studies rather than intuition.
Acknowledgement of Research Funding
This study was partially funded by a grant from the Faculty Research Assistance Program, Undergraduate Research and Creative Activities, College of Letters and Science, UCSB.

9A) 11:20 – 11:40

A dynamic field theory of tonality

Edward W. Large and Marc J. Velasco
Florida Atlantic University

Purpose
The universality of certain musical features suggests that general principles of neural computation may underlie particular aspects of music perception. One universal feature of music is tonality. In tonal music, a single tone provides a focus around which other tones are dynamically organized. This paper argues that neural oscillation gives rise to the perception of tonality. Neural oscillation can arise from the interaction of excitatory and inhibitory neural populations, a common architectural feature of the auditory nervous system.
Methods
Despite the fact that the physics of oscillators vary greatly, all share many universal properties, on which the current theory is based. These properties provide certain degrees of freedom but also significant constraints in modeling the perception of tonality. We exploit the universal properties of nonlinear resonance to provide predictions about the behavior of a dynamic resonant field that could arise from and respond to stimulation with tone sequences. Our predictions are based on both mathematical analyses and computer simulations of neural oscillation.
Results
Universal properties of nonlinear resonance predict preferences for small integer ratios and perceptual categorization, as well as perceptions of stability and attraction in tonal sequences. These predictions are compared with several empirical results including nonlinear auditory neural responses, infant and adult preferences for small integer ratios, and Krumhansl-Kessler stability profiles for Western and Indian listeners. The theory appears to provide satisfactory explanations in each case.
Conclusion
This approach provides a novel, neurally plausible theoretical framework for thinking about the perception of tonality. We further propose a Hebbian mechanism capable of learning sets of frequency relationships.
Research Implications
This theoretical approach challenges many current assumptions about tonality. Most importantly, it asserts that important aspects of tonal relationships may be intrinsic to the physics of neural oscillation. Thus, it predicts what kinds of tonal systems would be easy to learn, and which would be more difficult. In other words, neural resonance may underlie a kind of "universal grammar", a set of innate constraints that shape human musical behavior and enable the acquisition of musical knowledge.

Acknowledgement of Research Funding
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Session 9B Emotion I (*Chair: E. Glenn Schellenberg)*

9B) 10:20 – 10:40

Experienced tension in response to atonal melodies

Alexander Rozin[1], Lily Guillot[2], and Paul Rozin[3]
West Chester University[1], Yale University[2], University of Pennsylvania[3]

Purpose
This study is the first in a series that investigates how the various musical parameters generate experienced tension. Real music is a complex web of parametric information and so does not provide well-controlled stimuli. To begin the series of experiments, we eliminated as many parametric variables as possible: rhythm, meter, scale-degree function, dynamic level, timbre, dissonance, density, and registral span. The resulting stimuli (described below) generate tension through pitch height and interval. Results allow us to determine how listeners' experienced tension derives from pitch height and interval and serve as a basis upon which further experiments involving more complex stimuli can stand.
Methods
In several sessions in a large classroom, participants (n = 114) listened to 24 atonal and isochronous melodies and rated the experienced tension of the final note of each. The 24 melodies derive from six parent melodies, each of which generated four variants that were identical except for the penultimate note, that is, the note preceding the one rated by participants. For each session, the melodies were broken into two blocks, separated by other experimental stimuli. The order of the melodies in each block was randomized.
Results
The results from the experiment demonstrate that both pitch height (r = 0.57) and interval (r = 0.44) contribute significantly to experienced tension of atonal melodies. A multiple regression, accounting for 72% of the variance, indicates that listeners depend on interval twice as much as pitch height.
Conclusion
Both pitch height and interval contribute to experienced tension. The results suggest that the syntactical information (i.e., interval) is twice as important as the statistical information (i.e., pitch height), providing a window into how listeners integrate absolute characteristics of musical events (e.g., loud) with contextual ones (e.g., louder than what happened before).
Implications
This study opens a line of research examining how the various musical parameters evoke felt tension. With a better understanding of how pitch height and interval contribute, further studies can open stimuli to include rhythm and meter, timbre, dynamics, dissonance, and so on, eventually leading to a better understanding of how all of the parameters interact to create the complexity and subtlety of musical emotion.

9B) 10:40 – 11:00

Determining feature relevance for subject responses to musical stimuli

Morwaread Farbood and Bernd Schoner
New York University

Purpose
This work presents a method for detecting and quantifying the relevance of individual musical features in subject responses to complex stimuli. Rather than using linear correlation methods, we allow for nonlinear relationships and multidimensional feature vectors. We first provide a methodology based on polynomial functions and the least-mean-square error measure then extend the methodology to arbitrary nonlinear function approximation techniques and introduce the Kullback-Leibler Distance (information-theoretic cross-entropy) as an alternative relevance metric. In applying this method to data collected in a study on musical tension, we formulate a mathematically sound approach to determining the relative importance of individual musical features to subjects' perceptions of tension.
Methods
The method is demonstrated first with simple artificial data and then applied to experimental data. The artificial data was generated using Matlab and the experimental data was collected in a study where subjects were asked to move a slider on a computer interface in response to how they felt tension was changing in musical excerpts taken from the

classical repertoire. Analysis of subject responses was based on the assumption that perceived tension is a function of various musical parameters varying over time, such as harmonic tension, loudness, pitch height, and onset frequency. Each excerpt was analyzed and quantified according these musical parameters. We analyzed the data using a new estimator, termed the Relevance Ratio, derived from arbitrary nonlinear function approximation techniques and the least-mean-square error metric. Additionally, we employed a probabilistic metric known as the cross entropy (KL Distance) as an alternative estimator.

Results

Functionality of the Relevance Ratio was clearly demonstrated in the case of artificial test functions, where the estimator correctly identified relevant features. In the case of the experimental data, salient features were extracted for each of the complex musical excerpts (by Brahms, Bach, and Beethoven) and matched qualitative observations.

Conclusion

The result of determining feature relevance using our method was successful for the artificial data as well as the complex empirical data. In the latter case, we were able to gain valuable insights into the importance of certain salient features that contributed to the perception of musical tension.

Research and/or Educational/Clinical Implications

Our method can be used with most types of auditory or visual stimuli and most types of responses. For example, the response signal can be brain activity, as measured by imaging technology, a general biological response such as skin conductivity, or direct subject input by means of a computer interface.

9B) 11:00 – 11:20

Facial expressions and emotional singing

Steven R. Livingstone[1], William F. Thompson[2], Lisa Chan[3] and Frank Russo[3]
McGill University[1], Macquarie University[2], Ryerson University[3]

Purpose

Facial expressions are used in music performance to communicate structural and emotional intentions. Exposure to emotional facial expressions may also lead to subtle facial movements that mirror those expressions. This study focused on the nature and significance of facial expressions during the perception, planning, production, and post-production of emotional singing.

Methods

In experiment I, seven participants were recorded with motion capture as they watched and imitated phrases of emotional singing. In experiment II, four different participants were recorded using facial electromyography (EMG) while performing the same task. Participants saw and heard recordings of six musical phrases each sung with happy, sad, and neutral emotional connotations. They then imitated the target stimulus, paying attention to the emotion expressed. Facial expressions were monitored: (a) during the target; (b) prior to imitation; (c) during imitation; and (d) after imitation. In experiment I, two facial features were relevant to conditions: eyebrows & lip corners. A third feature, lower lip, acted as a control to separate vocalization from emotion-related movement. In experiment II, zygomatic (positive) and corrugator (negative) muscle activity were captured.

Results

Experiment I: Movement was observed in all epochs. There was significant eyebrow movement in the sad condition, and lip corner movement in the happy condition. Lower lip movement did not differ across emotion conditions. In experiment II, activity was reported as a composite of zygomatic and corrugator activity (sum of zygomatic in happy trials and corrugator in sad trials). The neutral composite was the sum of zygomatic in neutral trials and corrugator in neutral trials. Emotionality was significant across all four epochs, with more activity in the emotion composite.

Conclusion

Expressive activity was observed in all epochs, implicating a role of facial expressions in the perception, planning, production, and post-production of emotional singing.

Research Implications

Facial expressions of emotion supplement the acoustic channel of music in multiple ways. Movements were evident in all four epochs, suggesting that facial expressions function for (a) motor mimicry and/or emotional synchronization (b) motor and emotional planning; (c) direct emotional communication; and (d) extending the time frame of emotional communication beyond that conveyed by acoustic cues.

Acknowledgement of Research Funding

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9B) 11:20 – 11:40

Emotional communication in music: Relative contributions of performance expression and melodic structure

Lena Quinto and William F. Thompson
Macquarie University

Purpose
Emotional meaning is communicated by performance expression (Juslin, 2003) and melodic structure (Thompson & Robitaille, 1992). Given an emotionally neutral phrase, what is the scope of emotional communication that can be achieved by performers? How is emotional communication altered when musicians manipulate both melodic structure and performance expression? Experiment 1 examined the ability of performers to convey emotions through performance expression. These data were compared to the capacity of speakers to convey emotions prosodically. Experiment 2 addressed the capacity of vocalists and violinists to communicate emotion using (a) performance expression; (b) melodic structure; and (c) performance expression and melodic structure.

Methods
Experiment 1. Three musicians (guitarist, flutist, violinist) performed an emotionally neutral seven-note composition with the intention to express anger, fear, sadness, happiness, and tenderness. Performances were presented to 25 listeners. Experiment 2 compared emotional communication by performance expression, melodic structure, or both. Twenty vocalists or violinists performed emotionally neutral phrases with the intention to express the above emotions. They also composed emotional melodies (controlling the number of notes) and performed them with varying emotional intentions. Finally, composed melodies were presented with neutral expression (via MIDI). All performances were then decoded by a sample of listeners.

Results
When only cues of performance expression were available, happiness, sadness and tenderness were decoded well, but anger and fear were decoded below chance levels. There was no overall correlation between decoding rates for music (expression alone) and speech prosody. However, signal detection analyses revealed that individuals who discriminated anger and tenderness well in music also discriminated this pair well in speech. Experiment 2 is in progress but results will be available soon.

Conclusion
For brief phrases with an emotionally neutral structure, performers have a surprisingly restricted capacity to communicate emotion. The skill of decoding musical emotion may overlap somewhat with the skill of decoding emotion from prosodic cues.

Research implications
This project directly evaluates the capacity of musicians to communicate emotion through performance expression, melodic structure, or both. Our data suggest that the capacity of performers to introduce emotionality to an emotionally neutral melodic phrase is more restricted than traditionally assumed.

Acknowledgement of research funding
Supported by a Macquarie Postgraduate Research Fund awarded to LQ, and by a Discovery Grant by the Australian Research Council awarded to WFT.

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Session 10A Harmony (*Chair: Siu-Lan Tan)*

10A) 1:30 – 1:50

The perception of predominant chords

Jenine Lawson
Eastman School of Music

Purpose
In tonal theory, certain chords are described as being "pre-dominant" in function, as they generally precede the dominant chord (V). It is often stated that some predominant chords are "stronger" or more attracted to V than others. This study asks listeners to rate the perceptual attraction of predominant chords as they resolve to V, and compares these responses with theoretical measurements of attraction.

Methods
Twenty-one freshmen music majors at Ithaca College served as pilot subjects; further experimentation is expected in 2009. In each of 40 randomized trials, listeners heard three sonorities. All chord progressions were in C major/minor and heard in a synthesized piano timbre. Sonority 1 was tonic, sonority 2 was some predominant chord, and sonority 3 was V, each lasting 1.5 seconds. After each trial, listeners were asked to rate how well sonority 2 was attracted to the final sonority on a seven-point Likert scale.
Results and Conclusions
Results support typical theoretical assumptions. Predominant chords containing dissonances were more attracted to V than those without ($t(20) = 3.5$, $p = .002$). Chords from the minor mode were more attracted to V than those from the major mode ($t(20)=3.1$, $p=.005$). Chords in inversion were more attracted to V than chords in root position ($t(20) = 2.6$, $p = .019$). Chords containing chordal sevenths were more attracted to V than chords without sevenths ($t(20) = 3.05$, $p = .006$). Finally, chords containing non-diatonic notes such as #^4 and b^2 were more attracted to V than chords without these tones ($t(20) = 6.0$, $p = .000$). Listener responses were compared with theoretical measurements of attraction: There was no significant correlation between listener responses and predominant chords that move to V by the fewest number of semitones ($r = -.198$, p 0 =.233). Neither was there a significant correlation between listener responses and Cohn's (1998) DVLS (see also Santa, 2003) or Monahan's (2008) KDIs. Interestingly, a moderate correlation was found between listener responses and Lerdahl's (2001) attraction algorithm ($r = .454$, $p = .004$).
Educational Implications
Music theory textbooks attempt to address the issue of which predominant chords are more attracted to V, but there are often inconsistencies. For example, Laitz (2001) implies that predominants are stronger when they share notes of the V chord: When describing the difference between IV and ii6, he states that ii6 is more attracted to V because it shares a note in common with V (i.e.-^2) (p.227). He also states that the German6/5 chord "is usually the last event before the dominant," even though they do not share any notes in common (Laitz,-2001, p.507). By better understanding which predominants are more strongly attracted to the dominant, we can improve pedagogy of common-practice harmony, dictation, and composition.
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10A) 1:50 – 2:10

Preparing unexpected harmonies in piano and organ performances

Christopher Bartlette
Baylor University

Purpose
In a previous study (Bartlette, 2008), I examined the effect of harmonic distance – the extent to which a harmony is "closely" or "distantly" related to a context – on expressive timing and dynamics in piano performance. I concluded that distant chords were performed with delayed onsets and greater chord lengths, when compared to close chords in the same contexts. In this paper, I present a *post hoc* analysis of Bartlette (2008) – as well as a new study of organ performance – that considers alterations in performance expression before and after a distant, unexpected harmony occurs.
Methods
Twelve graduate piano students from the Eastman School of Music, and six undergraduate and graduate organ performance majors at Baylor University, performed ten short musical excerpts, grouped into five pairs. Within each pair of excerpts, one chord was altered such that the chord was either "close" or "distant" from its preceding chord; all other chords were held the same. The participants briefly prepared each excerpt before recording a performance in a "musical fashion." Organists performed using only the manuals; pedals were not used for the performances. The participants performed on MIDI-equipped instruments, so that performance data could be recorded and analyzed. The analysis considered data within one musical phrase, up to six beats before and after an altered chord.
Results
In the piano performances, distant altered chords – and their adjacent chords – had significantly greater chord lengths ($p < .001$). However, the lengths of the chords 4 and 5 beats before distant altered chords were significantly *shorter* than the same chords when played before close altered chords ($p = .02$ and .04, respectively). The organ performances have similar outcomes, although the results do not have the same level of significance: distant altered chords were lengthened ($p = .09$), and chords 4 beats before distant altered chords were shortened ($p = .07$).

Conclusion
Unexpected harmonies have an effect on performance that reaches beyond a single chord. In this study, altering one chord resulted in changes in timing several beats before the chord. It is intriguing that distant chords – which were lengthened in performance – were accompanied by an acceleration in the preceding chords (relative to their close counterparts).
Research Implications
Previous research on the relationship between harmony and performance expression has focused exclusively on the performance of single chords. This study serves as a reminder that we must consider phenomenological implications, as well as the role of the performer in the preparation of unexpected events.

10A) 2:10 – 2:30

Visualization of the Harmonic Structure of Music

Norman D. Cook
Kansai University

Purpose
The purpose of the present study was to use a psychophysical model of harmony perception (Cook, 2002; Cook & Hayashi, 2008) in order to visualize the overall harmonic structure of extended musical pieces on a 2D grid.
Methods
Music, by its very nature, is extended over time. Schenker (1954) showed that the temporal "unfolding" of music could be compressed to three different levels – each of which retained certain fundamental tonal features of the original piece. In the present study, a similar 3-level compression of music to two-dimensional "harmonic grids" has been achieved using a psychophysical model of harmony perception. The model includes both 2-tone interval effects (dissonance) and 3-tone triad effects (tension and modality). Using those quantitative features, the harmonic structure of a musical piece can be compressed onto a 2D grid on which foci of activation correspond to the chords and chord sequences used. The 2D grid is colorized according to the affective character (modality) of the harmony.
Results
The harmonic "footprint" that is obtained for a given musical piece is a unique 2D representation of its tonal structure. Several examples of the similarity/dissimilarity of the harmonic footprints of several songs in popular music are discussed: e.g., George Harrison's "My Sweet Lord" and the Chiffons' "He's So Fine".
Conclusion
Unlike various "screen-saver" visualizations of music, the present visualization technique has a solid foundation based upon three psychophysical properties of harmony. The first is the well-known consonance or dissonance of intervals – quantifiable using the 2-tone "dissonance curves" developed in the 1960s. The second is the "tension" of triads – quantifiable as the relative symmetry of 3-tone chords. The third is the major/minor "modality" of triads – quantifiable as the relative asymmetry of 3-tone chords.
Research and/or Educational/Clinical Implications
The success of our psychophysical model containing both 2-tone and 3-tone components in describing well-known features of simple triads (major and minor modality, and chromatic tension) indicates the importance of "bottom-up" acoustical effects in the perception of music. Without the 3-tone component, neither the stable/unstable character of triads nor their major/minor modality can be explained. I conclude that there is a strong acoustical foundation underlying both popular and classical Western diatonic music.

Session 10B Emotion II (*Chair: Gabriela Ilie)*

10B) 1:30 – 1:50

Like it or lose it: Listeners remember what they like

Stephanie M. Stalinski and E. Glenn Schellenberg
University of Toronto

Purpose
One of the most well established findings in memory research is that items that are processed deeply at time of encoding are remembered better than items that are processed in a more shallow manner. Here we examined whether such depth-of-processing effects may be driven by subject-specific mechanisms, such as preference, in a musical task.

Methods
Approximately 40 participants were tested in each of four experiments. Participants initially heard 24 music excerpts and rated how much they liked each excerpt on a scale from 1 (dislike a lot) to 7 (like a lot). Subsequently, they heard the same 24 music excerpts as well as 24 previously unheard excerpts and judged whether they recognized the excerpts and how confident they were in their judgments. Experiment 1 examined whether there was a memory benefit for liked items. Experiment 2 examined whether this effect was a consequence of making the initial evaluative ratings. Experiment 3 examined whether the effect extended across a 24-hour delay. Experiment 4 examined whether the effect was eliminated when deep processing was encouraged for all items.
Results
In Experiment 1, items that were liked were remembered better than items that were disliked or items that were neither liked nor disliked. In Experiment 2, the liking effect on memory was evident even when the initial encoding task involved rating the complexity of the excerpts, which shows that the effect is not due to focusing participants' attention on the dimension of liking. In Experiment 3, the liking effect on memory was maintained across a 24-hour delay, which shows that the effect is not due to short-term rehearsal of liked items. The liking effect was also evident in Experiment 4, which shows that the effect is not due to intentional deep processing of liked items.
Conclusion
Across all experiments, music excerpts that were liked were remembered better than excerpts that were disliked or neither liked nor disliked. The effect was evident across a variety of manipulations, which highlights the importance of liking on memory for music.
Research Implications
Listeners' immediate subjective responses to musical items (e.g., I like this) have profound implications for how much attention is paid to those items, how deeply the items are processed, how strongly the items are stored in memory, and how easily the items are retrieved. Subjective response factors should be taken into account in future research on memory for music.
Acknowledgement of Funding
National Sciences and Engineering Research Council of Canada; Ontario Graduate Scholarships

10B) 1:50 – 2:10

Openness to experience moderates the effect of exposure on liking

Patrick Hunter and E. Glenn Schellenberg
University of Toronto

Purpose
Previous studies have shown an inverted-U association between exposure and liking for music (Schellenberg, Peretz, & Vieillard, 2008; Szpunar, Schellenberg, & Pliner, 2004). Berlyne (1970) suggested that this was due to a preference for stimuli with moderate arousal potential: very unfamiliar stimuli are too arousing, overly familiar stimuli are not arousing enough. In the present study we sought to determine whether personality moderates this association. We expected that higher scores on Openness to Experience would be related to greater liking for novel pieces and lower liking of pieces that were over-exposed.
Methods
In an initial exposure phase, 80 undergraduate participants heard six excerpts from recordings of classical music with different exposure frequencies (2, 8, or 32). They subsequently heard the same pieces again along with six novel excerpts and made liking ratings for each. Participants also completed the Big Five Inventory (John & Benet-Martinez, 1998).
Results
Using median splits on the personality factors, we ran mixed-design ANOVAs with personality as a between-subjects variable and number of exposures as a within-subjects factor. Of the big five factors, only Openness interacted with exposure. Results confirmed hypotheses: high levels of openness were associated with greater liking for novel pieces and lower liking for very familiar pieces.
Conclusion
The effect of exposure on liking varies with the listener's degree of openness. Listeners who were low in openness showed the usual inverted-U association: an initial increase in liking as a function of exposure followed by a decrease. Listeners who were high in openness did not show a significant increase in liking with more exposures, although liking decreased after a large number of exposures.
Research Implications
The results highlight the role of individual differences in personality on liking for novel pieces of music. Openness to experience is of particular interest because it is linked to cognitive variables (e.g., IQ). Future research could examine the role of personality on liking for music from familiar and unfamiliar musical styles.
Acknowledgement of Research Funding
Social Sciences and Humanities Research Council of Canada

10B) 2:10 – 2:30

Affective responses to tonal modulation to selected steps

Marina Korsakova-Kreyn and W. Jay Dowling
University of Texas, Dallas

Purpose
The study used bipolar adjective scales to measure the intensity of affective responses and perceived tension to modulating stimuli.
Methods
Only three steps were selected as targets of modulation: the Subdominant (5), Dominant (7), and step 8. Each step was represented by eight progressions that were balanced for melodic contours of the soprano and bass lines, and by eight real music excerpts. All stimuli were in the major mode. Sixty five participants, 49 females and 16 males, heard two sets of stimuli: 24 eight-chord progressions written by the principal experimenter and 24 brief real music excerpts selected from classical piano compositions.
Results
The results indicate differentiated affective responses to the different modulations and their dependence on key proximity. Participants perceived modulations to the relatively distant step 8 as the most tense, compared to the close modulations to the Subdominant (5) and Dominant (7). This association between increase in key proximity and increase in perceived tension is in agreement with a theoretical model of key proximity based on the circle of fifths. In addition to the higher tension ratings, modulations to step 8 were perceived as “colder” and “darker” than modulations to the Subdominant (5) and Dominant (7), thus showing a link between negative synaesthesia-related ratings and higher tension ratings. Modulations to the Dominant (7) were perceived as “happiest," and modulations to the Subdominant (5) were heard as “weaker” than modulations to the Dominant. These findings are associated with asymmetry in perceived pitch proximity related to the direction around the circle of fifths, and are in agreement with musicological research recognizing a subdominant sphere as “weaker” than the dominant region. This finding also provides corroborating evidence to previous studies showing asymmetry in perceived key proximity; the asymmetry is related to clockwise motion around the circle of fifths versus counterclockwise motion.
The listeners demonstrated sensitivity to contour patterns in modulations to the Subdominant (5) and Dominant (7): modulations with simultaneous upward motion in soprano and bass lines were perceived as “happier” and “brighter” than modulations with the simultaneously falling soprano and bass lines. However, the contour patterns did not affect responses to the relatively distant step 8, which suggests that the effect of key proximity overrides the effect of contour patterns.
Research Implications
Overall, the results demonstrated a general similarity of responses in the real music excerpts and the harmonic progressions.

10B) 2:30 – 2:50

Mode, timbre, musical training, and personality influence emotional reactions to music

Laura Edelman, Patricia Helm, Benjamin Katz, and Serena Hatcher
Mulhenberg College

Abstract:
Musician and non-musicians listened to recordings of classical music, differing in mode and instrumentation. Participants rated each piece on happiness and arousal. Participants completed a Big 5 personality inventory. Mode and timbre both affected happiness. Timbre affected excitement. Personality and musical training interacted with the effects of mode and timbre.
Purpose:
Extensive research has been done on the effects of music on emotion (see Jackendoff and Lerdahl, 2006 for a review). However, studies exploring the effects of instrument timbre on mood have shown conflicting results. It is hypothesized that the timbre of an instrument playing a piece will cause the piece to be happier or sadder depending on the number of overtones that instrument has. The timbre is also is hypothesized to affect the perceived excitement of a piece.
Method:
Seventy-eight participants listened to twenty-five audio recordings of classical music, differing in mode and instrumentation. The instruments used were violin, flute, horns, and electronic synthesizer sounds, which were

recorded using a keyboard synthesizer and played on a CD player. For each piece, participants rated perceived happiness and arousal on a five-point scale. Participants completed a Big 5 personality inventory and answered questions related to years of musical training.

Results:

Mode and timbre both showed significant main effects on happiness. Pieces in the major mode were perceived as happier than pieces in the minor mode. Also, pieces played on horns were perceived as happiest and pieces played on violins were perceived as saddest. Interaction effects were also found between mode and timbre. While trumpets made major pieces sound happiest, violins made minor pieces sound saddest. There was a main effect for timbre on perceived excitement. Horns were rated as most exciting and violins were rated as least exciting. Musical training interacted with mode for excitement in which non-musicians found minor pieces more exciting than major pieces, differences between the modes were smaller for musicians. Musical training and extroversion had separate interactions with mode and timbre on perceived excitement. Conscientiousness also interacted with musical training and mode on excitement. A final interaction effect was found for mode, timbre, musical training, and extroversion on excitement.

Conclusions and Implications:

These findings have practical application in the daily lives of music listeners. Factors of music such as mode and timbre of instruments have a large effect on the emotional response and excitement to music. Also, listeners' individual characteristics, such as their personality and amount of musical training, also have a large effect on how they perceive music. These findings can be generalized to fields such as music therapy and advertising which use music to induce mood in target audiences. In knowing the personality of a target, different musical factors might be used to alter responses to ads or therapy sessions.

Poster Session III

3:00 – 5:00

44. Evolutionary origin of music from Lucy to Bach: from first steps to sound pleasure and emotions

Mark Riggle
Casual Aspects, LLC

A new theory for the evolutionary origin of music is proposed that starts with a pleasure that motivates learning to walk, then shows the evolutionary chain that leads to music and the role of music emotions. To motivate learning to walk, we have a pleasure from rhythmic vestibular stimulation where the brain mechanism created to generate that pleasure has a side-effect of generating pleasure from rhythmic sounds and entrainment. This may originate 5 million years ago with Australopithecus. Males who can supply a pleasure to females will gain a reproductive advantage. This leads to a strong selection force on the ability to create rhythmic sounds and the behavior of creating those sounds. These evolutionary forces lead our ancestor species to music along with great cognitive abilities and pleasures of creation. One stage of evolution began selecting for generating better music because it indicated better cognitive capacity. A strategy to improve that musical generation is to learn new music generating rules from other people's music which requires remembering music details. Emotions increase memory storage and recall through interactions of the hippocampal formation, amygdala, nucleus accumbens, and ventral tegmental area. Dopamine is needed in those interactions. Episodic memory works differently for happy and sad events and the structure of music is different for happy and sad music. Musical structure for sad music may be best remembered by the sad oriented detail memory and happy music by a more gist oriented semantic memory. Thus, to generate better music, evolution reused parts of the emotional circuits to prime musical memory so that we may learn new rules for music generation. A musical chill is likely dopamine and it lets the hippocampus remember. The emotions we feel with music are a side-effect of that memory enhancing emotion reuse. A wide variety of studies provide supporting evidence. The theory shows multiple distinct pleasure pathways for music. The conclusion is music making was a major factor in evolving our species over 5 million years.

45. Feeling the music: development of a new scale to predict strong physiological responses to music listening

Gillian M. Sandstrom and Frank A. Russo
Ryerson University

Purpose

In a previous study, we induced stress by telling participants they would need to make a speech. After dismissing the speech task, we administered a music intervention. Our goal was to examine the effect of musical characteristics (valence and arousal), and individual differences. We found that absorption, a measure of how intensely one tends to experience emotional events, was a significant predictor of the extent of physiological recovery from stress. However, the Tellegen Absorption Scale (TAS) is not specific to music, and participants found many of the questions difficult to understand. In the current study, we take the first steps towards developing a new, music-specific scale, intended to

predict strong physiological responses to music. We developed a long list of preliminary questions, based on the original TAS questions as well as concepts that have been empirically linked to absorption. We hypothesize that there are at least two factors involved in absorption in music: the ability to feel the music (empathy) and the willingness to allow oneself to feel strong emotions.

Methods

Participants will listen to 12 music excerpts (3 excerpts conveying emotion from each quadrant of Russell's circumplex) while we monitor their galvanic skin response (GSR), heart rate, respiration rate, and facial electromyography (EMG). Each music excerpt will be preceded by a baseline period of white noise, and followed by a washout period of silence. Participants will also be asked to fill out questionnaires: our new scale, the TAS, two alternative music absorption scales (Kreutz, Schubert & Mitchell's Empathizer/Sympathizer scale, 2008; Nagy & Szabo's Musical Involvement Scale, 2002) and a standard, multi-dimensional empathy scale (Davis, 1980).

Results

We will present a subset of questions that warrants further testing. Derivation of the subset will be based on correlations with physiological reactivity as well as factor loadings. We will look at relationships between the new scale and possible alternative scales, and will report the feasibility of using these alternative scales as predictors of physiological reactivity to music.

Research and/or Educational/Clinical Implications

This new scale will be useful to researchers looking at emotional reactions to music. It can be used to assess the impact of individual differences, or for screening purposes, to pre-select participants that are predicted to show strong physiological responses to music.

Acknowledgement of Research Funding

This study was supported by a SSHRC training grant awarded to the first author and an NSERC research grant awarded to the second author.

46. Gender and aging affect experiencing arousal in lyrics

Hui Charles Li, Psyche Loui and Gottfried Schlaug
Beth Israel Deaconess Medical Center and Harvard Medical School

Purpose

Singing is enjoyed by people around the world, regardless of age or gender. One reason people enjoy songs is for their emotional content. While the sharing of resources between language and music has been examined in various studies, little is known about the effects of lyrics on our musical experiences, especially of the perception of emotional arousal in music. The present study was designed to investigate the effects of lyrics on the perceived level of arousal. Additionally, we examined the modulation of lyrics-induced differences in arousal by demographic variables of age and gender.

Methods

Fifty participants (25 female, 25 male; median age: 37, range: 19-83) were recruited from the greater Boston area. Participants listened to 32 one-minute-long musical excerpts from karaoke box sets from contemporary Billboard hits. The 32 stimuli consisted of 16 excerpts of the full song with lyrics, and 16 excerpts of the same songs with the lyrics removed. For each excerpt, participants provided self reports of arousal ratings on a five-point scale, chills, and intense emotional responses experienced.

Results

Musical excerpts with lyrics were significantly more arousing than the instrumental version ($F(1,96)=1389$, $p<0.001$). An interaction between effects of lyrics and gender was also significant, with females rating excerpts with lyrics as more arousing in general ($F(1,96)=11.9$, $p<0.01$). A two-way interaction was found for arousal ratings between gender and age ($F(1,96)=4.17$, $p<0.05$), with older females (aged 37 – 83) being more aroused by lyrics than younger females (age 19 – 37), but older males being less aroused by lyrics than younger males. Music with lyrics also significantly elicited more chills ($t(49)=-4.13$, $p<0.001$) and intense emotional responses ($t(49)=-5.29$, $p<0.001$) in participants.

Conclusion

Music with lyrics is perceived as more emotionally arousing than instrumental music alone. Females were more influenced by lyrics than males, with older females being disproportionally more sensitive to the emotionally arousing effects of lyrics. This finding suggests that gender and aging both affect our perception of arousal in music, even in response to songs that are controlled in all aspects but the presence of lyrics.

Research Implications

Results suggest that the lyrics added to instrumental music stimulate and enhance emotional reactions to music, with older females being most susceptible. The neural interactions between music and language, and how they combine to elicit emotional responses, may depend on gender and aging factors.

Acknowledgement of Research Funding

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47. Individual differences in the effects of spectral centroid on perceived pitch

Michael D. Hall, Jonathan Schuett, Christopher Becker, and Elyse Ritter
James Madison University

Purpose

There are numerous demonstrations of individual differences in pitch given spectral changes in timbre as a function of musical training, such as the tritone paradox (e.g., Repp, 1997), pitch of the missing fundamental (Seither-Preisler, Johnson, Seither and Lütkenhöner, 2007), and examples from speeded classification (Pitt, 1994). Yet, a unified explanation for these findings has not been considered. Timbre research has revealed that brightness (which highly correlates with spectral centroid) makes separate contributions to timbre relative to spectral envelope shape (Hall & Beauchamp, in press), and pitch is affected by the locus of harmonics, which impacts brightness (Singh & Hirsh, 1992). Some listeners (particularly those without musical training) may frequently attribute changes in brightness, presumably in response to spectral centroids, to pitch changes. Two experiments were conducted to evaluate this potential role of the spectral centroid.

Methods

In both experiments listeners judged whether pitch descended, remained the same, or ascended across pairs of 500 ms tones. A standard tone, A4, was present on every trial (with order counterbalanced). Comparison pitches included A4, A#4, and F5. In Experiment 1 listeners responded to tones with a static spectral envelope derived from a violin, and comparison stimuli were presented with, or without, the fundamental frequency. The same listeners completed Experiment 2, a corresponding evaluation for some Shepard tones from Deutsch's (1995) CD and used to demonstrate the tritone paradox (e.g., Deutsch, 1987). In addition to a no-change condition (the standard twice), there were two timbre-change conditions. One contained a shift in spectral centroid produced by either a missing fundamental (Exp. 1) or a shift in spectral envelope (Exp. 2); in the other condition these comparison timbres were low-pass filtered to match the standard's spectral centroid. Pitch-change trials (p=0.5) were accompanied by either congruent (different centroid) or incongruent (same centroid) timbre changes (p=0.5).

Results

Preliminary results confirmed individual differences in the degree to which pitch judgments were influenced by timbre shifts, even in the absence of pitch changes. Furthermore, across both experiments certain listeners perceived the direction of particular pitch changes to reverse when the comparison tone was filtered to match the standard's centroid.

Research and/or Educational/Clinical Implications and Conclusion

These findings suggest that brightness perception could explain individual differences in pitch observed for Shepard tones and missing-fundamental stimuli. Brightness might also account for poor pitch-matching abilities, suggesting that initial training might benefit from eliminating spectral differences in timbre. Possible dependencies on musical training and other factors will be discussed.

48. The minor 3rd conveys sadness in speech prosody, but interacts with pitch height

Meagan E. Curtis and Jamshed J. Bharucha
Tufts University

Purpose

Previous research has revealed that music and speech utilize the interval of a minor 3rd in the communication of sadness. The prosody of sad, bisyllabic American English speech samples tends to contain a downward interval approximating a minor 3rd. Emotional ratings of the speech samples revealed that the occurrence of the minor 3rd was associated with the perception of sadness more strongly than cues such as intensity, mean fundamental frequency (F0), and duration. However, given that the minor 3rd was a typical feature of the speech samples tested, we questioned whether the minor 3rd actually caused the raters to perceive sadness, or if the correlation was simply due to the typicality of this feature in the sad speech samples.

Methods

We tested the association between the minor 3rd and perceived sadness by creating synthetic "sad" speech samples in which the size of the interval was modulated (as was the mean F0), but all other acoustic factors were controlled and were consistent with the acoustic properties of sad speech identified in our previous research. Participants rated these speech samples on a scale from 1 to 7 for how strongly each conveyed anger, happiness, and sadness.

Results

Mean F0 predicted a large proportion of variance on each rating scale. Sadness was associated with a low mean F0 and happiness was associated with a high mean F0. Even speech samples that had an interval of a minor 3rd were perceived as happy when vocalized with a relatively high mean F0. The variance attributed to the mean F0 was regressed out of the ratings to determine whether interval size was a significant predictor when mean F0 was controlled. The minor 3rd was positively associated with perceived sadness. The major 3rd was positively associated with perceived happiness.

Conclusions
Given the controlled nature of the experiment, we can conclude that interval size had a causal effect on the perception of sadness and happiness, but that it is secondary to mean F0.
Clinical Implications
It is possible that the minor 3rd may be a typical feature of speech in depressed individuals, although further research is needed to assess this possibility. Given the implicit association between the minor 3rd in speech and perceived sadness, it is likely that clinicians can be taught to attend to this feature of speech and, if it proves to have diagnostic value, use it as a measure of depression.

49. Events in music: Audience activity analysis through continuous ratings of experience

Finn Upham and Stephen McAdams
McGill University

Purpose
Continuous ratings of musical experience have been collected over the past several decades, using a number of devices to rate tension, aesthetic response, and different dimensions of emotion in real time. When considering a set of responses simultaneously, it has been common practice to study the mean rating as a function of time. This paper proposes an alternative measure to explore the population's, or audience's, experience over the course of the musical stimulus by considering the proportion of participants showing changes in rating as a function of time. This approach is referred to as "activity analysis" because it describes the distribution of active expressions of experience from participants moment by moment.
Methods
Examples of this approach use the continuous ratings of experienced emotional force collected by Stephen McAdams, Daniel Levitin, and others from participants attending a live concert of the Boston Symphony Orchestra and a digital audiovisual reproduction of the same concert in Montreal. We consider the proportion of participants changing their ratings, either increasing or decreasing the rated emotional force, in time intervals of three seconds for each population and piece. Numerical transformations are applied to compare the two populations' activity and the degree of disagreement among participants' rating changes as functions of time.
Results
Numerical and graphical presentations exhibit patterns of the populations' behavior over time. Despite the wide variation in individual rating profiles, many similarities emerge between the distributions of rating changes of the two populations. This result suggests that music has some predictable effects on audiences as a whole.
Conclusion
This measure of activity in time enables the comparison of emotionally catalytic moments in music and the exploration of a pluralistic representation of musical experience. Activity analysis presents different information than mean ratings in time by describing the popularity of changes rather than the sum of their strength.
Research Implications
Studies of subjective ratings in real time could extract more information from responses by considering the distribution of variation in the measures of experience as a function of time. Temporal concentrations of changes in ratings point to where music strongly excites change and where it maintains some degree of stability of experience, giving reasons to explore musical stimuli at specific moments for their consistency of effects on participants.
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50. An association between breaking voice and grief-related affect in Country & Western songs

Brandon Paul and David Huron
The Ohio State University

Purpose:
A feature of crying or grieving speech is the so-called "breaking voice" -- an abrupt shift in pitch register arising from alternations between modal (normal) and falsetto phonation. Although rare, this distinctive auditory cue can also be heard in sung music, notably in operatic and Country & Western vocal practice. The purpose of this study is to establish whether breaking voice is associated with grief-related musical content. Our hypothesis is that breaking voice provides one (or potentially many) affective cues in sad or grieving music.
Methods:
In order to minimize experimenter bias, informants (Country & Western fans) were recruited to identify commercial sound recordings where the singer's voice breaks. Again, in order to minimize experimenter bias, an independent researcher unfamiliar with the purpose of the study was asked to confirm each of the purported instances of breaking voice. Each confirmed example of breaking voice was paired with a control song randomly selected from the same album in which the vocalist's voice did not break. Printed lyrics were assembled for both the target and control songs and independent judges were asked to assess which of the paired lyrics (target or control) exhibited greater grief-

related content.
Results:
Results are pending.
Conclusion:
We predict a significant association between breaking voice and assessments of greater grief-related content in the lyrics for the sampled Country and Western songs.
Research Implications:
A number of researchers have investigated music in the context of mourning as well as specific grief-related repertoires, such as Russian laments (Mazo, 1994). In the extant research literature, as yet there has been no explicit demonstration implicating "breaking voice" as an affective auditory cue linked to grief. This study offers the first empirical test of this assumption.

51. Music and goosebumps: the how and the why

Hui Charles Li, Psyche Loui and Gottfried Schlaug
Beth Israel Deaconess Medical Center and Harvard Medical School

Purpose
Music has a powerful ability to induce moods and sensations. One of these intense emotional sensations is chills, which involves having goosebumps or shivers down the spine (Grewe et al., 2007; Panksepp, 1995). While chills perceived in music have been reported with their physiological and neural correlates (Blood & Zatorre, 2001), the psychological conditions and musical stimuli that induce chills are unclear. We aimed to address two questions: 1) are there musical excerpts taken from a wide variety of genres (not described as chill inducing before) that can reliably induce chills, and if so, 2) what are the predictors for experiencing intense emotional responses and chill sensations in musical excerpts.
Methods
140 total participants (79 females, 61 males; median age=29, range=18-82, SD=15) were recruited from the greater Boston area. In three different experiments, various subgroups listened to a total of 309 different one-minute musical excerpts varying in 11 genres, tempi, instrumentations, etc. For each excerpt, participants gave subjective ratings of chills, intense emotional responses (e.g., tearing) , continuous and overall emotional ratings of music in valence and arousal, overall liking, and familiarity. Of the 140 participants, the majority preferred rock/pop music; 21 reported their preferred genre to be classical music, whereas another 10 reported classical music to be their second-most preferred.
Results
Ten excerpts elicited chills in over 20% of participants, with one excerpt (Righteous Brothers' Unchained Melody) eliciting chills in 30% of participants. Each excerpt elicited chills from an average of 7% of participants. Positive correlations were observed between chills and intense emotional responses ($r=0.73$), and between chills and self-reported familiarity ($r=0.42$). Classical music disproportionately induced more chills than other genres ($X^2=26.6$, $p(10)=0.003$).
Conclusion
We have identified and validated sets of musical excerpts that elicit chills and intense emotional responses in participants. Music that elicited chills was more familiar and induced more intense emotional responses. Additionally, despite classical stimuli accounting for approximately 25% of all stimuli, classical music elicited over 40% of all chills.
Research Implications
We identified music that elicited chills in a relatively high percentage of the population. Familiarity, liking, and overall valence and arousal ratings are strong predictors of chills. Results suggest that preferred pieces of music are more likely to induce chills due to recognition of musical structures. The identified musical excerpts may be usable for future studies of chills in music, and of intense emotions more generally.
Acknowledgement of Research Funding
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52. Darker is sadder: The effects of Sul G timbre on perceived sadness

Kelly Jakubowski and Gary Yim
The Ohio State University

Purpose:
We will test the hypothesis that listeners perceive music with darker timbre as sadder than music with brighter timbre.
Method:
For this study, timbre will be controlled using the sul G technique on the violin, which is a musical indication to perform a given passage solely on the G string (the lowest string). A given pitch played in a high position on the G string, rather than in a lower position on another string, results in a darker timbre because the G string is thicker in diameter. A two-alternative forced choice paradigm will be used. Subjects will be undergraduate music students and not

violinists. They will be presented with thirty passages of solo violin music, ranging from four to eight measures in length. Each passage will be performed live by a violinist in two versions: once solely on the G string, and once on the higher strings. Other than this difference, performers will be instructed to play both versions in exactly the same way. (The absolute pitches of the two versions are identical.) The order of the passages will be randomized, and the occurrence of the sul G passage as first or second will also be random. The two versions of each passage will be paired, and subjects will be instructed to identify which version they perceive to be sadder.

Results:

We anticipate that subjects will tend to select the sul G versions to be sadder than the version played on higher strings.

Conclusions:

We expect the results to be consistent with the hypothesis that music with a darker timbre is perceived as having a sadder affect than music with a brighter timbre.

Research and/or Educational/Clinical Applications:

The research of musicologists and evolutionary psychologists is often concerned with the origins of music and its affective influences. One theory suggests that cognitive processes related to the affective cues of music were developed from existing processes for discerning affect in speech. One such cue is timbre: speech researchers have shown that one of the characteristics of sad speech is a darker timbre than usual. We anticipate that our findings will support a link between perception of affect in music and speech by demonstrating that sad music is also characterized by a darker timbre. This extends existing research on the prosodic features of sad speech in music. These studies show that lower average pitch, less pitch variance, softer volume, and slower pace are all features evident in music as well as speech. Areas of further research may include i) the specific interactions of the above prosodic features ii) affective states other than sadness and iii) a comparison of neural activation patterns in perceiving affective speech and music.

53. Application of signal detection theory to the Montreal Battery of Evaluation of Amusia

Molly J. Henry, Bryan T. Grushcow, and J. Devin McAuley
Bowling Green State University

Purpose

The Montreal Battery of Evaluation of Amusia (MBEA) is used to assess both acquired and congenital forms of amusia (Peretz, Champod, & Hyde, 2003). Four of the subtests (Scale, Contour, Interval, Rhythm) involve presenting pairs of melodies and a same/different judgment. The remaining two subtests (Meter, Memory) involve presenting a single melody; listeners make a march/waltz judgment for the Meter subtest and an old/new judgment for the Memory subtest. Previous studies using the MBEA have relied on proportion correct (PC) as the primary measure of performance. However, PC measures of performance are not ideal for comparing performance across subtests, especially for comparisons between two-stimulus and single-stimulus designs; moreover, PC does not permit a distinction between measures of perceptual sensitivity and response bias. The present study used signal detection measures in conjunction with a confidence rating version of the MBEA to provide a more comprehensive assessment of MBEA performance than has been previously undertaken.

Methods

Listeners with a range of musical training completed confidence rating versions of the six subtests of the MBEA. Confidence ratings were given according to a 1-6 scale; for the same-different tasks, 1 corresponded to a 'Sure Same' rating and 6 to a 'Sure Different rating, for the Meter task, 1 corresponded to 'Sure March' and 6 to 'Sure Waltz', and for the Memory task, 1 corresponded to 'Sure Old' and 6 to 'Sure New'. Receiver operating characteristic (ROC) curves were constructed for each listener on each subtest; associated signal detection measures of performance were then calculated in order to take into account differences between two-stimulus and single-stimulus designs.

Results

There were two main results. First, slope values for z-transformed ROC curves for five subtests were close to 1, indicating that the variances of the two distributions comprising the decision space are similar; however, Memory slope was less than 1. Second, sensitivity measures derived from ROC curves showed that performance is worse for the two-stimulus subtests than for the single-stimulus subtests.

Conclusions and Research Implications

Performance on the subtests of the MBEA varies across individuals; moreover, individuals assessed to be 'tone-deaf' differ in the profile of their deficits. The use of signal detection measures with a confidence rating version of the MBEA establishes a more detailed set of normative data, which has the potential to provide greater insight into the nature of acquired and congenital amusia.

Reference

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54. When is music communication? A music communication matrix based on assumption, intention, and meaning construction

Mark Shevy
Northern Michigan University

Purpose
One's position on the nature of music meaning and communication has strong implications for the type of research questions one will ask or consider as valid. Some say that music does not communicate but creates experiences for listeners, and thus music communication research is a waste of time. Others say that music does communicate meanings, either musical or extra-musical. This paper provides a means of reconciling these differences, helping scholars and researchers of differing perspectives understand one another, and perhaps increase collaboration.
Methods
The paper first defines meaning in terms of cognitive psychology (Osgood, Suci, & Tannenbaum, 1957) and film theory (Bordwell, 1989), then it examines models of communication such as the SMR transmission model and a model that places emphasis on sender and receiver intentions and assumptions (e.g., Sperber & Wilson, 1995). In this, the paper defines communication as the sharing of intended meaning between a sender and receiver(s). Based on these theories and models, the paper argues that music can have meanings that may or may not be intended by the sender (i.e., composer or performer), and receivers (listeners) will typically construct musical and extra-musical meanings regardless of the intention of the sender. The conditions that arise from the combinations of these variables are then organized and labeled according to whether they meet the definition of communication established in the paper.
Results
The analysis results in a 4x4 matrix of sender and receiver assumptions and intentions, where the intersections of these variables result in six types of music effects: communication, accidental communication, miscommunication, experience, mis-experience, and accidental experience.
Conclusion
There are indeed times when music should not be classified as communication, and there times when it should. There is also ample opportunity for receivers to construct meanings that are not intended by the sender by assuming that communication was intended when it was not, misinterpreting information, or constructing meaning from information the sender sent unintentionally. In fact, of the 16 matrix cells, only four have outcomes that meet the sender's goals for the music.
Research and/or Educational/Clinical Implications
The music communication matrix helps researchers to develop questions suitable for the various communication scenarios that exist. It can help scholars of varying views to understand one another's positions and see where there is room for each perspective in the range of communication possibilities. It can also help composers and performers identify how their pieces may fall short of their goals and make adjustments accordingly.

55. Cross-validation of a model for classifying musical sophistication

Joy Ollen
Douglas College

Purpose:
This study tested the predictive accuracy of a 10-item questionnaire to successfully categorize individuals as being more or less musically sophisticated compared with a musical expert's judgment of their level of musical sophistication.
Method:
The current study served to cross-validate previous work in which the researcher administered a 36-item questionnaire to 633 participants in three countries. The previous study sought to determine which of the questions would best correlate with experts' subjective ratings and serve as useful indicators of musical sophistication. A logistic regression analysis yielded a significant model with nine indicators (model chi-square = 296.133, df = 32, $p < .001$) that was able to classify 79.5% of the sample accurately. In the current study, the 10-item questionnaire was administered to a new sample of approximately 300 participants who ranged from being musically naïve to highly experienced professional musicians and who belonged to various types of groups involved in music-related behaviours (e.g., university music courses for non-majors, amateur choirs, professional orchestras, etc.). Group leaders—musical experts who work with the participants--supplied ratings of their level of musical sophistication.
Results:
Final results are not yet available as data collection is ongoing. Preliminary analysis performed on the current data set has shown the model to be classifying 70% of the sample accurately.
Conclusion:
The results will provide information about the generalizability of the model.
Research Implications:
Music researchers regularly test the hypothesis that participants will respond differently based on their levels of musical sophistication and use simple survey-type questions related to their musical background to classify their

participants. A survey of 743 published research studies and experiments showed that the most frequently used indicator was participants' formal musical training (e.g., years of music lessons). Yet, in this researcher's original study, this indicator only categorized 62% of the participants correctly compared with the expert ratings—a much lower accuracy rate than the 79.5% obtained by the complete model. If the current study provides findings that are consistent with the original study, researchers may wish to use the 10-item questionnaire as a tool to classify research participants.

56. Knowledge representation in an intelligent tutoring system architecture: A computational exploration of expertise in counterpoint writing

Panayotis Mavromatis
New York University

Purpose

We develop a knowledge-based programming framework for implementing an Intelligent Tutoring System (ITS) (Polson & Richardson 1988, Forbus & Feltovich 2001) for counterpoint writing. The knowledge representation developed in this connection is used (i) to code counterpoint rules in Prolog from natural language specifications; and (ii) to implement in Prolog effective counterpoint writing strategies used by experts, as reported in concurrent verbal protocols. The effectiveness of such strategies is evaluated by computer simulation.

Methods

The ITS's knowledge base and inference engine are coded in the programming language Prolog. The knowledge representation developed is based on the theory of ontologies (Brachman & Levesque 2004, Gasevic et al. 2006) and expressed as RDF Schemas (W3 Consortium 2004). Experimental subjects at various levels of expertise log on to the ITS and are assigned a counterpoint problem. The system monitors the solution process and reports to the subjects any rule violations at every step. Moreover, the ITS records the order and timing of the subjects' actions. At the same time, subjects are asked to "think out loud" and we obtain an audio recording of this concurrent verbal protocol (Newell & Simon 1972).

Results

The subjects' protocol is analyzed. The verbal descriptions they use to express their counterpoint writing strategies are cast into our knowledge representation scheme and are coded into Prolog. In this way, a rich set of heuristics is identified that dramatically improves the problem-solving process over brute-force search. These heuristics are subsequently tested by computer simulations of counterpoint writing as problem-space search (Newell & Simon 1972, Mavromatis & Brown 2008). We quantify the (in)effectiveness of each strategy as the number of decisions needed to complete the task, or alternatively, as the number of steps wasted in pursuing an unsuccessful solution path.

Conclusion

Our method offers a way of modeling computationally the knowledge and strategies that underlie expert counterpoint writing. Our simulations allow us to evaluate the effectiveness of human problem-solving heuristics, assessing their appropriateness for deployment in actual instruction.

Research and Educational Implications

When properly employed, ITSs can become a powerful educational tool that supplements human instruction, allowing the latter to focus on more creative aspects of counterpoint writing. Moreover, an ITS can be used as a tool for gathering data that document the problem-solving process in real time, offering a unique window into expert skill and its acquisition. A more fine-grained analysis of these problem-solving records, including timing data, will be pursued in a future work. Finally, we believe that the well-defined problem of counterpoint writing, where composers have honed their skills for centuries (Mann 1994), can shed valuable light on broader questions concerning the nature and development of compositional expertise.

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57. Towards a better understanding of the contrasting psychological effects of the subtonic-tonic and the leading tone-tonic gestures

Ivan Jimenez
University of Pittsburg

Purpose
The discussion of the subtonic that moves up one step to the tonic, a very important gesture for folk and popular musical styles, has been largely neglected in academic literature. This gesture has a modal connotation, and strongly contrasts with its tonal counterpart, the leading tone-tonic gesture. Contrast between the subtonic-tonic and the leading tone-tonic gestures is very important for the identity of a myriad of musical styles, and the examination of the contrast between these two gestures can greatly expand our understanding of those musical styles, as well as our understanding of tonal and modal systems in general.
Method
In an experiment I recently conducted with music students, modeled after David Huron's work on scale degree qualia (2006), I tested the extent to which different types of metaphors can consistently represent the difference of effect between the subtonic-tonic (modal) and the leading tone-tonic (tonal) gestures. In this experiment, 12 students of Music Theory 1 were asked to classify the effect of the leading tone-tonic and the subtonic-tonic gestures according to five dualities: natural vs. artificial, complex vs. simple, collective vs. individual, thick vs. thin, and harmonically relaxed vs. harmonically dramatic. Students were given excerpts from four relatively well-known pieces of music. Two versions of each excerpt, the original and a modified version, were provided: one with the subtonic-tonic gesture, and the other with the leading tone-tonic gesture. Students were asked to determine which side of each duality better described each version of the excerpt.
Result
The students' categorization was largely consistent with my own previous assessment of the effects of the subtonic-tonic and leading tone-tonic gestures (81% of the results matched my assessment).
Conclusion
The results of this experiment demonstrate that this particular set of metaphors consistently describes the effect of the subtonic-tonic and leading tone-tonic gestures.
Research and Educational Implications
This experiment also suggests that metaphors, and particularly metaphors presented as dualities can be used as powerful tools for the study of different theoretical topics. These dualistic pairs are more effective if the theoretical topics are also presented as basic dualities; the opposition between the subtonic-tonic gesture and the leading tone-tonic gesture being just one example of a basic duality. In addition, dualistic pairs such as subtonic-tonic vs. leading tone-tonic, are directly connected to classical and popular music styles, and for this reason provide a good opportunity to obtain a more complete picture of the possibilities of different musical structures by contrasting diverse musical practices.

58. Modeling the sonority of chord progressions: Toward a psychophysical explanation of the "rules" of traditional harmony theory

Marc De Graef[1] and Norman D. Cook[2]
[1]Carnegie Mellon University,[2]Kansai University

Purpose
The purpose of the present study was to calculate the overall "sonority" of chord progressions using a psychophysical model of harmony perception (Cook, 2002; Cook & Hayashi, 2008).
Methods
The methods were computational. Using a model of harmonic tension that is based on 3-tone effects (the tension inherent to triads containing two intervals of the same size, in semitone steps), the tension scores obtained from all triadic combinations of partials (n<9, with gradually decreasing amplitudes, 0.88^n) of two triad chords were calculated. The basic tension model gives a maximal tension score for any triad with two equivalent intervals (e.g., the augmented chord [4-4 semitone structure] or the diminished chord in root position [3-3]) and a tension score of zero when the intervals differ by 1.0 semitone or more (e.g., the major chord in root position [4-3] or the minor chord in root position [3-4]). Calculation of the effects among all combinations of upper partial triads is non-trivial.
Results
The computational results were compared with the cadences of traditional harmony theory (Piston, 1987), with the statistics on cadences for both popular and classical Western music (Huron, 2006), and with the results of "tonal distance" obtained using the probe-tone technique (Krumhansl, 1979). The chord cadences showing the lowest levels of tension were those entailing movement between a tonic chord and its dominant or subdominant.

Conclusion
The total tension calculated for pairs of triads reproduced the pattern of key relationships known as the Circle of Fifths. The idea that the tonic, dominant and subdominant chords are "close" comes as no surprise within the framework of traditional harmony theory, but psychophysical justification for the Circle of Fifths has been lacking. Specifically, calculation of the total dissonance between chord pairs does not result in this trio having the greatest consonance. Our results indicate that harmony perception is strongly influenced by both 2-tone and 3-tone configurations. We conclude that one of the most basic "rules" of traditional harmony theory, as expressed in the Circle of Fifths, is not an arbitrary social construct, but, on the contrary, has a firm foundation in the acoustical structure of the chords themselves.
Research and/or Educational/Clinical Implications
We have found that the psychophysics of harmony perception can explain one of the most important regularities of so-called Western music. Provided only that the effects of 3-tone configurations are examined, there is no justification for arguing that the well known regularities of diatonic music are arbitrary cultural artifacts.

59. The effect of style-priming on harmonic expectation

Bryn Hughes
Florida State University

Purpose:
Music theorists often suggest that chord successions in common-practice music are governed by syntax. In support of this, cognitive studies by Krumhansl, Bharucha, and others have shown that listeners expect chord successions that adhere to these syntactical rules. There is less agreement among music theorists regarding rules of chord succession in non-common-practice music, such as blues or rock. Some suggest that the syntax is the same for both contexts while others propose new syntactical rules for blues/rock music. This research investigates whether listeners expect chord successions presented in the context of the blues/rock idiom to adhere to common-practice syntax.
Methods:
In this experiment, two groups of subjects (N = 56) listened to pairs of triads and rated how good each harmonic succession sounded. Each triad pair was primed by a brief key-confirming recording of either blues/rock or classical music drawn from commercial recordings. All triads were constructed with Shepard tones to eliminate the effect of register and perceived voice-leading. Stimuli were presented in blocks corresponding to the musical style of the prime to strengthen listeners' notions of stylistic context.
Results:
In both contexts, listeners preferred harmonic successions in which the relationship between chord roots reflected common-practice syntax. While the results showed a negative correlation between listener ratings and the use of chords outside the prevailing key (i.e., non-diatonic chords), the effect was significantly less pronounced in a blues-rock context. Additionally, style priming affected listener preference for opening and closing chords. Among the three primary triads, listeners preferred tonic and dominant openings over subdominant openings in a classical music context. Conversely, in a blues/rock context, listeners rated subdominant openings higher than both tonic and dominant openings. While listeners preferred tonic endings in both contexts, dominant endings were preferred over subdominant endings in the classical context, whereas subdominant and dominant endings were rated equally in the blues/rock context.
Conclusion:
Although listeners hold similar expectations of the relationships between successive chords in both contexts, the results suggest that subdominant harmony has an elevated status in blues/rock music. This likely reflects the statistical prominence of this chord in that repertoire.
Research and/or Educational/Clinical Implications:
Hierarchical theories of harmony in common-practice music often privilege tonic and dominant chords. The results of this study support speculations made by Ken Stephenson and Richard Middleton, who suggest that subdominant harmony should assume a fundamental role in theories of blues/rock music.

60. Probing the minor tonal hierarchy

Dominique Vuvan, Jon Prince, and Mark Schmuckler
University of Toronto

Purpose
Previous perceptual work on Western tonal hierarchies has not investigated the subtleties inherent in theoretical descriptions of the minor key. This study was designed to rigorously test cognitive representations of the three forms of the minor scale (natural, harmonic, and melodic), and the effects of musical context type (chordal vs. scalar) thereon. It was predicted that participants would be able to differentiate between the three minor types, and furthermore that chord contexts might facilitate cognitive representations of the harmonic minor, whereas scale contexts might facilitate representations of the melodic minor.

Methods
Sixteen musician participants were presented with a musical context (chordal or scalar) that established one of the three forms of the minor tonal hierarchy. Next, participants rated how well a probe tone (consisting of one of the 12 chromatic pitches) fit with the preceding context, on a Likert scale of 1 to 7.
Results
Most importantly, and as expected, participants' ratings distinguished between the three minor types, producing unique probe tone profiles corresponding closely to theoretical descriptions of the natural, harmonic, and melodic minor. Contrary to predictions regarding the effect of context, however, the minor tonal profiles did not differ across chordal and scalar contexts.
Conclusion
These findings demonstrate that musically trained listeners' cognitive representations of minor tonalities are sensitive to the differences among the three minor types. This finding helps fill an obvious, if neglected, gap in the music cognition literature.
Research Implications
Previous research into cognitive representations of the minor key has often assumed that listeners perceive all minor forms similarly, and has neglected to distinguish between the three types. This study shows that instead, musically trained listeners clearly process the natural, harmonic, and melodic minor distinctly.
Acknowledgement of Research Funding
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61. An analytic method for atonal music that combines Straus's pattern completion and associational models with selection criteria based on cognitive criteria

Yeajin Kim
The Ohio State University

Purpose
In the early 1980s, Joseph Straus proposed the concept of the "pattern completion," which touched upon an interdisciplinary linkage between cognitive psychology and musical analysis. Straus later presented the "associational model," in which tones interspersed in a large-scale tonal space could be interrelated through specific pitch-class sets and thereby established theoretical justifications for what he proposed in his earlier articles. However, the premises of these concepts raise some issues that still await further logical and theoretical explanation, most importantly the establishment of selection and segmentation criteria.
Methods
In this respect, I critically examine Straus's concepts and briefly survey analytic methods for twentieth-century music. Finally, I suggest my own analytic model, which synthesizes Straus's pattern completion and associational models with my prerequisite conditions (modified from Lerdahl's "salient conditions"), which considers the listener's cognition in the establishment of selection criteria. As a test of my synthesis, I apply this analytic methodology to two atonal works by Isang Yun, Glissees for Violoncello Solo (1970) and Gasa for Violin and Piano (1963).
Research Implications
This analytical tool may prove useful in illuminating structural secrets latent in other post-tonal music.

62. Tonality perception as auditory object perception

Ji Chul Kim
Northwestern University

Background
Tonality refers to the organized relationships of tones that give rise to the dynamic quality of musical experience such as the sense of orientation, direction, and closure. Although many have acknowledged the importance of the temporal structure in tonality perception, the prevalent view in music psychology has been mainly concerned with the pitch content of musical structures.
Aims
I propose a theory of tonality perception conceived as auditory object perception. Coherent perception requires segregation of the perceptual world into structured subunits or objects. A musical surface is segregated and integrated at multiple spectral and temporal scales to form a complex of musical objects. I argue that this perceptual process of object formation, along with the influence of the previously learned objects, is behind the perceived sense of tonality as well as the way coherent tonal structures are shaped.
Main Contribution
When the brain segregates a musical surface and integrates individual sound events into auditory objects, the elements of an object are given new perceptual qualities in the relations with other elements. I argue that in order to form a coherent object with a stable mental representation, perceptually salient elements should serve as the

"perceptual reference points" of the object and other elements are encoded in relation to these reference elements. Along with the pitch structure, the temporal structure of the musical surface, especially the local segmentation structure, plays a deciding role in the emergence of the perceptual reference points in both pitch and time dimensions. When the reference points of adjacent objects align in pitch and time or at least don't disrupt each other, multiple objects can be encoded against the same or congruent reference points—to use musical terms, they are heard in the same key and meter. The extended perceptual reference points (the induced key and meter) influence the subsequent object formation by generating expectations and guiding attention. In addition to the established reference points, the previously learned patterns stored in both short- and long-term memory also influence the encoding of the incoming information.

Implications

The proposed theory suggests that the sense of key and meter comes from the internal structure of perceptual objects, thus should be very weak when individual events are not perceptually integrated; temporal structures like low-level segmentations contribute to tonality perception; the encoding of musical structures and the induction of key and meter are part of the same process of object formation.

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63. The time course of implied harmony perception: The effects of 'what' and 'when' expectations

Jung Nyo Kim
Northwestern University

Purpose

The importance of harmony perception in understanding tonal melodies has been extensively explored, but little is known about the processing of implied harmony. This study aims to explain 1) how each note of a tonal melody is harmonically interpreted and integrated with the previous and following notes as the melody unfolds and 2) how harmonic expectations of 'what' chord would follow and 'when' the chord change would occur affect the processing.

Methods

Thirty-six 18-tone melodies were constructed. Each was divided into six groups of 3 consecutive tones that belonged to the same chord. The first 15 tones implied I-V-I-ii-V and the last 3 tones (targets) implied either I (expected) or IV (unexpected). Also, the harmonic change to the last chord occurred either on the expected location (on the 16th note-position), one beat earlier than expected (on the 15th), or one beat later (on the 17th).

A gating paradigm was used. In the first of four blocks, participants heard the initial 15 tones of each melody and in each following block, one tone was added to the previous fragments. After hearing each melody, they sang the last tone as quickly as possible and the reaction times were measured.

Results & Conclusions

'What': RTs for the expected chord tones (C, E, or G in C major) were faster than those for the unexpected ones (F or A) on the 16th. Although G can be interpreted either as I or as V, it seemed to be interpreted as I because RTs for the other tonic-chord tones on the 17th and 18th got faster. Also, F on the 16th can be interpreted either as IV or as V7. The participants seemed to interpret it as V7 because RTs for the following subdominant-chord tones got slower. Similarly, RTs for F or A on the 17th after C got slower because the previous C was interpreted as I. However, RTs for A were faster than those for F, which confirms that vi is more probable than IV after V. In short, 1) the more expected the targets were, the faster RTs were and 2) the clearer the implied chords became over time, the faster RTs became.

'When': RTs were faster when the harmonic change occurred on the expected location than when it occurred one beat earlier or later. Moreover, RTs for the late change were faster than those for the early change.

Implication

This study suggests the importance of not only 'what' but also 'when' harmonic expectations in the online processing of implied harmony.

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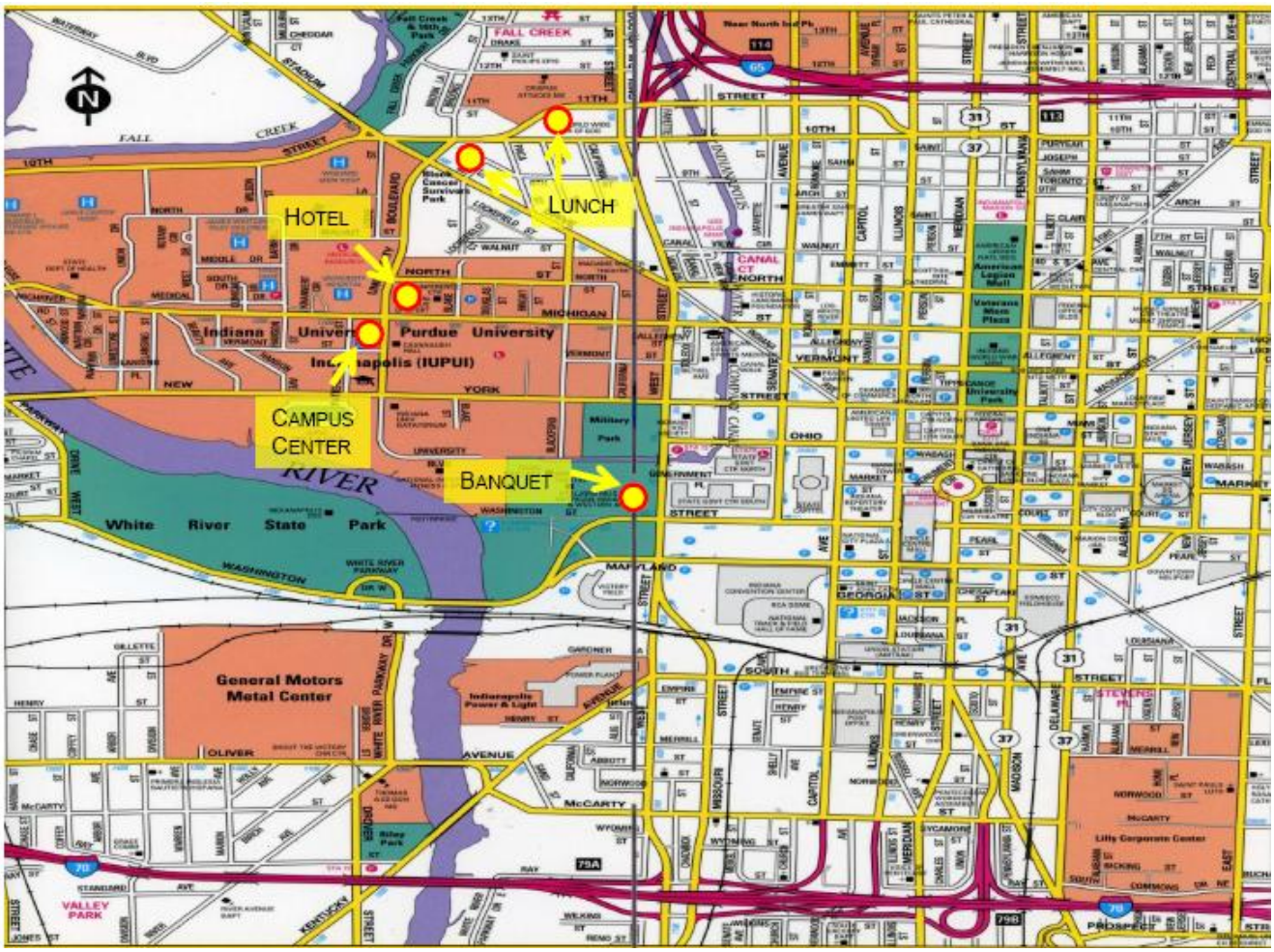
Map of Local Area



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