International Laboratory for
Brain, Music, and Sound Research

ANNUAL SCIENTIFIC DAY
May 25th 2009

DETAILED PROGRAM

Concordia University, Loyola Campus
7141 Sherbrooke West
Hingston Hall, room 130

9:30 - Douglas Eck (Université de Montréal)
"What can machines learn about music? An overview of machine learning techniques for sound and motion"

10:15 - Talar Hopyan (University of Toronto)
"Using Music as a Clinical Tool with Pediatric Populations"

11:00 - Poster session & coffee break (Science Pavilion – First floor atrium)
NOTE: The poster session will be held in the Science Pavilion Atrium

12:30 - Lunch (Science Pavilion – Ground floor atrium)
Annual Researcher's Assembly

2:00 - Data Blitz (Hingston Hall)

- Anne Bailey (Concordia University)
"Rhythm synchronization performance and auditory working memory in early and late-trained musicians"
- Julie Mercier (McGill University)
"Individual differences in executive function constrain spoken word recognition"

- Christine Lefebvre (Université de Montréal)
"Towards Neurophysiological Correlates of Acoustic Short-term Memory"

- Steven Livingstone (McGill University)
"Emotional Arousal corresponds with Musical Phrase Structure"

- Valorie Salimpoor (McGill University)
"Evidence for Striatal Dopamine Release During Music Listening"

4:00 - Coffee break

4:30 - Keynote speaker: Séverine Samson (Université Lille III, France)
"A neuropsychological model to study musical emotion"

6:00 - 5 à 7 musical (Department of Music)

BRAMS Annual Scientific Day 2009 is organised with the collaboration of Concordia University, Casavant Research Chair, the Montreal Neurological Institute, Canadian Institutes of Health Research (CIHR) and Natural Sciences and Engineering Research Council (NSERC).

DATA BLITZ PRESENTATION
ABSTRACT

ANNE BAILEY (Concordia University)

"Rhythm synchronization performance and auditory working memory in early and late-trained musicians"

Jennifer A. Bailey, Amanda Daly & Virginia Penhune
Department of Psychology, Concordia University

Previous work from our laboratory (Watanabe et al., 2007) has shown that musicians who began training before age 7 (early-trained; ET) performed better on a rhythm tapping task that those who began after age 7 (late-trained; LT), even when controlling for total years of musical training and experience. This suggested that there might be an early "sensitive" period during which musical training results in long-lasting benefits for sensorimotor integration later in life. Two issues were raised regarding the findings from this experiment. First, the task used in the previous experiment tested visual-motor synchronization, a skill not specifically trained in musicians. Second, possible pre-existing differences in specific cognitive functions between ET and LT musicians might mediate their better performance on this task. To address these questions, we tested a new sample of currently practicing ET and LT musicians who were matched for years of musical training, hours of current practice and experience. These musicians were tested on an auditory rhythm task (Chen et al., 2008) that required them to synchronize their finger tapping with woodblock rhythms at three levels of complexity. They were also tested on four subtests of the Wechsler Adult Intelligence Scale to examine the relationship between cognitive functioning, tapping performance and early or late start of training. The two groups of musicians differed in their task performance, such that the ET musicians were better at reproducing the temporal structure of the rhythms. There were no differences between the groups for any of the cognitive variables. However, across both groups, individual task performance was correlated with auditory working memory and years of formal training. Results will be discussed in terms of a sensitive period for musical training and the impact of musical training on specific cognitive skills.

CHRISTINE LEFEBVRE (Université de Montréal)

"Towards Neurophysiological Correlates of Acoustic Short-Term Memory"

Christine Lefebvre, François Vachon, Stephan Grimault, Synthia Guimond, Robert Zatorre, Isabelle Peretz, & Pierre Jolicoeur

We sought to uncover neurophysiological activity related specifically to the maintenance of acoustic stimuli in short-term memory (STM) using the event-related potential (ERP) technique. The EEG was recorded while participants performed a same /different task on two non-musical tone sequences separated by a 2-sec retention interval. Memory load was manipulated parametrically by varying the number of tones in a sequence. The 2, 4, or 6 tones were preceded by white noise fillers to equal sequence length across trials. The voltages measured during the retention interval of this STM task were compared to those measured during completion of a control task. In this control task, participants ignored the first sequence and completed a judgement task on the second sequence. We observed an increase in negativity with memory load at frontal sites in the Memory task, but not in the Control task.

We also found a correlation between memory capacity and voltage differences between the load conditions. These findings suggest that not only can we isolate electrical brain activity specifically related to the retention of pitch information in acoustic STM, but we can also link behavioural and electrophysiological data to explain individual differences.

STEVEN R. LIVINGSTONE (McGill University)

"Emotional Arousal corresponds with Musical Phrase Structure"

Steven R. Livingstone[1], Emery Schubert[2], Janeen D. Loehr[1], and Caroline Palmer[1]
[1] Dept of Psychology, McGill University, Canada
[2] School of English, Media and Performing Arts, University of New South Wales, Australia

Do listeners' emotional responses to an orchestral work reflect the phrase structure? Emotional response is influenced by contributions of both the composition and performance, and can be remarkably stable across listeners. We focus on listeners' emotional responses and their correspondence with compositional structure in an orchestral work. Sixty-seven participants with varied amounts of musical training responded to an orchestral recording of the Pizzicato Polka (Strauss) which contains the phrase structure (A1 B1 A'1, A2 B2 A'2). Participants gave continuous responses for perceived emotion in a two-dimensional Emotional Space (arousal and valence), sampled at 1Hz. Functional Data Analyses were applied to the arousal ratings to produce smoothed responses, as well as rates of change in arousal (velocity) and change in change in arousal (acceleration). Velocity and acceleration responses corresponding to each musical section were combined in two-dimensional phase-plane plots, and Procrustes analyses - which measure shape similarity - were performed to determine the correspondence between emotional arousal and the musical phrase structure. Participants' arousal ratings indicated significant degrees of similarity in the velocity and acceleration of arousal values across specific musical sections. Phase plane plots of arousal values for individual musical phrases showed a clear cyclical structure. Most important, there was a statistically higher degree of similarity between related musical sections (A1 to A'1, and B1 to B2) and statistically lower similarity among contrasting sections (A1 to B1, and A'1 to B2). These findings suggest that functional data analyses may provide a useful tool for structural analysis of emotional responses, and that listeners' change in emotional arousal corresponds to the phrase structure of the performance.

JULIE MERCIER (McGill University)

"Individual differences in executive function constrain spoken word recognition"

Julie Mercier, Irina Pivneva, & Debra Titone
Department of Psychology, McGill University, Montreal, QC, Canada.

Previous work in psycholinguistics has demonstrated that individual differences in executive function and working memory constrain several aspects of language processing, which include lexical ambiguity resolution and syntactic processing. However, such effects have never before been reported for the temporally dynamic processes involved in spoken language. In this study, we used the visual world paradigm to determine whether individual differences in executive function affect the time course of spoken word recognition. English speakers listened to spoken words following an instruction ("Click on the BATHTUB") while they looked at a display of pictures including the target word, a word onset competitor (BAGPIPES), and unrelated filler pictures. Participants also engaged in an executive function battery that included several inhibitory and working memory tasks.

In Experiment 1, 24 participants had advanced training with the pictures; in Experiment 2, 24 participants performed the task with no prior training. Although all participants were more likely to look at competitor pictures than other non-target pictures, executive function in the two experiments differentially correlated with looking behavior. When people were pre-trained on the pictures, increased interference from the competitor picture correlated with high inhibitory skills and high working memory span; when people were not pre-trained on the pictures, increased interference from the competitor picture correlated with low inhibitory skills. Thus, executive function plays a role in spoken word recognition in a way that is closely tied to the specific comprehension task under study.

When task conditions are most likely to simulate normal spoken word recognition, as in the no-training condition, individual differences in executive function are consistent with what has been found previously for other domains of language.

VALORIE N. SALIMPOOR (McGill University)

"Evidence for Striatal Dopamine Release During Music Listening"

Valorie N. Salimpoor[1,3], Mitchel Benovoy[2], Gregory Longo[1], Kevin Larcher[1], Alain Dagher[1], Jeremy Cooperstock[2], Robert J. Zatorre[1,3]

[1] *Montreal Neurological Institute, McGill University, Montreal, QC, Canada;*
[2] *Engineering Dept., McGill University,Montreal, QC, Canada;*
[3] *BRAMS Laboratory, Montreal, QC, Canada*

Listening to music has traditionally been used to induce highly pleasurable states, leading to the speculation that it may involve the dopamine reward system. Previous neuroimaging studies have been limited to showing only correlations in blood flow or oxygenation to striatal regions of the brain during music listening (Koelsch et al., 2006, Blood and Zatorre, 2001), but a direct connection has not been demonstrated. We used [C11]raclopride PET imaging to determine if listening to music leads to increased dopamine binding in the striatal areas. To index an objectively measurable affective state in response to music we used the well-established "chills" response, extremely pleasurable physical sensations accompanied by an intense emotional response (Panksepp and Bernatzky, 2002, Goldstein, 1980, Sloboda, 1991, Blood and Zatorre, 2001). Chills are accompanied by distinct psychophysiological correlates, thus, their occurrence can be verified objectively. We also used fMRI to examine the time-series of the striatal responses to chills, and to distinguish between neural activity in response to anticipation of the reward and the reward itself.

Methods

Ten healthy adults (5 women) with a wide range of musical experience participated in the study. Participants selected 5 pieces of music to which they consistently experienced "chills". Each participant listened to all other participants' musical selections and rated them on pleasure and familiarity. Baseline control stimuli were individually selected for each individual based on low ratings on pleasure and high ratings of familiarity. Thus, each piece of music was used once as control and once as experimental stimuli. [C11]Raclopride PET imaging involved two sessions during which participants listened to "chills" or "neutral" music. Dopamine binding potential differences were calculated between the two sessions. During fMRI scanning participants listened to chills and neutral music and indicated when they experienced chills. To examine the effects of anticipation, epochs before chills were identified and compared with chills epochs. Psychophysiological recordings were collected during PET and fMRI sessions.

Results

[C11]raclopride PET imaging revealed dopamine binding potential reductions in the dorsal and ventral striatal areas, particularly the right caudate and nucleus accumbens, and bilateral putamen, during chill-inducing music. fMRI imaging results showed a significant increase in BOLD response in the dorsal and ventral striatum, particularly the nucleus accumbens, while participants were experiencing chills, as compared with randomly selected non-chills epochs of the same music. Increased activity in the cerebellum and midbrain areas during chills was also observed. Anticipation of chills revealed modulation of BOLD response in the left amygdala. A significant increase in heart rate, respiration rate, and skin conductance, and a decrease in body temperature were also found during chills.

Conclusions

These results provide evidence for both dopamine binding and blood oxygenation differences in the striatal reward centers of the brain in response to pleasurable music listening. These regions have previously been implicated in response to other rewarding stimuli such as drugs and food. However, unlike these stimuli music does not have an external tangible basis or have a biologically relevant survival value. These findings thus have important implications for discovering the nature of the striatal reward system.

References

Blood, A. & Zatorre, R. J. (2001), 'Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion', *Proceedings of the National Academy of Science,* vol. 98**,** pp.11818-11823.

Goldstein, A. (1980), 'Thrills in response to music and other stimuli', *Physiological Psychology,* vol. 8**,** pp. 126-129.

Koelsch, S., Fritz, T., Cramon, D., Muller, K. & Freiderici, A. D. (2006), 'Investigating Emotion With Music:
An fMRI Study', *Human Brain Mapping,* vol. 27**,** pp. 239-250.

Panksepp, J. & Bernatzky, G. (2002), 'Emotional sounds and the brain: the neuro-affective foundations of musical appreciation', *Behavioral Processes,* vol. 60**,** pp.133-155.

Sloboda, J. (1991), 'Music structure and emotional response: some empirical findings', *Psychology of Music,*vol. 19**,** pp. 110-120.

POSTER PRESENTATION
ABSTRACT

1 - LARRY BAER (Concordia University)

"A comparison of musicians and non-musicians in a sensorimotor synchronization task"

Larry Baer, Wai Yen Tang, Emilie Sheppard, Virginia Penhune, Karen Li

Laboratory for Motor Learning and Neural Plasticity, Department of Psychology, Concordia University, Montréal, Québec, Canada

Synchronization of motor responses with auditory stimuli is an essential feature of musical performance. In order to study this in the laboratory, we employed the well-known experimental paradigm of finger-tapping to a metronome tone occurring at regular intervals. This process likely involves the integration of information from various sensory modalities. Balasubramaniam et al. (2004) found that as proprioceptive information (operationalized as finger velocity) increased in the downward flexion phase of a tap, the tapping response became more synchronous and suggested that this proprioceptive information may form part of an error correction process. The goal of the present study was to characterize the relative contributions of tactile and proprioceptive feedback to achieving synchrony with an external stimulus and to determine if trained musicians employed this information in a more efficient way compared to non-musicians. Sixteen right-handed subjects (8 musicians and 8 nonmusicians) were asked to tap their right index finger to an isochronous rhythm composed of a 20 ms 1 kHz tone that played at one of four different rates (1Hz, 1.5Hz, 2Hz, 3 Hz). Tapping was done on three different surfaces providing different levels of tactile feedback (air, tabletop, piano key). Each condition consisted of three blocks of 40 trials. Index finger motion was recorded at 200Hz using the Visualeyez 3D motion tracking system. A main effect of tapping rate was observed, such that as tapping rate slowed, finger movement in the flexion phase sped up (proprioceptive information increased) relative to the extension phase. Preliminary results also suggest that this effect of tapping rate is moderated by the degree of tactile information available such that as tactile information increases, finger flexion speed decreases, suggesting less of reliance on proprioceptive information. Thus, at slower tapping rates, when synchronization is more challenging, tactile information appears to be preferred over proprioceptive information in the synchronization process. Further analysis will examine differences between musicians and non-musicians.

2 - CHRISTINE BECKETT (Concordia University)

"Serial Technique in Rhythm and Dance Improvisations"

Given 6 implicative stimuli in each of drummed rhythm and contemporary dance, participants produced 12 spontaneously improvised continuations, 30 – 35s long. Musicians (13, 2 female, 4 percussion majors) and dancers (11, 6 female, all dance majors) all both drummed and danced. A high rate of motivic treatment was noted for every implicative stimulus. Some treatments were quite musically sophisticated (augmentation, diminution, fragmentation, elaboration including layering of contrapuntal voices, interpolation, and the like). Treatments went so far as to include serial techniques such as retrograde in the drummed rhythms, and mirror (inversion) as well as retrograde inversion in dance. Serial treatment was displayed both by musicians (who may have encountered serialism) and by dancers (who had no explicit training in the technique). Serial technique in 20th c music is sometimes criticized as overly

intellectual and too complicated for the average listener to perceive (Francès, 1956). That it should arise in these improvisations—for which participants had no time to prepare intellectually—is intriguing. The neural substrates of the phenomenon are unknown.

3 - MICHEL BERNAYS (Université de Montréal)

"Piano Timbre: from words to gesture to sound Perception, verbal description & gestural control of aggregate piano timbres by highly skilled pianists"

Timbre is a key to musical expressivity in virtuosic pianistic performance. When discussed amongst professionals, timbre is described with abstract terms such as dark, bright, round, velvety, shimmering, whose imagery aims at fitting the sonic nuances, but bypass the quantitative and functional characteristics of its production. Still, pianists seem able to avoid inter-individual misunderstandings in timbre description. This study then aims to determine the degree of consensus of this vocabulary among the pianistic community, and identify its gestural correlates at the keyboard level.

A professional pianist played 3 short pieces, with 8 adjectives as successive instructions to color the performances, on the computer-controlled recording acoustic piano Bösendorfer CEUS, that gathered data on key movement and hammer velocity, from which to extract the specific gesture parameters with custom Matlab functions. The audio recordings were used as stimuli, over which the pianist himself proved easily capable of retrieving the timbres. In the main task, 17 other pianists provided a verbal description of each timbre they could recognize, which fitted the expected descriptor roughly one third of the time. The results got much more conclusive, and way above chance, once accounting for the semantic proximity between adjectives. This indicates the expressive intentions of a virtuosic pianist can be perceived by his peers and can be verbally described in a consensual way.

Gesture analysis is now under way, with the aim of identifying meaningful correlations between statistics of synchronism, dynamics, touch, overlap, articulation, etc., and the timbres employed.

4 - LYSIANE BOUCHARD (Université de Montréal)

"How Does The Brain Encode Complex Sounds ? Using Machine Learning to Analyze FMRI Results from Spectro-temporal Modulations"

Little is known about the way the human brain encodes complex sounds. This is in part due to the limitations of the typical analysis of neuroimaging data based on the general linear model. From within this framework, small-scale variations of activity are regarded as noise, yet these variations have recently been shown to carry important information about underlying brain processes. In this study, we aim to overcome some of the limitations of the traditional analysis by using multivariate, "informationbased" approaches. We focus on a possible representation of complex sounds based on spectrotemporal modulations inspired by previous studies in animals (see [1]). We used fMRI recordings of brain responses of 7 subjects listening to 49 different spectrotemporal modulations. We then analyzed the data by applying and comparing several standard machine learning algorithms, including support vector machines, naïve Gaussian models and sparse logistic regression. Here, we briefly describe the stimuli and highlight the properties of the algorithms tested. We present preliminary results, and discuss possible avenues for future work.

[1] Depireux DA, Simon JZ, Klein DJ And Shamma SA. Spectro-Temporal Response Field Characterization With Dynamic Ripples in Ferret Primary Auditory Cortex. *J Neurophysiol: 85: 1220–1234, 2001.*

5 - RACHEL BROWN (McGill University)

"Auditory-motor integration in memory for music"

Rachel Brown, Melissa Trivisonno, Caroline Palmer

Dept. of Psychology, McGill University

Behaviors such as speaking or playing an instrument require the integration of auditory perception with motor production. Less is known about how sensorimotor integration influences performance memory. Auditory memory for performances may depend on auditory experience alone, a combination of auditory and motor experience, and/or mental imagery. We tested how auditory and motor learning influenced subsequent auditory memory for music in two experiments.

Methods

In the first experiment, trained pianists learned novel melodies in four learning conditions: auditory-only (listening only), motor-only (playing without sound), coupled auditory-motor (normal performance), and uncoupled auditory-motor (playing along while hearing a computer-generated recording). Participants practiced each melody three times. At test, pianists listened to computer-generated recordings of target and foil melodies and indicated whether or not they recognized each one. Post-tests examined pianists' auditory and motor imagery abilities. In a similar second experiment, pianists practiced melodies six times each in the learning conditions.

Results

More practice trials resulted in higher recognition scores in all learning conditions. In both experiments, auditory recognition following auditory-motor and auditory-only learning was better than recognition following motor-only learning. In the second experiment, recognition scores following coupled auditory-motor learning were higher than recognition scores following auditory-only learning, suggesting that motor experience aids auditory memory but only with sufficient practice. In both experiments, pianists with high auditory imagery scores had high recognition scores following motor-only learning, suggesting that auditory imagery compensated for missing auditory feedback at learning. In the second experiment, pianists with high motor imagery scores had high recognition scores following auditory-motor learning, possibly because motor imagery helped pianists recognize the melodies they had learned.

Conclusions

Results from the two experiments suggest that motor experience aids auditory memory for music but only when sounds and movements are coupled at learning, and when performers receive sufficient practice with a novel musical piece. Auditory and motor imagery abilities also influence auditory recognition, and may modulate the impact of sensorimotor learning on later recognition memory.

6 - FRANCOIS CHAMPOUX (Université de Montréal)

"Multisensory segregation in proficient vs. non-proficient cochlear implant users"

Champoux F, Lepore F, Gagné JP, Théoret H

Université de Montréal, Montréal, Québec, Canada

It has been shown that visual stimulation can activate cortical regions normally devoted to auditory processing in deaf individuals. This neural activity can persist even when audition is restored through the implantation of a cochlear implant, raising the possibility that cross-modal plasticity can be detrimental to auditory performance in cochlear implant users. To determine the influence of visual information on auditory performance after restoration of hearing in deaf individuals, the ability to segregate conflicting auditory and visual information was assessed in fourteen cochlear implant users with varied degree of expertise and an equal number of participants with normal-hearing matched for gender, age and hearing performance. An auditory speech recognition task was administered in the presence of three incongruent visual stimuli (color-shift, random-dot motion and lip movement). For proficient cochlear implant users, auditory performance was equal to that of controls in the three experimental conditions where visual stimuli were presented simultaneously with auditory information. For non-proficient cochlear implant users, performance did not differ from that of matched controls when the auditory stimulus was paired with a visual stimulus that was color-shifted. However, significant differences were observed between the non-proficient cochlear implant users and their matched controls when the accompanying visual stimuli consisted of a moving random-dot pattern or incongruent lip movements. These findings raise several questions with regards to the rehabilitation of cochlear implant users.

7 - TARIQ DAOUDA (Université de Montréal)

"Extracting Relevent Rhythm Patterns from a Sequence using Liquid Sate Machines"

Reservoir computing, the combination of a recurrent randomly connected neural network and a memoryless learner have proven to be a powerful way of learning online data. In this work we use a particular reservoir computing method called liquid state machine, in wich the reservoir is composed of binary spiking neurones to show that theses methods can also be fitted to extract relevent rhythm patterns from a sequence.

8 - JOHANNA DEVANEY (McGill University)

"Intonation tendencies in solo a cappella vocal performances"

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.

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.

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 is possible to explore which components of these theories are applicable and what, if anything, is missing.

9 - MEGHAN GOODCHILD (McGill University)

“The communication of voice emphasis in harpsichord performance”

Bruno Gingras[1, 2], Meghan Goodchild[2], Pierre-Yves Asselin[2], and Stephen McAdams[2]

1 Department of Computing, Goldsmiths College, University of London, United Kingdom
2 Schulich School of Music and CIRMMT, McGill University, Canada

Piano performance research has shown that performers emphasize a melody by playing its notes louder and earlier than nominally simultaneous notes in other voices (Goebl, 2001; Palmer, 1996). Recently, it was found that organists contrast individual voices mostly through articulation (Gingras, 2006). However, very little is known about the means used by harpsichordists to emphasize specific voices. Since dynamic differentiation is limited on the harpsichord (Penttinen, 2006), we hypothesize that, like organists, harpsichordists must rely on alternative expressive strategies to communicate voice emphasis. This study investigated the means used by harpsichordists to communicate voice-specific melodic emphasis as well as the listeners’ ability to perceive the performers’ intentions. Twelve harpsichordists were asked to perform a short Baroque polyphonic piece by Frescobaldi (1583-1643) on a harpsichord equipped with a MIDI console. Three conditions were tested, each requiring performers to emphasize a particular voice in the piece (soprano, alto, tenor). Performances were matched to the score of the piece using an algorithm developed by Gingras & McAdams (2007). Four parameters were analyzed: velocity, note onset asynchrony, timing deviations, and articulation. Mean onset asynchronies were much larger than those observed in organ or piano performance, averaging more than 100 ms between outer voices. However, asynchronies did not vary significantly between conditions, suggesting that they do not play a major role in communicating voice emphasis. On average, notes belonging to the upper three voices were struck with a higher velocity and played with a more detached articulation when they were emphasized. Although timing deviation patterns were globally similar across all conditions, we observed local differences that corresponded to passages in which a specific melodic gesture was accentuated by means of ritenuto, a short tempo deceleration. In a follow-up study, twenty musicians were invited to listen to a subset of these performances and rate continuously the relative salience of the three upper voices. The results indicate that while listeners’ perception of relative salience was dependent on the melodic activity of the voices as notated in the score, it was for the most part unaffected by the expressive strategies employed by performers.

10 - NICHOLAS E.V. FOSTER (McGill University)

"Grey matter in STG predicts music task performance"

Nicholas E.V. Foster (1,2), Robert J. Zatorre (1,2)

(1) Montreal Neurological Institute, McGill University
(2) BRAMS Laboratory, Montreal, Canada

Musicianship is a complex and commonly practiced skill. It offers a convenient model to study neural factors promoting and arising from long term learning. Several studies found differences in brain anatomy between musicians and non-musicians, particularly in auditory temporal areas. Two important unresolved questions about such effects are 1) whether these anatomical markers can predict behavior (i.e. performance on tasks of musical skill), and 2) to what extent anatomical differences are consequences of musical training rather than pre-existing, selective factors for musical success. We recruited 69 subjects with musical experience ranging from none to university level. Subjects were tested on several same-different musical discrimination tasks, and they received a T1 MRI scan. We used voxel based morphometry to find where neuroanatomy varied with training or musical task performance. The most significant effect was a greater grey matter concentration in right posterior superior temporal gyrus, associated with greater musical training and performance on the musical tasks. The greatest behavioral correlation at this location was for the Transposed Melody task, which requires precise encoding of pitch intervals. Musical training did not entirely account for the effect; when training was modeled out, grey matter still predicted Transposed Melody performance. The results demonstrate that neuroanatomy can predict a facet of musical ability, even independently of musical training.

11 - SYNTHIA GUIMOND (Université de Montréal)

« Indices neurophysiologiques du maintien de sons en mémoire à court terme auditive »

Synthia Guimond, François Vachon, Christine Lefebvre, Stephan Grimault & Pierre Jolicœur

Département de psychologie, CERNEC, BRAMS, Université de Montréal

Nous étudions les composantes de potentiels reliés aux événements (PRE) lors de la rétention en mémoire à court terme (MCT) auditive. Lefebvre et al. (2008) montrent une augmentation de l'activité négative aux électrodes fronto-centrales lorsque la longueur des séquences de sons variant en fréquence augmente. Afin de déterminer si cette activité reflète effectivement la charge en MCT auditive et non la rétention du contour mélodique d'une séquence, nous varions la charge mnésique sans utiliser de séquences de sons. On observe, durant la rétention, une augmentation marquée de l'activité négative aux électrodes fronto-centrales avec la charge mnésique. Ces résultats confirment qu'il existe une composante des PRE qui est spécifiquement reliée à la rétention de la fréquence de sons en MCT auditive. Ils suggèrent aussi que l'activation observée par Lefebvre et al. (2008) reflétait la rétention de la fréquence des sons en MCT et non pas celle du contour mélodique des séquences.

12 - PHILIPPE HAMEL (Université de Montréal)

"Automatic identification of instrument classes in polyphonic and poly instrument audio"

We present a model for automatic identification of instrument classes in polyphonic and poly instrument audio. The goal is to be able to identify which categories of instrument (Strings, woodwind, Guitar, Piano, etc.) are present in a given audio example. We use a machine learning approach to solve this task. We constructed a system to generate a large database of musically relevant poly instrument audio. Our database is generated from 346 different instruments classified in 8 categories. Musical audio examples are generated by mixing multi-track MIDI files with hundreds of instrument combinations. We compare two different classifier: a Support Vector Machine (SVM) and a Multilayer Perceptron (MLP). We show that a single hidden layer MLP has a slightly lower but comparable performance to a SVM for this task, but require significantly less time to train. Both these models achieve a good generalization performance on out-of-sample instruments.

13 - ZAKIA HAMMAL (Université de Montréal)

"Spatial Frequencies Mediating Music Reading"

Zakia Hammal, Frédéric Gosselin, Isabelle Peretz, Sylvie Hébert

The purpose of this study was to examine Spatial Frequencies (SFs) mediating music reading. The SFs Bubbles technique, which has recently been used to identify spatial frequencies mediating face identification (Willenbockel et al., 2009), was used. The main advantage to use the SFs Bubbles technique is to derive the precise SFs that are mainly responsible to successfully perform the undergoing task (in our case, music sight-reading) and to minimize the risk that participants adapt to a predictable stimulus manipulation. The SFs Bubbles technique consists in randomly sampling multiple SFs simultaneously on each trial, using a sampling vector. A set of 70 piano excerpts selected from the piano repertoire was used. The excerpts were about one- to two- phrases long and were displayed as 1024x1024 gray scale images shown on a computer screen located on the grand piano, in front of the participant. Four pianists (one male and three females with normal or corrected-to-normal vision), enrolled in a performance program at the Faculté de Musique of Université de Montréal, took part in the experiment. They were instructed to play each excerpt as accurately as possible. Each participant performed between three to seven blocks of 100 trials each with breaks between blocks. Percentage of correctly produced pitches (not rhythm) was used as a performance measure. More specifically, performance for a given excerpt was deemed correct if 75% of the pitches over the whole excerpt were produced correctly. To find out which SFs drove the participants' correct responses, a multiple linear regression was performed, and consisted in summing all sampling vectors weighted by the corresponding responses. The resulting vector was then Z-scored for each participant and a statistical test (Chauvin et al., 2005) was used to determine a threshold that selected the diagnostic SFs for accurate performance. Preliminary results obtained from the four participants revealed that high frequencies (SF> 15 cycles per degree of visual angle) preferentially mediates music reading (compared to 3 to 12 cycles per degree of visual angle for text reading). Further analyses remain to be done to refine these results.

References

Willenbockel, V., Fiset, D., Chauvin, A., Blais, C. Arguin, M., Tanaka, J., Bub, D. & Gosselin, F. (in press). Does Face Inversion Change Spatial Frequency Tuning? Journal of Experimental Psychology: Human Perception and Performance.
Chauvin, A., Worsley, K. J., Schyns, P. G., Arguin, M., & Gosselin, F. (2005). Accurate statistical tests for smooth classification images. Journal of Vision, 5 (9), 659-667.

14 - PASCALE LIDJI (McGill University)

"Speech and Song Perception and Production: A TMS Study"

Pascale Lidji[†‡*], Benjamin Stahl[‡], Frédérique Lessard[‡], Hugo Théorêt [‡], & Isabelle Peretz[‡]

[†] McGill University, Montréal, Canada
[‡] Université de Montréal, Canada
* Fonds de la recherche scientifique – FNRS , Belgium

Background
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 phenomenon has become well-known under the label of "mirror neurons". In humans, a similar motor activation seems to be present during speech perception (e.g. Watkins et al., 2003). However, it remains unclear whether such a system also exists for singing.

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) or audio-visual.

Results
Preliminary results suggest that both speech production and perception increase the excitability of the left motor cortex, whereas no clear lateralization has been found for singing (contrary to what was reported by Sparing et al., 2007).

15 - JANEEN LOEHR (McGill University)

"Effects of auditory and motor feedback on musical synchronization"

Janeen Loehr and Caroline Palmer

McGill University, Montreal, Quebec, Canada

Synchronization of actions with auditory events may be enhanced by auditory feedback or by movement-related (kinematic) feedback. We address whether musicians' temporal synchronization abilities are affected by the presence of auditory feedback or movement-related feedback. Seventeen pianists performed melodies with a metronome. Auditory and motor feedback were manipulated within melodies so that every other tone was produced with: auditory and motor feedback present (normal conditions), movement only (auditory feedback removed), auditory feedback only (computer-produced tones), or neither (empty interval). Temporal synchronization was affected most by auditory feedback of tones, but also by movement feedback. Finger motion trajectories showed the reverse pattern: movement feedback altered the trajectories of upcoming tones but auditory feedback had little impact. Thus, auditory and motor feedback both influence temporal synchronization performance; auditory feedback has greater impact on timing accuracy than motor feedback, and motor feedback changes the motion with which upcoming tones are produced.

16 - FRANCOIS MAILLET (Université de Montréal)

“Playlist generation by learning song similarity from radio station playlists”

The celestial jukebox is becoming a reality. Not only are personal music collections growing exponentially, but online music streaming services like Spotify or Last.fm are getting closer and closer to making all the music that has ever been made instantly available. In this context, a combination of personalized recommendation technology and automatic playlist generation will become a key component of music discovery.

This work's focus is on providing a basis on which to do personalized playlist generation. We use playlists from professional radio stations to learn a similarity function that takes audio files as input and outputs the probability of those two audio files being played one after the other in a playlist. By using radio station playlists, we have the advantage of having a virtually unlimited amount of training data while at the same time being able to generalize the application of the model to any song for which we have the audio file.

17 - ANDRÉANE McNALLY-GAGNON (Université de Montréal)

“When songs get stuck in your head: A study of obsessive songs in musicians and non-musicians”

McNally-Gagnon, Andréane; Hébert, Sylvie; Peretz, Isabelle

Université de Montréal, Canada

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
This research was funded by the Natural Sciences and Engineering Research Council of Canada.

18 - ALINE MOUSSARD (Université de Montréal)

"Music as a mnemonic in Alzheimer's disease"

Aline Moussard, Isabelle Peretz, Emmanuel Bigand

Introduction
Can music serve as a support for memory? Numerous studies have discussed this question in verbal memory, assessing effects of music on retrieval of texts, which are sung or spoken. Results highlighted several variables that modulate performance, such as familiarity with the musical material and learning conditions. These two factors will be tested in this study, with two populations which have not bean investigated yet, with this paradigm: normal elderly and suffering from Alzheimer's disease. The aim of this study is to determine the better conditions to help learning using music for these populations.

Method
Participants have to learn unfamiliar texts with an adaptative procedure (i. e., line per line). These texts are either spoken or sung on a familiar or unfamiliar melody. Moreover, two learning conditions are used: in the first condition, the participant has to listen and repeat the line after the model; in the second, he hears the model again during his production, so he repeats the line in unison with it.

Conclusion
This work presents two major implications, gathering knowledge about normal and pathologic memory functioning and more particularly about the link between memory and musical cognition, and offering new clinical prospects for memory rehabilitation.

19 - MELANIE A. PROVOST (Université de Montréal)

"The Many Faces of the Prevalence of Congenital Amusia"

Mélanie A. Provost[1,2], Isabelle Peretz[1,2], Nathalie Gosselin[1,2] & Benoit A. Bacon[3]

1. International Laboratory for BRAin, Music and Sound Research (BRAMS), Montréal
2. Département de Psychologie, Université de Montréal, Montréal
3. Department of Psychology, Bishop's University (Sherbrooke)

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, a validated test for the detection congenital amusia (Peretz et al., 2008), as this test uses unfamiliar melodies, presents no ceiling effect and includes a control (rhythm) condition.

1118 participants aged between 18 and 40, not preselected for their musical abilities, and who were currently completing or had completed a Bachelor's degree, were asked to fill out the Online 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: It helps differentiate between congenital amusics, who display a profile of pitch difficulties with spared rhythmic abilities, from participants whose difficulties are the result of a more generalized music problem or of another deficit (ex: ADHD), who would fail on all three subtests.

The criteria used to determine problematic results were scores on each subtest that fell below the 2.3 percentile (equivalent to -2SD in a two-tailed normal distribution), similar to Peretz et al., 2003. Furthermore, amusic participants were hypothesized to 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 preliminary prevalence was determined by the proportion of participants that scored below this cutoff on each subtest.

A preliminary prevalence of 7.3% was established. However, there appears to be 4 distinct patterns of performance on the Online test. First, there are participants (0.6%) who show poor performance on both pitch components ("Scale" and "Out-of-Key"), who fit the hypothesized pattern of performance for congenital amusia. However, there also seems to be equivalent proportions of participants who fail only one subtest: "Scale" (2.4%) and "Out-of-Key" (2.2%), who constitute participants also presenting pitch difficulties, as well as "Out-of-Time" (2.1%), the latter being considered possibly congenitally arythmic. This would indicate that 5.2% of the participants present some form of pitch difficulties, whereas 2.1% show only rhythm impairments. These four patterns of performance need to be explored further in order to clearly define what constitutes a congenitally amusic person. This is primordial if an exact prevalence rate of the disorder is to be established.

References:

Peretz, I. & Hyde, K.L. (2003). What is specific to music processing? Insights from Congenital Amusia. Trends in Cognitive Sciences, 7(8). 362-367

Kalmus, H. & Fry, D.B. (1980). On Tune Deafness (Dysmelodia): Frequency, Development, Genetics and Musical Background. Annals of Human Genetics, 43. 369-382

Peretz, I.; Gosselin, N.; Tillman, B.; Cuddy, L.L.; Gagnon, B.; Trimmer, C.G.; Paquette, S. & Bouchard, B. (2008). On-Line Identification of Congenital Amusia. Music Perception, 25(4). 331-343

20 - VEERLE SIMOENS (Université de Montréal)

"Psychosocial stress attenuates general sound processing and duration change detection"

Simoens VL, Istók E, Hyttinen S, Hirvonen A, Näätänen R, Tervaniemi M.

An EEG-compatible adaptation of the Trier Social Stress Test was developed to induce psychosocial stress in healthy subjects while investigating their auditory processing of unattended sounds and salivary levels of the stress hormone cortisol. The mismatch negativity (MMN) and N1/P2 were assessed using a multi-feature paradigm, while subjects were attending to visual tasks with either high or low attentional workload.
Only the responses to duration change were affected by the stress manipulation. Cortisol levels during stress were inversely related to the MMN amplitudes of duration deviants. During anticipatory stress, responses to the standard tones (general sound processing) increased, but their amplitude was not correlated with cortisol levels.
We found that psychosocial stressor anticipation attenuates both general and deviance-specific sound processing, suggesting that cortisol interferes with cortical memory trace formation.

21 - MICHAEL SPILKA (Concordia University)

"Imitation of complex bi-manual gestures: the impact of musical experience"

Michael Spilka, Christopher J. Steele and Virginia B. Penhune*

Department of Psychology, Concordia University

Imitation plays a crucial role in the learning of many complex motor skills, and anecdotal evidence suggests that it is important for learning of musical skills. Recent behavioural and neurophysiological evidence suggests that the ability to imitate is influenced by prior experience. To test the impact of musical training on motor imitation, musicians and non-musicians were tested on their ability to imitate videoclips of simple and complex two-handed gestures taken from American Sign Language. Subjects viewed a set of 30 gestures, one at a time and imitated them immediately after presentation. Subjects' imitations were videotaped and scored off-line. Musicians were currently practicing, with an average of 12 years of experience. Non-musicians were selected to have less than three years of musical training or experience (Avg = 1.2). Performance was assessed by raters who scored the accuracy of the imitation separately for the arm, hand and finger components of the movement. Accuracy was rated on a 5-point scale (1=unrecognizable; 5=exact imitation). A global accuracy score was calculated by summing the three scales. Time to move (RT) and response duration compared to the model were also assessed. Imitation accuracy was scored blind to subject group, and inter-rater reliability for global accuracy was excellent (r=.96). Results show that musicians and non-musicians performed similarly for the gross component of the gestures (arms), but that musicians performed better than non-musicians for the fine-motor components (hands and fingers). These findings support the view that the ability to imitate is influenced by past experience and support generalist theories of motor imitation. These theories explain imitation in terms of links between perceptual and motor representations of actions that become strengthened through experience. It is possible that musical training contributes to the ability to imitate manual gestures by influencing the personal action repertoire of musicians.

22 - ALEXANDRA TREMBLAY-CHAMPOUX (Université de Montréal)

“A different look on poor singers: when amusics sing in unison”

A. Tremblay-Champoux1, I. Peretz1, S. Dalla Bella2, M-A. Lebrun1

1 International Laboratory for Brain, Music and Sound (BRAMS), Université de Montréal, Montréal, QC, Canada
2 Music Performance and Brain Lab, University of Finance and Management, Warsaw, Poland.

Poor-pitch singing is often seen as a consequence of a poor perception. However, new research suggests that poor singing may result from other factors than perception. Pfordresher and Brown (2007) found poor-pitch singers in a sample of individuals who do not exhibit any difficulties in pitch discrimination (1). Moreover, people who are impaired in pitch perception, namely amusics, are able to produce two notes in the right direction even though they cannot tell if the second note was higher or lower than the first (2). Similarly, some amusics 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 the current 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.

One group of amusics (n=11) and matched controls (n=11) sang a well-known song with lyrics and on the 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 (2007,2009).

The analysis showed that for melodies sung on lyrics, amusics were impaired on the pitch dimension showing more pitch interval errors and contour errors then controls. When singing on the syllable /la/, more than half of the group of amusics failed to sing the complete rendition. Nevertheless, two amusics individuals showed performance as accurately as controls, despite their perceptual deficit. Unison singing did not improve performance of amusics as compared to when they sang alone on lyrics. In addition, all group succeeded to sing at least 80% of the rendition when singing with the model on the syllable /la/.

The results of this study suggest that choir singing can be helpful to produce 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 on the syllable /la/ could also be due to entrainment. Moreover, the two exceptions observed in the group of amusics, suggest evidence for the existence of separate neural pathways for auditory perception and action. More research will be done to evaluate theses possibilities.

References

(1) Pfordresher, P.Q. & Brown, S. (2007) Poor-pitch singing in the absence of tone-deafness, Music Perception, 25, 95-115. (2)Loui P, Gunther F, Mathys C, Schlaug G. (2008) Action-perception mismatch in Tone-Deafness. Current Biology, 18, 331-332. (3) Dalla Bella, S., Giguère, J-F., & Peretz, I. (in press) Singing in congenital amusia. Journal of The Acoustical Society of America. (4) Dalla Bella, S., Giguère, J-F., & Peretz, I. (2007) Singing proficiency in the general population, Journal of The Acoustical Society of America, 121, 1192-1189.

23 - FRANÇOIS VACHON (Université de Montréal)

"Informative tones receive enhanced processing: Electrophysiological evidence from the auditory P2 event-related potential"

François Vachon, Christine Lefebvre, Stephan Grimault, Synthia Guimond, & Pierre Jolicœur

Département de psychologie, CERNEC, BRAMS, Université de Montréal

To evaluate whether auditory processing is influenced by the temporal expectations ensuing from the context in which sounds are embedded, we examined event-related potential (ERPs) elicited during an auditory short-term memory task. On each trial, an auditory sequence composed of one, three, or five tones varying in pitch was presented before and after a 2-sec retention interval. Participants had to determine whether the two sequences were identical or not. To manipulate temporal uncertainty, the sequence length was either kept constant within each block of trials (predictable) or varied randomly from trial to trial (unpredictable). We observed enhanced P2 responses to 'uncertain' relative to 'certain' tones: When sequence length was unpredictable, the amplitude of the P2 component was larger for tones that provided information about forthcoming ones: the second tone of the 3-tone sequences and the second and fourth tones of the 5-tone sequences. No modulation of the P2 was observed when sequence length was perfectly predictable (blocked trials; or in the second sequence in each trial). These results suggest that tones that convey more information about the temporal structure of tone sequences receive more processing than less informative tones and that such effects take place relatively early in auditory processing.

24 - SEAN WOOD (Université de Montréal)

"Unsupervised Machine Learning Approaches to Polyphonic Music Analysis"

Musical instruments typically produce complex tones consisting of a set of partial frequencies including a fundamental frequency and a series of harmonic frequencies. Automatic pitch and timbre analysis of monophonic music involves determining the fundamental frequency and spectral envelope of a complex tone in isolation. These problems are well understood, with several commercial solutions available. Automatic pitch and timbre analysis of polyphonic audio is an active area of research, having recently been addressed using various unsupervised machine learning algorithms including Non-negative Matrix Factorization (NMF) and Shift Invariant Sparse Coding (SISC). These algorithms learn a set of basis vectors such that each input vector can be approximated as a sparse linear combination of the basis vectors. We present a comparison of these algorithms when applied to polyphonic music, and discuss difficulties involving destructive interference between sources.

25 – JEAN MARY ZARATE (McGill University)

“Brain regions involved in coarse and fine vocal pitch regulation”

Jean Mary Zarate and Robert J. Zatorre

Montreal Neurological Institute, McGill University, International Laboratory for Brain, Music, and Sound (BRAMS), Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT)

In our previous study, we found that singers displayed activity within a singing network including the anterior cingulate and auditory cortices during vocal pitch tasks. Here, we tested experienced singers to investigate mechanisms underlying fine vocal pitch regulation. Singers underwent fMRI scanning while singing a note with either normal or pitch-shifted auditory feedback; in pitch-shifted trials, subjects either ignored or compensated for small or large pitch-shifts (25 or 200 cents). Pilot studies showed that singers were less able to ignore the 25c- than the 200c-shift due to a prepotent pitch-shift response, whereas they suppressed this response with larger shifts. Thus, we hypothesized that different mechanisms may be involved in processing minute vocal-pitch corrections as compared to large ones. For all pitch-shifted tasks compared to simple singing, we found significant activity in auditory cortices, as expected, along with right frontal regions. In addition, both compensate tasks also recruited the insula, anterior cingulate cortex, and intraparietal sulcus, as seen in our previous findings. More auditory cortex activity was seen in the compensate-200c task than in the compensate-25c task, but there were no significant differences in auditory activity between ignore-200c and -25c tasks. Enhanced auditory activity for the compensate-200c task may be due to increased auditory monitoring to ensure that the vocal output has been fully corrected for the pitch shift. We hypothesize that compensating for a large pitch shift is under greater volitional control than for smaller shifts, and that the differential auditory cortex activity reflects this top-down influence.