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CONFERENCE REPORT

Report of the Summer School of Pitch, Music and Associated Pathologies (Lyon, July 9–11, 2014)

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The summer school on Pitch, Music and Associated Pathologies was held for 2½ days, July 9–11, 2014, at the Valpré conference center in Lyon. Fifty-five researchers and students from universities and research institutions from 11 countries participated in it. The summer school was organized in 2 larger sessions: One dealing with pitch and associated pathologies and covering topics from general pitch processing to various topics of pitch processing with cochlear implants. The other session dealt with music and associated pathologies, covering topics from congenital amusia to music processing in cochlear implants. Altogether, the organizers brought together 11 speakers covering these yet connected topics. The goal of this summer school

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was not only to pass on knowledge but also to connect young scientists with each other and with established researchers in this field in the hope of fostering new collaborations and networks. To facilitate this, the attendants were given the chance to present their own research in the form of a poster. Twenty-five posters were presented in the summer school, and the students were given numerous chances to discuss their own research with the speakers.

Keywords: summer school, pitch perception, music perception, cochlear implants, congenital amusia

The summer school on Pitch, Music and Associated Pathologies was held for two and a half days, July 9–11, 2014, at the Valpré conference center in Lyon. The summer school was organized thanks to the support of the Centre Lyonnais d'Acoustic (CeLyA), the Lyon Neuroscience Research Center (CRNL), and the Centre de Recherche Cerveau et Cognition (CerCo).

There were 55 researchers and students from universities and research institutions from 11 countries who participated in it. The summer school was organized in two larger sessions: One dealing with pitch and associated pathologies and covering topics from general pitch processing to various topics of pitch processing with cochlear implants. The other session dealt with music and associated pathologies, covering topics from congenital amusia to music processing in cochlear implants. Altogether, the three organizers, Pascal Barone, Anne Caclin, and Nicolas Grimault, brought together 11 speakers covering these diverse yet connected topics. The goal of this summer school was not only to pass on knowledge but also to connect young scientists with each other and with established researchers in this field in the hope of fostering new collaborations and networks. To facilitate this, the attendants were given the chance to present their own research in the form of a poster. Twenty-five posters were presented in the summer school, and the students were given numerous chances to discuss their own research with the speakers.

Pitch and Associated Pathologies

The first session was opened by Dr. Daniel Pressnitzer, researcher at the École normale supérieure, with a comprehensive introduction to the topic of "perception of pitch." He started with the composition of sounds and culminated in how the brain perceives changes in pitch. The standard definition of pitch as *an attribute of sounds that allows them to be ordered from high to low* fails to elucidate it as a unique dimension of sound different from loudness as well as its role in perception of periodicity and auditory scene analysis.

An interesting question that arises given the complicated physics of sounds is how the brain codes for pitch. The basilar membrane in the cochlea contains hair cells that respond to specific frequencies of incoming sounds. These receptors are arranged tonotopically on the membrane with high frequencies activating the hair cells near the base and progressively lower frequencies activating cells closer to the apex, arranged in a coil. Several models have been proposed to explain how basilar membrane activity translates into pitch coding.

In terms of neural data, timing cues are extracted and subsequently converted to rate code, which seems to be sufficient for pitch perception. Although subcortical areas have been implicated in these conversions, Heschl's gyrus in the cortex is the candidate for being the pitch center. Numerous psychoacoustics studies also shed light on pitch perception, demonstrating a robust memory trace for pitch as well as the difference in pitch perception abilities between patients with cochlear implants and normal hearing (NH) subjects. These studies also shed light on what the mechanism of pitch coding might be by supporting or weakening models/theories of pitch coding.

Dr. Pressnitzer concluded his talk by demonstrating how changes in pitch are perceived when the context is changed. In a sequence of tones or a melody, perception of changes in pitch is heavily influenced by the context, more specifically the relative characteristics of the preceding tone. He highlighted the need for further research to resolve the interesting, but unresolved, questions about pitch perception from acoustics to integration with other sensory perception and modalities.

The second talk of the first session was delivered by Christophe Micheyl, senior researcher at Starkey Hearing Research Center in Berkeley, California. His talk focused on the interplay of cochlear damage with pitch discrimination and auditory scene analysis. Micheyl pointed out the detrimental effects of hearing loss on quality of life. In particular, impaired pitch perception crucially affects the ability for selective listening.

Experimental tasks such as pitch discrimination, matching, and fundamental frequency (F0) tracking have widely been used to assess individual sensitivity to pitch modulations. A large body of work has unanimously reported enhanced perceptive thresholds as a function of hearing loss and/or increased age. As shown by notched-noise measurements, the broadening of auditory filters prevents the resolution of spectral details in the periphery. In discussing these results, Micheyl emphasized the high variability of individual performance, as well as the need for precise age-matching between hearing-impaired subjects and control groups.

Traditional approaches to pitch coding, exploiting either place of maximal excitation or phase-locking, come with their respective set of deficits. As the saturation level of auditory nerves sets a limit to place coding, this method might benefit from the selective stimulation of unsaturated fibers. On the other hand, more recent research suggests the integration of both spatial and temporal information based on patterns of neural response latencies. Such a spatial–temporal code may compute phase lags across auditory channels. However, timing information obtained from interchannel calculations appears to be highly level-dependent.

Chris James's lecture titled "Cochlear implants and sound coding: So what about pitch perception" was the third lecture in this session. He started his talk with an explanation of cochlear implant (CI) systems and the problems that CI users have in understanding the sensation of pitches (place pitch and temporal pitch). It seems that although CIs are successful neural prostheses to date, users have much greater difficulty than NH listeners in recognizing speech under realistic situations such as speech presented in competition with other talkers, for example, at a cocktail party or a restaurant where background noise is always present, and recognition of music and tonal languages.

In contemporary CI coding strategies, loudness can be encoded through amplitude or duration of pulses that are delivered to the electrodes. It is easier to have constant timing for current pulses. This leads to poor temporal pitch sensation in CI users, which may improve through encoding with pulse rate or modulation rate. For temporal pitch coding via pulse rate, there is an upper limit or saturation level in CI users, which is about 300 pulses per second. This limitation discourages attempts to improve CI coding strategies by encoding temporal fine structure. Place pitch coding is also limited to the number of electrodes in current CI systems, which can vary between 12 to 22 electrodes. One possible way of improving the number of electrodes is using virtual channels.

A new coding strategy for CIs, named STEP (Spectrally and Temporally Enhanced Processing), with the aim of improving the perception of prosodic information was introduced. This strategy uses a dual filter-bank approach with a bank of narrow filters for spectral and a bank of parallel wide filters for temporal envelopes. Spectral filters allow better extraction of the low harmonics of voiced signals, and temporal filters increase modulation bandwidth to better represent periodicity in the extracted temporal envelopes. Voice intonation discrimination and pitch ranking tasks were evaluated for this strategy compared with ACE (Advanced Combined Encoder), another speech-processing strategy. Overall, this strategy increased pitch ranking scores compared with ACE. The performance of subjects was better than or similar to ACE on the intonation discrimination task.

In conclusion, several new CI strategies targeting at improved F0 and/or music coding have been proposed in recent years, but there are still many unresolved issues that warrant further research.

The fourth lecture on pitch and associated pathologies was given by Olivier Macherey, who is currently leading a research group in Marseille working on electrical hearing. The name of his talk was “Limitation on pitch discrimination by cochlear implant listeners.” Even though his talk was a continuation of the topic of pitch in impaired hearing and in cochlear implants, he presented various new methods and angles on the topic. Macherey opened his talk with an explanation of the importance of pitch for cochlear implant patients (CIp), namely, that a study by Zeng, Rebscher, Harrison, Sun, & Feng (2008) found that for speech perception in noise, CI patients needed a positive signal-to-noise ratio of about 10 dB, while NH participants performed well when the noise was about 7 dB louder than the speech stimuli. For tone perception, CIp performed significantly worse compared with NH participants when reorganizing melodies and tones. Macherey proceeded to show examples of place pitch and temporal pitch in CIp, and raised the question whether using one or the other may result in different pitch percepts. A study from 1983 by Tong and colleagues supports this idea (Tong, Dowell, Blamey, & Clark, 1983). Using a multidimensional scaling paradigm, stimuli varied in electrode position (place theory) and rate of stimulation (time theory). The CIp perceived these two types of stimuli as two independent dimensions. Further research found no advantage in combining place or temporal changes (McKay, McDermott, Carlyon, 2000). Also, subjects may arbitrarily judge the temporal and place cues differently throughout one experiment. Melody recognition seems to engage both types of cues (Moore & Rosen, 1979; Swanson, Dawson, & Mcdemott, 2009).

After a short introduction to pitch perception in NH individuals, Macherey focused on place and temporal pitch limitations in CIp. He explained that the range of place pitch is not directly constrained by the limited number of electrodes used in the implant and that creating so-called “virtual channels” (for an explanation see Donaldson, Kreft, & Litvak, 2005) between electrodes and beyond an electrode cluster might improve the hindered frequency-to-place mapping. He also reported that temporal pitch is limited to rates below about 300 to 500 pulses per second (Macherey, Deeks, & Carlyon, 2011), although this limit is highly influenced by individual variability across patients. Therefore, increasing the pulse rate above this limit will not improve pitch perception. Another potentially important problem of individual differences between patients is the survival of neurons. Different patterns of electrode variability might stem from this. Although stimulating the apex of the cochlea seems to increase the upper limit of temporal pitch, discrimination abilities at high rates remain low (Macherey et al., 2011). Macherey closed his talk by raising controversial questions to make the audience reflect on, and think about the presented material (e.g., how can we transfer knowledge of resolved harmonics and pure tone perception in NH to CIp).

The next talk in this session was given by Dan Gnansia, who is head of the Scientific and Clinical Research Department in the French cochlear implants company Neurelec. Gnansia focused on the difficulties in pitch perception by CI users, starting with a brief introduction on the mechanisms of spatiotemporal sound encoding in the NH auditory system, reiterating some of the facts from the first talk of this session and adding new information: The frequency of the incoming acoustic signal is encoded by the place of excitation along the basilar membrane (BM), known as spatial coding or tonotopy. Data from Sellick, Patuzzi, & Johnstone (1982) show how the BM is sharply tuned for the characteristic frequencies distributed along the BM from basal to apical locations. The bandpass filters that describe the frequency selectivity of each part along the BM are referred to as auditory filters.

The output of these filters is a group of narrow band signals that can be characterized by their envelope and temporal fine structure (TFS). The tonotopy of the BM encodes the envelope fluctuations (Shannon, 1985; Smith, Delgutte, & Oxenham, 2002), while the TFS is encoded in the phase-locking mechanism of the spiral ganglion cells (Johnson, 1980; Joris, Schreiner, & Rees, 2004; Palmer & Russell, 1986).

Gnansia then presented the limitations of current CI coding strategies. CI pulse stimuli do not account for any temporal coding, as only the tonotopic representation is encoded in a typical coding strategy. Moreover, due to the channel interaction between electrodes, the overall perceived frequency resolution is poor compared with NH listeners (Friesen, Shannon, Baskent, & Wang, 2001). Despite these limitations, CI users are still able to understand speech rather well in quiet conditions (Shannon, Zeng, Kamath, Wygonski, & Ekelid, 1995); however, in situations where there is a competitive talker or background noise, their performance drops significantly (Fu and Nogaki, 2005; Nelson, Jin, Carney, & Nelson, 2003). In addition, pitch perception is also highly degraded for CI listeners.

Possible methods to improve the frequency resolution in current CI coding strategies are *current steering* and *current focusing*. In *current steering*, two neighboring electrodes are stimulated using different current amplitudes to direct, or *steer*, the current toward an intermediate neural population that could not be previously stimulated with standard techniques. As for *current focusing*, the current spread is limited via stimulating the two neighbors of a target electrode with reverse polarity current pulses of a smaller amplitude. Results that show clear benefits from both techniques are lacking however.

To encode the TFS, one way is to extract the F0 from the input signal and use that to amplitude modulate the stimulating pulse train. However, extracting F0 from the signal is challenging. Another technique is to detect zero crossings of the acoustic signal and to use this timing information to encode the pulse train modulating the envelope. Unfortunately, there are also no clear data that show a real advantage to those strategies so far.

Thus, the ultimate goal in CI research is still to conceive of a strategy that conveys good pitch and fine temporal structure information.

Monita Chatterjee, working at the Auditory Prostheses & Perceptual Lab, Boys Town National Research Hospital, Omaha, closed the session dedicated to pitch and associated pathologies. She proposed empirical data on how children with cochlear implants process pitch, prosody, and lexical tones. Chatterjee introduced her topic through evidence-based studies on how children discriminate F0 cues, underlining that CI children have poorer F0 discrimination compared with their NH peers.

Pointing out the importance of pitch discrimination in language communication and acquisition, she showed a series of studies on pitch-driven aspects of speech perception and production, for which voice pitch inflections are the dominant acoustic cue. The key point of this presentation was to understand whether CI children, who have poor ability in pitch perception, can use other acoustical information to compensate their difficulty with F0 discrimination compared with their NH peers.

In a question–statement identification task, results indicated that NH children mostly rely on F0 cues, ignoring other acoustic cues such as intensity and duration for speech intonation recognition, whereas CI children rely less on F0 cues and more on the other cues. In a lexical tone recognition task with Mandarin-speaking CI children, results indicated that NH children rely primarily on F0 cues for lexical tone recognition, whereas Mandarin-speaking CI children rely less on F0 cues and more on duration.

To date, fundamental frequency perception, which conveys important cues for speech perception, remains a problem in cochlear implant users. The data presented by Monita Chatterjee suggest that despite their greater difficulty with F0 discrimination, children with cochlear implants can compensate by using other acoustic cues in everyday communication. This may have important implications for aural rehabilitation of children with cochlear implants.

Music and Associated Pathologies

The second session dealt with music and associated pathologies. The first speaker was Marion Cousineau, working at the International Laboratory for Brain, Music and Sound Research in Montreal, who presented some of her work on congenital amusia.

She defined congenital amusia as *an unexpected failure to develop normal musical capacity despite normal intelligence and normal language*. Symptoms can range from an inability to recognize familiar songs without lyrics to an inability to detect incorrect notes, to difficulties in learning how to play an instrument. It is not caused by insufficient exposure to music, a hearing deficiency, brain damage, or intellectual impairment (Ayotte, Peretz, & Hyde, 2002). About 4% of the general population is said to be affected (Kalmus & Fry, 1980).

Congenital amusia is diagnosed with the Montreal Battery of Evaluation of Amusia (Peretz, Champod, & Hyde, 2003), which consists of six subtests, assessing melodic and temporal organization as well as musical memory.

The behavioral deficits of amusics have so far been found in melody and contour perception (Peretz et al., 2003), singing in tune, (Dalla Bella, Giquere, & Peretz, 2009), memory for pitch (Tillmann, Schulze, & Foxton, 2009; Williamson, McDonald, Deutsch, Griffiths, & Stewart, 2010), and dissonance perception (Ayotte et al., 2002).

The underlying cause of this disorder has been hypothesized to be a fine-grained pitch processing deficit (Ayotte et al., 2002; Hyde & Peretz, 2004), a working memory deficit specific to nonverbal sequences (Gosselin, Jolicœur, & Peretz, 2009; Tillmann et al., 2009; Williamson & Stewart, 2010), or a learning disability with respect to statistical learning (Loui & Schlaug, 2012; Peretz, Saffran, Schön, & Gosselin, 2012).

On the neurological level, structural neuroimaging has shown differences in the inferior frontal and superior temporal cortex (Hyde, Peretz, & Zatorre, 2008; Hyde, Zatorre, Griffiths, Lerch, & Peretz, 2006), while diffusion tensor imaging has shown reduced structural connectivity in the right branch of the arcuate fasciculus (Loui & Schlaug, 2009), and a reduction of the activation in the right inferior frontal cortex has been shown with functional MRI (Hyde, Zatorre, & Peretz, 2010). And lately, Albouy et al. (2013) showed differences in the auditory cortex using magnetoencephalography.

After this general introduction to congenital amusia, two of Dr. Cousineau's studies were discussed: One about pitch perception and one about consonance perception.

Three tasks were employed for the pitch perception study: One determining the pitch threshold of amusics, one assessing spectral resolution, and one assessing temporal resolution. Spectral resolution and temporal resolution are found to be normal in amusics, while poorer pitch thresholds are found. This is taken to point to a deficit in the processing of fine specto-temporal cues in resolved harmonics. The results of the experiments also indicate that peripheral auditory coding is intact and that some of the different findings concerning pitch perception thresholds for amusics in the literature may be explained by the different tasks that were utilized.

The second study assessed congenital amusics' perception of consonance and dissonance using a perception and rating paradigm. It shows that amusics have an abnormal perception of dissonance, and that they show a different rating pattern than controls and that they have an inconsistent rating pattern (Cousineau, McDermott, & Peretz, 2012).

The results of these studies point to a deficit in the processing of fine spectral information, which could explain some of the different pitch perception deficits in congenital amusia. Although congenital amusia has long been assumed to be domain specific to music (Peretz et al., 2002), these results might suggest a more domain-general pitch processing deficit (Cousineau et al., 2012).

The second talk in this session was given by Barbara Tillmann. She gave an introduction to music cognition research which investigates questions such as "What is the knowledge of music?," "How is this knowledge acquired?," and "What are the unique aspects of music in the brain?." The talk focused on (a) pitch perception of nonmusicians, people without any formal musical education, and (b) pitch processing impairment of amusics.

Nonmusician listeners are able to acquire implicit knowledge via mere exposure and to differently process sequences that belong to the learned system. The question is how they acquire and use such knowledge in processing music. The mechanisms that play an important role are those for recognizing and learning statistical regularities (frequencies of occurrence and co-occurrence), for example, the tonic, the most stable chord in Western tonal system, is most frequently used in tonal contexts and in structural organization for stimuli (Tillmann, 2012). To investigate musical structure processing, a priming paradigm was introduced as useful because thereby the processing on the unconscious or implicit level can be studied. In this priming paradigm, the context either fits the listeners' knowledge or not, which leads to different reaction times (RTs) for the performance on another independent task, which is done at the same time. If the priming context is consistent with the knowledge (e.g., tonic at the end of the tonal sequence), the RTs of the other task will be faster than in the condition that is inconsistent with the knowledge. It was, for example, shown with this paradigm that nonmusician listeners as well as children (around six years old) possess implicit knowledge of the Western tonal system (Schellenberg, Bigand, Poulin-Charronnat, Garnier, & Stevens, 2005). This shows that everyone is, in theory, an implicit learner of music. However, people suffering from amusia show deficits in music processing: They have an impaired fine-grained pitch discrimination ability (but not all amusics) and pitch memory deficit. For a long time it was assumed that amusics show a music-specific impairment of pitch processing. Now several studies show that the pitch discrimination deficits of amusics are not necessarily limited to the musical domain and that pitch in speech processing is affected as well (Liu, Patel, Fourcin, & Stewart, 2010; Tillmann et al., 2011). However, when memory is investigated, the deficit seems to be music specific: Amusics possess impaired memory for nonverbal material such as pitch and timbre, but not for verbal material (Tillmann et al., 2009).

Future inquiries of implicit learning, knowledge of music, and specific impairments such as congenital amusia will help to further our understanding of music cognition. In addition, looking beyond the traditional Western tonal system and considering other musical cultures will also help to understand music cognition in a more general way.

Mathieu Marx, a physician working in the department of otology-neurotology, Toulouse Purpan, and also member of the CerCo laboratory in Toulouse, presented the third lecture in the second session titled "Beyond speech recognition: processing nonlinguistic information with a cochlear implant."

Stating that speech perception is generally acceptable for cochlear implant users, Marx emphasized their difficulties in perceiving voice features, music, and environmental sounds. To study these points, Marx uses the voice perception model (Belin, Fecteau, & Bédard, 2004), in which the general low-level auditory analysis is replaced by the cochlear implant sound processing. Throughout his lecture, he showed how the degraded vocal information delivered by the CI affects the three analysis modules of this model, that is, the voice detection, the voice affect analysis, and the voice recognition units. Regarding the first module, he showed a big deficit (>50%) in the performance of CI users in vocal speech analysis, which is comparable with that of NH subjects with 4-channel vocoded syllables and nonsense words (Massida et al., 2011). As for identity voice recognition, CI users are able to categorize gender. The performance deficits of CI users compared with NH subjects do not completely hinder their abilities to categorize gender (Massida et al., 2013) and voice affect. However, their performance does not seem to improve over time. As this is probably related to the F0 perception deficit in CI users, Marx discussed the new stimulation strategies proposed by CI manufacturers (current steering of Advanced Bionics or the fine structure processing of MedEl). In view of the lack of significant improvements related to these strategies, he proposed alternative solutions: On the one hand, during the surgical intervention, place-matched stimulation can be improved by adapting the electrode array emplacement to the cochlea tonotopy by using advanced imaging technologies. On the other hand, as 27% to 50% of CI candidates have low-frequency residual hearing, Marx proposed the improvement of F0 perception by bimodal stimulation that is, associating electrical (CI) and acoustic (residual hearing) stimulation. For speech prosody perception, Marx highlighted the efficiency of bimodal stimulation in improving the perception of F0 variations compared with the exclusive CI use. In fact, he argues that unilateral implantation is probably more beneficial than bilateral stimulation for patients with residual hearing. The presented results clearly have an impact on the surgical gestures of cochlear implantation. They demonstrate the importance of preserving residual hearing in the implanted ear.

Regarding melody perception, recent studies failed to show a global benefit of bimodal stimulation (Cullington & Zeng, 2010; El Fata, James, Laborde, & Fraysse, 2009). Nevertheless, Marx points out that certain CI deaf patients can develop real musical abilities. In this view, he proposes that more ecological tests should be designed to characterize global auditory perception for CI patients. In this aim, Marx concluded with an original preliminary multidimensional analysis tool to understand how CI patients use acoustic cues.

The fourth talk was given by Elvira Brattico, who leads the Neuroaesthetics of Music Group at the University of Helsinki and who is also a scientist in the Brain & Mind Laboratory at Aalto University. She presented the lecture: "The automatic and conscious feature processing in the brain." Her presentation covered the automatic and attentive neural processing of perceptual and emotional features of music and its modulation by musical expertise. She presented strong evidence of a nonlinear tonotopic processing of the pitch in Heschl's gyrus (Kanold, Nelken, & Polley, 2014), which is subdivided in primary area, rostral and rostroventral regions. Using the mismatch negativity (Näätänen, Paavilainen, Rinne, & Alho, 2007), she showed that the auditory cortex is automatically modulated by a pitch change in regular sound sequences (according to certain rules). For instance, Brattico, Tervaniemi, Näätänen, & Peretz (2006) and Leino, Brattico, Tervaniemi, & Vuust (2007) showed that a violation of a local basic rule of Western music (chromatic scale) elicits a modulation in the mismatch negativity in the auditory cortex. Afterward, Dr. Brattico presented new evidence obtained with functional MRI (fMRI) of similar brain activations across individual brains during listening to three musical pieces, particularly in the frontal pole and the bilateral inferior frontal gyrus contrasting the music familiarity to those pieces. Familiarity with music also interacts with emotional responses: The researcher showed that the emotion- and reward-related regions of the brain, such as the ventral striatum, the amygdala, the supplementary motor area, and the hippocampus, are recruited when musical pieces are familiar to the listener, irrespectively of whether he or she likes them or not (Pereira et al., 2011). Finally, Brattico introduced a novel ecological paradigm first published in Alluri et al. (2012). In this paradigm, subjects are allowed to freely listen to a whole musical piece, instead of excerpts, similarly to real life, without the need to perform a behavioral task, while fMRI or EEG are recorded. The variables for data processing are obtained with computational extraction of the piece musical features by means of the MIRToolbox implemented at the University of Jyväskylä. The musical feature variables are correlated with the brain signal resulting in brain-specific activations to each feature. In the future, this ecological approach, combined with behavioral measures can allow for a better understanding of emotional or perceptual processing of musical pitch in real-world situations.

The last talk of this session was given by Bénédicte Poulin-Charronnat. Her presentation focused on music and language perception. She presented various approaches of researchers' views on this topic. She started by explaining that people, even nonmusicians, have internal cognitive structures and processing ability in relation to music. People, according to a cognitive approach, internalize the knowledge of a musical system based on tonal and harmonic hierarchies of music. However, according to a psycho-acoustical approach, sensory priming effects also play a role (Huron & Parncutt, 1993; Leman, 1990). By comparing responses to musical sequences ending either on tonic (expected) or subdominant chords (less expected), researchers found cognitive components that are more prevalent than sensory components (Bigand, Poulin, Tillmann, Madurell, & D'Adamo, 2003).

The next question that was addressed is the neural processing of music. Several event-related potential studies (ERPs) investigating different ERP components were presented, for example, the N5 activation, involving musical integration processes, and the early right anterior negativity for expectancy violations. It was shown that both these components are affected by the neapolitan chord, which is harmonically correct in the middle of the harmonic sequence but not at the end but includes two out-of-key tones and dissonant clusters, which are both harmonically and acoustically incorrect (Koelsch, Gunter, Friederici, & Schröger, 2000). When using the subdominant chord, which has no out-of-key tone, only the N5 is elicited (Poulin-Charronnat, Bigand, & Koelsch, 2006).

Further, neuroimaging studies (Maess, Koelsch, Gunter, & Friederici, 2001; Tillmann, Janata, & Bharucha, 2003) showed that there are shared neural networks involved in both music and language processing, especially pointing to the inferior frontal gyrus and Broca's area.

Different views on music and language perception were presented. Processing of both can be seen as domain-specific or domain-general. Evidence from studies pertaining to linguistic and musical syntax was presented: When syntactically complicated sentences or wrong chords are presented, then both stimuli elicited a P600 ERP-component (Patel, Gibson, Ratner, Besson, & Holcomb, 1998).

Slevc, Rosenberg, and Patel (2009) used the garden path effect for language stimuli for syntactic violations and the harmonic expectancy violation for music stimuli. Bigger RT differences were shown when the linguistic syntax was violated than when musical syntax was violated, while such an effect was not observed for the semantic violations. However, Perruchet and Poulin-Charronnat (2013) showed that semantic garden path effects were enhanced when participants were simultaneously presented with an out-of-key chord, suggesting that more general attention processing is involved.

The last part of the lecture dealt with implicit learning of language and music, presenting, for example, Saffran, Aslin, & Newport's (1996) study. This talk highlighted that there are still many unresolved issues pertaining to language and music processing and that further research is needed to ascertain what is shared between them and what is not.

Conclusion

This report provides an overview of the different topics that were discussed during the Pitch, Music and Associated Pathologies Summer School. A comprehensive overview of both sessions was given, covering pitch and associated pathologies and music and associated pathologies respectively. Not all details could be discussed and the research presented during the poster session could also not be covered.

In general, this summer school was a successful event, with its goals being achieved.

Despite the varying backgrounds of the audience, with participants coming from different fields such as audiology, musicology, or linguistics, everyone profited from the talks. While some gave a more comprehensive introduction, other talks focused on very specific aspects of pitch or music processing. A lot of questions by the audience were answered or discussed and many issues were clarified. But this gathering also showed that there are still many unanswered questions concerning the relationship between pitch and music (processing) and open issues to be addressed for example, concerning arising opportunities for rehabilitation. Hopefully, some of the exchange, new contacts, and collaborations arising from this meeting will help shed some light on these issues.

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