Auditory Processing Differences Between Formally Trained and Self-Taught Musicians

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Abstract

Musicians are known to have enhanced auditory processing abilities compared to non-musicians. However, it is not known if informally trained, self-taught musicians exhibit similar auditory enhancements as their formally trained counterparts. The present study sought to determine the influence of music training type on auditory processing abilities. It was hypothesized that self-taught musicians would exhibit similar auditory processing performance as formally trained musicians, in comparison to non-musicians. Three groups of participants were recruited: 1) formally trained musicians ($n = 16$, $M_{age} = 30.25$) who received formal music training through the conservatory or private lessons, 2) self-taught musicians ($n = 11$, $M_{age} = 36.27$), who learned to play music through informal methods, such as with books, videos, or by ear, and 3) non-musicians ($n = 12$, $M_{age} = 35.00$), who had little or no music experience. Subjects' auditory processing abilities were assessed across three tasks, which included the ability to understand speech in noise, music processing abilities, and automatic auditory processing using EEG. Findings revealed differential impacts of music training type on auditory processing. Automatic auditory processing is enhanced in formally trained musicians compared to both self-taught and non-musicians, but self-taught musicians still clearly show advantages over non-musicians in understanding speech in background noise and music processing abilities. Analysis of additional data collected during this study will be conducted in the future, aiming to address these differential impacts of music training type on auditory processing.

Auditory Processing Differences Between Formally Trained and Self-Taught Musicians

Musicians are known to have enhanced auditory and cognitive abilities compared to non-musicians (Koelsch, Gunter, Friederici, & Schröger, 2000; Koelsch, Jentschke, Sammler, & Mietchen, 2007; Koelsch, Schröger, & Tervaniemi, 1999; Parbery-Clark, Skoe, Lam, & Kraus, 2009; Rogenmoser, Kernbach, Schlaug, & Gaser, 2017; Royal et al., 2016; Tervaniemi, Castaneda, Knoll, & Uther, 2006; Zendel & Alain, 2012). A growing body of research demonstrates that formal music training and practice, both short-term and lifelong, can benefit hearing and cognitive abilities across the lifespan (Chan, Ho, & Cheung, 1998; Fujioka, Trainer, Ross, Kakigi, & Pantev, 2004; Schellenberg, 2004; Zendel & Alain, 2012; Zendel, West, Belleville, & Peretz, 2017).

Music practice is associated with both functional and anatomical effects on the brain (Fujioka et al., 2004; Gaser & Schlaug, 2003; Parbery-Clark et al., 2009; Schneider et al., 2002). Musicians have enhanced pre-attentive auditory processing (Koelsch et al., 1999), and are better able to recognize pitch change in auditory stimuli (Fujioka et al., 2004). Musicians also have an enhanced ability to detect and understand speech in background noise (Parbery-Clark et al., 2009; Zendel et al 2015). The QuickSIN (Quick speech-in-noise) task assesses the ability to understand speech in noise, reflecting realistic auditory situations comprised of complex auditory stimuli (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004). Music practice enhances musical perception (Koelsch, 2009), but benefits also transfer across multiple domains. Musicians have enhanced reading and language abilities (Tierney & Kraus, 2013), working memory (Chan et al., 1998; Parbery-Clark et al., 2009), auditory perceptual skills (Koelsch et al., 1999; Zendel & Alain, 2009), and general intelligence (Schellenberg, 2004). Musicians also exhibit structural differences in the brain compared to non-musicians associated with improved auditory and motor skills (Gaser & Schlaug, 2003; Schneider et al., 2002). Musicians' brains are consequently often used as models for neuroplasticity (Fujioka et al., 2004; Gaser & Schlaug, 2003; Schneider et al., 2002). Musicians have thicker gray matter than non-musicians in motor and auditory cortices, and greater activation of the auditory cortex in response to simple tonal stimuli (Gaser & Schlaug, 2003). A greater volume of gray matter in Heschl's gyrus is strongly correlated with musical aptitude, supporting the notion of structural adaptations in the brain in response to music practice (Gaser & Schlaug, 2003; Schneider et al., 2002).

Cross-sectional studies have used correlational data to infer that the functional and structural brain changes were caused directly by music practice and experience (Chan et al., 1998; Koelsch et al., 1999; Parbery-Clark et al., 2009). However, observed anatomical changes or auditory and cognitive enhancements may be a result of confounding factors, such as genetic differences or education (Kraus & Chandrasekeran, 2010; Schellenberg, 2004). Cross-sectional studies measure performance at a specific point in time, and therefore cannot definitively determine whether effects observed are due to music practice or extraneous variables (Kraus & Chandrasekeran, 2010). Longitudinal studies, however, allow for data collection from the same subjects over a period of time, and have been used to confirm that music practice causes auditory and cognitive enhancements (Fujioka et al., 2004; Hyde et al., 2009; Schellenberg, 2004; Tierney & Kraus, 2013; Zendel et al., 2017).

Schellenberg (2004) found a causal association between music lessons and general intelligence (IQ) in children. In this longitudinal study, children received formal music training in either keyboard or voice for 36 weeks, while two control groups received either drama lessons or no lessons (Schellenberg, 2004). Music lessons and drama lessons both included practice/rehearsal, memorization, and auditory expression, but only children who received music lessons showed widespread enhancements in cognitive function beyond increases in all groups due to maturation (Schellenberg, 2004).

Fujioka et al. (2004) examined contour and interval encoding in formally educated musicians who played more than one instrument and who had regularly practiced for at least 10 years. Music practice enhances automatic discrimination and detection of abstract melodic information (Fujioka et al., 2004). Further, musical practice mainly affects pitch contour and associations between tones compared to single tone presentations, shown by enhanced auditory activation in response to melodies with deviant tones (Fujioka et al., 2004). Results support that musical practice and experience leads to neural changes that enhance auditory processing of abstract melodic information (Fujioka et al., 2004). Zendel et al. (2017) found further evidence that music lessons enhance auditory performance in older adults. After six months of music lessons in piano, older adults showed an enhanced ability to understand speech in noise compared to older adults in two control groups who either learned to play a video-game or had no lessons at all (Zendel et al., 2017).

Hyde et al. (2009) used deformation-based morphometry (DBM), to measure changes in brain morphology over the course of 15 months of formal music training, finding that structural changes in the brain of music-relevant areas were correlated with improvements in motor and auditory skills, compared to those who did not receive formal music training. This study was the first to directly link structural changes in the developing brain to improved behavioural performance on motor and auditory tasks in relation to formal music training (Hyde et al., 2009). From previous research, it is now known that music lessons and music practice cause enhancements in auditory and cognitive abilities, which promotes the formation of new neural connections (Fujioka et al., 2004; Hyde et al., 2009; Kraus & Chandrasekeran, 2010; Schellenberg, 2004; Zendel et al., 2017).

Electroencephalography (EEG) is a neurophysiological test that measures electrical activity in the brain caused from the firing of groups of neurons by tracking and recording brain wave patterns (Luck, 2012). EEG is a non-invasive technique with high temporal resolution, making it particularly useful for detecting time changes in neural processing (Luck, 2012). The event-related potential technique is a method of isolating brain responses to a particular stimulus by presenting hundreds or thousands of trials and averaging the brain's response to these presentations. These averaged responses are then computed to create an output of a wave of electrical activity over time. Event-related potentials (ERPs) generated from EEG consist of the sum of positive and negative voltage deflections from underlying components, and can measure responses to stimuli without requiring behavioural action (Luck, 2012). ERPs are uniquely useful for studying differences in processing between musicians and non-musicians as these studies typically investigate auditory and cognitive processing abilities, as measured by differences in speed of neural activity (Gaser & Schlaug, 2003; Koelsch et al., 2007; Luck, 2012; Tervaniemi et al., 2006).

One of the most fundamental aspects of hearing is detecting change in the auditory environment (Brattico et al., 2006; Koelsch et al., 1999; Koelsch et al., 2007; Kraus & Chandrasekeran, 2010; Winkler, 2003). The ability to detect pitch change in auditory stimuli is critical for perception and encoding of both music and language (Brattico et al., 2006; Koelsch et al., 1999; Royal et al., 2016; Winkler, 2003). Pitch encoding begins with extracting information from the auditory environment, but does not require attention (Brattico et al., 2006). Electrophysiological evidence indicates that sounds are automatically analyzed before voluntary attention (Koelsch et al., 1999), highlighting the importance of attentional control as a factor in auditory processing studies (Brattico et al., 2006). Formally trained musicians automatically detect pitch changes in auditory stimuli that non-musicians cannot distinguish, providing evidence for enhanced pre-attentive auditory processing in musicians (Koelsch et al., 1999). This is demonstrated by the brain's automatic change-detection response, which is represented electrically as an ERP component called the mismatch negativity (MMN; Koelsch et al., 1999; Koelsch et al., 2007). The MMN response is generated in the auditory cortex from irregularity of pitch change in repetitive sequences in the auditory environment commonly referred to as an oddball sequence or paradigm (Koelsch et al., 2001; Koelsch et al., 2009). The magnitude of the response depends on the degree of pitch change from the expected note (Brattico et al., 2006; Koelsch et al., 2009). While MMN occurs in both musicians and non-musicians, the response is larger and may be evoked by smaller deviants in pitch for professional musicians compared to non-musicians (Koelsch et al., 1999).

The ability to detect pitch change is related to the ability to detect tonal violations in music. Traditional Western tonal music, also referred to as major-minor tonal music, is based on the concept of tonality, or musical key (Krumhansl & Kessler, 1982). Tonality is the arrangement of pitches or chords (i.e., multiple tones simultaneously) in a hierarchy of perceived association to the tonic, which is one single pitch that serves as a reference point for the entire system (Krumhansl & Kessler, 1982). The chromatic scale in Western music contains 12 tones in an equal-tempered tuning system: 7 of these tones make up the diatonic scale and are said to be “in-key”, while the remaining 5 tones are “out-of-key” (Brattico et al., 2006; Krumhansl & Kessler, 1982). Consequently there are associations between pitches in a key, meaning that tones within the chromatic scale can be closely or distantly related (Krumhansl & Kessler, 1982). Interestingly, these associations are related to the notion of statistical learning (SL), which refers to an implicit human ability to extract statistical regularities in the environment to learn (Vasuki, Sharma, Demuth, & Arciuli, 2016). Musicians perform better than non-musicians in the auditory task of frequency distribution and the cognitive task of backward digit span (Vasuki et al., 2016). This was the first study to show behavioural differences between musicians and non-musicians on statistical learning, where music practice is positively associated with enhanced statistical learning (Vasuki et al., 2016).

Due to the hierarchical and organization structural of Western music, strong expectations are formed about specific future notes in a musical sequence (Brattico et al., 2006; Krumhansl & Kessler, 1982). Listeners familiar with Western tonal music automatically expect certain chords to follow (Koelsch et al., 2000), and these predictions are based on principles of music theory and complex organization of acoustic information, called music-syntactic regularities (Koelsch, 2009). As a result of exposure to Western tonal music, even non-musicians show expectancies about closure of harmonious auditory stimuli (Koelsch et al., 2000; Koelsch et al., 2001). Koelsch et al. (2000) found a response similar to MMN elicited by chord sequences containing music-syntactically irregular chords, which were therefore highly unexpected when presented at the end of a sequence. Similar to the MMN response, the evoked ERP component had a negative polarity, a similar scalp distribution, and a peak latency of 150-180 ms, but this evoked potential uniquely reflects the neural response to harmonic irregularities from chords rather than simple pitch changes (Koelsch et al., 2000; Koelsch et al., 2001). It was determined that this "music-syntactic MMN" evoked potential would be termed an early right anterior negativity (ERAN), which electrically reflects music-syntactic processing, or processing related specifically to music structure (Koelsch et al., 2009, p. 180). A key difference between MMN and ERAN is that MMN is elicited from pitch deviances while the elicitation of ERAN relies on long-term memory representations of music-syntactic regularities (Koelsch et al., 2009). Neither MMN nor ERAN require attentional focus, and can therefore be evoked under passive or active attention conditions (Koelsch et al., 2009).

Music processing can be particularly well observed when auditory stimuli are presented in a melodic context (Brattico et al., 2006). In a melodic context, tones that do not match expectations based on prior context are recognized as “wrong” tones, and this discrimination occurs pre-attentively, supporting the hypothesis that pitch incongruities can be detected automatically and without attentional awareness (Brattico et al., 2006). There is also evidence to suggest that pitch change detection in both melodic and non-melodic contexts is associated with significant activation in the right superior temporal gyrus, which preferentially responds to out-of-tune compared to out-of-key deviants in a melodic context (Royal et al., 2016). This pre-attentive processing is more advanced in musicians, but is not exclusive to them, as non-musicians tend to exhibit implicit knowledge presumably acquired from everyday listening experiences (Koelsch et al., 1999; Koelsch et al., 2000). For both musicians and non-musicians, pitch incongruities in a presented melody elicited an ERAN that was not modulated by attentional focus (Koelsch et al., 1999).

In the case of music processing, the ERP component elicited under attention conditions in response to music-syntactic changes is called the P600 (Brattico et al., 2006; Koelsch et al., 2000). The P600 is displayed electrically as a late positivity occuring roughly 600 ms after stimulus onset, and is evoked from an increase in positive activity from a bad note when paying attention to harmonic frequencies (Brattico et al., 2006). The P600 is observed only under attention conditions, and tonal violations are known to evoke both an ERAN and a P600 over central-partial electrodes (Brattico et al., 2006). While MMN and ERAN are evoked under both active and passive attention, no P600 is observed from automatic, passive processing of tonality violations (Brattico et al., 2006). The attention-related P600 component is larger in amplitude to out-of-tune and out-of-key notes compared to congruous pitches that fit within the key signature (Brattico et al., 2006). However, evoked responses to salient out-of-tune pitches and less salient out-of-key pitch violations are similar in latency, suggesting that attentional focus enhances music processing (Brattico et al., 2006).

The majority of musician studies have concentrated on professional musicians with extensive, high-intensity formal music training (Koelsch et al., 1999; Oechslin et al., 2013; Zendel & Alain, 2009), but this does not represent all musicians. Many musicians perform as amateurs, and consequently may not have the extensive formal training and knowledge in musical theory and history complimenting their musical abilities (Tervaniemi et al., 2006). Amateur musicians may practice less often on average than professional musicians, and have a lower training intensity (Oechslin et al., 2013), but studies are beginning to investigate similarities and differences in auditory and cognitive processing between amateur musicians and professionals musicians (Oechslin et al., 2013; Rogenmoser et al., 2017; Schneider et al., 2002; Tervaniemi et al., 2006).

Schneider et al (2002) compared auditory processing in professional musicians, amateur musicians, and non-musicians using Magnetoencephalography (MEG). All professional musicians had completed a professional music education diploma and were actively performing, while amateur musicians had received "special instruction" in music (Schneider et al, 2002, p. 692). Amateur musicians were included in this study to sample the effect of starting age and intensity of music practice (Schneider et al., 2002). Amateur musicians had significantly more gray matter than non-musicians in anterior portions of Heschl's gyrus (HG), but still less than professional musicians (Schneider et al., 2002). Results showed that gray matter volume in this area was the critical factor influencing earlier activation of the auditory cortex (Schneider et al., 2002). Both morphology and neurophysiology of HG impact musical aptitude, which correlates strongly with increased intensity in musical practice (i.e. in professional musicians compare to amateur musicians) (Schneider et al., 2002).

Tervaniemi et al. (2006) compared non-musicians to amateur musicians (without long-term formal music training) who primarily played in rock, indie, or jazz bands. A larger mismatch negativity response was evoked for amateur musicians compared to non-musicians by frequency deviances in a multi-feature paradigm (Tervaniemi et al., 2006). This suggests enhanced sound discrimination abilities among amateur musicians (Tervaniemi et al., 2006). Results further suggested that amateur musicians have more sensitive music encoding of spatial information related to their particular genre of music compared to non-musicians (Tervaniemi et al., 2006). Even with limited systematic training, amateur musicians encode location information more accurately than non-musicians (Tervaniemi et al., 2006). Among the amateur musicians in this study, 6 of 13 had received formal music training outside of school, but it is unknown what type of music training the remaining 7 amateur musicians received, if any (Tervaniemi et al., 2006).

Oechslin et al. (2013) used functional magnetic resonance imagine (fMRI) to examine the influence of musical practice intensity of expert musicians, amateur musicians, and non-musicians on brain plasticity related to music-syntactic processing. All musicians in this study were pianists, where amateur pianists were actively playing but not in excess of 10 hours per week (Oechslin et al., 2013). Results suggest practice intensity modulates brain plasticity, as indicated by hierarchical enhanced encoding from expert musicians with high intensity music practice, to amateur musicians with low intensity practice, to non-musicians with no music experience (Oechslin et al., 2013).

Rogenmoser et al. (2017) compared the age-decelerating effects of making music between professional musicians and amateur musicians. Professional musicians were performing artists, full-time music teachers or conservatory students, while amateur musicians were regularly playing musicians whose profession or education was not related to music (Rogenmoser et al., 2017). Interestingly, amateur musicians showed slightly greater age-decelerating effects, possibly suggesting that amateur music making as one of several activities may be more beneficial than intense music practice and experience in a single discipline (Rogenmoser et al., 2017).

Studies comparing professional to amateur musicians provide support for music practice intensity modulating brain plasticity, specifically promoting the neural processing of sound, and support that amateur musicians have similar auditory and cognitive benefits as professional musicians compared to non-musicians (Oechslin et al., 2013; Rogenmoser et al., 2017; Schneider et al., 2002; Tervaniemi et al., 2006). However, each of these studies provides unclear and highly variable definitions of both professional and amateur musicians, and there were significant variances in practice intensity, namely that professional musicians practiced more hours per week on average than amateur musicians (Oechslin et al., 2013; Rogenmoser et al., 2017; Schneider et al., 2002; Tervaniemi et al., 2006). While these professional to amateur comparison studies reflect the influence of current music engagement on auditory and cognitive processing, they do not control for the type of training musicians received. Previous cross-sectional and longitudinal studies have examined almost exclusively auditory and cognitive differences in formally trained musicians compared to non-musicians, without consideration of the previous music experience of individuals up to the point of neurophysiological testing. In professional to amateur comparison studies, nearly all musicians had formal music training (Oechslin et al., 2013; Rogenmoser et al., 2017), while some studies did not specify what type of training, if any, amateur musicians had received (Schneider et al., 2002; Tervaniemi et al., 2006).

Irrespective of current music engagement status, this study sought to investigate differences in auditory processing of musicians of different training types. Many musicians are self-taught, having not received formal training, but self-taught musicians may exhibit similar hearing enhancements to formally trained musicians, as compared to non-musicians. Technology has allowed for vast expansion in the availability of informal training tools, such as online applications, videos, and tutorials, and thus the potential for an associated increase in the number of self-taught, non-formally trained musicians. Benefits of self-guided music training include accessibility, self-paced and flexible training, and accommodation to a variety of learning styles, at minimal or no cost. Even in formal training settings, there are individual differences in learning abilities, and non-standardized training techniques have benefited many musicians (Ginocchio, 2009). It remains unknown if training type impacts the benefits of musicianship.

Thus far, studies have exclusively examined musicians with formal training backgrounds, and not informally trained, self-taught musicians. The question of whether non-formally trained, self-taught musicians experience similar auditory benefits as their formally trained counterparts has yet to be addressed.

The current study aimed to investigate whether informally trained, self-taught musicians experience similar benefits as their formally trained counterparts. Given previous research findings, it was hypothesized that informally trained musicians would exhibit similar neuroplastic benefits as formally trained musicians, compared to non-musicians. This would suggest that music skill actualization, the ability and act of playing music, is the critical factor that drives brain plasticity rather than the regimented, formal music training process. Findings from this study may help guide future research in developing individualized music-based rehabilitation programs for hearing loss.

Three groups of adults were recruited: 1) formally trained musicians, 2) self-taught musicians, and 3) non-musicians. The present study is part of a larger ongoing research study, and therefore only portions of data collected have been analyzed and reported. Behavioural data was collected and analyzed for a music-processing task (detection of a bad note in a short melody). The amplitude and latency of brain activity in an automatic auditory processing task was extracted from the electroencephalogram, analyzed, and reported in the present findings.

Specifically, it was expected that behavioural responses in the music-processing task (detection of a bad note in a short melody) would be enhanced similarly in both formally trained and self-taught musicians compared to non-musicians. It was further expected that automatic auditory processing as measured by EEG would be similar in amplitude and latency for both formally trained and self-taught musician groups, compared to non-musicians.

Method

Participants

Thirty-nine participants were recruited: 16 formally trained musicians, 11 self-taught musicians, and 12 non-musicians (See table 1 for demographic information). Formally trained musicians were defined as people who had received formal music training through either the conservatory or private lessons, with at least 3 years of formal training (*M* = 9.50, *SD* = 4.65). Self-taught musicians were defined as people who had little to no formal music training, and who learned to play music through informal methods such as through books, online videos, tutorials, by ear, or from a few informal lessons. All formally trained and self-taught musicians were actively engaged in music practice for at least 5 hours per week on average in the past year. Non-musicians were defined as people who did not currently play any musical instrument, and who had little to no previous music training or experience. Participant demographics are shown in Table 1. All participants were healthy, right-handed adults who had no neurological conditions and who were not taking psychotropic medication. Participants were assessed for hearing loss, and all adults had pure tone thresholds within the normal range (i.e. below 25 dB HL at all frequency octaves), indicating normal hearing. The majority of participants were monolingual, and 4 were bilingual.

Table 1. Participant Demographics

Group	*Formally Trained*	*Self-Taught*	*Non-musicians*
Age (Years)	18-54 (*M* = 30.25, *SD* = 13.38)	18-59 (*M* = 36.27 *SD* = 13.39)	18-58 (*M* = 35.00 *SD* = 16.10)
Gender	11 women, 5 men	5 women, 6 men	8 women, 4 men
Education (Years)	12-21 (*M* = 16.56, *SD* = 2.85)	12-21 (*M* = 16.09, *SD* = 2.66)	12-24 (*M* = 15.83 *SD* = 3.56)
Started Playing (Age)	3-15 (*M* = 8.88, *SD* = 3.44)	4-36 (*M* = 14.72, *SD* = 7.99)	-
Music Playing Experience (Years)	7-44 (*M* = 21.50 *SD* = 12.81	3-40 (*M* = 21.55, *SD* = 11.17)	-
Music Practice (Hours per Week)	5-40 (*M* = 10.00, *SD* = 8.64)	5-28 (*M* = 11.45, *SD* = 7.22)	-
Formal Music Training (Years)	3-23 (*M* = 9.50, *SD* = 4.65)	-	-

Overall Procedure

Participants were pre-screened for basic information about their music training backgrounds prior to arrival in the lab. All testing took place in the Cognitive Aging and Auditory Neuroscience Lab (Grenfell Campus, AS 121). Upon arrival in the lab and after completing written informed consent, participants completed a short oral questionnaire. Based on the pre-screening questions and collected responses in the questionnaire (see Appendix A), participants were placed in one of three groups: 1) formally trained musician, 2) self-taught musician, or 3) non-musician. All groups went through the same testing and EEG procedure, but certain sections in the questionnaire were specific to the participants' music training background. Seated in a sound-attenuating booth, participants first completed a pure-tone audiometry assessment, then a speech in noise task to assess ability to understand speech in background noise. Participants were then fitted with an EEG cap outside of the booth, and returned to the sound-attenuating booth for the remainder of the experiment. A melody task that assessed participants' ability to detect a bad note in a melody was completed while recording EEG. There was first an active (paying attention) melody task, followed by a passive melody task, where participants were not paying attention to the stimuli. Only the behavioural results of the active melody task are reported here, and the results of the passive melody task were not included in analysis. The final task was a mismatch negativity task, which recorded EEG responses to the detection of pitch change in auditory stimuli.

Procedure and Stimuli

Pure-tone thresholds. Participants completed a pure-tone audiometry assessment in a sound-attenuating booth to identify hearing thresholds and assess hearing loss. This test ensures a healthy sample of participants for hearing abilities. For this assessment, participants were presented with a series of tones, and instructed to press a button each time they detected a tone. Pure tone thresholds were collected using the standard clinical procedure for each octave between frequencies of 250 to 8000 Hz binaurally using an audiometer (model AC40). The procedure began by presenting a 1000 Hz tone to the right ear at 30 dB HL. If the participant detected the tone, the amplitude was reduced by 5 dB HL, and these 5 dB HL reductions were subsequently applied until the participant no longer responded to the tone. The amplitude of the tone was then increased by 5 dB HL; if detected the tone was lowered again by 5 dB HL; if not detected the tone was increased again by 5 dB HL until detected, and this amplitude was recorded as the pure-tone threshold for the ear of presentation. This procedure was repeated for each ear at each of six frequencies. If the participant could not detect the tone at 30 dB HL, the amplitude was increased in 5 dB HL increments until the participant first detected the tone. The procedure then continued as stated above. Tones were presented at irregular time intervals to prevent false positive responses, and the same procedure was repeated for each frequency octave in each ear.

Speech-in-noise. Participants completed a QuickSIN (Quick Speech in Noise) task, which measured SNR loss (signal-to-noise ratio loss), indicating the ability of participants to hear speech in noise. Participants listened to short, pre-recorded sentences in the presence of multi-talker babble noise, and were asked to repeat the words they heard. The sound was presented binaurally at 70 dB SLP, and the SNR ratio decreased in 5-dB steps from 25 dB to 0 dB, progressing from normal to severe difficulty impairment in performance. The background noise was initially very low, and increased progressively, making it more difficult for participants to decipher the recorded sentences. Each participant was presented with six lists of six sentences, each containing five key words per sentence. Participants were given one point for each of the correct five words per sentence. The SNR loss was determined by subtracting the total number of words correct from 25.5, which represents the SNR required for participants to correctly identify 50% of the key words (Killion, 1997).

EEG set up. Next, participants were fitted with an EEG cap. This involved measuring their head, fitting the correct size cap to their head, filling the port for each electrode with a conductive gel, and then attaching electrodes to each port. Six external electrodes were attached to the face and behind the ears to each of the mastoid bones to measure facial muscle movement including blinking. The EEG system was then calibrated, which potentially involved removing electrodes, adding more conductive gel, or gently rubbing the surface of the scalp to move hair out of the way to improve conductivity. Once the EEG system was properly calibrated, participants completed the main portion of the study.

Melody Task. A set of 40 melodies was used as stimuli for the melody task. All melodies were in a major key and varied in rhythm (Brattico et al., 2006). Melodies consisted of between 7 and 15 successive notes, (*M* = 10.3, *SD* = 1.90), and were played at 120 beats per minute (500ms per beat). The entire set of melodies was spread over two octaves, ranging in pitch from B4 to C5. These melodies were synthesized in 6 versions, varying with regard to instrumental timbre (piano or guitar) and condition (in-tune, out-of-tune, out-of-key), which resulted in 240 total melody presentations. All melodies were presented at 75 dB SPL using an Interacoustics AC40 Audiometer, through Etymotic ER3A Insert earphones. For each melody, the pitch change always affected the same critical tone, which lasted 500 ms in duration and was presented on the first downbeat in the third bar of the four-bar melody. For in-tune melodies, all tones were in tune and fell within the key of the melody. Out-of-tune melodies contained a target tone that was shifted by half a semitone interval from the preceding tone, which presented an incongruity from the chromatic scale or tuning of the melody (Brattico et al., 2006). For out-of-key melodies, the target tone was shifted by a semitone from the preceding tone, which placed this tone outside the key of the melody, but was still close in pitch and contour (Brattico et al., 2006). Congruous pitches that were always a part of the major scale (in-key) served as control comparisons and were located at corresponding locations in the melodies. Melodies were presented in either difference keys (A, Bb, B, C, D, Eb, F, or G) in an effort to minimize sensory novelty of tones presented in-key and out-of-key. Ten pitches were used as out-of-key targets (A, Bb, B, C, Db, Eb, E, F, G, Ab) and nine pitches served as in-key targets (A, Bb, B, C, Db, D, E, F, Gb). There was no significant difference in the frequency of occurrence between the in-tune, out-of-tune, and out-of-key target tones, *t*(15) = 0.09, *p* = .93.

Participants completed three blocks of 80 trials each, during which they heard a series of melodies that sometimes contained either an out-of-tune or out-of-key note. Participants were instructed to pay attention to the melodic auditory stimuli and make a judgment about whether or not they hear a “bad” note (yes, no), and how confident they were of their response (sure, not sure). A bad note in this experiment was defined as either of two kinds of pitch deviances: an out-of-tune or out-of-key note, as outlined in Brattico et al. (2006). Participants did not need to distinguish between these deviances. Choices were presented on a computer screen after each melody and participants pressed a button on a response box to indicate their response.

MMN Task. The MMN task contained repeated tones with regulated pitch variations. The MMN response is generated from irregularity of change in the auditory environment, with magnitude depending on the degree of pitch change from the expected note. The wave files for the MMN task had duration of 100 ms (rise and fall of 10 ms) and were normalized in energy with Adobe Audition V3.0 at 44.1 kHz in 16-bit format. A frequent standard tone was played at pitch level of C6 (1047 Hz). The infrequent deviant or oddball tones were higher or lower in pitch compared to the standard tone by either 200 cents (933 or 1175 Hz; 100 cents corresponding to one semitone) or 25 cents (1032 or 1062 Hz). Participants heard a series of tones synthesized to sound like a single piano note. For this task, participants were instructed to watch a silent, subtitled film on Netflix and ignore auditory stimuli (Pettigrew et al., 2004). The sequence contained 900 standard tones (probability of occurrence = .81) and 50 tones each for the four pitch deviances (probability of occurrence = .045; 200 deviants in total). In total, 1100 tones were presented with an interstimulus interval that randomly varied between 800-1100 ms. The presentation of sounds was pseudo-randomized such that every deviant tone was preceded by at least four standard tones. For this experiment, deviant tones were not used as standards or vice versa due to practical time constraints.

Recording and Analysis of Electrical Brain Activity. Neuroelectric brain activity was collected continuously from 64 scalp locations using a band-pass filter of 0.05 – 100 Hz and a sampling rate of 1024 Hz per channel and stored for analysis. Four electrodes, two below and two horizontal to the eyes monitored ocular activity. For data analysis electrodes were re-referenced to the linked-mastoid.

Trials containing excess noise (±125 AV) at electrodes, excluding those adjacent to the eyes (i.e., IO1, IO2, LO1, LO2), were rejected before averaging of the trials. ERPs were averaged separately by condition and stimulus type. Analysis included a sample of 9 electrodes (i.e. F1, Fz, F2, FC, FCz, FC2, C1, Cz, C2). First brain responses to standard, 25-cent and 200-cent oddball tones were averaged with a 100 ms baseline, and 500 ms of post-stimulus activity. Sets of ocular movements were obtained for each participant prior to the experiment (Picton et al., 2000). Averaged eye movements were calculated from these sets for eye blinks, lateral eye movements, and vertical eye movements. A principal component analysis (PCA) of these averaged recordings created a set of movement components that best explained eye movements. The scalp activity associated with these eye movements was subtracted from each ERP to minimize interference from ocular activity for each participant average. ERPs were then low-pass filtered to attenuate frequencies between 0.1 and 20 Hz. Next difference waves were calculated between the standard and 25-cent oddball, and between the standard and 200-cent oddball, yielding two difference waves. The MMN was defined as the peak amplitude of this difference wave between 100-350 ms after the stimulus onset. All averages were computed using BESA software (version 6.0).

Results

Behavioural Data

QuickSIN. The average performance measured by QuickSIN SNR threshold level is presented in Figure 1. A one-way analysis of variance (ANOVA) revealed a trend level effect of group on QuickSIN scores ($F(2, 36) = 2.93$, $p = .066$, $\eta_p^2 = .14$). Planned comparisons revealed that formally trained musicians and self-taught musicians did not significantly differ ($p = .571$) in

QuickSIN performance. Further planned comparisons showed that self-taught musicians had significantly lower (better) average QuickSIN scores compared to non-musicians (*p* = .029) and formally trained musicians had a trend towards lower QuickSIN scores compared to non-musicians (*p* = .066).

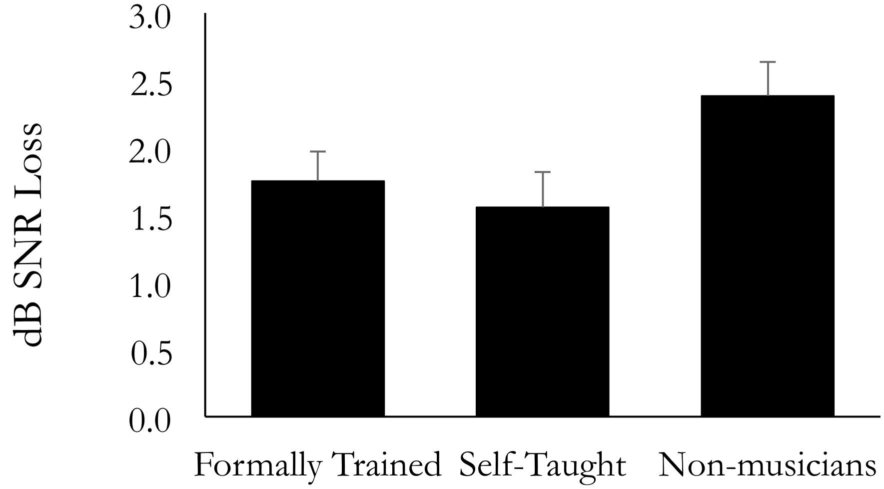

Figure 1. Average SNR performance on QuickSIN task by group.

Melody Task. Both accuracy and confidence were measured on this task. The average accuracy for detecting a bad note, both out-of-tune and out-of-key notes, in a melody across groups is presented in Figure 2. Accuracy was calculated as % hits – % false alarms, whereby a hit is the correct identification of a bad note in a melody, and a false alarm is the incorrect identification of a bad note when no bad note was present. This method of calculating accuracy helps to eliminate response bias.

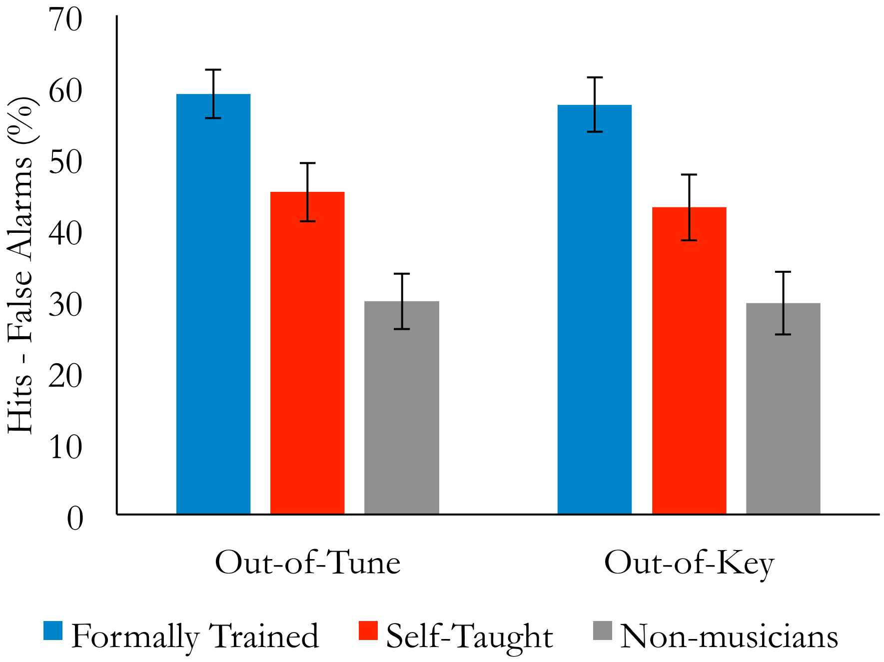

Figure 2. Average accuracy of detecting both out-of-tune and out-of-key notes in a short melody across subject groups.

A one-way ANOVA analyzed the accuracy of behavioural responses for out-of-tune and out-of-key notes separately. There was a significant effect of group for the accuracy in detection of a mistuned note ($F(2, 36) = 14.48$, $p < .001$, $\eta_p^2 = .45$). Follow up comparisons revealed that formally trained musicians significantly differed from both self-taught musicians and non-musicians in their accuracy of detecting a mistuned note. Formally trained musicians had significantly higher accuracy in detecting a mistuned note than self-taught musicians ($p = .010$), and self-taught musicians had a significantly higher accuracy in detecting a mistuned note than non-musicians ($p = .024$).

Analyses revealed a similar significant effect of group for the accuracy of detecting an out-of-key note in a melody ($F(2, 36) = 12.60$, $p < .00$, $\eta_p^2 = .41$). Formally trained musicians significantly differed from both self-taught musicians and non-musicians in their accuracy of detecting an out-of-key note. Formally trained musicians had a significantly higher accuracy in detecting an out-of-key note compared to both self-taught musicians (p = .026) and non-musicians (p < .001). Self-taught musicians were significantly better at detecting an out-of-key note in a melody than non-musicians (p = .021). Overall, the effect of musician status did impact accuracy in detection of both mistuned and out-of-key notes.

Confidence was measured by averaging the “sure” or “not sure” responses on the behavioural melody task, independent of accuracy. Figure 3 presents the confidence of detecting an out-of-tune and out-of-key note respectively in short melodies across the three subject groups.

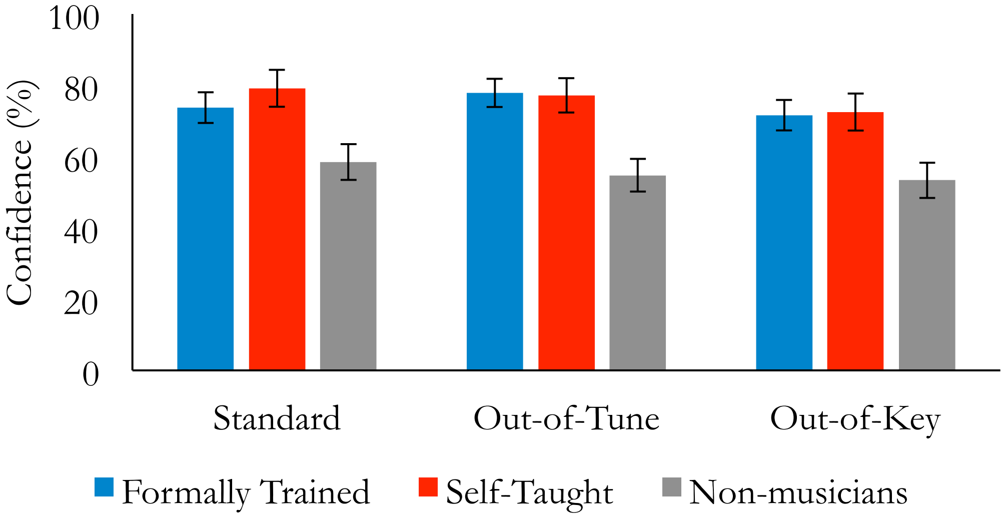

Figure 3. Average confidence of detecting standard, out-of-tune, and out-of-key notes in a short melody across three subject groups.

A one-way ANOVA analyzed the confidence of behavioural responses for standard, out-of-tune, and out-of-key notes separately. There was a significant effect of group for the confidence in detecting when a standard tone was presented (i.e. no bad note), ($F(2, 36) = 4.56$, $p = .017$, $\eta_p^2 = .20$). Follow up comparisons revealed that formally trained musicians had significantly higher confidence in detecting the standard note than non-musicians (p = .027).

Self-taught musicians also had significantly higher confidence for detecting the standard melody compared to non-musicians (p = .007). Formally trained musicians and self-taught musicians did not significantly differ in confidence of detecting the standard tone (p = .427).

There was a similar effect of group for confidence in detecting an out-of-tune note (F(2, 36) = 8.50, p = .001, η_p^2 = .32). Follow up comparisons revealed that formally trained musicians had significantly higher confidence in detecting a mistuned note compared to non-musicians (p = .001). Self-taught musicians also had significantly higher confidence for detecting a mistuned note compared to non-musicians (p = .002). Formally trained musicians and self-taught musicians did not significantly differ in confidence of detecting an out-of-tune tone (p = .909).

There was a significant effect of group for confidence in detecting of an out-of-key note (F(2, 36) = 4.83, p = .014, η_p^2 = .21). Follow up comparisons revealed that formally trained musicians had significantly higher confidence in detecting an out-of-key note than non-musicians (p = .009). Self-taught musicians had significantly higher confidence for detecting an out-of-key note compared to non-musicians (p = .012). Formally trained musicians and self-taught musicians did not significantly differ in confidence of detecting an out-of-key tone (p = .899). Overall, musician groups, regardless of training type had similar elevations in confidence of detecting standard, out-of-tune, and out-of-key notes compared to non-musicians.

Electrophysiological Data

Figure 4 shows the average ERP responses of the three subject groups for two oddball types during a mismatch negativity task. All data were analyzed using a mixed design repeated measures ANOVA. Music training type (formally trained musician, self-taught musician, non-musician) was the between subjects factor, and there were two within subjects factors (response to 25-cent oddball tone and response to 200-cent oddball tone). These were measured from a montage of 9 separate electrodes. The purpose was to obtain a stable estimate of the MMN response; therefore effects of electrode are not reported. Analysis was conducted on both the amplitude and latency of responses to two difference waves (200-cent minus standard and 25-cent minus standard). Response to these oddball tones is represented by a difference wave, which was calculated using a point-by-point subtraction of the responses to the standard tones and oddball tones. The largest difference waves peaked between 100-350 ms after stimulus onset, which is shown across all subject groups as the largest negative peak in the 200-cent oddball columns in Figure 4.

For the easier to detect, 200-cent tone, the amplitude of the mismatch negativity did not differ between groups ($F(2, 34) = 0.32$, $p = .728$, $\eta_p^2 = .02$). There was no effect of group for MMN latency in response to the 200-cent tone ($F(2, 34) = 0.05$, $p = .956$, $\eta_p^2 = .002$). For the 25-cent deviant tone there was a significant group difference in MMN amplitude, $F(2,34) = 4.45$, $p = .019$, $\eta_p^2 = .21$). Follow up comparisons revealed that formally trained musicians had a larger MMN compared to both self-taught ($p = .008$) and non-musicians ($p = .056$). Self-taught musicians and non-musicians had similar MMN in response to detecting a 25-cent deviant tone at the automatic level ($p = .484$). There was no effect of group for MMN latency in response to the 25-cent tone ($F(2, 34) = 0.80$, $p = .460$, $\eta_p^2 = .05$).

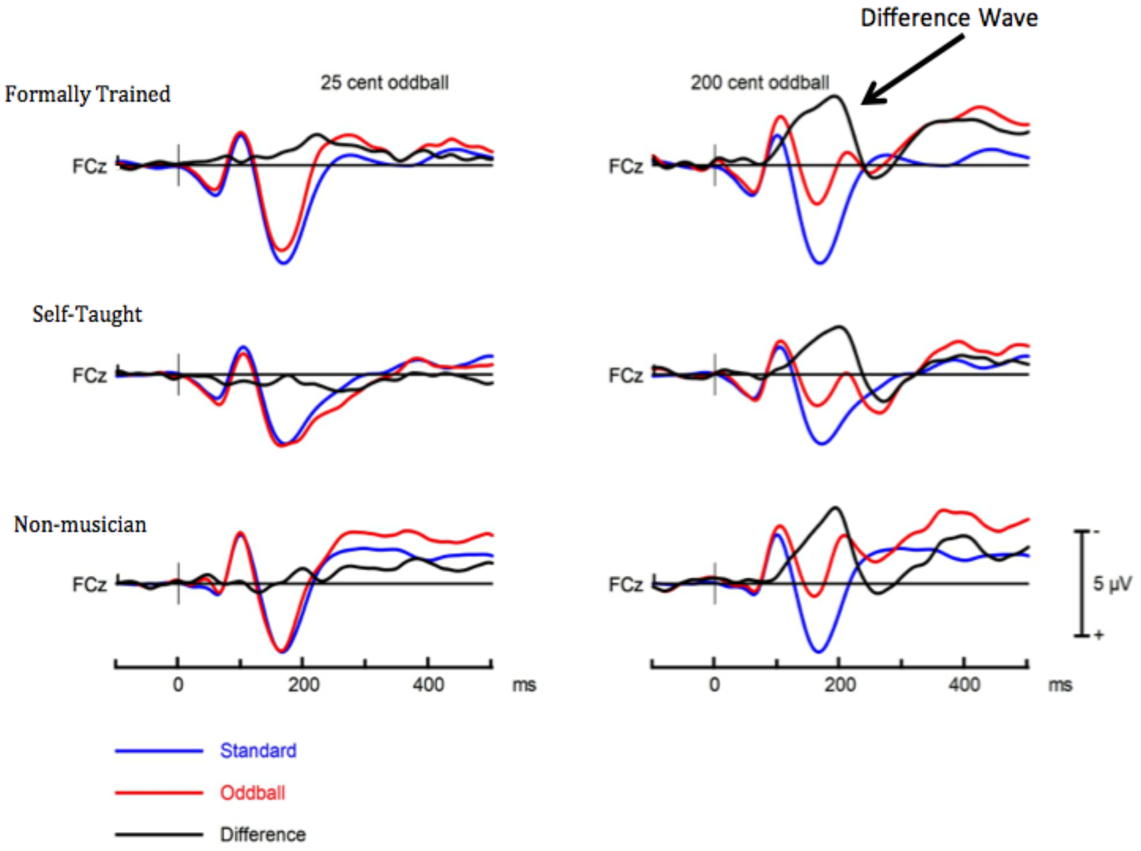

Figure 4. Average amplitude and latency at representative electrode (FCz) of ERP responses to 25-cent and 200-cent deviant tones across three subject groups during a mismatch negativity task.

Discussion

The purpose of this study was to examine the influence of music training type on auditory processing. Music training type had a differential effect on the three auditory tasks. Consistent with previous findings, formally trained musicians had advantages over non-musicians on all auditory processing tasks (Brattico et al., 2006; Fujioka et al., 2004; Koelsch et al., 1999; Parbery-Clark et al., 2009; Zendel et al., 2017). In this study, musicians, regardless of training type, had advantages over non-musicians in understanding speech in noise. Formally trained musicians outperformed self-taught musicians on the ability to detect a bad note in a melody (music processing task), but self-taught musicians clearly outperformed non-musicians on this task, showing an advantage for self-taught musicians over non-musicians. MMN amplitude was enhanced for the 25-cent oddball in formally trained musicians compared to the other groups, suggesting that only formal music training is associated with enhancements in the automatic detection of pitch change in the auditory environment. Findings suggest differential impacts of music training type on auditory processing.

The QuickSIN task assessed participants' ability to understand speech in noise, and both formally trained and self-taught musician groups showed an advantage over non-musicians on this task. This is consistent with previous research showing an advantage of formally trained musicians over non-musicians in the ability to understand speech in background noise (Parbery-Clark et al., 2009; Zendel et al., 2017). Importantly, self-taught musicians had the same advantage for understanding speech in noise as formally trained musicians. This suggests that music training type is not a critical factor for benefits in understanding speech in noise. However, given that understanding speech in noise is not a music related task, it is possible that the advantages shown by self-taught musicians are not purely low-level auditory processing benefits.

The central auditory system is comprised of two stages, or two hierarchical levels of functioning. The first is low-level, automatic processing, which is an exogenous process. This stage of the auditory system functioning does not require attention, and formally trained musicians are known to have enhancements in low-level auditory processing compared to non-musicians (Kraus, & Chandrasekaran, 2010). The second stage is high-level cognitive processing, which occurs later. This is an endogenous process that is dependent on attention and cognition.

Formally trained musicians have enhanced cognitive processing in the auditory domain compared to non-musicians (George & Coch, 2011; Faßhauer, Frese, & Evers, 2015). The P300 (or P3) wave is an ERP component associated with high-level cognitive functioning, and is elicited during the decision-making process (Luck, 2012), which is required for both the speech in noise task and melody task after early auditory processing occurs. The latency and amplitude of the P300 wave are commonly used as a measure of cognitive functioning, where an earlier evoked P300 suggests faster updating of working memory, and a larger P300 suggests a greater allocation of neural resources in response to stimuli (George & Coch, 2011; Faßhauer et al., 2015). Long-term formal music training is associated with both earlier and larger evoked P300s during an oddball task (responding to infrequent deviant stimuli amongst frequent standard stimuli), supporting an advantage for formally trained musicians over non-musicians for high-level cognitive processing (George & Coch, 2011). Formally trained musicians are also better at understanding speech in noise, a task requiring both stages of processing, compared to non-musicians (Zendel, Tremblay, Belleville, Peretz, 2015).

Within the auditory system, there are interconnected ascending (bottom-up) and descending (top-down) pathways involved in sound discrimination, which influence cortical and subcortical structures (Chandrasekaran & Kraus, 2010). Thus, early low-level auditory processing may facilitate later cognitive processing as well. Throughout the course of formal music training, musicians must attend to minute changes in the acoustics of musical sound (Kraus & Chandrasekaran, 2010). Musicians with regimented, formal music training experience have enhanced auditory processing, which is associated with heightened performance on music related tasks. This has been shown by increased brainstem plasticity in formally trained musicians in response to music stimuli, and explains the superior performance of formally trained musicians over non-musicians on musically relevant tasks in this study. Formally trained musicians also have enhanced automatic neural responses to speech stimuli compared to non-musicians (Kraus & Chandrasekaran, 2010).

Understanding speech in noise is a complex cognitive process that relies on both lower-level auditory and higher-level cognitive processing (Chandrasekaran & Kraus, 2010; Zendel et al., 2015). Specific tasks influence which hierarchical level is used, and how this process functions at the neurophysiological level appears to differ between formally trained and self-taught musicians. Self-taught musicians were better able to understand speech in noise compared to non-musicians. Self-taught musicians may have enhanced higher-level cognitive processing compared to non-musicians, similar to that of formally trained musicians. Interestingly, these enhancements in cognitive processing appear to be associated with the act and ability of playing music, regardless of music training type. The effect of training type did not impact performance on the QuickSIN task, and both musician groups had a significantly better ability to understand speech in noise.

The behavioural melody task analyzed both accuracy and confidence of participants' ability to detect both out-of-tune and out-of-key notes in a melody. As the same pattern of results was found in analyses for the detection of both out-of-tune and out-of-key notes, the term "bad note" will subsequently be used to represent the results of both analyses. As expected, formally trained musicians had higher accuracy and confidence at detecting a bad note in a melody compared to non-musicians, which supports previous findings on auditory processing advantages for musicians over non-musicians (Fujioka et al., 2004). What is particularly important is that self-taught musicians also had higher accuracy on this task compared to non-musicians, but still had lower accuracy when compared to the formally trained musicians. This provides support for the proposal that the auditory benefit associated with being a self-taught musician is different from the benefit observed in formally trained musicians. As this task directly involved music abilities for which formally trained musicians have specific training (i.e. the detection of a bad note in a melody), this could explain their advantage over musicians without formal training. Formal music training provides specific instruction and training in pitch, timing, and timbre, with an emphasis on listening skills for music-relevant auditory stimuli. This expertise in attending to musically relevant stimuli and detecting pitch change can be explained by the formal music training experience. Self-taught musicians, in contrast, have no specific training focus, and therefore do not parallel formally trained musicians on the ability to detect a bad note in a melody. Self-taught musicians do however still significantly outperform non-musicians on the ability to detect a bad note in a melody. Detecting a bad note in a melody relies on low-level auditory processing to detect the note automatically, but also relies on cognitive mechanisms to identify the note as “bad”, and to do so, one must have learned what constitutes both a “good” and “bad” note, based on exposure and cultural influence. This provides an explanation for the enhanced performance of self-taught musicians over non-musicians.

Interestingly, despite a significantly enhanced performance in formally trained compared to self-taught musicians, both musician groups exhibited similar levels of confidence on detecting bad notes in melodies, suggesting that self-taught musicians may be overconfident in certain music processing abilities. However, while the self-taught musicians’ confidence may be out of proportion compared to their accuracy, they still show both higher accuracy and confidence than non-musicians on the melody task.

Although self-taught musicians appear to have high-level cognitive processing enhancements similar to formally trained musicians over non-musicians, they do not appear to have an advantage in low-level auditory processing. Formally trained musicians had an enhanced MMN for a small pitch deviant compared to both self-taught and non-musicians, suggesting an advantage in the automatic stage detection of pitch change in the auditory environment. The advantage for formally trained musicians over non-musicians supports previous research findings (Brattico et al., 2006; Koelsch et al., 1999). Importantly, self-taught musicians differed from formally trained musicians in MMN amplitude. The results of this task highlighted the differential impacts of music training type of auditory processing, and further supports the idea that formal music training may impact the early automatic stages of auditory processing and the later, high-level controlled/cognitive stages of auditory processing, while self-directed musical training only impacts the latter.

It is important to note that both musician groups in this study were matched on demographic variables that were not comparable in previous research studies. In previous research studies comparing professional to amateur musicians, there were differences in demographics among subject groups in the amount of regular music practice, number of years of music experience, the amount of public music performance, and music education. In general, amateur musicians among these studies were those who practiced/played less on average, performed less, and there was limited information provided about the duration of music experience (Oechslin et al., 2013; Rogenmoser et al., 2017; Schneider et al., 2002; Tervaniemi et al., 2006). Critically, amateur musicians in previous studies either had received extensive formal music training, or in some cases there was ambiguous or no information given about music training type of amateur musician subject groups. The present study differs from previous analyses in that differences between musician groups were small, if any existed. In the current study, both formally trained and self-taught musicians played on average a minimum of 5 hours per week over the past year, with self-taught musicians actually practicing slightly more hours on average compared to formally trained musicians. Self-taught and formally trained musicians in the present study had been playing music for a similar number of years and had a similar number of years of academic education (see Table 1 for participant demographics). These factors help to reduce differences between musician groups that existed in previous studies.

It is also possible that the advantage for formally trained musicians over self-taught musicians for accuracy is related to the age of onset of playing music. Aside from music training type, the only demographic variable in which self-taught and formally trained musician groups differed was their average age of onset of playing music. In this study, formally trained musicians started playing music on average at age 8.88 years (*SD* = 3.44), while self-taught musicians on average started playing music at age 14.72 years (*SD* = 7.99). This was an unavoidable discrepancy between the two musician groups, as music training commonly starts at a young age, and very young children are not cognitively able to teach themselves music, while young children can still learn through music lessons. In the present study, one participant in the self-taught subject group started playing music at age 4, which is much earlier than the average age of onset of playing. This participant began music lessons at age 4 which lasted approximately one year, after which the participant received no formal music training, and learned to play a different musical instrument through informal methods at a later age. This participant qualified as a self-taught musician based on the criteria used in the present study, as music lessons ended before age 6 and the person learned through informal methods for several years prior to the study.

Self-taught musicians appear to have high-level cognitive processing enhancements compared to non-musicians. Self-taught musicians performed similarly to formally trained musicians in their ability to understand speech in noise, and had enhancements over non-musicians for detecting a bad note in a melody, but less of an advantage than formally trained musicians. Finally, self-taught musicians did not show any benefit compared to non-musicians for the automatic detection of a bad note in a melody, while formally trained musicians did show enhancements. There are two possible explanations for the change in low-level processing seen only in formally trained musicians. First, it is possible that the age of onset of training plays an important role in low level automatic auditory processing. It is also possible that formal, regimented music training triggers these low-level processing differences, and therefore self-taught musicians would not show these benefits.

Self-taught musicians may be receiving higher-level cognitive benefits from being a musician and music practice, but not receiving the same low-level auditory benefits as formally trained musicians. Neither formally trained nor self-taught musicianship teach the ability to understand speech in noise. Formal music training may, however, facilitate enhanced MMN responses elicited by pitch change (oddball tones) in the auditory environment. Formal music training requires the ability to identify notes that are out of tune, and as a result of the importance of this ability, brain regions responsible for the automatic detection of small frequency changes become enhanced.

However, the melody task included things that both formally trained and self-taught musicians do: identifying a bad note in a melody. It appears that the further the auditory task is from being music related, the more similar both musician groups perform, whereas differences between music training type groups are more pronounced for music related tasks. The differential impacts of music training type on auditory processing suggest a broader pattern for how training type influences the neural processing of sound than was expected. Self-taught musicians appear to be receiving high-level cognitive processing benefits compared to non-musicians, but are not receiving similar lower-level auditory processing benefits to formally trained musicians over non-musicians.

It is important to note that this study is cross-sectional in nature, and therefore cannot determine whether music training type is the causal factor driving these differences in auditory processing. It is possible that group differences are not related to training type, but rather are explained by inborn differences. People with ‘musical’ families may be more likely to be enrolled in formal music lessons, and it is also possible that people who are more musically inclined may be more likely to self-teach music. Despite these limitations, it is likely that different types of music training (i.e. formal vs. self-taught) have differential effects on auditory processing.

Conclusion

Music training type (formally trained vs. self-taught) is shown to have differential impacts on auditory processing abilities. Self-taught musicians show similar advantages as formally trained musicians on the abilities to understand speech in noise, but no difference compared to non-musicians in MMN amplitude in response to the automatic detection of pitch change in the auditory environment. Formally trained musicians outperform self-taught musicians on the ability to detect a bad note in a melody, and self-taught musicians in turn outperform non-musicians on this task. This study revealed differential impacts of music training type on brain plasticity and task performance. Understanding these differential impacts of music training type may be beneficial in settings such as healthcare, where the integration of music is becoming more prevalent. There are many potential health benefits of music training, and music practice has been used for auditory rehabilitation programs, as well as to help children focus in school settings. As clinicians have started to incorporate music and music training into healthcare settings, it is critical to understand how training type impacts these outcomes. It is important to know whether the implementation of these music programs require formal music training and instruction to yield the desired outcomes. Whether for auditory rehabilitation, increasing academic focus in children, or other purposes, understanding the impact of music training type is a key factor with the potential to influence success rates for music based rehabilitation programs and the many clinical uses of music and music training.

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Appendix

Music Status Questionnaire

Survey: The impact of music training type on how your brain recognizes and interprets sound (auditory processing)

Psychology 4951

Subject ID: ____________________________________

DOB: _______________________________________

What gender do you identify as? ______________________

Languages

First Language learned as a child: _________________

Second: _______________ Speak___ Read___ Write___

Third: _________________ Speak___ Read___ Write___

Fourth: ________________ Speak___ Read___ Write___

Where were you born? (City & Province) _______________________________________

Where were you raised? (City & Province) ______________________________________

Where were your parents born? (City & Province)________________________________

Where were your parents raised? (City & Province)______________________________

Do you listen to music? Yes No (circle)

How often? ______________________ (hours per week)

How do you listen to music?

Headphones____ Earphones____ In the car___ With speakers___ Live___

Are you a musician? Yes: Formally trained Yes: Self-taught Non-musician

If non-musician, please proceed to Section C.
All musicians please complete "Musicians: Basics"
If formally trained, please complete Section A
If self-taught, please complete Section B

Musicians: Basics

Do you play a musical instrument/sing? Yes No (circle)

How Often? ___________________________________ (hours per week)

Do you conduct music? Yes No (circle)

Do you compose music? Yes No (circle)

How often (within last year)? _______________ (hours per week)

Do you use computer software for composition? Yes No (circle)

Do you arrange music? Yes No (circle)

How often (within last year)? ________________ (hours per week)

Do you improvise? Yes No (circle)

How often (within last year)? ________________ (hours per week)

Do you perform publicly? Yes No (circle)

How often (within last year)? ________________ (hours per YEAR)

Do you teach students? Yes No Past (circle)

How many (current)? ______________________

How often (current)? ______________________ (hours per week)

Principal Playing Style: Jazz Classical Pop Rock Contemporary Folk (circle)

If not listed, please describe: _______________________________________

Other music activities (describe) ____

____

NOTE: if status has changed significantly, fill in older information at the end of this form

Current Music Status

Primary Instrument: ____________________________

Instrument Type: Woodwind Brass String Percussion Voice Piano (circle)

Age Started: __________________________________

Practice Instrument: ____________________________ (hours per week)

Secondary Instrument: ____________________________

Instrument Type: Woodwind Brass String Percussion Voice Piano (circle)

Age Started: __________________________________

Practice Instrument: ____________________________ (hours per week)

Tertiary Instrument: ____________________________

Instrument Type: Woodwind Brass String Percussion Voice Piano (circle)

Age Started: __________________________________

Practice Instrument: ____________________________ (hours per week)

First instrument learned as child

Instrument: ___________________________________

Age started: __________________________________

Age stopped: _________________________________

Institution: ____________________________________

Highest level of achievement (Degree, RCM grade, etc…): ________________________

____

Miscellaneous

Do you have perfect pitch? Yes No (circle)

Do you have any musicians in your family? Yes No (circle)

Please list them: ____

____

Section A: Formally Trained Musicians

Music Education

Current Status (or most recent)

Instrument: ____________________________________

Specialization: __________________________________

Institution: _____________________________________

Year started: ___________________________________

Year finished (or in progress): ______________________

Did you study theory as part of this program? Yes No (circle)

Highest level of achievement (Degree, RCM grade, etc…): _________________________

Previous Training

Instrument 1: ____________________________________

Specialization: _________________________________

Institution: _____________________________________

Year started: ___________________________________

Year finished (or in progress): ______________________

Did you study theory as part of this program? Yes No (circle)

Highest level of achievement (Degree, RCM grade, etc…): _________________________

Instrument 2: ___________________________________

Specialization: ________________________________

Institution: ____________________________________

Year started: __________________________________

Year finished (or in progress):_____________________

Did you study theory as part of this program? Yes No (circle)

Highest level of achievement (Degree, RCM grade, etc…): ________________________

Section B: Self-Taught Musicians

When did you first learn to play music? _______________________________________

How long have you been playing? ____

How did you learn to play? (Ex. family member, books, online video, etc.) ___________

____

____

Can you read sheet music? Yes No Somewhat

Were you given any music lessons in school or elsewhere? If yes, when and how long did they last?

____

Section C: Non-musicians

Have you been given music lessons or were you taught music in school or elsewhere? If yes, how old were you and how long did they last? ______________________________

____

Do you have any musicians in your family? Yes No (circle)

Please list them: ____

Previous Music Status (Fill in if status has changed significantly)

What years is this status for? _______________ TO ______________

How often? __________________________________ (Hours per week)

Did you compose music? Yes No (circle)

How often? ____________________________ (hours per week)

Did you arrange music? Yes No (circle)

How often? ____________________________ (hours per week)

Did you improvise? Yes No (circle)

How often? _____________________________ (hours per week)

Did you perform publicly? Yes No (circle)

How often? ____________________________ (hours per YEAR)

Did you teach students? Yes No Past (circle)

How many? ____________________________

How often? ____________________________ (hours per week)