Pitch Discrimination in Speech; Behavioural and Electrophysiological Differences across Type of Musical Training

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ABSTRACT

The aim of this study was to examine the effect of different types of musical training on pitch discrimination in speech. A sample of 40 participants were presented with 20 paired phrases and asked to distinguish which of these sentences contained a change of pitch. In addition to recording error rates, EEG activity of the temporal lobe was examined across non-musicians, vocalists, instrumentalist and musicians with combined training. While we expected vocal musicians to perceive more changes of pitch than non-musicians, as well as to show significantly different changes in EEG activity, this was not the case. Similarly, musicians with combined musical training did not differ in pitch discrimination ability from other training types. Given this, the positive transfer effects of musical training to pitch discrimination in speech previously seen in instrumentalists may not be generalizable to other training types.

INTRODUCTION

In the wake of the Rauscher et al (1993) study on the so called 'Mozart Effect', both academic researchers and popular media became intrigued with the concept that music may have an influence on other areas of cognition. This particular study controversially claimed that listening to Mozart's music temporarily improved participant's performance during a spatial-reasoning task, but it was heavily criticised in relation to its design. Various attempts to replicate this study have found inconsistent results (Steele et al, 1999; Chabris, 1999) and a recent meta-analysis consisting of over 40 studies with more than 3000 participants claims to have found little evidence for a performance enhancing Mozart effect (Pietschnig et al, 2010). One significant outcome of Rauscher's study however, was the interest it generated in the area of music psychology. While listening to Mozart's sonatas may not reliably improve spatial reasoning abilities, positive transfer effects from musical exposure have since been demonstrated in a number of cognitive areas, including verbal memory (Chan et al., 1998), mathematical abilities (Gardiner et al., 1996) and visuo-spatial abilities (Brochard et al., 2004).

Perhaps the most consistently studied music-cognition link however, is that between two auditory systems; music and language. According to the broad evaluation of these two domains presented by Rebuschat et al (2012, p xiiv), the underlying assumption in their comparison is that it may result in a deeper understanding of the structural and functional properties of both music and language, as well as serving as a test case for theories of how the mind and brain work.

Music and Language; the Similarities

Generally, the most striking connection between music and language to researchers is that both are auditory systems which involve the perception and production of sound elements (Rebuschat et al, 2012; Patel, 2002). However, there are a number of other similarities which have interested academics from a variety of disciplines, including psychology, psychoanalysis, anthropology, linguistics and neuroscience. According to Cross & Woodruff (2008, p3) "all cultures of which we have knowledge engage in something which, from a Western perspective, seems to be music", the same also holds true for language. Both behaviours can be observed universally, are unique to humans and an implicit understanding of the principles governing each develop with minimal instruction and without conscious effort (Ayotte et al. 2002; Hyde et al, 2010; Peretz et al, 2002; Roberts, 2010). Music and language also appear to consist of a similar structure whereby individual, hierarchical elements of sound are combined or grouped in meaningful ways within closed systems according to rules and principles of grammar or harmony (Fabb & Halle, 2012; Patel, 2003; Rebuschat et al, 2012). According to Patel (2003) the similarities may be the result of 'shared resources' in the neural areas underpinning syntactical processing for both domains, while semantic processing may be separate for each; what she terms a 'shared syntactic integration resource hypothesis (SSIRH)'. Such a theory aims to address the apparent divergence of neuropsychology and neuroscience –whereby aphasias in language can occur while leaving musical functioning intact, but neuroscientific evidence shows overlap in musical and linguistic processing (Patel, 2003). One example of such evidence is the research by Maess et al. (2001), who found that syntactical violations of music elicit activity in the regions of the brain that have long been associated with language. In an MEG study they found that Broca's area and its right-hemisphere homologue were involved not only in auditory language comprehension but in the analysis of incoming harmonic sequences (Maess et al, 2001).

According to Magne et al (2006), while a number of such experiments have emerged comparing neural and behavioural similarities in aspects of music and language perception such as syntax and semantics, the more objectively comparable aspect of pitch processing appears to have been neglected. Rather than examine the wealth of research looking at the overlap between music and language, the current study will address those relating to this relatively unexamined acoustic parameter shared by both; pitch.

Pitch Processing

According to the American National Standards Institute (as cited in Besson et al, 2007, p400), pitch can be defined as the “attribute of auditory sensation in terms of which sounds may be ordered on a musical scale”. As an acoustic parameter fundamental to both music and language, pitch processing acts as a significant point of comparison for these two domains. According to Cross (2012, p 325), while the importance of pitch in music is widely accepted, it is generally considered as constituting a background aspect of language in spite of the fact is fundamental in distinguishing between statements and questions and is needed to “facilitate affective communication”. The fact that variations in pitch are one of the means in which emotions are expressed in both music and language for example, forms the foundation of a study by Thompson et al (2001), who examined whether music lessons promote sensitivity to emotions conveyed by speech prosody.

Some researchers however, while acknowledging that much can be learned from the comparison of music and language, are sceptical as to the extent that processing of pitch overlaps for these two domains. Peretz et al (2012) for instance, argue that while music and language share many overlapping features and functions, pitch based musical abilities are governed by different genes and brain regions than that of language (Peretz, 2012). These researchers cite disorders of musical pitch impairment where language processing remains unhindered as evidence for this so called modularity of music, arguing that it is a “cognitively unique and evolutionary distinct faculty” (Peretz, 2003, p688). However, this disorder, termed amusia, is characterized by an inability to perceive a change in pitch of less than one semitone (Ayotte et al, 2002; Hyde et al, 2010) and as music in Western societies generally utilizes much more subtle changes in pitch (Nguyen et al, 2009) an amusic person’s perception of music is very limited. Language on the other hand, uses more pronounced changes of pitch (Hutchins et al, 2010). In French and English, for example, pitch changes are on the order of 5-12 semitones (Nguyen et al, 2009) Given this, it’s not unexpected that pitch perception in language remains relatively spared in cases of amusia.

As further support of this theory, several researchers have found that when asked to identify pitch changes in languages that rely on tonal changes to convey meaning, namely tonal languages such as Mandarin, amusics have shown impairment in pitch processing in language as well as music (Nguyen et al, 2009). Tillman et al (2011) for example demonstrated that this was not a domain specific deficit in an experiment which asked non-speakers of tonal languages (native French speakers) to identify changes in lexical tone sentences spoken in Mandarin Chinese and in Thai. They found that participants with congenital amusia demonstrated inferior pitch discrimination than their non-amusic counterparts. Hutchins et al (2010) also found differences in native French speaking amusic and non-amusic participants’ ability to identify statements versus questions based on rise in pitch when the variations in pitch were more fine-grained than those in the earlier studies on amusia by Peretz et al (2003). Liu et al (2010) demonstrated a similar effect in English speaking participants. Given this significant support that deficiencies of musical pitch processing can affect processing of pitch in speech, it seems reasonable to infer that aspects of pitch processing do in fact overlap for these two domains.

Musical Training and Language; Positive Transfer Effects for Pitch Processing

If pitch processing for these two areas does indeed overlap, it follows that the shared features would allow for training which promotes sensitivity to pitch in one domain to facilitate pitch processing in other (Moreno, 2009). According to Moreno (2009), by increasing sensitivity to pitch in music, musical training will also enhance pitch detection in speech. One of the earliest studies examining the possible effects musical training might have on pitch processing in language was that by Schon et al (2004). These researchers claimed that because both prosody and melody relied on the same acoustic parameter, namely pitch, then musical training should facilitate processing of pitch in language too. In addition they claimed that if pitch perception relied on common neural mechanisms for both domains, then both prosodic and melodic pitch violations should elicit similar electrophysiological responses in participants. They presented a sample consisting of eighteen non-musicians and musicians (with an average of 15 years of musical training) with 120 spoken sentences and 120 melodies and recorded their responses as to whether pitch changes had taken place. There were three conditions in this experiment, phrases and melodies either ended on a congruous (no change of pitch), a weakly incongruous (35% change in pitch), or a strongly incongruous tone (120% change in pitch). While there was little difference between the two groups for congruous or strongly incongruous conditions, musicians showed superior pitch discrimination in both the music and language conditions for the more difficult to detect, weakly incongruous endings. Musicians detected incongruous prosodic and melodic tones both faster and with more accuracy than their non-musician counterparts indicating musical training did in fact facilitate pitch processing, not only in music but also in language. Interestingly, the differences between these two groups also appeared to be reflected in the electrophysiological data recorded from the experiment. Schon et al (2004) found that both weakly and strongly incongruous endings elicited larger positivities than congruous endings over parieto-temporal sites bilaterally, and these positivities had shorter onset latency for musicians.

Building on this research, Magne et al (2006) conducted a similar study, aiming to test if the differences in pitch discrimination ability between musicians and non-musicians could be demonstrated after just three to four years of instrumental musical training. Using a sample of twenty six, 8-year old children, half of which were non-musicians and half of which had three to five years of instrumental musical training. They presented the children with both musical and linguistic stimuli and asked them to detect strongly and weakly incongruous pitch variations among them. They found that musician children not only outperformed the non-musician children in detecting weakly incongruous pitch changes but their recorded event-related brain potentials showed early negative components in the musical tasks and late positive components in the language tasks that were not present in the non-musicians. However, there are some important things to note when looking at both the Schon et al (2004) and the Magne et al (2006) studies. Firstly, neither of these studies can eliminate the possibility of a pre-disposition towards musical ability in the samples that they used.

Besson et al (2007) aimed to address this issue of potential musical predispositions by conducting a longitudinal study in which half of a sample of eight-year-old, non-musician children were given musical training while the other half received training in painting. The same tests administered in the Magne et al (2006) experiment were administered in this study to test pitch discrimination ability, both before and after 8 weeks, and then again at 24 weeks of training. If the results seen in Schon et al (2004) and Magne et al (2006) for pitch processing in language were the result of musical training rather than any musical predisposition, then it would be expected that they would be replicated here for the musically trained group. Besson et al (2007) found that while behavioural differences (i.e. error rates and reaction times) were not yet present across the two groups at 8 weeks of training, the 24 weeks were enough for the musically trained participants to outperform those with training in painting. Interestingly, electrophysiological differences between the two groups were noted at 8 weeks, before any behavioural differences became apparent. At 8 weeks of training strong incongruities of pitch in the language task elicited smaller P600 in the musically trained children that wasn't present in the painting group. After 24 weeks, differences in electrophysiological response to pitch violations also included increased amplitude of the N300 to musical weak incongruities in the musical group that was not seen in the painting group.

Another point that was never addressed in the Schon et al (2004), the Magne et al (2006) or indeed the Besson et al (2007) study was the effect of musical training type on pitch processing. Each of these studies used a sample that solely consisted of instrumental musicians, while vocal training was not examined. Given that vocalists receive similar training to instrumentalists, in that it promotes sensitivity to pitch, as well as the fact that both pitch perception in speech and singing involves the perception of pitch in vocal production, it seems to be a more obvious point of comparison. In spite of this, studies examining whether positive transfer effects of musical training can be generalised to vocal training are very sparse. One study which acknowledges this lack of differentiation between vocal and instrumental musicians in current research is that of Nikjeh et al (2008). According to these researchers vocal musicians are unique in that "their instrument is endogenous to the body" and that they have had "significant auditory and kinaesthetic exposure to the acoustic features of their musical instrument long before actual music training begins" (Nikjeh et al, 2008, p994). Given this fact, they expected to find superior pitch perception in vocal musicians compared to instrumental musicians and non-musicians by examining mismatch negativity to pitch deviances and difference limen for frequency (the just noticeable difference between two pitches) across these groups. In a sample that consisted of all female university students with a minimum of five years of professional music instruction, they not only replicated the findings above, whereby musicians outperformed non-musicians, but they found vocal musicians who had also received instrumental training demonstrated superior pitch discrimination overall. However, they also found that auditory pitch discrimination did not differ significantly across vocal and instrumental musicians. While this study acknowledged the fact that pitch discrimination ability may differ across type of musical training, unlike the other studies described above, their findings were not applied to the domain of speech. There were also some aspects of the experimental design that leave the findings open to questioning. The sample consisted entirely of female university students, which may lead to questions of ecological validity; can these findings be generalised to male musicians, or to non-students?

Aims and Design of the Current Study

The current study examined whether the behavioural differences in pitch discrimination abilities between musicians and non-musicians seen in previous research (Schon, 2004; Magne, 2006; Besson, 2007; Moreno; 2009) can be demonstrated with other musical training types, namely vocal and combined vocal and instrumental training. While this issue was examined in the context of harmonic tones in the Nikjeh et al. (2008), the current study aims to look at pitch processing in the context of speech. Given that the electrophysiological data in the studies mentioned above all relate to activity in regions within the temporal lobe, and given that a change in wave pattern is indicative of a change in consciousness such as increased auditory attention, the current study also aims to look at whether the pitch discrimination task will generate changes in temporal lobe activity that differs for non-musicians and vocal musicians. Finally this study aims to address some of the methodological issues seen in the Nikjeh et al (2008) study, by using a sample representative of both genders and consisting of individuals both inside and outside the university environment.

Participants were divided into four groups based on existing musical training; non-musicians, vocal musicians, instrumental musicians and musicians with combined vocal and instrumental musical training. All participants were presented with the same auditory stimuli, consisting of paired phrases, half of which were selected at random and parametrically altered so that the pitch was 35% higher in the second phrase of the pair. Participants were asked to distinguish when a change of pitch had taken place and their response was recorded in order to determine the error rates across groups. In addition, electrophysiological measurements during the pitch perception task were taken in the form of surface EEG activity from the temporal lobe.

Hypotheses

By using both behavioural and electrophysiological measures of pitch discrimination abilities in speech the current study aimed to show that;

1. Vocalists will perceive significantly more changes of pitch between two sentences than non-musicians.

2. Musicians with vocal training will show significantly different changes in EEG activity in the temporal lobe compared with non-musicians.

3. Musicians with combined instrumental and vocal training will perceive significantly more changes of pitch between two sentences than non-musicians or musicians with vocal or instrumental training alone.

METHODS

Participants:

In order to recruit a diverse sample of participants with musical training as well as non-musicians for this study, a combination of sampling methods was used; self-selecting and snowball sampling. The choirs of Dublin were sent an email with a basic outline of the study and asked that those interested in taking part contact the researcher, as well as passing the information on to any others who might be interested. In addition, the same brief description of the study was given verbally to a number of classes at Dublin Business School. As with the choirs, those interested were asked to contact the researcher and pass the information on to other potentially interested individuals. Those who contacted the researcher were then screened to ensure they met the inclusion criteria before participating. Because Besson et al (2007) reported that eight weeks of training was not long enough to produce any behavioural differences across different training types (i.e. differences in error rates) as well as electrophysiological differences, all participants who were in the vocal, instrumental or combined training groups were required to have had at least 12 weeks of training in their field. To be grouped exclusively as vocal or instrumental musicians rather than combined, participants were required to have no more than 4 weeks of musical training in a second field of music.

A total of 40 participants took part in this study, all of whom were over the age of eighteen and had no self-reported hearing impairments (N=40). Of those participants 12 were male and 28 were female. The average age of participants was 35.20 years, with a range from 21 to 70 years (*M=35.20, SD= 13.595).* 30% of these participants were non-musicians (n=12), of which 2 were male and 10 were female. The average age of non-musicians was 29 and ranged from 21 to 47 *(M=29.00, SD= 9.155)*. 20% of participants were vocalists (n=8), 3 of whom were male and 5 were female. Their average age was 47.63 and ranged from 29 to 70 *(M=47.63, SD = 14.569)*.

22.5% were instrumental musicians (n=9), 4 of whom were male and 5 were female. Their mean age was 30.11 and ranged from 22 to 57 (*M=30.11, SD=11.634).* Finally, 27.5% had received combined vocal and instrumental training (n=11), 3 of whom were male and 8 of whom were female. The mean age of participants with combined musical training was 37.09 and ranged from 21 to 63 *(M=37.09, SD=13.225).*

Materials and Apparatus:

Stimuli: Audacity 2.0.2 was used to record and copy 20 phrases from Saint-Exupéry's (1945) *'The Little Prince'* (see appendices for a transcript of these phrases). Half of the copied phrases were then selected at random and manipulated using the same programme so that the pitch was raised by 35%.

Three types of measurements were recorded during this study in order to measure relevant variables; behavioural, electrophysiological and demographic.

Behavioural Measurements: Each pair of sentences was presented to participants, accompanied by a blank screen, using Superlab 4.5 on a HP Compaq micro tower Desktop (2.66 GHz) running Window XP. This was followed by the written on screen question "do you think a change in pitch has taken place?" to which participants indicated their response using the keyboard. Because this was not a repeated measures study and practice effects were not an issue, the order of sentences was kept consistent across all participants. Superlab 4.5 recorded the response of participants which was then interpreted using Cedrus Data Viewer.

Electrophysiological Measurements: In order to record EEG activity during this study, participants wore a MLAEC2 EEG Electro-cap during the auditory task, used with a PowerLab 26T (LTS) Biofeedback Unit. This unit was connected to a Lenovo Intel 2140 (1.60 GHz) running Windows XP. LabChart 7 was used to interpret EEG results.

Demographic Measurements: Information on type of musical training received by participants, as well as age and gender were obtained using a demographic questionnaire (see appendices for a copy of this questionnaire).

Design:

This was a quantitative, between-group study in which participants were allocated to groups on the basis of the type of musical training received. Because participants were not randomly assigned and did not receive musical training as part of this study, but were divided on the basis of pre-existing differences, this was a quasi-experimental design. The first part of this study tested whether vocal musicians showed superior pitch discrimination than non-musicians, by examining the number of pitch changes perceived (DV) across type of musical training (IV). The second part of the study tested whether changes in EEG in the temporal lobe would differ for non-musicians and vocal musicians; type of musical training acted as the independent variable while EEG frequency during pitch changes acted as the dependent variable. Finally, this study tested whether musicians with combined vocal and instrumental musical training would show superior pitch discrimination than the three other groups by looking at number of pitch changes perceived (DV) across type of musical training, including non-musicians, vocal musicians, instrumental musicians and musicians with combined vocal and instrumental training (IV).

Procedure:

Each participant was given a demographic questionnaire to fill out, attached to which were written instructions informing them that this was a study looking at musical training, language and underlying brain activity (see appendices for a copy of these instructions). It was verbally explained that the experiment would involve listening to a series of sentences recorded from a children's book, each of which would be presented twice, while wearing an electrode cap. They were told that in some cases the pitch of the final word in the sentence would have changed and they would be asked to try and distinguish if this change had taken place. The participants were then invited to ask questions if they felt they did not understand what was being asked of them and reminded that they had the right to withdraw at any stage before proceeding.

On completing the questionnaire, each participant was asked to wear the electrode cap. They were then seated in front of a desktop computer and given ear phones to wear. The computer displayed a summary of instructions and asked participants press any key to begin. Each sentence was presented followed by its pair and accompanied by a blank screen. After each pair of sentences had been heard, a written prompt appeared on the screen asking participants to indicate whether or not they thought a change in pitch had taken place by pressing 'Y' or 'N' on the keyboard. This stage of the study took approximately 10 minutes. On completing the study participants thanked for taking part and were invited to ask any questions they might have. They were also reminded that their data was confidential but that they had the right to withdraw their data from the study by contacting the researcher at any stage before publication, which was expected to be within a month of data collection.

RESULTS

Data was analysed using SPSS (Statistical Package for the Social Sciences) version 18.0.

Behavioural Results

Hypotheses one and three were tested in this section, whereby the total number of pitch changes perceived was compared across groups as a measure of behavioural differences across type of musical training. Overall the error rate in this sample was quite high, with just over half of the 9 pitch changes being perceived (*M=5.45, SD=2.49).* Vocal musicians perceived a lower than average number of pitch changes (M=4.00, SD=2.62) while non-musicians (M=5.83, SD=2.89), instrumental musicians (M=6.11, SD=2.67) and musicians with combined vocal and instrumental musical training (M=5.55, SD=1.51) all perceived a slightly higher than average number of pitch changes. The mean number of pitch changes for each group is displayed in Table 1.

Table 1 *Means and standard deviations for number of pitch changes for each group.*

Group	Mean	Standard Deviation
Non-Musicians	5.83	2.89
Vocal Musicians	4.00	2.62
Instrumental Musicians	6.11	2.67
Musicians with Combined Musical Training	5.55	1.51

Vocal Musicians and Non-Musicians - Hypothesis 1:

Because it was found the data for this sample was not normally distributed, a non-parametric test was chosen to test the first hypothesis. While it was expected that vocal musicians would perceive more changes of pitch than the non-musicians, a Mann-Whitney U test for differences found that this was not the case. Non-musicians had a mean rank of 12.17 compared to the mean rank of 8.00 for vocalists and there was no significant difference between these two groups (U= 28.00, P=.135, 1-tailed).

All Musical Training Types – Hypothesis 3:

While we expected to find that musicians with combined musical training would perceive significantly more changes of pitch than the other three groups, again this was not the case. Non-musicians had a mean rank of 22.17, vocal musicians had a mean rank of 13.81, and instrumental musicians had 23.50 while musicians with combined vocal and instrumental musical training had a mean rank of 21.09. Although the instrumental musicians performed in line with previous research, in that they perceived more pitch changes on average than the non-musicians, a Kruskal Wallis one-way ANOVA showed that pitch discrimination ability for non-musicians, vocal musicians, instrumental musicians and musicians with combined vocal and instrumental musical training did not differ significantly (X^2(3)=.3.554, P=.314). The number of pitch changes perceived in each group can be seen in Figure 1

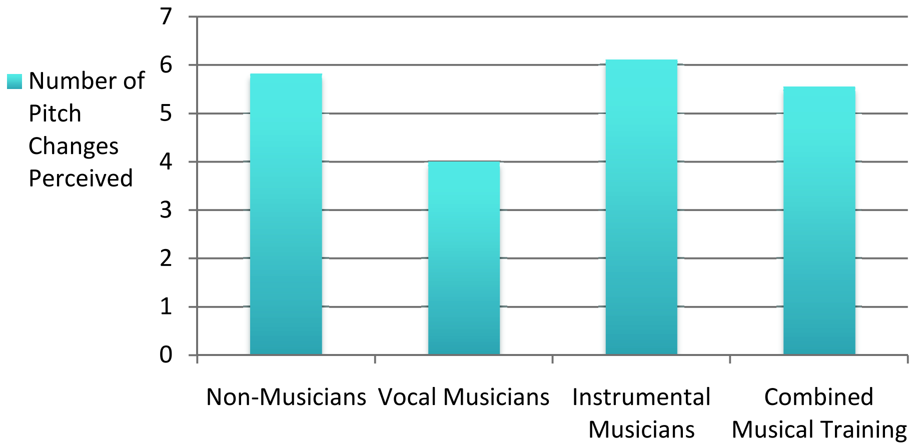

Figure 1. A bar chart showing number of pitch changes perceived in all musical training types.

Electrophysiological Differences

Hypotheses two was tested in this section, whereby EEG activity in the temporal lobe during each pitch change was examined for non-musicians and vocal musicians. Overall the baseline EEG frequency for this sample was in the theta to slow wave alpha range (M=7.95, SD= .30). The baseline EEG frequency was slightly lower for non-musicians (M= 7.91, SD = .25) as well as the vocal musicians (M=7.94, SD=.35). The mean EEG across all pitch changes for this sample was slightly higher than baseline at 8.10Hz (M=8.10, SD= .23). For non-musicians this was 8.17Hz (M=8.17, SD=.31) and for vocal musicians it was 8.07Hz (M=8.07, SD=.17). See Tables 2 for Mean EEG frequency during each pitch change.

Table 2. *Standard deviations and mean EEG frequencies in Hz for each pitch change*

	Non-Musicians	**Vocal Musicians**
Pitch Change 1		
Mean	7.98	8.02
SD	.34	.15
Pitch Change 2		
Mean	8.05	8.04
SD	.30	.40
Pitch Change 3		
Mean	8.15	8.22
SD	.36	.33
Pitch Change 4		
Mean	8.07	8.07
SD	.38	.33
Pitch Change 5		
Mean	8.21	7.89
SD	.70	.36
Pitch Change 6		
Mean	8.39	8.07
SD	.43	.28
Pitch Change 7		
Mean	8.19	8.19
SD	.41	.25
Pitch Change 8		
Mean	8.28	8.13
SD	.61	.41
Pitch Change 9		
Mean	8.17	8.00
SD	.47	.25
Overall Pitch Changes		
Mean	7.91	7.94
SD	.25	.35

Vocal Musicians and Non-Musicians - Hypothesis 2:

While a Wilcoxon-Sign test showed that changes in EEG frequency from the baseline frequency during changes of pitch were significant across this sample overall ($Z=-2.833$, $P=.005$), this difference was significant only for non-musicians ($Z=-2.917$, $P=.028$) but not for vocal musicians ($Z=-1.183$, $P=.237$). While there was a significant difference in the EEG baseline frequency and the mean EEG during changes of pitch for five of the nine pitch changes for the non-musicians, there were no significant changes in the vocal group. See Table 3 for a summary of significance tests for each pitch change.

Table 3 *Wilcoxon-Sign Test results for differences in EEG frequency from baseline during each pitch change*

	Non-Musicians	Vocal Musicians
Pitch Change 1		
z	-784	-.507
p	.433	.612
Pitch Change 2		
z	-.1344	-.676
p	.182	.499
Pitch Change 3		
z	-.1961	-1.521
p	.050	.128
Pitch Change 4		
z	-1.647	-1.183
p	0.99	.237
Pitch Change 5		
z	-1.647	-.169
p	0.99	.866
Pitch Change 6		
z	-2.275	-1.521
p	.023	.128
Pitch Change 7		
z	-1.961	-1.183
p	.050	.237
Pitch Change 8		
z	-2.040	-1.183
p	.041	.237
Pitch Change 9		
z	-1.334	-.845
p	.182	.398
Overall Pitch Changes		
z	-2.197	-1.183
p	.028	.237

While we expected EEG activity to differ significantly for the non-musicians and the vocal musicians, this was not the case. The vocal musicians and the non-musicians did not differ significantly for any of the nine pitch changes (summary in Table 4). Overall the non-musicians had a mean rank of 12, while the vocal musicians had a mean rank of 7 and a Mann Whitney U test for differences found that they did not differ significantly in mean EEG frequency during pitch changes (z=-.169, p=.866, 2-tailed).

Table 4 *Mann-Whitney U test results for differences in EEG frequency for non-musicians and vocalists during each pitch change*

	Non Musician Mean Rank	**Vocal Musician Mean Rank**	**Z**	**p**
Pitch Change 1	9.75	10.43	-2.54	.800
Pitch Change 2	10.25	9.75	-2.54	.800
Pitch Change 3	9.50	10.86	-.507	.612
Pitch Change 4	10.33	9.43	-.338	.735
Pitch Change 5	11.67	7.14	-1.690	.091
Pitch Change 6	11.75	7.00	-1.775	0.76
Pitch Change 7	9.50	10.86	-.507	.612
Pitch Change 8	10.50	9.14	-5.07	.612
Pitch Change 9	10.75	8.71	-.761	.447
Overall Pitch Changes	10.71	9.71	-.169	.866

DISCUSSION

The aim of this study was to examine if the differences in pitch discrimination ability between instrumental musicians and non-musicians that was demonstrated in previous research could also be seen across different types of musical training, namely in vocal and combined vocal and instrumental training. It was hypothesised that the vocal musicians in this study would perceive significantly more changes of pitch between two sentences than the non-musicians and that the musicians with combined vocal and instrumental musical training would perceive significantly more changes of pitch than the non-musicians, the vocal musicians and the instrumental musicians. We also aimed to test whether changes in temporal lobe activity during the pitch perception task would differ significantly for the vocal musicians and the non-musicians.

Behavioural Findings:

Though they did not differ significantly, in outperforming the non-musicians in the pitch discrimination task on average, the overall trend for the instrumental musicians was in line with the results seen in previous research. Given that individuals who show deficiencies in pitch processing (amusics) have been shown to have difficulty in pitch perception in both music and language (Hutchins et al, 2010; Liu et al, 2010; Nguyen et al, 2009; Tillman et all, 2011) we expected the reverse to also be true; i.e. that greater abilities in pitch processing would affect pitch perception in both music and language. We expected vocal musicians, having received training to promote sensitivity to pitch, to demonstrate the same pitch discrimination abilities for speech seen in instrumental musicians in previous studies (Besson, 2007; Magne, 2006; Schon, 2004). In examining the first hypothesis of this study however, it was discovered that the vocal musicians performed surprisingly poorly. Based on the research by Nikejeh et al (2008) we expected vocal musicians to show superior pitch discrimination ability than non-musicians. Having received similar training to that received by instrumental musicians, and having been exposed to their ‘instrument’ (their voice) longer than the instrumental musicians in that they are practicing from their first word, as well as the fact that pitch perception in speech and singing both involve perceiving differences in vocal productions, we expected vocal musicians to perceive significantly more changes of pitch between two sentences than non-musicians. However this was not in fact the case, they not only perceived fewer pitch changes than the non-musician participants, but performed the poorest on the pitch discrimination task across all of the groups.

Similarly, based on the Nikejeh et al (2008) study we expected that combined musical training, in promoting sensitivity to both instrumental and vocal pitch, to have the greatest effect on pitch discrimination ability for speech overall. We expected these musicians to perceive more pitch changes between two sentences on average than the other three types of training, however there was no significant differences among these groups. Though the musicians with combined vocal and instrumental musical training performed better than the musicians with vocal training alone, the non-musicians and the instrumental musicians both performed better on average than this group. This result was particularly surprising. Though there was only one study which looked at vocal training (Nikejeh et al, 2008), there was a larger body of research supporting the positive transfer effects of instrumental training – given that musicians with combined training would have received instrumental training it was surprising that they did not perform in line with previous research looking at instrumental musicians (Schon et al, 2004, Magne et al, 2006, Besson et al., 2007). Interestingly, the musicians performed better on average with instrumental training alone than with combined training, and the vocal musicians performed poorest of all – indicating that vocal training may in fact have a detrimental effect on pitch discrimination ability for speech.

Given that there is little research examining pitch discrimination across different types of musical training to compare the Nikejeh et al (2008) study with, it is possible that the results seen in their study may reflect the effect of some other aspect of musical exposure than the training type itself. Given that the various studies looking at the effect of instrumental musical training found that training had a positive effect on pitch discrimination in both music and language, we expected the Nikejeh et al (2008) studies to be generalizable to the language domain, however given that their study focused on pitch discrimination in music alone it is also possible that their findings do not apply to pitch perception in speech. However, it is also possible that, given the fact that participants in the current study (having included males and non-students) formed a more diverse sample than that seen in Nikejeh et al (2008), the positive transfer effects from instrumental musical training seen in earlier research are not generalizable to vocal training or combined training when these particular confounding variables are accounted for.

However, another possibility is that the current results reflect the duration of training that the participants received rather than the type. Given that differences between instrumental musicians and non-musicians were not yet apparent after 8 weeks of training in the Besson et al (2007) study, it could be that the minimum 12 weeks of training required in this study was also insufficient to produce differences across groups and future research having a longer period of training as inclusion criteria may produce different results.

Finally, one another possible explanation is that the quality of musical training may not have been adequately addressed in the current, quasi-experimental design. While the current study relied upon relied upon a minimum of 12 weeks of existing training as a means of assigning participants to each groups, it meant that it was not possible to quantifiably control for the quality of musical training that participants had been exposed to across all groups. Given this, it is possible the results reflect quality of training received, rather than a reflection on the type of training itself. Future research utilising a longitudinal, experimental design whereby training is administered consistently across all groups, may address this issue.

Though the overall results of this study do not support the hypotheses that vocal and combined musical training facilitates pitch processing in speech, the fact that the overall trend for instrumental musicians remains in line with previous research is encouraging. Future research using a longitudinal experimental design, thus controlling for quality of training, whereby participants receive training over a period longer than 12 weeks may produce more positive results in favour of vocal or combined musical training.

Electrophysiological Findings:

Though we expected to find differences between the non-musicians and the vocal musicians for the changes in temporal lobe activity during the changes of pitch, this was not the case. Surprisingly, the opposite was true; though changes in EEG frequency from the baseline frequency were not significant for vocal musicians, there were significant changes in temporal lobe activity for the non-musicians. EEG frequency did not differ significantly across these two groups for any of the nine pitch changes.

Given that previous research indicated activity in structures in the temporal lobe differed across instrumental musicians and non-musicians, we expected this to generalise to the vocal musicians in the current study. While this was not the case, the electrophysiological results are not altogether surprising when the lack of significant results for any behavioural differences between these two groups is taken into account. The factors described above that may have affected the behavioural results (such as the quality of training) may also have prevented the fine-tuning of the neural networks that overlap for pitch processing in both music and language.

However, it is also important to note that while the current study aimed to eliminate hearing impairments as a possible confounding variable, it relied on self-report measures. Behaviours that were observed during the course of this study however, indicated that some participants were not reliably able to report on their own hearing ability. Some of the participants with vocal training for example, consistently asked for the instructions to be repeated throughout the procedure. Such impairments may have not only influenced the error rates of vocal participants but the activity in the temporal lobe during the task. It is recommended that future research use more quantifiable methods of controlling for hearing ability when assessing if participants meet the inclusion criteria.

Conclusions

While the original hypotheses were not supported in the current study, it is important to note that this is a relatively new area of psychological research. Few studies have examined the positive transfer effects of musical training to pitch processing in speech, and even fewer have looked at the role of different types of musical training. The current study was important to see if the results in the Nikejeh et al (2008) study could be seen in the context of speech, and though the results were not significant this could contribute to our understanding of the overall effects of musical training. The overall trend for instrumental musicians was in line with previous research, and while vocal training appeared to have a negative influence on pitch discrimination ability overall this could be a reflection of the quality of training rather than type. It is recommend that future research use a longitudinal, experimental design to control for this in order to get a better idea of the role of different musical training types in speech based pitch perception, to examine if the surprisingly negative effect of vocal musical training on behavioural and electrophysiological results seen here was the result of type or quality of training received.

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APPENDICES

TRANSCRIPT OF PHRASES USED FROM 'THE LITTLE PRINCE'

1. Grown-ups never understand anything by themselves, and it is tiresome for children to be always and forever explaining things to them.
2. There I saw a most extraordinary small person, who stood there examining me with great seriousness
3. The little prince, who asked me so many questions, never seemed to hear the ones I asked him.
4. Children should always show great forbearance toward grown up people.
5. If I try to describe him here, it is to make sure that I shall not forget him
6. Perhaps I am a little like the grown-ups, I have to grow old.
7. The information would come very slowly, as it might chance to fall from his thoughts.
8. I was carried beyond myself by the inspiring force of urgent necessity.
9. It is only with the heart that one can see rightly.
10. What is essential is invisible to the eye
11. You become responsible forever for what you've tamed
12. It is such a secret place, the land of tears.
13. Well, I must endure the presence of a few caterpillars if I wish to become acquainted with the butterflies
14. I ought to have judged by deeds, and not by words.
15. When someone blushes, doesn't that mean 'yes'?
16. Conceited people never hear anything but praise
17. No one is ever satisfied where he is.
18. He had taken seriously words which were without importance, and it made him very unhappy.
19. All grown-ups were once children... but only few of them remember it
20. It is the time you have wasted for your rose that makes your rose so important

DEMOGRAPHIC QUESTIONNAIRE

1. **Please circle your gender;** **Male/Female**

2. **Please fill in your age;** ______

3. **Please indicate if you;**

   a) Are a non-musician ☐

   b) Are a vocalist ☐

   c) Are an instrumentalist ☐

   d) Have received combined musical training ☐

INSTRUCTIONS

Dear Participant,

This experiment aims to look at musical training, language and underlying brain activity. If you agree to participate you will be asked to listen to a series of recordings and then answer questions based on what you have heard while wearing an electrode cap.

This is an EEG cap; it is non-invasive and is used to measure underlying brain activity while you participate in this auditory task.

The data collected during this experiment will be confidential. Your results will be merged with other participants so that you will not be identified if this research is presented at a later date. Your personal information will not be seen by anyone other than my supervisor and me. If you wish to withdraw from the experiment at any time please let me know and we will stop. If, after completing the experiment, you choose not to have your data included please contact me and I will remove it from my study.

If you have any questions please do not hesitate to ask. If you have any further questions after the experiment please feel free to contact me by emailing [redacted]

Naoise O Toole
Undergraduate Student
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