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Investigation of the Temporal Characteristics of Absolute Pitch and Relative Pitch Using EEG

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Investigation of the Temporal Characteristics of Absolute Pitch and Relative Pitch Using EEG

By

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Submitted in partial fulfillment

of the requirements for

Honors in the Department of Neuroscience

UNION COLLEGE

June, 2011

Abstract

MINER, CAITLIN Investigation of the Temporal Characteristics of Absolute Pitch and Relative Pitch Using EEG
Department of Neuroscience, June 2011

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Itoh, Suwazono, Arao, Miyazaki, and Nakada, (2005) compared relative pitch (RP), with absolute pitch (AP) and found a left posterior-temporal negative Event Related Potential (ERP) at 150ms for pitch listening and pitch naming in AP. The present study tested if AP is due to pitch expertise that is not present in RP by comparing pitch naming with instrument naming. Recordings were performed during instrument naming, instrument listening, pitch naming, and pitch listening tasks. At a negatively deflected ERP (156-228ms) a three-way interaction was found, such that voltage differed between instrument listening and instrument naming tasks, but not between pitch listening and pitch naming. At two positively deflected ERPs (240-340 and 380-440ms), interactions were found, such that voltage differed between pitches and instruments. These data indicated expertise for instrument naming, but not pitch naming in this musically untrained group, which provides hypotheses for future studies with AP and RP.

Investigation of the Temporal Characteristics of Absolute and Relative Pitch Using EEG

Absolute Pitch and Relative Pitch

Two different cognitive approaches have been identified for classifying of musical pitches. These two strategies are known as relative pitch (RP) and absolute pitch (AP). AP is a cognitive ability, which can be learned over many years of musical training, to identify pitches in isolation without reference to another pitch. People who possess AP utilize the 'fixed doh-solmization system', in which each solfege syllable (doh, re, me etc.) is associated in a fixed relationship within a single key (C, D, E etc.). In other words, as the key changes, the syllable doh remains in a fixed position in relation to the other solfege syllables in the musical scale. For example, people who possess AP and utilize this fixed-doh solmization system would be able to tell a G apart from an F# without reference to any other tone, regardless of the musical key. People who possess AP are very accurate with pitch labeling and can accurately name over 90% of isolated pitches correctly (Chin, 2003). People who have imprecise AP can also name pitches, but with a slightly lower accuracy rate (50-90%) than people who possess high AP (Chin, 2003). These differences in pitch naming accuracy between people who possess AP and imprecise AP suggest that AP is a cognitive phenomenon that exists along a continuum. RP is also a cognitive ability that can be learned over many years of musical training. Those who possess RP use the 'movable doh-solmization system', in which solfege syllables represent different pitches under different keys. In other words, as the musical key changes, the position of the syllable doh also moves in relation to the other syllables in the musical scale. A person who possesses RP, for example would not be able to identify a SO without reference to some other tone and would not be able to tell you if it was a G unless they were informed that the key was c-major, whereas a person who possesses AP would have no difficulty identifying this tone as SO or G in isolation. Nevertheless, RP is still a form of expertise because RP enables one to identify musical intervals, whereas an untrained person would not even be able to do this. Thus, AP and RP represent two different levels of expertise, with AP being more advanced than RP because AP possessors can identify pitches in isolation, whereas RP possessors cannot. The major cognitive difference between these two classification approaches is that a person who possesses AP has the ability to compare a pitch with a stored template of pitches in long-term memory, whereas a person who possesses RP has to hold the tone in working memory, compare it with nearby tones on the musical scale, and then compare these intervals with a stored template for intervals in long-term memory (Levitin and Rogers, 2005). As a result, RP utilizes many more cognitive resources than AP, which may suggest that RP may just be a level of expertise below the expertise of AP.

Critical Period for AP

It is commonly believed that everyone has the potential to develop AP; however, there may only be a very short window of time during the developmental years in which a child has the ability to acquire AP. During this critical period, children may be predisposed to attend to the absolute, rather than the relative features of pitches (Chin, 2003). This critical period may be particularly important for young children because they have not yet gone through a developmental transition from thinking about the world unidimensionally to multidimensionally (Chin, 2003). Unidimensional thinking involves thinking about the parts of objects, or concepts without relation to the whole, whereas multidimensional thinking involves thinking about the parts in relation to the whole. For example, if a child in the unidimensional phase was shown two water glasses (one short and the other tall) with the same amount of water in it, he or she will report that there is more water in the tall glass; however, a child in the multidimensional phase will say there is the same amount of water in both glasses because he or she will be able to recognize that the glasses are of 2 different heights (Parke, Gauvain, Hetherington, and Locke, 2008). It may be the case that during the unidimensional years, children are able to attend to objects and concepts, such as pitches, in isolation (AP), but when they transition into the multidimensional years, they lose this ability in favor of the ability to process information in a relational way (RP). A transition from unidimensional to multidimensional thinking is paralleled by another cognitive transition from the absolute to the relational processing of information. Relational processing actually requires greater cognitive resources than absolute processing because it involves making comparisons between objects or concepts. Interestingly, RP can be considered relational processing and AP can be considered absolute processing.

There are several lines of evidence that suggest that the critical period is associated with these cognitive transitions. The mean age at which AP possessors begin musical training is 5.4 years, whereas the mean age at which non-AP possessors begin training is 7.9 years (Chin, 2003). Thus, it is theorized that early musical exposure (i.e, before 7 years of age) can lead to the acquisition of AP because the brain is very plastic during this period of development and can form semantic memories for pitches in the auditory cortex (Levitin and Rogers, 2005). If an individual is exposed to musical training during this critical period, it is possible to sharpen AP abilities for pitches in isolation and avoid the cognitive transition into relational processing with regard to pitches, which is seen in RP. In support of the early music exposure theory, Miyazaki (1990) examined how quickly and accurately AP possessors could respond to different pitch classes. In two experiments, Miyazaki (1990) assessed the speed at which AP possessors could identify tones presented in isolation by instructing participants to respond using a keypad. Miyazaki (1990) found that the accuracy of pitch identification varied among pitch classes and that participants were significantly faster and more accurate for white-key notes than for black-key notes. These findings suggest that, memory for the white-key notes may have been more firmly established in long-term memory than memory for the black-key notes. This difference supports the idea that AP develops during a critical period of development, in which the brain is highly plastic and susceptible to reorganization because when children learn the piano, they tend to learn the notes corresponding to the white-keys first, and notes corresponding to the black-keys may have been learned after the critical period. It is also interesting to note that speakers of tonal languages, such as Mandarin Chinese, are more likely to develop AP than speakers of non-tonal languages because tonal languages require early attentional focus on the pitch component of language (Levitin and Rogers, 2005). Since language learning usually occurs during the first few years of development, speakers of tonal languages are more likely to be exposed to pitches during the hypothesized critical period for AP development and are, therefore, more likely to develop AP than speakers of non-tonal languages.

Cognitive Style

In addition to the importance of musical training during the critical period of development, it is hypothesized that individual cognitive style may also play a role in the predisposition towards AP. According to Chin (2003), different cognitive styles may underlie the development of either AP, or RP. People who possess AP tend to have a 'field-independent' cognitive style, which involves the processing of information in piecemeal. These people are more likely to perceive information with narrow attention and to focus on musical pitches in isolation from other pitches. In contrast, individuals who possess RP tend to utilize a 'field-dependent' cognitive style, which involves the tendency to attend to the context of information, rather than the individual components. These individuals tend to perceive information with broader attention and look at the intervals/relations between adjacent notes (Chin, 2003). Exposure to musical training during the critical period, along with a field-independent cognitive style may be part of what predisposes some people towards developing AP, rather than RP

Anatomical Differences

One of the major anatomical correlates of AP is thought to be left hemisphere lateralization for musical processing. Possessors of AP, who are right-handed, may actually be dominant for musical pitch in the left hemisphere, which is also where language is processed (Chin, 2003). More specifically, an area of auditory cortex found in both temporal lobes, known as the planum temporale (PT), has been found to be larger on the left side of the brain in AP possessors compared to non-AP musicians and non-musicians (Chin, 2003). Similarly, Keenan, Thangaraj, Halpren, and Schlaug (2001) tested whether early exposure to music as a child influenced the degree of PT asymmetry between brain hemispheres. Anatomical Magnetic Resonance Imaging (MRI) was used to look at the adult brains of AP musicians, non-AP musicians, and non-musicians and it was found that AP musicians had greater leftward lateralization of the PT than both non-AP musicians and non-musicians. Keenan et. al (2001) theorized that the leftward asymmetry of the PT in the brains of AP possessors may be due to 'pruning' of the right PT, rather than an enlargement of the left PT. This suggests that early developmental pruning of the right PT during a critical period may create an anatomical dominance of the left over the right PT.

Neural Resources

In addition to the PT, it is also important to examine the neural resources that have been found to be associated with AP. Wu, Kirk, Hamm, and Lim (2008) used an electrode net to collect EEG to examine the auditory ERPs from the scalps of AP musicians, non-AP musicians, and non-musicians. During EEG recording, participants were instructed to label tones following the presentation, or lack of presentation of a reference tone. Wu et. al (2008) found that when participants were asked to label tones without a reference note, AP possessors showed more electrophysiological activity than non-AP musicians from both the left and right hemispheres of the brain and also were more accurate (99.6%) for pitch labeling than non-AP musicians (84.6%). This heightened activity in the brains of AP possessors suggests that when not given a reference tone and asked to identify a particular tone, AP possessors are able to recruit more neural resources than those who do not possess AP. These neural resources may allow AP possessors to process pitch information with greater interhemispheric efficiency than non-AP musicians (Wu et. al, 2008). It is important, however, to make the distinction that AP possessors do not necessarily have different neural connections than non-AP possessors, but that they have the unique ability to recruit additional neural resources for the specialization of tone labeling in isolation (Wu et. al, 2008); therefore, these additional neural resources are thought to give AP possessors the ability to identify tones without the need for a reference note. It may be the case that AP possessors, who have a field-independent cognitive style, would develop a more efficient neural network for pitch labeling than RP possessors, who have a field-independent cognitive style.

Memory Differences

Barnea et. al (1994) examined the differences in ERP between AP and non-AP musicians for both lexical and non-lexical musical tasks. The lexical stimulus involved a pre-recorded vocalization of the name of notes, whereas the non-lexical stimulus involved notes that had been previously played on a piano. Barnea et. al (1994) found differences between AP and non-AP musicians in the intensity of the P300 wave amplitude across the scalp. The P300 wave, which usually peaks with a latency of 300-600ms following a task-related stimulus, was used as an indirect measure of the verbal categorization of notes in working memory (Barnea et. al, 1994). Since AP musicians already had pitches stored in long-term memory, they did not need to make comparisons of pitches in working memory. Accordingly, Barnea et al. (1994) observed a decreased P300 wave intensity for AP musicians. In contrast, non-AP musicians needed to recruit more resources to working memory than AP musicians because non-AP musicians did not have individual pitches stored in long-term memory and had to categorize pitches in intervals in working memory, and thus demonstrated an increased P300 wave. These ERP differences between AP and non-AP musicians further suggest that AP musicians are able to utilize long-term memory to process pitch labeling without the need to refer to subsequent tones, whereas non-AP musicians need to use working memory to categorize pitches with reference to some other tone (Barnea et. al, 1994). Having a field-independent cognitive style with a more efficient neural network established in long-term memory, may be part of what enables AP possessors to identify pitches better than RP possessors.

ERP Correlates

In addition to differences in the memory storage and processing of pitches for AP and non-AP musicians, there are also specific ERP correlates associated with AP and non-AP musicians. Besson, Schon, Santos, and Magne (2007) investigated the effects of musical expertise on pitch processing in both adult and children musicians and non-musicians with the hypothesis that musical expertise, defined as increased pitch discrimination, would improve both pitch processing and language abilities. Participants were asked to listen to 120 musical and linguistic phrases. Half of these phrases ended with an expected note/word, whereas the other half ended with a final note that was increased by 1/5 or 1/2 of a tone, or a final word whose contour was increased by 35 or 120% in terms of the linguistic frequency of voice fundamental (F0). While listening to these phrases, participants were instructed to decide if the final note/word was normal, or strange and ERPs were time-locked with the final note/word of each phrase. Besson et. al (2007) expected that musicians and non-musicians alike would detect congruous and strongly incongruous tones with equal accuracy because these would be easy to identify; however, musicians should detect weakly incongruous tones with greater accuracy than non-musicians because a 1/5 difference in a tone is a very subtle change in pitch that would only be apparent to a musically trained individual. It would also be expected that musically trained individuals could detect a 35% increase in word F0 with greater accuracy than non-musicians, but that there would be no differences between these groups for both congruous and strongly incongruous words. Besson et. al (2007) found that errors to weak pitch incongruities was lower for musicians than for non-musicians for both music and speech. Weak incongruities elicited early negative ERPs (N300 waves) with latency of 100-300ms in both musicians and non-musicians for both music and language; however, these ERPs were distributed differently across the scalp for music (right fronto-temporal) compared to language (temporal bilateral). It was also found that weakly incongruous tones/words elicited a larger positive ERP with latency of 200-600ms (P600 waves) than congruous tones/words for musicians only. This finding is particularly important because it shows that musical expertise improved both musical and language pitch discrimination in musicians, but not in non-musicians. Thus, the presence of N300 and P600 ERPs in response to weakly incongruous tones/words suggests that musical expertise can actually influence both musical pitch and language-processing abilities (Besson et. al, 2007). These results can be applied to the musical expertise of AP. Since it is theorized that AP possessors have greater musical training (i.e., expertise) than both RP and untrained individuals, it is likely that AP possessors have sharper pitch discrimination ability for similar sounding pitches than RP and untrained individuals.

Itoh, Suwazono, Miyazaki, and Nakada (2005) was the first group known to use ERP to investigate the cortical pitch processes by comparing the ERPs of high-AP, medium-AP, low-AP, and untrained participants during pitch naming and pitch listening tasks. Itoh et al. (2005) found a large difference in the ERPs between naming and listening tasks in the RP (medium and low AP) and untrained groups, but found little difference in the ERPs associated with these tasks in the high AP group. Itoh et. al (2005) found 3 significant ERPs for participants who were identified to have RP. These included a P3b peak, which was centro-parietally distributed with an onset of 300-450 ms, a parietal positive slow wave with an onset of 450 ms, and a frontal negative slow wave with an onset of 400ms, following the onset of the P3b wave. The amplitude of these ERPs differed between listening and naming tasks. In contrast, the high-AP group elicited a left posterior temporal negative peak at 150 ms, regardless of whether the task involved pitch listening, or naming. These results suggest that AP requires fewer cognitive resources in pitch labeling because the ERP of AP-possessors occurred more locally over the left posterior temporal cortical region, whereas the ERPs associated with RP occurred over a much broader area of cortex (Itoh et. al, 2005). These ERP differences suggest that AP represents greater pitch labeling expertise than RP because it enables the ability to label pitches in isolation utilizing less cortical resources, whereas RP utilizes much more cortical area to perform a less sophisticated task (naming pitches in relation to other pitches).

The goal of the present ERP study was to extend the findings of Itoh et. al (2005) by comparing pitch naming with a task all musically untrained participants should have in common: instrument naming. The expectation of this study was that untrained participants would show ERPs when naming instruments that were similar to previous findings with AP participants because these untrained participants would still have expertise with naming instruments.

Method

Participants

12 right-handed undergraduate students between the ages of 18 and 23 years old from Union College with no history of neurological disorders or conditions and not currently taking any mood or performance altering medication, were recruited for this study.

Material and Apparatus

For the Absolute Pitch (AP) test, E-Prime software was used to present prerecorded piano tones in a sound attenuated room. These piano tones consisted of pitches ranging from middle C to middle B on the musical scale. Participants responded by a key-press indicating their identification of each pitch. For the EEG recording, the STIM software package was used to present either instrumental, or pitch tones. Instrumental tones included the piano, clarinet, violin, tuba, and guitar, whereas pitch tones (played by the piano in the key of C) included do, re, me, fa, and so in the key of C (i.e., Middle C, D, E, F and G). Each stimulus was presented through 2 speakers for 350ms.

Electroencephalogram (EEG)was recorded using a NuAmps 40 Channel Quik-Cap (Compumedics NeuroMedial Supplies). The electrodes on each cap were distributed according to the internationally recognized 10-20 system and the Acquire program, within the NeuroScan software package, was used to record EEG.

Procedure

Prior to beginning the study, all participants provided written informed consent as approved by the Union College Internal Review Board for human subject research.

Participants first took part in a behavioral AP test to assess their musical ability. During this task, participants identified the pitch class (i.e. C, C#, etc.) of 60 randomly presented piano tones. Participants responded after each tone by pressing keys on a keyboard. No training of this task preceded this test and no feedback of response correctness was given during, or following this test. Pitch-naming responses during the AP task resulted in the formation of one musically untrained group.

Participants then proceeded to the EEG cap administration. Each participant sat in a chair while an EEG cap was fitted to their scalp and electrode gel was applied to all electrodes. After the EEG apparatus was setup, the overhead lights were turned off and participants were asked to participate in 4 different tasks: instrument naming, instrument listening, pitch naming, and pitch listening.

Participants were given practice with these different sounds used for these tasks prior to actually performing them. These tasks were then used to assess participants' accuracy for pitch naming and instrument naming compared to the baseline of listening. Task order was counterbalanced between subjects. Each task consisted of 150 trials and participants were given specific instructions for each task. In the naming tasks, participants were presented with either an instrument playing the same note (C), or sounds of the piano playing different pitches, and were instructed to name an instrument in the instrument naming task, or a pitch in the pitch naming task following a cue that was presented 900 ms after the onset of the stimulus and 2s before the onset of the next stimulus. In the listening tasks, participants were instructed to vocalize the syllable "ah" after being presented with a different random order of the same pitch or instrument sounds following the same cue used in the naming task. Electroencephalogram was collected continuously during the performance of each task.

Results

Behavioral Analysis

Participants' mean accuracy was very low for the AP test (M = .05, SD = .221). As mentioned above, this resulted in a single sample of musically untrained participants that did not possess RP or AP. Participants' mean accuracy in the pitch and instrument naming tasks performed during EEG recording was much higher (M =. 97, SD = .180) for instrument naming than for pitch naming (M = .28, SD = .445). There was no correlation between participants' pitch and instrument naming performance, $r(10)$ = .032, p = .921, . Thus, an independent-samples T-test was conducted to compare the mean accuracies for instrument and pitch naming in this sample, which revealed that participants had a significantly higher accuracy, t (11) = 59.160, $p < .000$, for instrument naming than pitch naming.

EEG Preprocessing and Analysis

In order to analyze the EEG results, the ERPs for each participant for each condition were first preprocessed in Acquire. Continuous EEG waveforms were epoched from 100ms prior to and 900ms following the onset of each stimulus. These epochs included the time in which the stimulus was processed, but not the time in which responses were given. The resulting ERPs were then baseline corrected in order to ensure that each electrode began recording from the same baseline based on the pre-stimulus period average. The data were then artifact rejected at +/-140μV. The previous study conducted by Itoh et. al (2005) used an artifact rejection interval of +/-100 μV, which is slightly more conservative. A slightly less conservative artifact rejection interval was used in this study in order to get a large enough sample. Non-rejected ERPs were then linearly detrended in order to remove the upward fluctuation in voltage at the end of each segment due to signal drift. These segments were then averaged for each participant in order to create an average EEG waveform for each participant for each of the 4 tasks. These individual averages were then averaged separately by condition across all participants in order to make 4 grand averages for instrument naming, instrument listening, pitch naming, and pitch listening.

Once the ERPs were preprocessed, 3 peaks of interest were identified across the EEG waveforms. These included an early negative peak with a latency of 156-

256ms, which was thought to be an 'auditory N100' wave previously associated with perception of the stimulus, a middle positive peak with a latency of 240-340ms, and a later positive peak with a latency of 380-440ms. These 2 later peaks were similar to P3a and P3b waves. A repeated measures 6x2x2 ANOVA was then conducted with the following factors: electrode, which had 6 levels (3 frontal electrodes - F3, FZ, and F4 and 3 posterior electrodes – P3, PZ, and P4), task, which had 2 levels (listening and naming), and stimulus, which also had 2 levels (pitches and instruments). These 6 electrodes were chosen to facilitate topographic analysis of the ERPs. These results are shown in Table 1. Significant main effects were not interpreted when these factors were involved in a mediating interaction.

Table 1. Significant Main and Interaction Effects of Electrode, Task, and Stimulus on Voltage for each ERP Peak

Effect	**Peak 1: 156-228ms**	**Peak 2: 240-340ms**	**Peak 3: 380-440ms**
Main Effect Electrode	$F(1,5) = 994.77$, $p = .000$	$F(1,5) = 12.91$, $p = .000$	$F(1,5) = 18.90$, $p = .000$
Main Effect Task	$F(1,1) = 737.04$, $p = .000$	$F(1,1) = 5.95$, $p = .003$	None
Main Effect Stimulus	$F(1,1) = 764.75$, $p = .000$	$F(1,1) = 10.94$, $p =.007$	None
Interaction Effect Electrode x Task	$F(1,5) = 1059.09$, $p = . 000$	None	None
Interaction Effect Electrode x Stimulus	$F(1,5) = 1058.28$, $p = .000$	**$F(1,5) = 14.27$, $p = .000$**	**$F(1,5) = 4.40$, $p = .002$**
Interaction Effect Task x Stimulus	$F(1,1) = 1375.38$, $p = .000$	None	None

Interaction Effect Electrode x Task x Stimulus	***F*(1,5) = 1156.12, *p* = .000**	None	None

At the first peak, which was a negative deflection in voltage with latency of 156-228ms, there was a significant interaction between electrode, task (listening/naming), and stimulus (pitches/instruments), F (1,5) = 1156.12, p = .000, on voltage. As shown in Figure 1, it is clear that there is no effect of task on voltage for the 3 frontal electrodes (F3, FZ, and F4), but voltage did vary due to task for the 3 posterior electrodes (P3, PZ, and P4), such that there was a clear difference between instrument listening and naming, but no difference between pitch listening and naming.

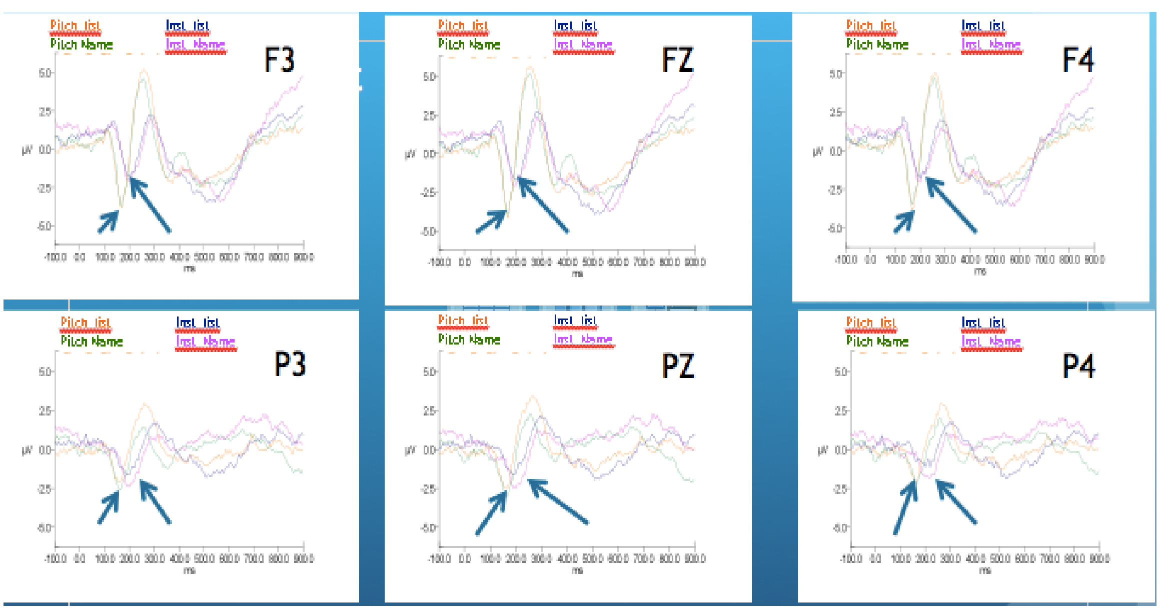

Figure 1. ERP graphs showing a significant 3-way interaction effect on voltage between electrode, task, and stimulus across all 6 electrodes of interest. There is no difference between the effects of listening and naming alone on voltage across the 3 frontal electrodes; however, there is a difference between the effects of listening and naming alone on voltage across the 3 posterior electrodes. There is a difference between the effects of pitch naming and instrument naming on voltage across the frontal electrodes, but this difference in voltage is not seen across the posterior electrodes.

At the second peak, which was a positive deflection in voltage with latency of 240-340ms, there was a significant interaction between electrode and stimulus (pitches/instruments), *F* (1,5) = 14.27, *p* = .000, on voltage. As shown in Figure 2, it is clear that there was an effect of stimulus on voltage across all 6 electrodes, regardless of task, such that pitches generated greater positivity on voltage than instruments at this second peak. It is also clear that there was a greater change in voltage due to stimulus for the 3 frontal electrodes (F3, FZ, and F4), than the 3 posterior electrodes (P3, PZ, and P4).

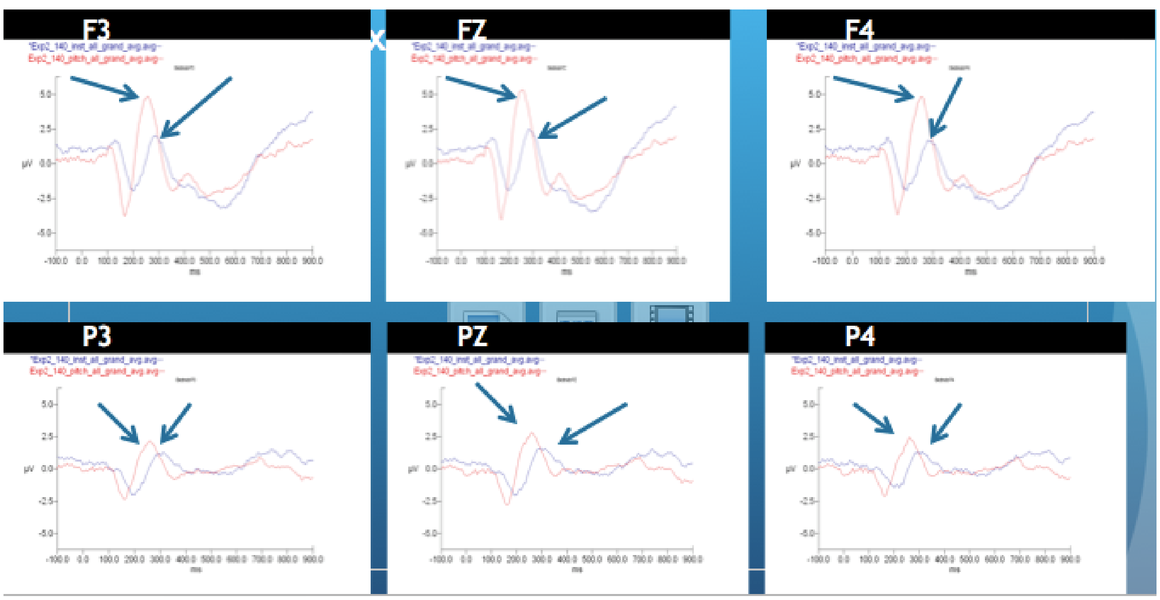

Figure 2. ERP graphs showing a significant interaction effect on voltage between electrodes and stimuli (pitches/instruments) at peak 2. There is a greater difference between the effects of pitches and instruments on voltage across the 3 frontal electrodes than 3 posterior electrodes.

At the third peak, which was a positive deflection in voltage with latency of 380-440ms, there was also a significant interaction between electrode and stimulus (pitches/instruments), *F* (1,5) = 4.40, *p* = .002, on voltage. As shown in Figure 3, it is clear that there was an effect of stimulus on voltage for the 3 frontal electrodes (F3, FZ, and F4), such that pitches generated greater positivity on voltage than instruments; however, voltage did not vary due to stimulus for the 3 posterior electrodes (P3, PZ, and P4).

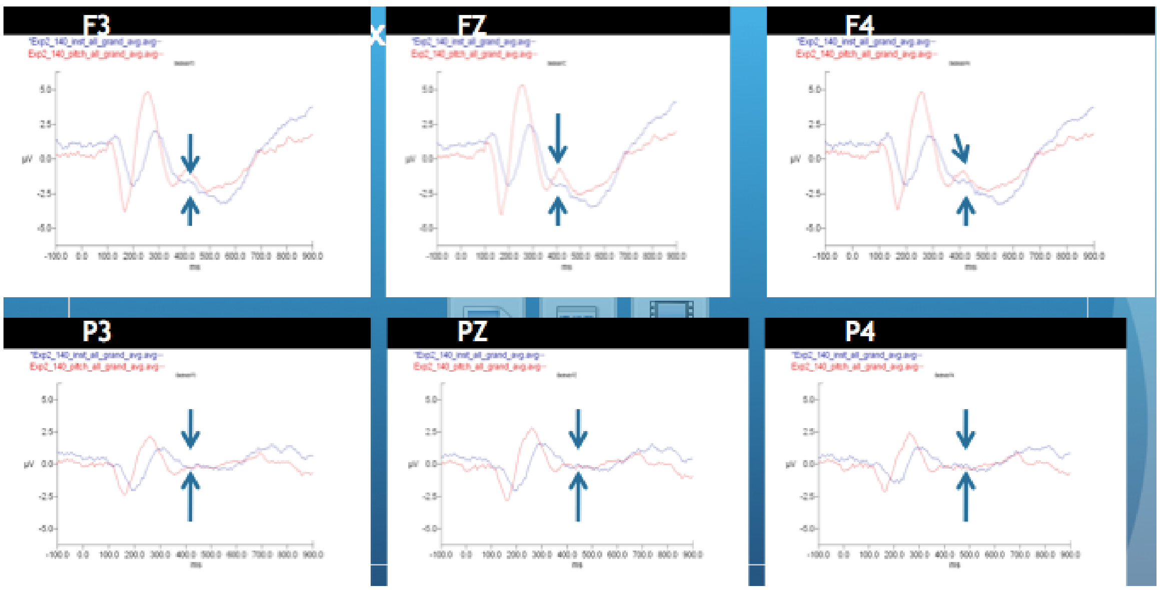

Figure 3. ERP graphs showing a significant interaction effect on voltage between electrodes and stimuli (pitches/instruments) at peak 3. There is a difference between the effects of pitches and instruments alone on voltage across the 3 frontal electrodes, but this difference is not seen in the 3 posterior electrodes.

Discussion

There are two important findings from this study that suggest evidence for an expertise effect for instrument naming, but not for pitch naming in this untrained group. The finding that there was a difference at the first peak between the effects of instrument listening and instrument naming on voltage, but no difference between pitch listening and pitch naming suggests that there were differences in processing due to expertise with instrument naming that these participants did exhibit for pitch naming in this study. These results enable specific predictions for future work using these tasks with participants with RP and AP. Specifically, it would be expected that both RP and AP participants would also show a significant difference between the effects of instrument listening and instrument naming on voltage, since instrument naming is an ability that most people have. In contrast to the untrained group, there would be a difference between the effects of pitch listening and pitch naming on voltage for both the RP and AP groups that would be similar to Itoh et. al (2005), with a larger difference for an AP group than an RP group. A difference between pitch listening and pitch naming in an RP group would suggest that expertise for pitch naming in RP possessors would allow for greater accuracy than an untrained group when given a reference tone. A larger difference between pitch listening and pitch naming in an AP group, compared to an RP group, would be suggestive of a even greater expertise in pitch naming for AP because AP possessors are able to label pitches in isolation without a reference tone. Secondly, a significant difference at the second and third peaks between the effects of pitches and instruments alone on voltage, regardless of task, suggests that these musically untrained participants had expertise for instrument naming, but not for pitch naming. It would be expected that both RP and AP participants would show an expertise for both instruments and pitches. An AP group would show a smaller difference in voltage between pitches and instruments than an RP group because AP possessors have a more developed pitch labeling expertise than RP possessors. Therefore, as musical ability increases from untrained, to RP, to AP, there would be an increasing difference between the effects of pitch listening and pitch naming on voltage (due to an increasing expertise for pitch naming compared to the baseline of listening) and a decreasing difference between the effects of pitch and instruments alone, regardless of task on voltage (due to an RP and AP group having similar expertise for both instruments and pitches).

In addition to the voltage differences examined in the present study, it would also be beneficial to examine how the interaction between the 3 independent variables (electrode, task, and stimulus) affected latency at each peak. In this present study, there seems to be a difference in ERP latency for instruments and pitches at the second and third peaks; however, there did not seem to be a difference in ERP latency between pitches and instruments at the first peak. This may be because the first ERP peak is only involved in the initial perception of the stimuli. Itoh et. al (2005) identified 3 different ERPs (P3b at 300-450ms, parietal positive slow wave at 450ms, and frontal negative slow wave at 400ms) in an RP group and found differences in ERP latency between pitch naming and pitch listening. The P3b (300-450ms) and parietal positive slow wave (450ms) identified by Itoh et. al (2005) for pitch naming of RP possessors is closely paralleled to the two positive ERPs (240-340ms and 380-440ms) found in the present study. These results suggest that RP possessors may process pitch naming in a similar way that untrained people process instrument naming. In future work with these tasks with RP participants, there may be less of a difference in ERP latency between pitch listening and pitch naming and also between pitch naming and instrument naming than in the untrained group in the present study, due to RP participants' expertise for both pitches and instruments. Itoh et. al (2005) identified 1 ERP at 150ms in an AP group and found little to no difference in ERP latency between pitch listening and pitch naming. This suggests that AP participants would be expected to demonstrate even less of a difference in ERP latency than the RP group between pitch listening and pitch naming and also pitch naming and instrument naming, due to an even greater expertise for pitch naming than the RP group. According to data that suggests that AP requires fewer cognitive resources in pitch labeling than RP, the ERP of AP possessors would be much faster and more localized spatially than the ERPs associated with RP, which would occur later and over broader areas of cortex. Therefore, it can be hypothesized that increasing musical ability from untrained, to RP, to AP, would decrease the differences in ERP latency between pitch listening and pitch naming and also pitch naming and instrument naming, due to RP and AP possessors having greater expertise for both pitches and instruments than the untrained group in the present study.

It is evident from this present study that the untrained group had expertise for instrument naming and also expertise for instruments, regardless of task, but had no expertise for pitch naming and no expertise for pitches, regardless of task. These results suggest that musically untrained individuals have expertise for instruments, due to general familiarity with instruments, but not for pitches because pitch labeling requires musical training and higher expertise.

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