THE ENIGMA OF ABSOLUTE PITCH

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Introduction

In the summer of 1763, the Mozart family embarked on the famous tour of Europe that established the young composer's reputation as a musical prodigy (front cover). Just before they left, an anonymous letter appeared in the *Augsburgischer Intelligenz-Zettel* describing seven year old Wolfgang's extraordinary abilities. The letter included the following:

"Furthermore, I saw and heard how, when he was made to listen in another room, they would give him notes, now high, now low, not only on the pianoforte but on every other imaginable instrument as well, and he came out with the letter of the name of the note in an instant. Indeed, on hearing a bell toll, or a clock or even a pocket watch strike, he was able at the same moment to name the note of the bell or time piece.[1]"

This passage provides a good characterization of absolute pitch—the ability to name or produce a note of a given pitch in the absence of a reference note. This ability, which is also known as "perfect pitch," is very rare in our culture, with an estimated overall prevalence of less than one in ten thousand.[2] People with absolute pitch name musical notes as rapidly and effortlessly as most people name colors. Yet absolute pitch is often regarded as a mysterious endowment that is available only to a few gifted individuals. This impression is strengthened by the fact that most famous musicians, such as Bach, Beethoven, Handel, Menuhin, Toscanini, Boulez, and so on, were known to possess this ability.

In contrast with the rarity of absolute pitch, the ability to judge one musical note in relation to another is very common. So, for example, most musicians, when presented with the note F and given its name, have no difficulty in naming the note two semitones higher as G, the note four semitones tones higher as A; and so on. (A semitone is the pitch relation formed by two adjacent notes on a keyboard, and corresponds to a frequency ratio of approximately 18:17.) What most people, including most musicians, cannot do is name a note when they hear it out of context.

As someone with absolute pitch, it has always seemed puzzling to me that this ability should be so rare. When we name a color, for example as green, we do not do this by viewing a different color, determining its name, and comparing the relationship between the two colors. Instead, the labeling process is direct and immediate. Consider, also, that note naming involves choosing between only 12 possibilities; namely the 12 notes within the octave (termed *pitch classes*) shown in Figure 1. Such a task should not be difficult; indeed, it should be trivial for professional musicians, who spend many thousands of hours reading musical scores, playing the notes they read, and hearing the notes they play. As another point, most people can easily identify well-known melodies when they hear them; yet the amount of information required to do this is vastly greater than is required to name a single note. A lack of absolute pitch, viewed from this perspective, appears akin to the syndrome of color anomia, in which the person can recognize and discriminate between colors, yet cannot associate them with verbal labels.[3] So the real mystery of absolute pitch is not why some people possess this ability, but instead why it is so rare.

Background

Although absolute pitch is most prevalent among highly accomplished musicians, it is not necessarily associated with superior performance on other musical processing tasks. For example, people with absolute pitch do not necessarily outperform others in judging the octave in which a note occurs,[4] or in judging musical intervals,[5,6] or on tasks involving short term memory for pitch when verbal labels cannot be used as cues.[7] Most importantly, nonpossessors have been shown to possess an implicit form of absolute pitch, even though they cannot label the notes they are judging.

The tritone paradox[8,9] provides a good example of implicit absolute pitch. The basic pattern that produces this illusion consists of two successively presented tones that are

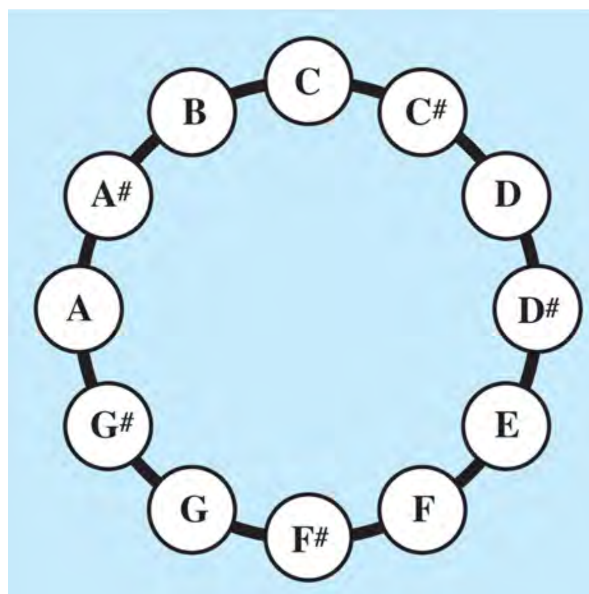

Fig. 1. The pitch class circle. The notes of the traditional Western musical scale are produced by dividing the octave into 12 semitone steps. A semitone is the pitch relation formed by two adjacent notes on a keyboard, and corresponds to a frequency ratio of approximately 18:17. Each of the twelve notes within the octave is assigned a name: C, C#, D, D#, E, F, F#, G, G#, A, A#, and B. The entire scale is generated by repeating this series of note names (or 'pitch classes') across octaves. When people with absolute pitch identify notes by name, they are identifying the positions of the tones along the pitch class circle.

related by a half-octave (an interval comprised of six semitones, known as a tritone). The composition of the tones is such that their note names are clearly defined, but they are ambiguous with respect to which octave they are in. So, for example, one tone might clearly be a C, but in principle it could be Middle C, or the C an octave above, or the C an octave below. So when listeners are asked to determine whether a pair of such tones forms an ascending or descending pattern, there is literally no correct answer. (Tones such as these were used by Roger Shepard and Jean-Claude Risset to produce illusions of endlessly ascending scales and glides.[10])

Surprisingly, when one such tone pair is played (say, D followed by G#) some listeners clearly hear an ascending pattern, whereas other listeners clearly hear a descending one. Yet when a different tone pair is played (say, F# followed by C) the first group of listeners now hears a descending pattern whereas the second group now hears an ascending one. Furthermore, for any given listener, the pitch classes generally arrange themselves perceptually with respect to height in a systematic way: Tones in one region of the pitch class circle are heard as higher and those in the opposite region as lower. This is illustrated in Fig. 2, which displays the judgments made by four different listeners. Since their judgments varied systematically depending on the positions of the tones along the pitch class circle, the listeners must have been employing an implicit form of absolute pitch in making these judgments.

It has been found that the way the pitch class circle is oriented with respect to height is related to the language or dialect to which the listener has been exposed,[11] particularly in childhood,[12] and also to the pitch range of his or her speaking voice.[12,13] Such findings have led to the conjecture that the implicit form of absolute pitch that is reflected in judgments of the tritone paradox originally evolved to sub-serve speech.[14] This hypothesis is bolstered by findings that the pitch range of an individual's speaking voice is related to his or her linguistic community, and not to physiological features such as height, weight, chest size, length of vocal tract, and so on.[15]

"if we assume that early in human history absolute pitch developed as a feature of speech, and that the circuitry responsible for its processing can also be applied to musical tones, we have a viable framework for understanding absolute pitch and its characteristics, particularly its rarity in our culture."

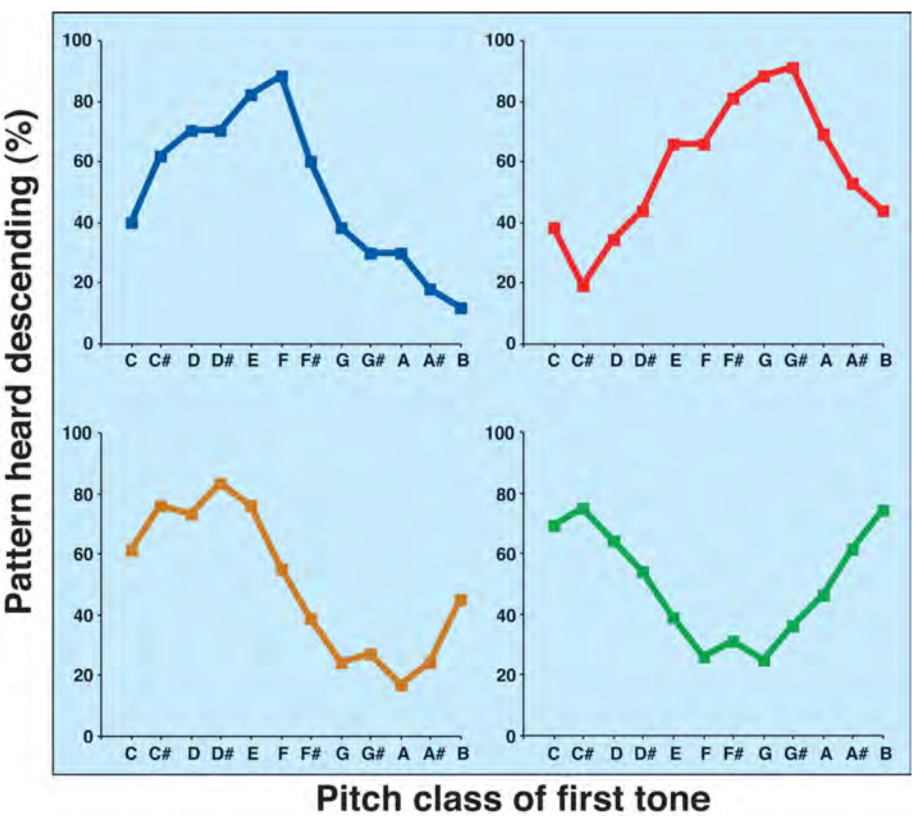

Fig. 2. Judgments of the tritone paradox made by four different listeners. To produce this illusion, pairs of tones are played that are in opposite positions along the pitch class circle (see Fig. 1). For example, C is played followed by F#, or D followed by G#. Listeners judge whether each pair of tones forms an ascending or a descending pattern. The judgments of most listeners vary in an orderly fashion depending on the positions of the tones along the pitch class circle, showing that the listeners employ an implicit form of absolute pitch in making these judgments. (Data taken by the author.)

There is other evidence that people who do not possess absolute pitch as conventionally defined nevertheless possess the ability in implicit form. In one study, musically trained listeners were presented with excerpts of Bach preludes, and 30% of those without absolute pitch were able to differentiate the correct version from one that had been pitch-shifted by a semitone.[16] Other research has shown that people without absolute pitch tend to be fairly consistent in the pitches with which they hum or sing familiar songs on different occasions;[17] further, when asked to sing a popular song that had been recorded in only one key, they produce pitches that are close to those in the recorded version.[18]

Given the evidence for implicit absolute pitch, the inability of most people to label isolated notes is indeed baffling. The evidence strongly indicates that the problem is not one of long term memory, but is instead related to verbal labeling, and so to speech processing. We shall be examining this conjecture in detail below.

The genesis of absolute pitch

Given the rarity of absolute pitch, there has been considerable speculation concerning its genesis. One view, which has been championed for over a century,[19] is that this ability is available only to rare people who have a particular genetic endowment, and that it becomes manifest in these people as soon as circumstances allow. There are two general arguments for this view: First, absolute pitch generally appears at a very young age, and often when the child has had little or even no formal musical training; second, the ability often runs in families.[2] The problem with both of these arguments is that there are alternative explanations in terms of very early childhood exposure—babies born into families whose members have absolute pitch would frequently be exposed to pitches in association with their names very early in life, so that they would have the opportunity to develop this ability at a very young age. Nevertheless, there is a vigorous, ongoing, search for a DNA marker for absolute pitch,[20] though at this writing the search has so far proved unsuccessful.

Others have espoused the opposite view; namely that absolute pitch can be acquired by anyone at any time, given intensive practice. Indeed, on browsing the Web one encounters an impressive number of offers to supply the reader with training programs for absolute pitch that are guaranteed to produce success. Unfortunately, however, these claims are unsupported by the scientific evidence.[21] The one reliable report of partial success comes from Brady[22] who subjected himself to a heroic regimen in which he listened to training tapes for about 60 hours, following which he obtained a score of 65% correct on a test of absolute pitch. At best, Brady's report underscores the extreme difficulty of acquiring absolute pitch in adulthood, in contrast with its unconscious and effortless acquisition in early childhood.

There is considerable evidence that the acquisition of absolute pitch is associated with early musical training—the earlier the musical training the stronger the association. For example, in a large scale survey, 40% of respondents who began music lessons at or before age 4 stated that they possessed absolute pitch, and this percentage decreased with increasing age of onset of music lessons, so that only 3% of those who began music lessons at or after age 9 stated that they possessed the ability.[20] Such findings strongly indicate that the acquisition of absolute pitch involves a critical period. Although this period is generally regarded as beginning at age 3 or so, formal musical training cannot reasonably be initiated at a younger age, which leaves open the possibility that absolute pitch might be most readily acquired in infancy.

There is an intriguing parallel between the timetables associated with the acquisition of absolute pitch on the one hand and of speech and language on the other. Lennenberg[23] was perhaps the first to argue persuasively that the acquisition of speech involves a critical period. Learning a second language after puberty is self-conscious and labored; and even following many years of experience, a second language that is learned in adulthood is generally spoken with a "foreign accent." Several lines of research have provided strong support for the critical period hypothesis, for both first and second languages. For example, children who were socially isolated early in life, and so were deprived of the opportunity to acquire speech, were unable to acquire normal language when they were later placed in a normal environment.[24] The course of recovery from brain injury at different ages also points to a critical period. The prognosis has been found to be best when the injury occurred before age 6, and very poor after puberty.[25] In other studies it was found that individuals who were given the opportunity to learn a second language in early childhood became most proficient in this language, with proficiency declining with increasing age of initial exposure to the second language, reaching a plateau with initial exposure in adulthood.[26] The time course for acquisition of absolute pitch, as a function of age of onset of music lessons, appears to be remarkably similar to that for second language acquisition. Although there are critical periods for the development of other functions, no other critical periods have been documented that show the same correspondence with that for speech and language in terms of timeframe.

The case for a link between absolute pitch and speech is strengthened by consideration of tone languages, such as Mandarin, Cantonese, and Vietnamese. In these languages, words take on entirely different meanings depending on the *lexical tones* in which they are enunciated, with tones being defined both by their pitch heights (or *registers*) as well as by their pitch contours. (In Beijing Mandarin, for example, the first tone is high and level, the second is mid-high and rising, the third is low and initially falling and then rising, and the fourth is high and falling.) This contrasts with intonation languages such as English, in which pitch is employed to convey prosody and emotional tone, but is not involved in determining the meaning of individual words. For example, in Mandarin the word "ma" when spoken in the first tone means "mother," in the second tone means "hemp," in the third tone means "horse," and in the fourth tone means a reproach. So pitches in such languages are used to create verbal features, analogous to consonants and vowels. Therefore when speakers of Mandarin hear the word "ma" spoken in the first tone and attribute the meaning "mother," or when they hear "ma" spoken in the third tone and attribute the meaning "horse," they are associating a pitch—or a series of pitches—with a verbal label. Analogously, when people with absolute pitch identify the sound of the note F# as "F#," or the note B as "B" they are also associating a pitch with a meaning, or a verbal label.

As a further argument that absolute pitch in tone languages may be packaged with other features of speech, the brain structures responsible for processing lexical tone have been shown to overlap with those involved in processing phonemes (i.e., vowels and consonants). For example, while the communication of prosodic features of language appears to be a function of the non-dominant hemisphere (i.e., the right hemisphere in most right-handers) for speakers of both tone and intonation languages,[27,28] the processing of lexical tone appears to be a function of the dominant hemisphere (i.e., the left hemisphere in most right-handers).[29] So when speakers of tone language perceive pitches and pitch contours as signifying meaningful words, circuitry in the dominant hemisphere is involved. Given the evidence on critical periods for the acquisition of speech, we can then hypothesize that such circuitry is developed very early in life, during the period in which infants acquire other features of their native language.[30] If the opportunity to form such associations is unavailable during this critical period, these associations later become very difficult to acquire. Indeed, it has been argued that when infants acquire intonation languages, they learn to disregard absolute pitches, since individual words here carry the same meaning regardless of the pitch level in which they are pronounced.[31]

My colleagues and I have been examining the conjecture that absolute pitch is initially acquired by tone language speakers as a feature of speech, and that its rarity in speakers of intonation languages such as English can be explained by the lack of opportunity to acquire it in infancy. The hypothesis that absolute pitch may in principle be acquired very early in life is strengthened by findings that infants can carry out perceptual learning tasks that involve referring to the absolute pitches of tones.[32]

Absolute pitch and tone language

If tone languages speakers use absolute pitch as a cue to differentiate the meaning of words, then we would expect them to refer to stable and precise absolute pitch templates in reciting the same list of words on different days. In one experiment to examine this conjecture,[14] we tested seven speakers of Vietnamese, none of whom had received any significant musical training. The subjects were handed the same list of ten Vietnamese words to read out in two sessions, which were held on different days. Then for each spoken word, we took pitch (f0) estimates at 5 ms intervals, and averaged these pitches along the musical scale (i.e., along a log frequency continuum), so producing an average pitch for each word. Then for each speaker we calculated the difference between the average pitches produced by each word as it was spoken on the different days, and we averaged the signed differences across the words in the list.

Our results showed remarkable consistencies: All speakers showed averaged pitch differences of less than 1.1 semitone, with two of the seven speakers showing averaged pitch differences of less than a quarter of a semitone. So the speakers must have been referring to precise and stable absolute pitch templates in reciting the list of words.

In our next experiment, we tested 15 speakers of Mandarin, who (with one exception) had also received little or no musical training. All these subjects had grown up in China, and spoke Mandarin as their primary language. One purpose here was to test the generality of our findings to a different tone language. A second purpose was to explore whether there would be less consistency in reciting the word list on different days, compared to reciting it twice in succession, since on the absolute pitch hypothesis we would not expect to see a reduction in consistency with the passage of time. We generated a list of 12 Mandarin words, with each of the four tones occurring three times in the list.

The subjects were tested in two sessions, which were held on different days, but now they read out the word list twice in each session, with the readings separated by roughly 20 seconds. We calculated four difference scores: Between the first readings on Days 1 and 2; between the second readings on Days 1 and 2; between the first and second readings on Day 1, and between the first and second readings on Day 2.

Table 1 shows, for each comparison, the numbers of subjects whose averaged signed difference scores fell into each 0.25 semitone bin. It can be seen that remarkable consistencies were again obtained. For all comparisons, half of the subjects showed averaged pitch differences of less than half a semitone, and one-third of the subjects showed averaged pitch differences of less than a quarter of a semitone. And importantly, there were no significant differences in the degree of pitch consistency in reciting the word list on different days compared with reciting it twice in immediate succession. In fact, the differences between comparisons across days and under immediate repetition did not begin to approach significance. This leads to the conclusion that although the pitch discrepancies we obtained were very small, they still underestimated the precision of the absolute pitch templates that influenced the subjects' speech.

How do speakers of intonation language perform on this task? To examine this, we tested a group of 14 native speakers of English on a list of 12 English words, using the same procedure as for the speakers of Mandarin. We found that the English speakers showed roughly the same degree of consistency as did the Mandarin speakers in reciting the word list twice in immediate succession; however, they were significantly less consistent than the Mandarin speakers in reciting the list on different days. So the speakers of English differed from those of Mandarin in terms of pitch consistency, both

Table 1. *Pitch difference scores produced by speakers of Mandarin on reading out the same list of words on different occasions. The table displays, for each comparison, the number of subjects whose pitch difference scores fell into each 0.25 semitone bin.*

Across Sessions						
■	5	4	4	0	1	1
◆	5	5	3	1	1	0
Within Sessions						
●	5	4	6	0	0	0
⬟	6	4	3	1	1	0
	0-.25	**.25-.5**	**.5-.75**	**.75-1.0**	**1.0-1.25**	**1.25-1.5**

PITCH DIFFERENCE (FRACTIONS OF A SEMITONE)

■ **First reading; Day 1 vs. Day2**
◆ **Second reading; Day 1 vs. Day 2**
● **First vs. Second Reading; Day 1**
⬟ **First vs. second reading; Day 2**

qualitatively and quantitatively.

These findings indicate that speakers of Vietnamese and Mandarin possess a remarkably precise form of absolute pitch for the tones of their language, which was here reflected in their enunciation of words. Only one of the 22 tone language speakers in the study had received any significant musical training. We can therefore hypothesize that this ability resulted from their early acquisition of tone language, so that they had learned to associate pitches with meaningful words in infancy.

So far, we have been arguing for the conjecture that absolute pitch, which has traditionally been viewed as a musical faculty, originally evolved to subserve speech. This leads to the further conjecture that when infants acquire absolute pitch as a feature of the tones of their language, and they later reach the age at which they can begin taking music lessons, they can then acquire absolute pitch for musical tones in the same way as they would acquire the tones of a second tone language. In contrast, children who instead have acquired an intonation language such as English would need to learn the pitches of musical tones as though they were the tones of a first language. So, given the findings showing the extreme difficulty in acquiring a first language beyond early childhood,[24,30] speakers of an intonation language should be at a serious disadvantage in acquiring absolute pitch for musical tones.

This line of reasoning in turn leads to the conjecture that the prevalence of absolute pitch should be much higher among tone language speakers than among speakers of intonation languages such as English. To explore this, my colleagues and I examined the prevalence of absolute pitch in two large groups of music students.[33] The first group consisted of 88 first year students who were enrolled in a required course at the Central Conservatory of Music in Beijing. These subjects all spoke Mandarin. The second group consisted of 115 first year students who were enrolled in a required course at Eastman School of Music. These were all nontone language speakers, and both their parents were nontone language speakers. All students who were invited to take the test agreed to do so, so there was no self-selection of subjects from within either group.

Our test for absolute pitch consisted of the 36 notes that spanned the three-octave range from the C below Middle C ($f0 = 131$ Hz) to the B almost three octaves above ($f0 = 988$ Hz). To minimize the use of relative pitch as a cue, all intervals between successive notes were larger than an octave. The notes were piano samples that were generated on a Kurzweil synthesizer and recorded on CD. The subjects listened to the CD, and identified each note in writing.

We divided each group into subgroups by age of onset of musical training, and to make meaningful comparisons we considered only those subgroups that contained at least nine subjects. Figure 3 shows, for each of the subgroups, the percentages of subjects who obtained a score of at least 85% on

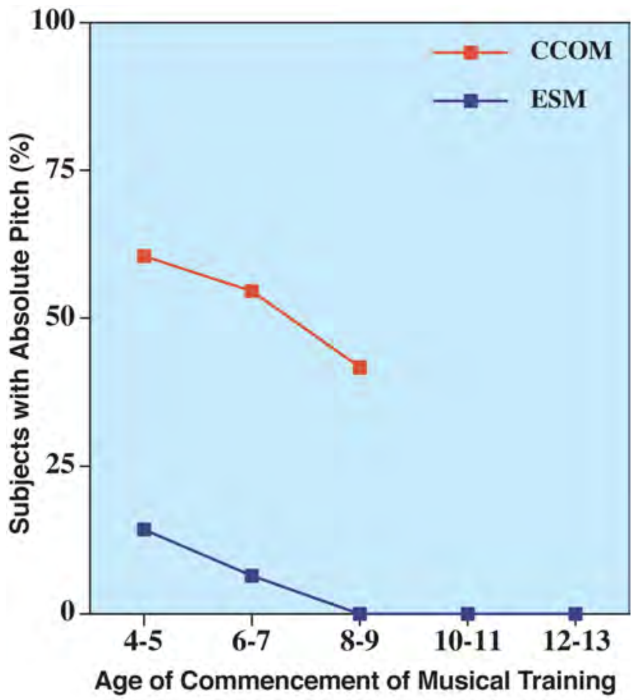

Fig. 3. Percentages of subjects who obtained a score of at least 85% correct on the test of absolute pitch. The data are plotted as a function of age of onset of musical training. Red boxes show the results from students at the Central Conservatory of Music (CCOM), Beijing, China; all these subjects were speakers of the tone language Mandarin. Blue boxes show the results from students at Eastman School of Music (ESM), Rochester, New York; all these subjects were nontone language speakers. (From Deutsch et al., Journal of the Acoustical Society of America, 2006).

this test for absolute pitch. As can be seen, both the Central Conservatory students (that is, the Mandarin speakers) and the Eastman students (that is, the U.S. nontone language speakers) showed orderly effects of age of onset of musical training—the earlier the age of onset, the higher the probability of meeting the criterion for absolute pitch.

It can also be seen that, for all levels of age of onset of musical training, the percentage of those who met the criterion was far higher for the Central Conservatory group than for the Eastman group. For students who had started taking music lessons at ages 4 and 5, approximately 60% of the Mandarin speakers met the criterion, while only 14% of the U.S. nontone language speakers did so. For students who had begun music lessons at ages 6 and 7, approximately 55% of the Mandarin speakers met the criterion, whereas this was true of only 6% of the U.S. nontone language speakers. For those who had begun music lessons at ages 8 and 9, roughly 42% of the Mandarin speakers met the criterion, whereas none of the U.S. nontone language speakers did so. We also made comparison between the male and female subjects within each subgroup, and no effects of gender were found; and there was no overall trend based on gender in either direction.

What happens when we relax the criterion for absolute pitch? Figure 4 displays the percentages of subjects who obtained a score of at least 85% on the same test, but now allowing for semitone errors. Again, it can be seen that both the Central Conservatory and the Eastman students showed orderly effects of age of onset of musical training. And it can also be seen that the difference between the Central Conservatory and the Eastman students was even more extreme. For students who had started taking music lessons at ages 4 and 5, approximately 74% of the Mandarin speakers met the criterion, whereas only about 14% of the U.S. nontone language speakers did so. And of those who had begun music lessons at ages 6 and 7, roughly 68% of the Mandarin speakers met the criterion, whereas this was true of only about 10% of the U.S. nontone language speakers. And of those who had begun music lessons at ages 8 and 9, again roughly 42% of the Mandarin speakers met the criterion whereas none of the U.S. nontone language speakers did so. Again, there were no differences depending on gender in either group or any subgroup.

These findings support the conjecture that, when given the opportunity, infants can acquire absolute pitch for the tones of their language, so that they can later acquire absolute pitch for musical tones in the same way as they would the tones of a second tone language. In fact, the findings obtained here for the acquisition of absolute pitch in tone language and nontone language speakers reflect a very similar picture, in terms of timeframe, to the critical periods inferred by linguists for the acquisition of first and second languages respectively. This supports the hypothesis that, for speakers of tone languages, the acquisition of absolute pitch during musical training is analogous to learning the tones of

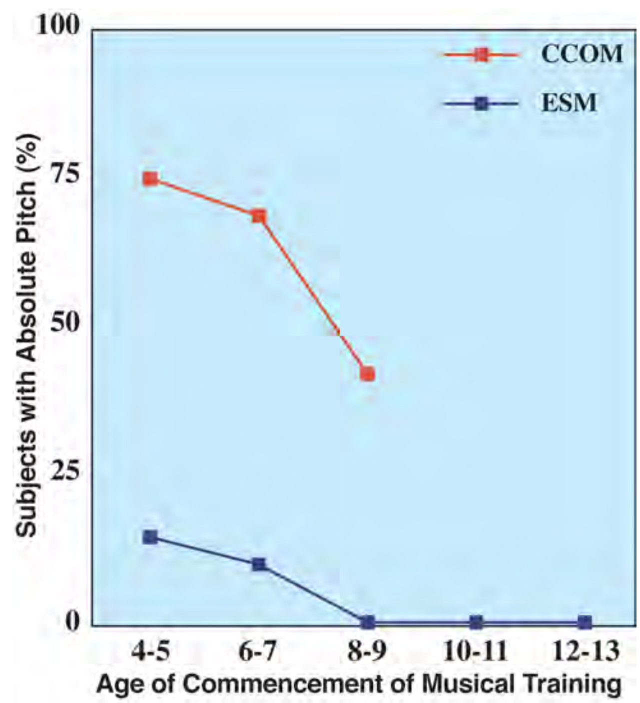

Fig. 4. Percentages of subjects who obtained a score of at least 85% correct on the test of absolute pitch, allowing for semitone errors. The data are plotted as a function of age of onset of musical training. Red boxes show the results from students at the Central Conservatory of Music (CCOM), Beijing, China; all these subjects were speakers of the tone language Mandarin. Blue boxes show the results from students at Eastman School of Music (ESM), Rochester, New York; all these subjects were nontone language speakers. (From Deutsch et al., Journal of the Acoustical Society of America, 2006).

a second language. So speakers of nontone languages such as English, who do not have the opportunity to associate pitches with meaningful words in infancy, are at a disadvantage for the acquisition of absolute pitch for musical tones.

The evidence for this view has so far been applied only to speakers of tone languages such as Mandarin and Vietnamese, in which pitch is prominently involved in attributing the meaning of words. However, the same principle might also apply to speakers of other Asian languages such as Japanese and certain dialects of Korean. Japanese is a pitch-accent language, in which the meaning of a word can change depending on the pitches of its constituent syllables. For example, in Tokyo Japanese the word “hashi” means “chopsticks” when it is pronounced “high-low,” “bridge” when it is pronounced “low-high,” and “edge” when there is no pitch difference between its constituent syllables. In Korean, the Hamkyeng and Kyensang dialects are considered tonal or pitch accent. For example, in the South Kengsyang dialect, the word “son” means “grandchild” or “loss” when spoken in a low tone, “hand” in a mid tone, and “guest” in a high tone. We may therefore conjecture that there might also exist a higher prevalence of absolute pitch among people who were exposed to these languages or dialects in infancy.

As a related point, in a survey of music students in the United States, it was found that those respondents who designated their ethnic heritage as “Chinese,” “ Japanese” or “Korean” reported a higher prevalence of absolute pitch than did those who designated their ethnicity as Caucasian.[34] The authors argued from these findings that ethnicity is a predisposing factor in the acquisition of absolute pitch. However, they omitted to state that the large majority of the Asian respondents had designated an Asian country as their “country of early music education,” and so had presumably spent their early childhood in Asia. On further analysis, the reported prevalence of absolute pitch was found to be far higher among Asian respondents with early childhood in Asia than among Asians with early childhood in the North American continent.[35] The findings from this study therefore point instead to an environmental factor as responsible for the group differences that were obtained, and fit well with the present hypothesis in terms of first language acquisition.

Finally, we address the rare instances of absolute pitch among people who speak an intonation language. Those who were born into families of practicing musicians would have been exposed frequently to pitches associated with their names, and so would have been given the opportunity to acquire absolute pitch in infancy. In the case of people for whom such as explanation is not feasible, we can conjecture that they may have a critical period of unusually long duration, so that it extends to the age at which they can begin formal musical training. It is possible that a predisposition for an unusually long critical period might have a genetic basis, though other predisposing factors could also be responsible.

Evidence that an innate predisposition may be involved in the acquisition of absolute pitch by people in our culture comes from findings that Western musicians with absolute pitch tend to exhibit an unusual brain asymmetry. The planum temporale—a brain region that is important to speech processing—is larger on the left than on the right in most people. The degree of this asymmetry has been found, on a statistical basis, to be larger among musicians with absolute pitch than among those who did not possess this ability.[36] However, the reason for this association is at present unknown.

Summary and conclusions

Viewed simply as a musical ability, absolute pitch presents us with an enigma. What would be the adaptive significance of a rare musical ability that is subject to a critical period with a time course very similar to that of speech? And why should most people have an implicit form of absolute pitch, yet be unable to perform the simple task of naming notes that are presented in isolation? On the other hand, if we assume that early in human history absolute pitch was packaged with other features of speech, and that the circuitry responsible for its processing can also be applied to musical tones, we have a viable framework for understanding absolute pitch and its characteristics, particularly its rarity in our linguistic culture.

At a more general level, there is currently much debate concerning the relationships between the brain structures underlying speech on the one hand and music on the other.[37] The evidence and arguments presented in this paper are consistent with the view that while certain aspects of speech and music are subserved by separate brain mechanisms, other aspects of these two forms of communication are subserved by common neural circuitry. **AT**

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