ARCHIVES OF ACOUSTICS
32, 3, 529–540 (2007)

ABSOLUTE PITCH AND ITS IMPLICATIONS FOR MUSIC

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(*received May 21, 2007; accepted July 24, 2007*)

Absolute pitch is defined as an ability to identify musical pitch of single tones presented in isolation. There has been so far little empirical research investigating in detail how people with absolute pitch perceive musical pitch, so absolute pitch is still surrounded by mystery. This article summarizes a series of the author's experiments exploring the perception of musical pitch and melodies by listeners having absolute pitch. Absolute pitch has been considered an important part of musical ability, and is assumed to be acquired primarily through early music training at the age from 3 to 6 years. However, critically important is relative pitch (pitch relations) on which melodies and harmonic structures are constructed. In contrast, absolute pitch that enables its possessors to name isolated tones is not crucial to music. Moreover, the experimental findings suggest that absolute pitch may sometimes be disadvantageous for musicians since it may, in some cases, be incompatible with processing and learning of relative pitch.

Keywords: absolute pitch, music perception, melody, early learning, music training.

1. Introduction

Pitch, among other auditory attributes, provides important information for human beings. For example, pitch contour carries substantial linguistic and extra-linguistic meaning in speech. Pitch assumes a more important role in music as musical essentials, such as melody and harmony, are formed by a set of different pitches. Psychophysically, pitch is a sensory attribute that corresponds to the fundamental frequency of the sound. One perceives the pitch change from low to high as a tone sweeps from low to high in frequency. The human auditory system is extremely sensitive to the difference in frequency, the frequency difference limen being approximately 0.3% in adults with normal hearing [14].

Despite such a high sensitivity to frequency differences, human beings have serious difficulties in absolute judgment of pitch. In an experiment where subjects were required to classify tones of different frequencies presented randomly, the number of categories differentiated reliably was no more than seven [16]. This limitation is imposed not only on pitch but also on other sensory experiences, such as perceived sound intensity, light intensity, length of line segments, and weight. In a seminal paper titled "The magical number seven plus or minus two", MILLER [8] summarized the findings of experiments on sensory identification, and concluded that sensory limitation reflects the limit of human information processing, whose amount of information transfer is approximately 2.8 bits ($2^{2.8} = 7$).

When comparing the pitches of two consecutive tones, we can retain the pitch of the first tone in working memory and therefore achieve fine discrimination by comparing the memorized pitch of the first tone with the pitch of the second tone presented subsequently. However, when identifying pitch with no reference tone given, most of us can only make rough categorization since we have no internal reference pitch.

This inability to perceive pitch absolutely poses practically no problem when we listen to music, since the musical pith system is not absolute, but relative in nature. When given a reference pitch, we can establish a tonal context in mind and perceive melodies and harmonic relations in this context, and have almost no difficulty in enjoying and playing music, so far as we are able to perceive the pitch relations. This ability to perceive pitch in a tonal context is called relative pitch. Fortunately, most of us usually possess this ability.

In rare cases, however, there are people who are capable of naming single tones instantly or singing the correct pitch of designated tones. This faculty is called absolute pitch (AP) and is believed to be a special talent associated with music. Psychologists have had much interest in AP from the early days of scientific psychology [18, 21, 26]. Research on AP has primarily focused upon its etiology, addressing issues whether AP has hereditary links or can be acquired [5–7, 24]. However, the basic characteristics of AP itself, such as how the AP possessors perceive musical pitch, melodies, and harmonic relations, are not yet well known.

2. Perception of absolute pitch

The basic AP test traditionally used in AP studies consists in presenting a set of tones (sinusoidal tones, piano tones, or other complex tones) in a pitch range of several octaves, and having the subjects identify the pitch name of each tone presented. In an experiment conducted with the use of such a method [9], the subjects identified the pitches of 84 synthesized piano tones ranging from C1 (32.7 Hz) to B7 (3971 Hz) on a standard chromatic scale. Each test tone was presented once in a trial block, and each listener participated in four trial blocks. The tones were presented in a pseudo-random order with the constraint that two consecutive tones were separated by more than one octave in order to prevent the subjects from relying on relative judgment of pitch. On each trial, the subjects gave the pitch name of the presented tone by pressing a corre-

sponding key on a musical keyboard, as fast as possible. The subjects were seven music students screened as AP possessors in a preliminary test.

Percentage of correct responses for individual participants was 85–100%, with a mean of 92%, when ignoring the misplacement of octave positioning. There were a substantial number of responses (14% of all responses) that were correct in pitch class naming but incorrect in octave placement. Such errors, known as octave errors, are typical for AP possessors and are usually not regarded as errors in experiments [2, 22]. The above pattern of responses indicates that AP listeners are able to accurately identify the pitch class (the position of a tone on the chromatic scale) but appear to be as inaccurate as non-AP listeners in identifying the octave positioning (pitch height).

For the purpose of comparison, listeners who had no AP and no specific music training beyond the compulsory education also took part in the same AP test. Their responses were almost randomly distributed over the pitch classes, but the non-AP subjects could roughly classify the tones into their octave categories (seven octaves) on the basis of pitch height or some sort of timbral characteristics that changed as a function of frequency.

It seems that AP listeners go through a two-stage processing, first identifying the pitch class of the test tone and then judging its octave positioning. Although AP listeners are extremely accurate and fast in identifying pitch classes, they are probably less accurate in judging the pitch height as has been demonstrated by the occurrence of a substantial number of octave errors; AP listeners may be therefore no better than non-AP listeners in identifying pitch height. Seen in this light, the term of "absolute pitch" is considered to be inaccurate, and "absolute pitch class" may be a more adequate term.

Accuracy of AP identification is influenced by various stimulus characteristics of the test tone. Among them, the most important are timbre and the pitch region. In the experiment discussed above [8], the effects of timbre and pitch region were also examined using three different timbre qualities (acoustic piano tones, synthesized piano tones by FM synthesis, and pure tones) over a range of seven octaves. The identification of pitch was most accurate for piano tones (mean percentage correct: 94.9%), least accurate for pure tones (74.4%), and in-between for synthesized piano tones (84.3%). As expected, the effect of pitch region was also significant; the identification was most accurate for tones in the middle pitch region, and least accurate for tones at the low and high extremes.

These effects of timbre and pitch region could be explained by the familiarity of the listeners with certain kinds of sounds. AP listeners are considered to be more familiar with piano sounds than with synthesized tones and sinusoidal tones, since they have primarily acquired AP through piano lessons in early childhood. In a similar vein, tones in the middle frequency region are heard most frequently in music and therefore believed to be well memorized, whereas tones at the low and high extremes are heard much less frequently. Moreover, the sense of pitch (pitch strength or pitch definition) is weak in the extreme pitch regions and tones of such regions are unsuitable for playing melodies. For instance, tones of the lowest pitch region of the piano sound like roaring or rumbling noises, and tones of the highest region sound like metallic sounds of some percussion instruments.

3. Difference in identifiability between white-key notes and black-key notes

Accuracy of AP identification differs depending on pitch classes. In a next experiment [10], 60 chromatic tones over a five-octave range were used as test tones. The test tones were produced by a piano-tone generator and their timbre closely resembled real piano sounds. Thirty two music students, who served as subjects, were classified into three subgroups of about equal size, depending on the subjects' accuracy of responses, i.e., the accurate group (more than 90% correct), the intermediate group (70–90% correct), and the inaccurate group (less than 70% correct). A general tendency observed in the experiment was that white-key notes (notes with no accidental in musical notation) were correctly identified more often than black-key notes (notes with an accidental). This difference was the most pronounced for the inaccurate group, whereas it was the least pronounced for the accurate AP group. The accurate AP listeners made few errors even for the black-key notes. As a consequence, whereas the difference among the three subgroups was not so large in the identification of white-key notes, it became much more pronounced for black-key notes, because the group of inaccurate AP listeners made most of the errors for the black-key notes. The percentage of correct responses for the white-key notes vs. the black-key notes was approximately 95% vs. 90% for the accurate group and about 80% vs. 40% for the inaccurate group.

The differences in performance among the subject groups and between the note categories were also evident in the response speed. The accurate AP group was fastest in responding (mean RT = 0.605 sec), the inaccurate group was slowest (1.167 sec), and the intermediate group was in-between (0.717 sec). Moreover, the white-key notes were more quickly identified than the black-key notes by all subgroups. Similar findings were also obtained by TAKEUCHI and HULSE [22].

The analysis of error patterns revealed a pronounced asymmetry between the white-key and the black-key notes in the distribution of errors. The inaccurate AP group showed this asymmetry most clearly; that group made relatively few errors mistaking the white-key notes for the adjacent black-key notes and a greater number of errors mistaking the black-key notes for the adjacent white-key notes. For example, of the total 195 responses to the C# (or D flat) pitch, 62 were semitone errors saying the lower adjacent note C, and 44 were errors saying the upper adjacent note D, whereas the number of errors in a reverse direction confusing the C with the C# and confusing the D with the C# was only 17 and 8, respectively.

There were some subjects, particularly in the intermediate and inaccurate AP groups, who were relatively accurate in identifying the white-key notes well but failed to identify the black-key ones. This type of AP could be called partial AP, i.e., AP for only the white-key notes. The difference in performance and the asymmetric occurrence of error responses between the note categories (the white-key and the black-key notes) could be due to the presumed acquisition process of AP during early childhood. In usual music lessons (primarily piano lessons) for children, AP for the white-key notes is presumably more easily established than AP for the black-key notes, since piano lessons usually begin with practicing musical scales and pieces in the C-major key, and children hear

the white-key notes much more frequently than the black-key notes. The most effective period for acquiring AP is considered to be at the age from 3 to 6 years [22]. During that period the black-key notes are much less often heard than the white-key notes are, since the black-key notes are gradually introduced after the white-key notes. It may be, therefore, possible that acquiring AP for the black-key notes is more difficult than for the white-key notes, because the sensitive period for learning AP ends when the black-key notes are introduced to the piano lessons.

4. Prevalence of absolute pitch

An issue of primary interest is how many people among the general population or among musicians have AP. It has long been believed that AP is extremely rare ability. However, it is difficult to estimate the population of AP accurately, since there were few systematic investigations on the prevalence of AP possessors, and the resulting estimates might vary enormously depending on the adopted criterion of AP and the method of measurement used. Nevertheless, several researchers have provided the estimates of the AP incidence that are extremely small. For example, PROFITA and BIDDER [17] estimated the proportion of AP possessors at less than 1:1500, and BACHEM [2] mentioned that it is even less than 1:10000 in the general population. However, these estimates are not very reliable because they are mainly based on anecdotal reports with no explicit criteria and may overemphasize the rarity of AP. Nevertheless, AP is a rare ability among the general population, although it is not easy to provide a reliable estimate of the prevalence of AP. On the other hand, AP is not as rare among musicians, as it is associated with experience in music. Estimated incidence of AP among musicians varies, probably depending on the differences in criteria of AP and in samples; for example, the estimate is from 3.4% [19], 8.8% [25], to about 15% [3].

Figure 1 shows rough estimates of the proportion of AP possessors among music students in Japan and Poland. Although these are merely preliminary data that were drawn from AP screening tests in several experiments carried out for other purposes, and were obtained only a limited number of samples with possible sampling bias, it is useful to get an overview. The listeners were 36 students of the Faculty of Music, Kyoto City University of Arts, Japan, 37 students majoring music education at the Faculty of Education, Niigata University, Japan, and 27 students of the Fryderyk Chopin Academy of Music, Warsaw, Poland. All the listeners were given a short version of the AP test described above, in which they heard 60 different tones within a range of a five-octave chromatic scale and identified each tone by pressing a corresponding key on a musical keyboard. The percentage of correct responses represents the proportion of responses of correctly identified pitch classes, i.e., counting octave errors as correct.

Each bar represents the percentage of AP listeners of different accuracy in AP identification for each of the three different music schools. It can be seen that the proportion of accurate AP listeners who gave correct responses of 90% or more is approximately 30% of the Japanese music students, whereas it is 11% of the Polish music students.

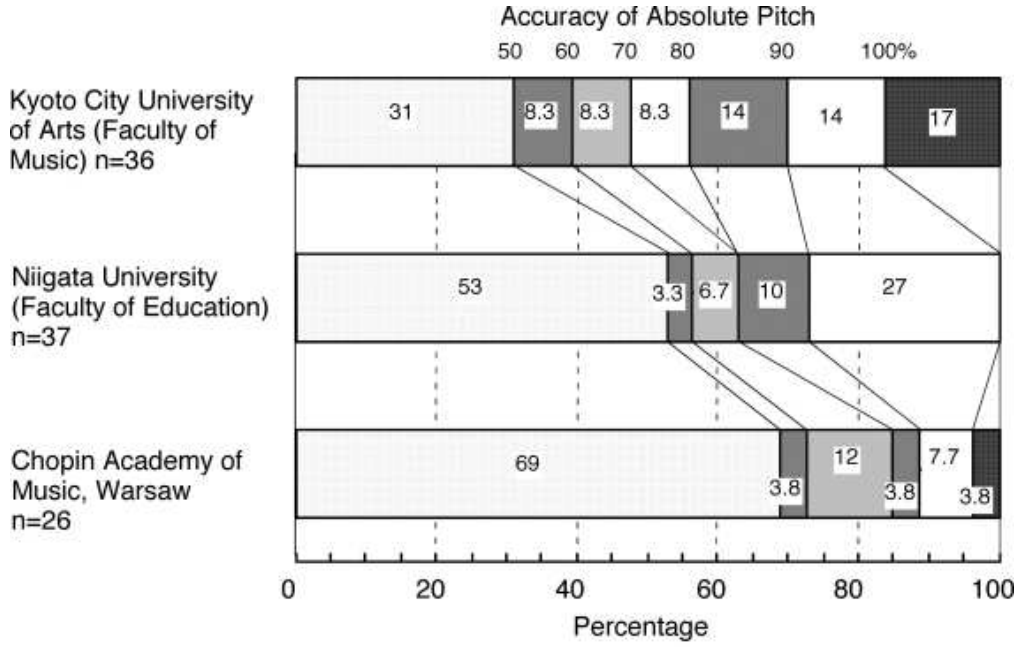

Fig. 1. Proportion of participants of different performance levels in identifying absolute pitch among music students in Japan and Poland. Numerical values shown at the top of the figure represent the percentage of correct responses in the absolute pitch test, and values within divided sections of each bar represent the percentage of the participants of different performance levels.

When adopting a more liberal criterion, those who gave correct responses of 50% or more approach to 70% of the students of the Kyoto City University of Arts and 50% of the students of the Niigata University, whereas it is about 30% of the students of the Fryderyk Chopin Academy of Music. It should be added that the students of the Niigata University were in a course of music education, and the students of the Kyoto City University of Arts were in a course for professional musicians. The difference in the proportion of AP possessors between the two Japanese groups may reflect the possible difference in the amount and quality of musical training they received particularly in their childhood.

The most impressive feature of the results is the difference in the accuracy of AP between the Japanese music students and the Polish music students. This could be accounted for by the difference in the circumstances of early music education between Japan and Poland. In Japan, early music training is widespread, and there are a number of private music schools that provide small children with introductory music lessons mainly in piano playing. AP is considered to be acquired through these early music lessons. This speculation could be supported by the fact that both the Polish and Japanese students who obtained high scores in the AP test generally had received music lessons from early childhood. This correlation between AP possession and the early commencement of music training has also been reported in the literature [3, 20, 22].

5. The learning process of absolute pitch

There is a rich body of literature that suggests the association of AP possession and early music training, but they are often based on indirect retrospective reports of the participants on their early musical experiences. There has been little evidence showing directly the acquisition process of AP during childhood. MIYAZAKI and OGAWA [13] carried out a cross-sectional investigation in which Japanese children who attended a Yamaha music school in Tokyo were tested for their AP ability.

Children enter the school at the age of 4. In the first two-year program, the fundamental musical skills and ear training are emphasized through various music activities, for example repeatedly singing songs with lyrics or pitch syllables in the fixed-do manner, and playing songs on the piano with or without singing in solmization. Through this training, children are encouraged to make associations of individual pitches with their verbal labels, beginning with C ("do" in the fixed-do naming system), and then other notes of the C major diatonic scale. Of these notes, C, D, and E are given priority over the other diatonic tones, because these are the first three tones of the C-major scale and are easy to produce vocally and to represent in mind. As the songs of different keys other than the C major are introduced in the lessons, children begin to learn notes with an accidental (a sharp or a flat), F sharp and B flat in the first year, followed by C sharp, A flat, and E flat in the second year. Thereby all 12 pitch classes are learnt.

In the AP test, 104 children at the age of 4 to 10 years participated. The test tones were 36 chromatic pitches over three octaves, fundamental frequencies of which ranged from 130.8 Hz (C3) to 987.8 Hz (B5). The test sessions were conducted individually in a lesson room and the test tones were played by a tester on the piano. The children were told to name the pitch class of each test tone out loud using their familiar sol-fa names.

Percentage of correct responses was calculated for each participant. The performance of the different age groups is shown in Fig. 2. Divided sections of each column represent the proportions of participants of different performance levels in each age group. As expected, the overall performance improved with the participants' age. More specifically, whereas almost all children of the age group 4 were less than 20% correct, the proportion of the children who achieved the performance level of more than 80% was about 40% for the age group of 7, and about 75% for the age group of 8 and 9. It can be seen that, in general, the most significant increase of performance occurred between age 4 and 7, and during this period, particularly at the ages 5 and 6, the performance level differed widely among individual participants.

Figure 3 shows the average percentage correct separately for the diatonic tones (the white-key notes) and the non-diatonic tones (the black-key notes) in the C major scale, as a function of children's age. As a whole, accuracy for the white-key notes increased consistently from the age of 4 to 7 and leveled off thereafter. On the other hand, the accuracy for the black-key notes began to increase later in age, and a marked increase occurred between the ages of 6 and 8. It is worth noting that the accuracy for the black-

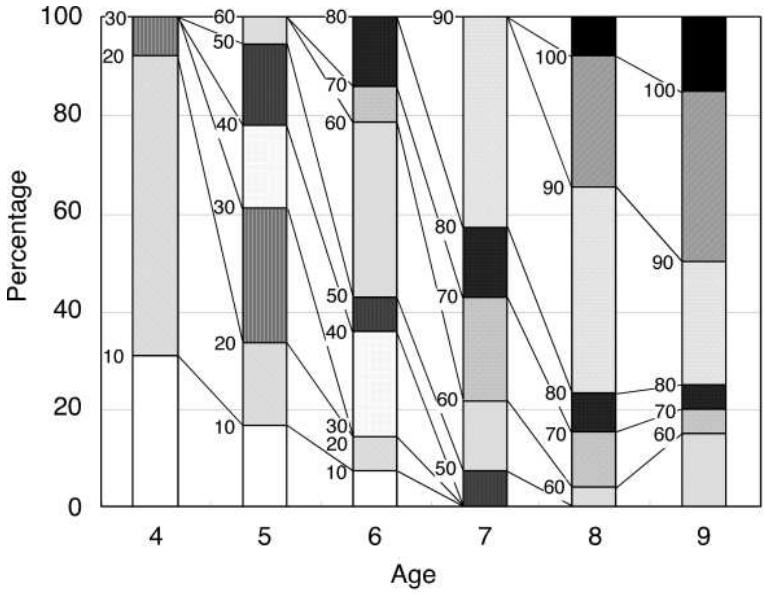

Fig. 2. Proportion of children of different performance levels in identifying absolute pitch for different age groups. Numerical values beside each bar represent the percentage of correct responses in the absolute pitch test. Redrawn from MIYAZAKI and OGAWA [13].

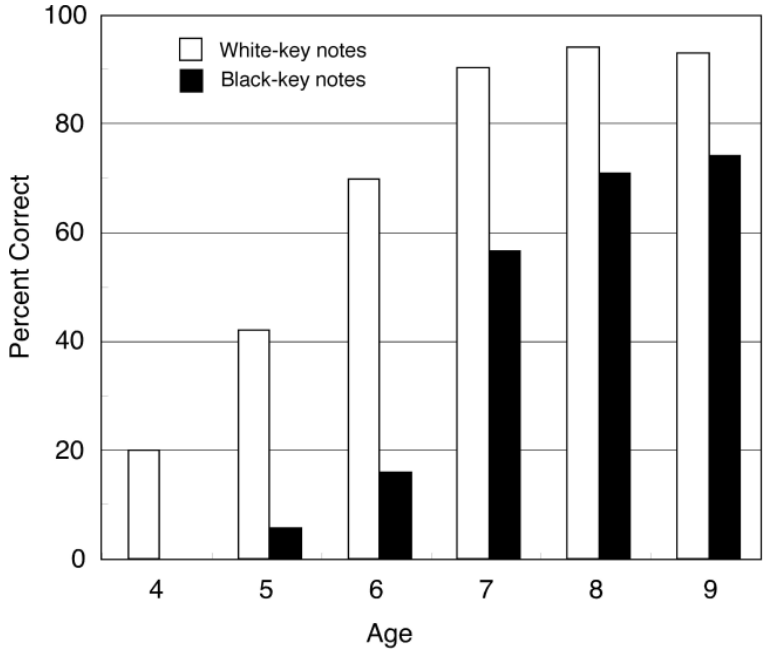

Fig. 3. Average percentage correct responses for the white-key tones and the black-key tones as a function of the children's age. Redrawn from MIYAZAKI and OGAWA [13].

key notes remained lower than that for the white-key notes even at the age of 9 when the overall performance had reached a plateau, indicating that a number of participants were still inaccurate for the black-key notes, compared with the white-key notes, when the supposed sensitive period for learning AP seemed to have expired. The time lag between the development of AP for the black-key notes and that for the white-key notes may be the cause of the existence of a particular type of adult AP possessors only for the white-key notes (partial AP) and the general weakness of adult AP possessors to recognize the black-key notes.

It may be concluded from the results presented in Figs. 2 and 3 that most of the older children developed AP though its accuracy varied from intermediate to perfect. However, one should be cautious about concluding from these results that any children can develop AP with adequate training. The children who participated in the test might be biased samples since they may have had a higher degree of interest and motivation in music and had come from a more musically oriented environment. Furthermore, due to the limitation of the cross-sectional study, the observed improvement of AP accuracy should not be taken as a direct effect of training, and the accuracy observed for the older age groups might have been boosted because there might have been some unexamined children who failed to reach a certain level of achievement and dropped out of school. Despite these cautions, it is pertinent to say that our study described here shed more insight on the learning process of AP through specific type of music training.

6. Implications of absolute pitch for music

It has been commonly believed that AP is a remarkable musical ability. Indeed, AP is useful in musical activities, such as music dictation in which a heard musical passage is transcribed into musical notation, or sight-reading of a complicated atonal melody. It is pointed out, however, that truly important for music is not absolute pitch but relative pitch, since music is basically constructed on the basis of pitch relations. While AP may be technically useful, it is no more than a specific ability to identify a single pitch without musical context. It could be argued, therefore, that AP is irrelevant to music.

Absolute pitch may be a disadvantage when a musician with AP listens to a transposed piece of music. When a piece of music is transposed, all its constituent tones change. This poses no problem to non-AP listeners for whom musical phrases and harmonic sequences are transposable on the pitch dimension, keeping their musical identities (the Gestalt principle of the tonal equivalence under transposition). However, transposition may bother AP listeners. All the tones may sound to them like wrong tones, as those tones have shifted upward or downward by a certain amount of musical interval.

Gerald MOORE, a highly reputed accompanist, once wrote in his autobiographical essay [15] as follows: “As a young man I was gifted with what is known as “perfect pitch” [absolute pitch], and this was rather an impediment than an advantage to me when I had to transpose: playing a piece of music in B flat, when my eyes saw the

page printed in C natural, upset my ears and brain, I found my fingers subconsciously wandering back to the tones I could hear with my inner ear – the tones that I saw on the printed page. . . . The gradual loss of perfect pitch has been an advantage to me as an accompanist, since it makes the act of transposing less hazardous for me – and for the singer."

There is a rich body of anecdotal reports describing the shortcomings of AP in certain musical activities, however, there was little empirical evidence for these disadvantageous aspects of AP. Miyazaki and Rakowski (2002) conducted an experiment of recognition of transposed melodies with AP listeners and no-AP listeners as participants. In this experiment, participants were 26 Polish students majoring music at the Fryderyk Chopin Academy of Music, Warsaw. Based on the preliminary AP test, they were divided into the AP group ($n = 9$, 55–100% correct responses) and the no-AP group ($n = 17$, less than 45% correct responses). The result of the preliminary AP test was already shown in Fig. 1.

In the experimental task, the participant compared a melody presented visually on a computer display in form of musical notation (standard melody) and a melody presented auditorily (comparison melody). The standard melody was always notated in the C major key, and the comparison melody was played in a piano timbre either at the same pitch level (untransposed) as the notated standard melody or at the different pitch level (transposed by four semitones downward or six semitones upward). The standard and the comparison melody pair was either exactly the same in relative pitch or different with one tone shifted upward or downward by one or two semitones. The participant had to indicate in each trial, by pressing a key on a computer keyboard, whether the standard and the comparison melodies were same or different in relative pitch, despite of the difference in absolute pitch.

As expected from the principle of equivalence under transposition, no-AP participants performed equally well in the transposed and untransposed conditions. In contrast, AP participants made significantly more errors in recognizing transposed melodies, as compared with the untransposed melodies. In the untranposed condition, the AP group excelled the no-AP group in performance probably due to the benefit of AP and more extensive musical experience; in the transposed condition, the AP group was significantly poorer than the no-AP group. The poor performance of the AP listeners in the transposed condition was caused by the discrepancy in absolute pitch between the heard melody and the notated standard melody. If the AP listeners could use relative pitch suppressing their AP sense, there should have been no difference in performance between the transposed and untransposed conditions. The obtained results suggest that AP listeners have a strong tendency to rely on AP even when AP is not useful, as in the case of identifying transposed melodies. Similar results were obtained also from Japanese music students in the same experimental paradigm [12].

These results raise questions about the musical significance of AP, and further imply its drawbacks. AP is sometimes useful, but, on the other hand, it may sometimes cause

problems in certain music activities. It has been quite naively believed that AP entails a good ear for musical pitch. However, the experimental results described here suggest that it is not necessarily the case. If AP is really irrelevant to music, and has certain drawbacks as described here, it could be argued that training AP has no essential merit to music and may even cause possible negative outcomes. For this reason, it may be necessary to provide music students who have acquired AP with some sort of remedial program carefully designed for controlling AP.

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