Absolute pitch among American and Chinese conservatory students: Prevalence differences, and evidence for a speech-related critical period (L)[a)]

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Absolute pitch is extremely rare in the U.S. and Europe; this rarity has so far been unexplained. This paper reports a substantial difference in the prevalence of absolute pitch in two normal populations, in a large-scale study employing an on-site test, without self-selection from within the target populations. Music conservatory students in the U.S. and China were tested. The Chinese subjects spoke the tone language Mandarin, in which pitch is involved in conveying the meaning of words. The American subjects were nontone language speakers. The earlier the age of onset of musical training, the greater the prevalence of absolute pitch; however, its prevalence was far greater among the Chinese than the U.S. students for each level of age of onset of musical training. The findings suggest that the potential for acquiring absolute pitch may be universal, and may be realized by enabling infants to associate pitches with verbal labels during the critical period for acquisition of features of their native language. © *2006 Acoustical Society of America.* [DOI: 10.1121/1.2151799]

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I. INTRODUCTION

Absolute pitch—the ability to name or produce a note of particular pitch in the absence of a reference note—is extremely rare in the U.S. and Europe, with an estimated prevalence in the general population of less than one in 10 000 (Profita and Bidder, 1988). Because of its rarity, and because many famous musicians have been known to possess it, absolute pitch is often considered to be a sign of exceptional musical ability. However, it is not necessarily accompanied by superior processing on other musical tasks (Lockhead and Byrd, 1981; Rakowski and Morawska-Büngeler, 1987; Takeuchi and Hulse, 1993; Burns and Campbell, 1994, Miyazaki and Rakowski, 2002). Furthermore, most people who do not have absolute pitch can nevertheless display surprisingly accurate long-term memories for pitch when verbal labeling is not required (Deutsch *et al.*, 1987; Levitin, 1994). The genesis of absolute pitch therefore presents a challenge for auditory theory.

Deutsch *et al.* (2004) found that speakers of two tone languages—Vietnamese and Mandarin—exhibited a remarkably precise and stable form of absolute pitch in reciting lists of words. Given these findings, it was conjectured that absolute pitch evolved as a feature of speech, analogous to other features such as vowel quality. [In tone languages, words take on entirely different meanings depending on the *tones* in which they are enunciated. Tones are defined both by their pitch heights ("registers") and by their pitch contours. For example, in Mandarin the word "ma" means "mother" when spoken in the first tone, "hemp" when spoken in the second tone, "horse" when spoken in the third tone, and a reproach when spoken in the fourth tone.] It was further conjectured that tone language speakers acquire this feature in infancy, during the critical period in which infants acquire other features of their native language (Kuhl *et al.*, 1992; Doupe and Kuhl, 1999) and so can later acquire absolute pitch for music in the same way as they acquire the features of a second tone language. This in turn led to the hypothesis that there should be a much higher prevalence of absolute pitch for music among tone language speakers than among speakers of nontone languages such as English. The acquisition of absolute pitch by rare individuals who are nontone language speakers was hypothesized to be associated with a critical period of unusually long duration, so that it encompasses the age at which the child can begin taking music lessons.

The present study examined the hypothesis of a speech-related critical period for acquiring absolute pitch, by comparing its prevalence in two large groups of music students. An on-site test was administered to the two groups under

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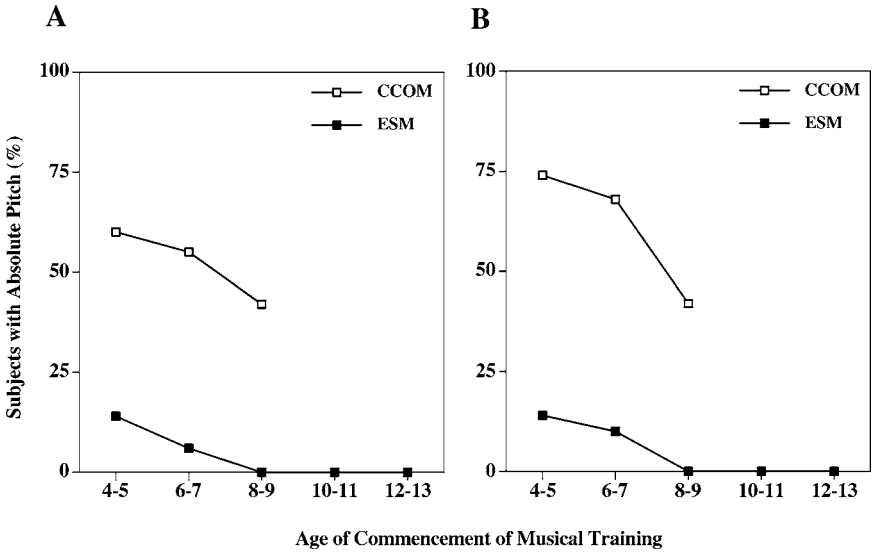

FIG. 1. Percentages of subjects who obtained a score of at least 85% correct on the test of absolute pitch, as a function of age of onset of musical training. (**A**) No semitone errors allowed; (**B**) semitone errors allowed. Unfilled boxes show the results from students at the Central Conservatory of Music (CCOM) in Beijing, China; these were all tone language speakers. Filled boxes show the results from students at Eastman School of Music (ESM), Rochester, NY, who were nontone language speakers.

highly similar conditions. The first group consisted of first-year students who were enrolled in a required course at the Central Conservatory of Music (CCOM) in Beijing; all these subjects spoke the tone language Mandarin. The second group consisted of first-year students who were enrolled in a required course at Eastman School of Music (ESM) and who were nontone language speakers, with both parents being nontone language speakers (see below).

II. METHOD

The CCOM group consisted of 88 subjects who all spoke Mandarin. These were 28 male and 60 female, with a mean age of 20 (range 17–34) years. The ESM group consisted of 115 subjects, 54 male and 61 female, with a mean age of 19 (range 17–23) years; these were all nontone language speakers, with both parents being nontone language speakers. (The data from an additional 18 students at ESM were excluded from analysis on the grounds that they, or at least one of their parents, spoke an Asian language. This was the case for all those students who described their ethnic background as Asian.) In both groups, all students who were invited to take the test agreed to do so; there was therefore no self-selection of subjects within either group. The two groups were subdivided into subgroups by age of onset of musical training. In order to make meaningful comparisons, only those subgroups that contained at least nine subjects were considered. These were CCOM: ages 4–5, $n=43$; ages 6–7, $n=22$; ages 8–9, $n=12$; ESM: ages 4–5, $n=21$; ages 6–7, $n=31$; ages 8–9, $n=24$; ages 10–11, $n=20$; ages 12–13; $n=9$.

The subjects were presented with a set of 36 notes that spanned the three-octave range from C_3 (131 Hz) to B_5 (988 Hz), and they were asked to indicate the name of each note in writing. In order to minimize the use of relative pitch as a cue, all intervals between successively presented notes were larger than an octave. The notes were piano tones generated on a Kurzweil K2000 synthesizer which was tuned to the standard A4 of 440 Hz, and were 500 ms in duration. They were presented in three blocks of 12, with 4.25 s intervals between onsets of notes within a block, and 39-s rest periods between blocks. The test blocks were preceded by a practice block of four notes. No feedback was provided, either during the practice block or during the test blocks. The notes were played to subjects via a CD or DVD player, amplifier, and two loudspeakers. The subjects were also asked to fill out a questionnaire concerning their music education, where they and their parents had lived, the languages they and their parents spoke, and (for the ESM group) what they considered to be their primary ethnic background.

III. RESULTS

Two separate criteria for absolute pitch were employed: The first consisted of obtaining a score of at least 85% correct on the test, and the second also consisted of obtaining a score of at least 85% correct, allowing for semitone errors. The data were analyzed separately according to both criteria.

The main results of the experiment are shown in Fig. 1, which displays two major findings. First, both the CCOM and the ESM groups showed orderly effects of age of onset of musical training: The earlier the age of onset, the higher the probability of meeting the criteria for absolute pitch. Second, the prevalence of absolute pitch was far higher for the CCOM than for the ESM group. Statistical analyses on the numbers of subjects meeting the criteria for absolute pitch showed overall effects of age of onset of musical training (with no semitone errors allowed: $\chi^2=11.44$, df=2, $p<0.01$; with semitone errors allowed, $\chi^2=16.85$, df=2, $p<0.001$). Comparisons between the CCOM and ESM groups were therefore made separately for each level of age of onset of musical training (Fisher Exact Probability Tests were used for all remaining comparisons). All comparisons were highly significant: With no semitone errors allowed, for those who began musical training at ages 4–5, $p<0.001$; at ages 6–7, $p<0.001$; and at ages 8–9, $p<0.005$. With semitone errors allowed, for those who began musical training at ages 4–5, $p<0.001$; at ages 6–7, $p<0.001$; and at ages 8–9, $p<0.005$. Comparisons were also made between the male and female subjects within each subgroup (six comparisons with no semitone errors allowed; six comparisons with semitone

errors allowed). No effects of gender were found ($p > 0.05$ for all comparisons, and there was no overall trend based on gender in either direction).[1]

IV. DISCUSSION

The present findings support the hypothesis that, if given the opportunity, infants can acquire absolute pitch as a feature of speech, which can later generalize to musical tones. Indeed, the plots shown here for the acquisition of absolute pitch in nontone language and tone language speakers reflect a very similar picture, in terms of time frame, to the critical periods inferred by other researchers for the acquisition of first and second languages, respectively (Johnson and Newport, 1989; Newport, 1990; Bates, 1992; Doupe and Kuhl, 1999). It should be noted that although other critical periods have been documented, for example for the development of ocular dominance columns in the visual cortex of cats (Hubel and Wiesel, 1970), and for auditory localization in barn owls (Knudsen, 1988), no other critical periods have been identified that show a similar correspondence with speech and language in terms of time frame.

Further supporting evidence for a speech-related critical period hypothesis comes from the finding that 8-month-old infants can perform perceptual learning tasks that require referring to the absolute pitches of tones (Saffran and Griepentrog, 2001), indicating that preverbal infants have the capacity to acquire absolute pitch. Other evidence linking absolute pitch to speech comes from structural MRI findings that musicians with absolute pitch have an exaggeration of the normal leftward asymmetry of the planum temporale—an area that is considered to be critically involved in speech processing (Schlaug *et al.*, 1995). As a further indication, the probability of acquiring absolute pitch has been reported to be inversely related to the age of onset of musical training (Baharloo *et al.*, 1998; Profita and Bidder, 1988), suggesting a critical period for its acquisition.

The present findings should also be considered in relation to the results of surveys obtained by Gregersen *et al.* (1999, 2000) involving students taking music classes within the U.S. The responses indicated a higher prevalence of absolute pitch among those who described their ethnic background as "Asian" than among "nonAsians." Although language was not considered in these studies, the majority of respondents in the Asian category had been born in Asia, and their primary language would therefore have been a tone language or a pitch accent language.[2] Furthermore, of those born in the U.S., a large number would have had an Asian language as their first language. Because the data obtained by Gregersen *et al.* (1999, 2000) were obtained from surveys—and so involved self-selection and were based on self-report—and because the reported prevalence of absolute pitch was not documented as a function of age of onset of musical training for the different Asian linguistic groups taken separately, their relationships to the present findings are unclear. Nevertheless, it may alternatively be proposed that the differences between the two groups obtained in the present study were due to genetic factors (see also Baharloo *et al.*, 1998). Indeed, both critical period and genetic factors might be involved, since there may be strong selective pressure among tone language speakers to possess absolute pitch (Deutsch *et al.*, 2004). In any event, this paper reports the first large-scale study which demonstrates a difference in the prevalence of absolute pitch in two normal populations, as determined by administration of an on-site test, without self-selection from within the target populations, and controlling for gender and for age of onset of musical training.

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[1]Some semitone errors may have resulted, in part, from experience with different scales and tuning systems, particularly in childhood. This would be expected to apply more, in general, to those subjects who were brought up on Asian musical scales.

[2]Many Asian languages, for example, Mandarin, Cantonese, Vietnamese, and Thai are tonal, and certain others, for example Japanese and certain dialects of Korean, are pitch accent; i.e, the pitch structure of certain words is used to differentiate meaning (Pickett, 1999).

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