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Brief Reports

Ethnicity effects in relative pitch

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Absolute pitch (AP), the rare ability to identify a musical pitch, occurs at a higher rate among East Asian musicians. This has stimulated considerable research on the comparative contributions of genetic and environmental factors. Two studies examined whether a similar ethnicity effect is found for relative pitch (RP), identifying the distance or interval between two tones. Nonmusicians ($n = 103$) were trained to label musical intervals and were subsequently tested on interval identification. We establish similar ethnicity effects: Chinese and Korean participants consistently outperformed other participants in RP tasks, but not in a "relative rhythm" control task. This effect is not driven by previous musical or tone-language experience. The parallel with the East Asian advantage for AP suggests that enhanced perceptual–cognitive processing of pitch is more general and is not limited to highly trained musicians. This effect opens up many research questions concerning the environmental and genetic contributions related to this more general pitch-based ability.

Previous research has uncovered ethnicity effects in pitch processing among highly trained musicians. Absolute pitch (AP), the rare ability to identify or produce by name (e.g., C, C♯, D) a musical pitch without a reference tone, is more common among East Asians than among non-Asians (e.g., Deutsch, Henthorn, Marvin, & Xu, 2006; Gregersen, Kowalsky, Kohn, & Marvin, 2000). This ethnicity effect has prompted considerable attention from geneticists and cognitive neuroscientists primarily due to the potential interaction of genetic factors and environmental factors, such as tone-language experience, musical training style, a critical learning period, and location of childhood. In the present article, we examine whether a similar ethnicity effect is found for relative pitch (RP), the ability to identify musical intervals by name (e.g., major second [M2], perfect fourth [P4], and perfect fifth [P5].)

Several studies provide evidence for a genetic component in AP. Siblings of AP possessors were more likely to have AP, and this familial aggregation was strong, even when shared environmental factors were controlled for (Baharloo, Johnston, Service, Gitschier, & Freimer, 1998). In another study, the rate of AP among music theory students in the U.S. was only 12% (Gregersen et al., 2000). However, within that sample, the rate among East Asian students (47.5%) was markedly higher than it was among Caucasian students (9%), and higher rates of AP were "present among all the major ethnic subgroups—Japanese (26%), Korean (37%), and Chinese (65%)." This Asian advantage suggests a potential genetic component, inasmuch as higher rates among East Asians cannot be attributed simply to cultural factors (the three cultures are distinct) or to tone-language experience (Zatorre, 2003).[1]

Environmental factors also appear to contribute to AP. A comparison of conservatory students in China and the U.S. showed higher rates of AP for the Chinese in China (~50%) than for the non-Asians in the U.S. (~10%; Deutsch, Henthorn, & Dolson, 2004). This led them to argue that early exposure to tone language can predispose individuals to AP, because, if pitch carries meaning in language, babies might attend more to pitch cues and be more likely to develop AP than if pitch carries no meaning. Consistent with this, a reanalysis of data from Gregersen et al. (2000) contends that the observed East Asian AP advantage appears only for individuals who spent their early childhoods in East Asia, potentially due to more tone

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or pitch-accent language exposure (Henthorn & Deutsch, 2007). Conversely, this geographic effect could be driven by a music training method that is more common in Asia, rather than by a language exposure (Gregersen, Kowalsky, & Li, 2007). Finally, AP has a critical period: Adults with AP started music lessons early (Baharloo et al., 1998; Profita & Bidder, 1988).

To sum, after considerable research attention, the relative contributions of these environmental and genetic factors remain elusive, due largely to the entanglement of genes and environment and the extreme rarity of AP (AP rates are estimated as low as 1 in 10,000 in the general population; Takeuchi & Hulse, 1993; cf. Levitin & Rogers, 2005).

RP has been studied much less than AP has, even though RP is well developed in almost all trained musicians, is more musically useful than AP, and thus is of interest in and of itself. Moreover, some considerations suggest commonalities between the two abilities. Both require forming associations between pitch-based sensory events and arbitrary labels. Indeed, a brain area involved in conditional associations, the dorsolateral prefrontal cortex (DLPFC), was similarly active when AP possessors heard a tone and when non-AP musicians made RP judgments (Zatorre, Perry, Beckett, Westbury, & Evans, 1998), and also when nonmusicians identified chords with an arbitrary label (Bermudez & Zatorre, 2005). Because of this common neurocognitive mechanism underlying AP and RP, in conjunction with the Asian AP advantage, we examine potential ethnicity effects in RP.

Some evidence has emerged for both genetic and environmental components in non-AP pitch tasks. Identification of mistuned intervals in melodies was more similar for identical twin pairs than for fraternal twin pairs: Genetic heritability estimates of pitch recognition were at around .75 (Drayna, Manichaikul, de Lange, Snieder, & Spector, 2001). Tone-language experience improved identification of speech tones, but not of pitch sweeps or the just-noticeable-difference threshold for pitch (Bent, Bradlow, & Wright, 2006). In a test of pitch memory that does not require labeling, Japanese children more accurately identified pitch-shifted familiar melodies than did their Canadian counterparts (Trehub, Schellenberg, & Nakata, 2008). However, in another study with this nonlabeling task, no difference was observed between Chinese- and European-Canadian children (Schellenberg & Trehub, 2007).

In the two present studies, we investigated RP recognition by East Asian and Caucasian nonmusicians who were unfamiliar with assigning labels to musical intervals. Working with nonmusicians is advantageous, because it mitigates factors such as training method. Here, they were trained to identify three pitch intervals by arbitrary color labels and subsequently were tested on identification accuracy. In addition to ethnicity, participants reported language experience, musical training, musical environment, primary language in the home, and country of early childhood.

STUDY 1

In order to examine the relative contributions of ethnicity and tone language in RP-interval identification, we compared pitch-interval identification of three groups of nonmusicians: Chinese, a native tone-language speaking group previously showing pitch processing advantages; Hmong, also a native tone-language group, but culturally and genetically distinct (Wen et al., 2004); and Caucasian.

Method

Participants. Thirty-eight unpaid volunteers from secondary schools participated. Three groups participated: students in China and Taiwan (henceforth referred to as *Chinese*, $n = 10$, mean age = 16.6 years), Caucasian students in the U.S. ($n = 14$, mean age = 16.3 years), and Hmong students in the U.S. ($n = 14$, mean age = 16.5 years). The Hmong students were all native Hmong speakers, half of whom were born in the U.S. and half born in Thailand or Laos and immigrated to the U.S. (5 before age 5, 2 at age 10); this did not affect performance. Participants were nonmusicians, having no more than 3 years of musical instrument or singing lessons or classes. They were not currently playing an instrument or singing and were unfamiliar with labeling musical intervals. The extent of musical training did not differ across the Chinese ($M = 1.2$ years), Caucasian ($M = 1.8$ years), and Hmong ($M = 0.9$ years) groups ($p > .15$).

Materials. The stimuli consisted of three ascending intervals: M2, P4, and P5. The intervals began with one of two reference pitches, C4 or F♯4, in order to limit a strategy of recognizing intervals on the basis of only the second pitch. Participants identified the intervals by using color labels chosen arbitrarily: M2s were red, P4s were green, and P5s were blue (see Figure 1). All tones were presented in a MIDI metallophone timbre over circumaural headphones and each lasted 500 msec, with 250 msec of silence separating the reference tone and the higher tone in the interval. Stimuli were presented and responses were recorded on a Macintosh computer running a MAX/MSP program.

Procedure. First, participants were introduced to the experimental structure and the task of labeling pitch intervals. The experimenter presented the different intervals and explained that the distance between the two pitches determined the interval. Participants briefly

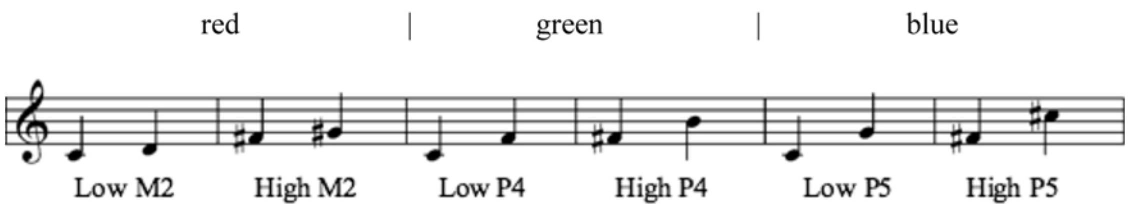

Figure 1. Stimuli in Study 1: three pitch intervals starting on one of two reference pitches. Participants identified the intervals by using arbitrarily chosen color labels: Major seconds (M2s) were red, perfect fourths (P4s) were green, and perfect 5ths (P5s) were blue.

practiced the interval-identification task, in which they heard the two tones of the interval in succession and indicated which interval they thought they heard by pressing one of three colored keys. The subsequent training phase consisted of 20 blocks, each containing the six stimuli intervals (3 intervals × 2 reference pitches) in random order, for 120 total training trials. A colored square appeared on the screen, indicating the to-be-produced interval. Participants produced the intervals by first pressing the space bar for the reference pitch and then pressing the appropriate colored key for the higher interval tone.

Following training, participants performed the interval-identification test. The interval sounded, to which the participants responded with the appropriate colored key. The test was 96 trials for the Caucasian and Hmong groups, but was reduced to 48 trials for the Chinese group due to time limitations.[2] The experiment lasted approximately 25 min for the Caucasian and Hmong groups and 20 min for the Chinese group.

Results and Discussion

Pitch-interval identification was analyzed in a 3 (ethnicity: Chinese, Hmong, Caucasian) × 3 (interval: M2, P4, P5) × 2 (reference pitch: C, F♯) mixed-model ANOVA. The main effect of ethnicity was highly significant [$F(2,35) = 18.1$, $p < .001$, $\eta_p^2 = .51$]. See Figure 2. The Chinese ($M = 72.0\%$) outperformed the Caucasians ($M = 45.5\%$) and the Hmong ($M = 45.5\%$, pairwise comparison, $ps < .001$), and no difference occurred between the Caucasian and Hmong groups ($p > .9$, Bonferroni corrections were applied to these and all subsequent pairwise comparisons). Additionally, a significant main effect of interval was observed [$F(2,70) = 4.9$, $p = .010$, $\eta_p^2 = .12$]; pairwise comparisons revealed significantly higher recognition only for M2s over P4s ($p = .018$). No main effect of reference pitch was observed ($p > .5$).

The interval × reference pitch interaction was highly significant [$F(2,70) = 55.2$, $p < .001$, $\eta_p^2 = .61$]: Recognition was better for the small M2 interval on the lower reference pitch (C) than on the higher reference pitch (F♯), whereas recognition was better for the large P5 interval on the F♯ than on the C. This indicates that AP height cues can influence perception of interval size. Ethnicity did not interact with interval or reference pitch in two-way interactions ($ps > .1$). The ethnicity × interval × reference pitch three-way interaction approached significance [$F(4,70) = 2.2$, $p = .080$, $\eta_p^2 = .11$]. This marginal three-way interaction was driven by the Chinese group's better identification of M2s on the F♯ reference pitch, which demonstrates that the Chinese group was less susceptible than were the others to misapplying AP height cues. Previous musical training did not correlate with the interval-recognition scores ($r = .14$, $p = .4$).

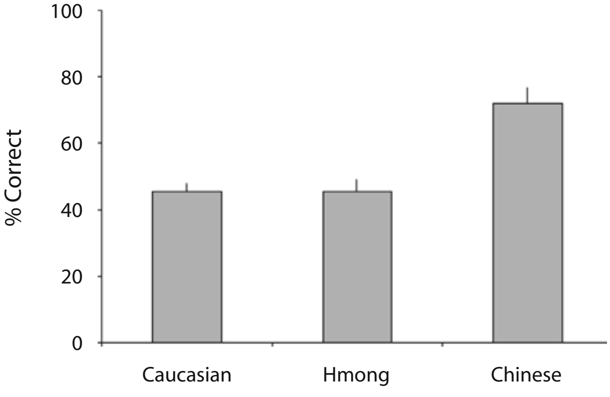

Figure 2. Pitch-interval identification by group for Study 1.

The Chinese advantage for nonmusicians in this RP task parallels the previously established AP advantage for highly trained Chinese musicians. Identical performance for Caucasian and the native tone-language-speaking Hmong group indicates that tone-language experience does not necessarily improve pitch-interval identification.

STUDY 2

Study 2 further investigated ethnicity effects in a similar RP identification task and included an analogous "relative rhythm" task (identifying time intervals rather than pitch intervals). This was added, in order to control for possible motivational, memory, or general cognitive differences. For example, both RP and relative rhythm tasks involve *context*, or the *relation* between stimuli, and hence might favor more context-sensitive East Asian cultures (e.g., Masuda & Nisbett, 2001). Conversely, if groups performed differently in the pitch task, but not in the rhythm task, one could infer that those group differences truly arose from differences in the pitch domain.

Method

Participants. Sixty-five Cornell undergraduates participated for course credit or $8/hr. Participants were nonmusicians, having no more than 3 years of musical training. There were three groups: Caucasian ($n = 30$, musical training = 0.9 years), Chinese ($n = 24$, musical training = 1.4 years), and Korean ($n = 11$, musical training = 1.5 years). The duration of musical training did not differ across groups ($p > .1$). Participants reported their primary home language and language experience on a 1–5 scale (1 = *understanding, but trouble speaking* and 5 = *fluency*). All Chinese participants reported having tone-language experience ($M = 4.0$, $SD = 1.4$), and all Korean participants reported speaking Korean ($M = 4.6$, $SD = 0.8$). Some dialects of Korean are pitch-accent languages, but the vast majority of our participants (and their parents) spoke only Seoul or standard South Korean, which do not have pitch accents (Sohn, 1999). We excluded 13 additional participants, 1 due to corrupted data and 12 due to ethnicities that were not Caucasian, Chinese, or Korean.

Materials and Procedure. The pitch-interval identification task included the same intervals as were used in Study 1: M2 (red), P4 (green), and P5 (blue) on two reference pitches (C and F♯). See Figure 3A. Each stimulus presentation consisted of the reference tone alone, followed by two iterations of the interval (the second and third tones and then the fourth and fifth tones, for five tones total).

In the rhythmic-pattern task, participants learned to identify rhythmic patterns by color. As shown in Figure 3B, three rhythmic intervals were used: 8th notes with a 1:1 ratio (red), triplets with a 2:1 ratio (green), and 16th notes with a 3:1 ratio (blue). Each pattern consisted of seven clicks, with the rhythmic interval presented twice (by the second, third, and fourth clicks, and then by the fifth, sixth, and seventh clicks). Each rhythm pattern was presented at one of two tempi, to ensure that participants learned the *relative* time intervals, not the absolute times. The corresponding interonset intervals (IOIs) appear in msec for slow and fast tempi in Figure 3B. The rhythms were presented in a MIDI woodblock timbre.

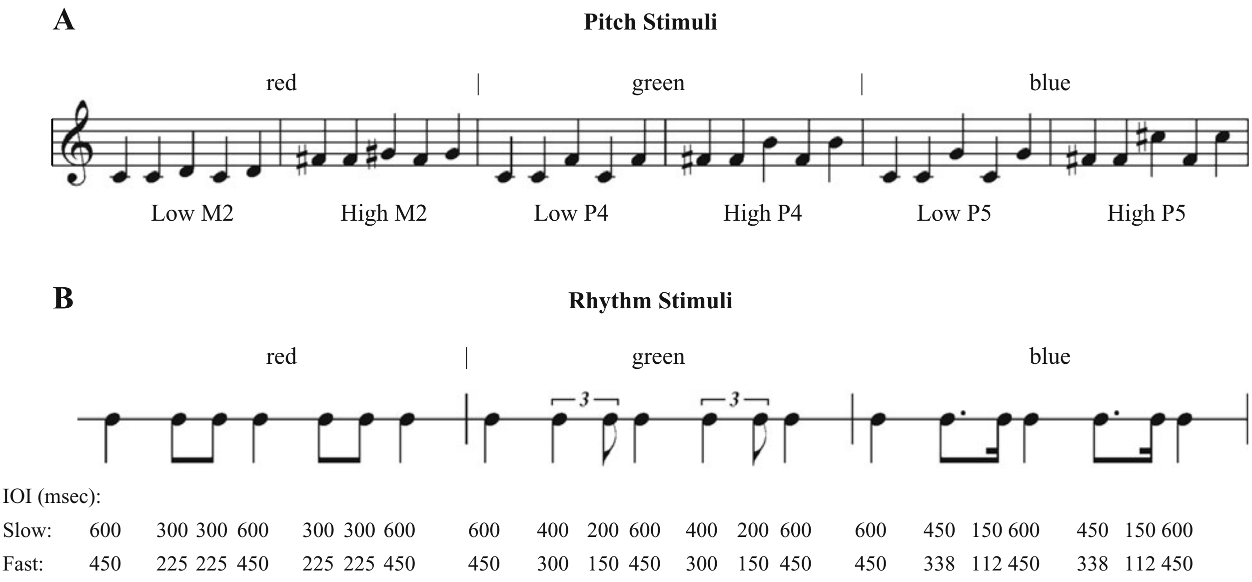

Figure 3. Stimuli in Study 2: three pitch intervals starting on one of two reference pitches (A) and three rhythmic sequences in musical notation with interonset intervals (IOIs) in msec for slow and fast tempi (B). Participants identified the intervals by using arbitrarily chosen color labels: Major seconds (M2s) and 8th notes were red, perfect fourths (P4s) and triplets were green, and perfect 5ths (P5s) and 16th notes were blue.

The procedure for the counterbalanced pitch and rhythm portions was identical. The experimenter defined the intervals for the participants, who were then given a short practice. The subsequent training phase consisted of 96 trials (16 blocks containing the randomized intervals). During training, the color of the upcoming interval appeared on the screen and a space bar press started the interval. Each training phase lasted approximately 10 min. Then, participants completed a 96-trial test. The session was self-paced and lasted approximately 1 h.

Results and Discussion

Average percent correct for the pitch and rhythm tasks (see Figure 4) was analyzed in a 3 (ethnicity: Caucasian, Chinese, Korean) × 2 (task: pitch, rhythm) mixed-model ANOVA. Overall performance did not differ between the pitch (M = 66.7%) and the rhythm (M = 65.4%) task [$F(1,62) = 3.1$, $p = .08$, $\eta_p^2 = .05$]. In the critical test, the task × ethnicity interaction was significant [$F(2,62) = 5.5$, $p < .01$, $\eta_p^2 = .15$], indicating that ethnicity had a substantially larger effect on the pitch-interval identification than on the rhythm-pattern identification. Further unpacking of performance in separate pitch and rhythm analyses (reported below) revealed that ethnicity significantly affected pitch-interval recognition, but not rhythm-pattern recognition.

Pitch-interval recognition was analyzed in a 3 (ethnicity: Chinese, Korean, Caucasian) × 3 (interval: M2, P4,

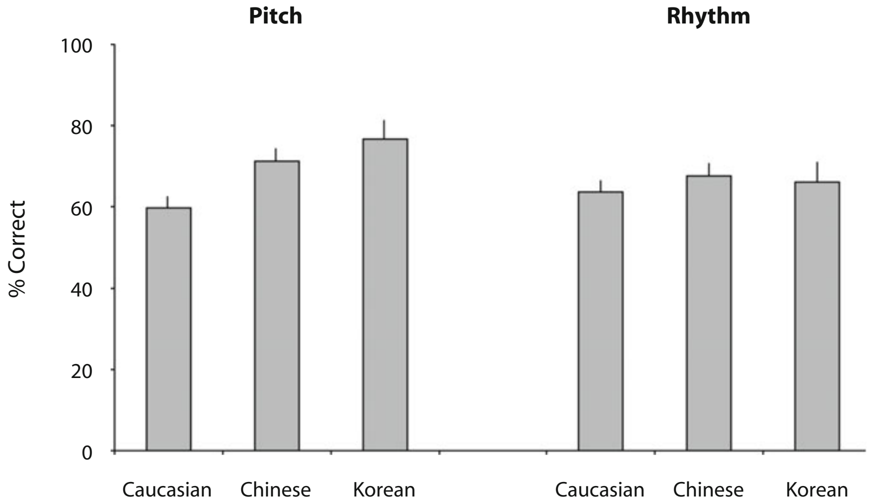

Figure 4. Average percent correct for Caucasian, Chinese, and Korean participants in pitch- and rhythm-interval identification.

P5) × 2 (reference pitch: C, F♯) mixed-model ANOVA. Ethnicity significantly affected pitch-interval recognition [$F(2,62) = 8.77$, $p < .001$, $\eta_p^2 = .22$]. Pairwise comparisons showed that the Chinese (M = 72.2% correct) and Koreans (M = 78.2%) outperformed the Caucasians (M = 58.2%, $ps < .01$) but that no difference occurred between the Chinese and Korean groups ($p > .8$). Additionally, interval had a main effect on recognition [$F(2,62) = 13.50$, $p < .001$, $\eta_p^2 = .18$], with better recognition for the M2s than for the P4s and P5s ($ps < .01$). Reference pitch had a main effect as well [$F(1,62) = 27.5$, $p < .001$, $\eta_p^2 = .30$], with better recognition occurring for intervals with the higher, F♯ reference pitch. The interval × reference pitch interaction was highly significant [$F(2,124) = 94.30$, $p < .001$, $\eta_p^2 = .60$]: Recognition was better for M2s that started on the C reference pitch than on the F♯, whereas recognition was better for P5s that started on the F♯ reference pitch than on the C. Ethnicity did not interact with interval or reference pitch in two-way interactions ($ps > .25$). However, the three-way interaction, ethnicity × interval × reference pitch, was significant [$F(2,124) = 5.00$, $p = .001$, $\eta_p^2 = .14$]: The Chinese and Korean groups were less likely to misapply AP height cues when identifying intervals. Unlike in Study 1, the duration of previous musical training significantly correlated with interval-recognition performance ($r = .41$, $p = .001$).[3]

The rhythm-interval recognition was analyzed in an analogous 3 (ethnicity: Chinese, Korean, Caucasian) × 3 (rhythmic pattern: 8th note, triplet note, 16th note) × 2 (tempo: fast, slow) mixed-model ANOVA. No effect of ethnicity on rhythmic recognition was observed between the Chinese (M = 67.8%), Korean (M = 66.5%), and Caucasian (M = 63.2%) participants [$F(2,62) = 0.7$, $p = .5$]. Tempo did not affect performance ($p > .3$). A main effect of rhythmic pattern was observed [$F(2,124) = 88.9$, $p < .001$], where recognition was best for the 8th-note (1:1) rhythm ($ps < .001$) and performance was better for the triplet (2:1) than for the 16th-note (3:1) rhythm ($p < .05$). No ethnicity interactions were significant ($ps > .5$). The extent of previous musical training did not correlate with rhythm recognition performance ($p > .3$).

Next, we examined the potential role of language on pitch-interval identification. As reported above, there was no difference between the Chinese participants (all with tone language experience) and the Korean participants (all Korean speakers). The Korean participants were predominately non-pitch-accent speakers, thus we find no evidence that the ethnicity effect is driven by lexical use of pitch.[4] Additionally, the *degree* of tone-language experience did not affect performance: Within the Chinese group, the 15 participants who rated themselves as fluent (M = 67.2%) tended to score *lower* on the pitch test than did the 9 participants with nonfluent tone-language experience (M = 80.4%, $p = .07$). The primary language spoken in the home (tone language vs. non-tone language) had no effect ($ps > .6$). Finally, we observed no difference between those East Asians whose early childhoods were spent in East Asia (M = 77.6%, $n = 15$) and those whose early childhoods were spent in North America (M = 71.5%, $n = 20$, $p > .3$).[5]

In sum, Study 2 demonstrates an ethnicity effect in RP, but not in relative-rhythm identification. This effect is not driven by tone-language experience. Since ethnicity differences among Chinese, Koreans, and Caucasians emerged in the pitch task, but not in the analogous rhythm task, we can more confidently conclude that the observed differences reliably reflect differences in pitch identification, rather than effects of motivation, strategy, or other cognitive differences.

DISCUSSION

The two studies reported here indicate an ethnicity effect in RP identification: The Chinese and Korean groups better identified musical pitch intervals, but not rhythm intervals, in a control task. This Asian advantage for RP among nonmusicians parallels the well-established Asian advantage in AP, suggesting that this perceptual–cognitive advantage in labeling pitch-based sensory events is more general and is not limited to highly trained musicians. Although the exact cultural, environmental, or genetic factors in this ethnicity effect must be ascertained, we observe no evidence supporting tone-language effects. Compared with English-speaking Caucasians, the tone-language-speaking Hmong group showed *no* advantage in Study 1, whereas the non-tone-language-speaking Korean group did show an advantage in Study 2. Numerous uncontrolled-for factors could affect performance, but the large ethnicity effects remained stable across two studies with very different sets of participants.

Overall, participants more accurately identified small intervals starting on the low reference pitch and large intervals starting on the high reference pitch, indicating that AP height cues were misapplied in these RP judgments. This was less true for the Chinese and Korean groups, who more appropriately applied the relative cues. However, this did not drive the ethnicity effect, because the Chinese and Korean participants were consistently more accurate across intervals in both high- and low-pitch ranges.

RP identification inherently involves context or the relation between stimuli; thus, the observed ethnicity effect might be an auditory analogue of the greater context sensitivity shown by East Asian cultures in the visual domain (e.g., Masuda & Nisbett, 2001). However, the null effect in the relative-rhythm task and the well-established ethnicity effects in AP, which does not involve relational processing, make it unlikely that this result is due only to context sensitivity and that it is more specific to musical pitch.

Ethnicity effects in AP, and now RP, potentially involve the ability to form associations between pitch-based sensory events and labels, inasmuch as little or no ethnicity effects are observed in low-level auditory tasks (Bent et al., 2006) or in pitch memory tasks not requiring labeling (Schellenberg & Trehub, 2007). Both AP and RP identification necessitate the ability to form an association between a pitch (AP) or a combination of pitches (RP) and a long-term memory representation, and they involve similar activation of the DLPFC, which has been implicated in conditional associations (Zatorre et al., 1998).

Genetics is another possible factor in ethnicity effects on RP identification and has been identified in other pitch-perception abilities, including identifying a mistuned interval (Drayna et al., 2001) and AP (Baharloo et al., 1998; Gregersen et al., 2000; Theusch, Basu, & Gitschier, 2009). Recently, Dediu and Ladd (2007) showed that the population frequencies of two derived haplotypes of brain development genes, ASPM and Microcephalin, correlate with whether that population speaks a tone language. The haplotypes could affect subtle cortical organization and lead to cognitive biases, such as in pitch perception or tonal–verbal associations, which would facilitate the acquisition of tone language (manifest in *linguistic* change over many generations). The East Asian populations showing better pitch-interval identification here have derived ASPM and Microcephalin frequencies consistent with the proposed cognitive bias for pitch processing (Evans et al., 2005; Mekel-Bobrov et al., 2005). However, the Hmong population also has this pattern of derived ASPM and Microcephalin, but Hmong participants in the present study showed no pitch-interval identification advantage. Thus, although behavioral genetic work represents a potentially fruitful avenue, genetic factors are clearly not acting alone in ethnicity effects of pitch perception.

Indeed, in their recent article on AP, Gregersen et al. (2007) took a broad view: "'Ethnic' differences encompass all the cultural, environmental, and genetic differences that can be found between the major population groups" (p. 105). Establishing the relative contribution of cultural, environmental, and genetic factors in the emergence of AP has proven to be difficult, due to the entanglement of these factors, and compounded by the rarity of AP possessors. Here, we establish an ethnicity effect in RP identification in nonmusicians that previously was seen only in highly trained musicians with AP. This opens up many research questions concerning the genetic and environmental contributions related to this and to more general pitch-based auditory abilities.

AUTHOR NOTE

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REFERENCES

Baharloo, S., Johnston, P. A., Service, S. K., Gitschier, J., & Freimer, N. B. (1998). Absolute pitch: An approach for identification of genetic and nongenetic components. *American Journal of Human Genetics*, **62**, 224-231.

Bent, T., Bradlow, A. R., & Wright, B. A. (2006). The influence of linguistic experience on the cognitive processing of pitch in speech and nonspeech sounds. *Journal of Experimental Psychology: Human Perception & Performance*, **32**, 97-103.

Bermudez, P., & Zatorre, R. J. (2005). Conditional associative memory for musical stimuli in nonmusicians: Implications for absolute pitch. *Journal of Neuroscience*, **25**, 7718-7723. doi:10.1523/JNEUROSCI.1560-05.2005

Dediu, D., & Ladd, D. R. (2007). Linguistic tone is related to the population frequency of the adaptive haplogroups of two brain size genes, ASPM and Microcephalin. *Proceedings of the National Academy of Sciences*, **104**, 10944-10949.

Deutsch, D., Henthorn, T., & Dolson, M. (2004). Absolute pitch, speech, and tone language: Some experiments and a proposed framework. *Music Perception*, **21**, 339-356.

Deutsch, D., Henthorn, T., Marvin, E., & Xu, H. (2006). Absolute pitch among American and Chinese conservatory students: Prevalence differences, and evidence for a speech-related critical period. *Journal of the Acoustical Society of America*, **119**, 719-722.

Drayna, D., Manichaikul, A., de Lange, M., Snieder, H., & Spector, T. (2001). Genetic correlates of musical pitch recognition in humans. *Science*, **291**, 1969-1972. doi:10.1126/science.291.5510.1969

Evans, P. D., Gilbert, S. L., Mekel-Bobrov, N., Vallender, E. J., Anderson, J. R., Vaez-Azizi, L. M., et al. (2005). *Microcephalin*, a gene regulating brain size, continues to evolve adaptively in humans. *Science*, **309**, 1717-1720. doi:10.1126/science.1113722

Gregersen, P. K., Kowalsky, E., Kohn, N., & Marvin, E. W. (2000). Early childhood music education and predisposition to absolute pitch: Teasing apart genes and environment [Letter to the editor]. *American Journal of Human Genetics*, **98**, 280-282.

Gregersen, P. K., Kowalsky, E., & Li, W. (2007). Reply to Henthorn and Deutsch: Ethnicity versus early environment: Comment on "Early childhood music education and predisposition to absolute pitch: Teasing apart genes and environment" by Peter K. Gregersen, Elena Kowalsky, Nina Kohn, and Elizabeth West Marvin [2000]. *American Journal of Medical Genetics*, **143A**, 104-105.

Henthorn, T., & Deutsch, D. (2007). Ethnicity versus early environment. "Early childhood music education and predisposition to absolute pitch: Teasing apart genes and environment" by Peter K. Gregersen, Elena Kowalsky, Nina Kohn, and Elizabeth West Marvin [2000]. *American Journal of Medical Genetics*, **143A**, 102-103.

Ladd, D. R. (2008). *Intonational phonology*. Cambridge: Cambridge University Press.

Levitin, D. J., & Rogers, S. E. (2005). Absolute pitch: Perception, coding, and controversies. *Trends in Cognitive Sciences*, **9**, 26-33.

Masuda, T., & Nisbett, R. E. (2001). Attending holistically versus analytically: Comparing the context sensitivity of Japanese and Americans. *Journal of Personality & Social Psychology*, **81**, 922-934.

Mekel-Bobrov, N., Gilbert, S. L., Evans, P. D., Vallender, E. J., Anderson, J. R., Hudson, R. R., et al. (2005). Ongoing adaptive evolution of *ASPM*, a brain size determinant in *Homo sapiens*. *Science*, **309**, 1720-1722. doi:10.1126/science.1116815

Profita, J., & Bidder, T. G. (1988). Perfect pitch. *American Journal of Medical Genetics*, **29**, 763-771.

Schellenberg, E. G., & Trehub, S. E. (2007). Is there an Asian advantage for pitch memory? *Music Perception*, **25**, 241-252.

Sohn, H.-M. (1999). *The Korean language*. Cambridge: Cambridge University Press.

Takeuchi, A. H., & Hulse, S. H. (1993). Absolute pitch. *Psychological Bulletin*, **113**, 345-361.

Theusch, E., Basu, A., & Gitschier, J. (2009). Genome-wide study of families with absolute pitch reveals linkage to 8q24.21 and locus heterogeneity. *American Journal of Human Genetics*, **85**, 112-119.

Trehub, S. E., Schellenberg, E. G., & Nakata, T. (2008). Cross-cultural perspectives on pitch memory. *Journal of Experimental Child Psychology*, **100**, 40-52.

Wen, B., Li, H., Lu, D., Song, X., Zhang, F., He, Y., et al. (2004). Genetic evidence supports demic diffusion of Han culture. *Nature*, **431**, 302-305.

Zatorre, R. J. (2003). Absolute pitch: A model for understanding the influence of genes and development on neural and cognitive functions. *Nature Neuroscience*, **6**, 692-695.

Zatorre, R. J., Perry, D. W., Beckett, C. A., Westbury, C. F., & Evans, A. C. (1998). Functional anatomy of musical processing in listeners with absolute pitch and relative pitch. *Proceedings of the National Academy of Sciences*, **95**, 3172-3177.

NOTES

1. However, note that Japanese and some Korean dialects are pitch-accent languages, in which pitch can carry some lexical meaning (Ladd, 2008; Sohn, 1999).

2. This did not alter performance: Analysis of the 96-trial tests for the Hmong and Caucasian groups revealed no differences (e.g., fatigue effects) between the first 48 trials and the second 48 trials.

3. However, as is noted above, the extent of musical training did not differ between groups, and ethnicity effects in pitch-interval identification remained highly significant when removing the variance associated with the musical training covariate in a supplemental ANCOVA.

4. Excluding the 1 Korean participant who spoke a pitch-accent dialect (a mix of Gyeongsang and Seoul dialects) does not significantly alter the results.

5. These analyses on subsets of data involve less statistical power, and the null results should be interpreted cautiously. For example, although the location of childhood here did not approach significance, the numerical trend for higher pitch-interval recognition among East Asian participants who grew up in Asia might encourage further examination.

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