Ethnicity Effects in Relative Pitch Learning

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Abstract

Higher rates of Absolute Pitch among East Asian musicians has garnered considerable research interest for it position to uncover relative contributions of genetic and environmental factors such as musical training and tone-language knowledge. In three studies with non-musicians (n=134) on learning Relative Pitch (the relation between tones), we establish similar ethnicity effects. East Asians consistently outperformed other participants in relative pitch tasks regardless of tone-language knowledge; no difference was observed in a 'relative rhythm' control task. Results suggest genetic and environmental factors in identifying musical intervals.

Keywords: Pitch perception, Relative pitch, ethnicity effects, genetic differences.

Introduction

Phenotypic variation between ethnic groups in medical, cognitive, and perceptual traits is receiving great scientific interest, as it provides insight into understanding relative genetic and environmental contributions. Musical pitch processing varies between ethnicities. Absolute pitch (AP), the rare ability to identify or produce a musical pitch without a reference tone, is more common among East Asians than non-Asians (e.g., Deutsch, Henthorn, Marvin, & Xu, 2006; Gregersen, Kowalsky, Kohn, & Marvin, 2000). This effect has prompted attention from geneticists and cognitive neuroscientists primarily due to the interaction of genetic factors and environmental factors, such as tone-language knowledge, style of musical training, a critical learning period, and location of childhood.

Several studies provide evidence for a genetic component in AP. Siblings of AP possessors were more likely to have AP than siblings of non-AP possessors and this effect of familial aggregation was strong even after controlling for shared environmental factors (Baharloo et al., 1998). Second, a bimodal distribution of pitch-naming skills (participants tend to either have AP, or they do not) suggests "the possibility that AP ability could be governed by the influence of only one or a few genes" (Athos, et al., 2007). In another study, rates of AP among U.S. music theory students was only 12%, however the rate among East Asian students (47.5%) was markedly higher compared to Caucasian students (9%). Higher rates of AP were "present among all the major ethnic subgroups — Japanese (26% AP+), Korean (37% AP+), and Chinese (65% AP+)" (Gregersen et al., 2000). This suggests a potential genetic component, as higher rates among East Asians cannot simply be attributed to cultural factors (the three cultures are distinct) or tone-language experience (Zatorre, 2003). However, note that Japanese and some Korean dialects are considered pitch accent languages, in which pitch can carry some lexical meaning (Ladd, 1996, Sohn, 1999).

Environmental factors contribute to AP. A comparison of conservatory students in China and the U.S. showed much higher rates of AP for the Chinese (~ 50%) than the non-Asians in the U.S. (~10%), leading the authors to argue that early exposure to tone language can predispose individuals to AP; however, they also acknowledge possible genetic factors (Deutsch, Henthorn, Marvin & Xu, 2006). Deutsch and colleagues (2004) proposed that if pitch carries meaning in language (as in tone or pitch-accent languages), babies will attend more to pitch cues and hence will be more likely to develop AP. The location of childhood is another potential factor in AP: a recent reanalysis of data from Gregersen et al. (2000) contends that the observed East Asian AP advantage appears only for individuals who grew up in East Asia, potentially due to more tone or pitch accent language exposure (Henthorn & Deutsch, 2007). However in a reply to this reanalysis, Gregersen and colleagues (2007) show that the effect could be driven by a music training method that is much more common in Asia: AP correlates with "fixed *do*" training, wherein each solfége syllable is always associated with the same pitch, such that *do* = C, *re* = D, etc. Finally, converging evidence also indicates a critical period: adults with AP started music lessons early (Baharloo et al. 1998; Profita & Bidder, 1988).

A multiplicity of environmental and genetic factors appear to contribute to the emergence of AP. Gregersen (2007) takes "ethnic differences" to "encompass all the cultural, environmental and genetic differences that can be found between the major population groups." The relative contributions of these factors remain contentious and 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; Profita & Bidder, 1988; Takeuchi & Hulse, 1993).

The skill explored in this paper is relative pitch (RP), the ability to make pitch judgments about the relation between pitches in musical intervals. AP and RP are distinctly different skills, employing distinct brain processes (Zatorre, Perry, Beckett, Westbury, & Evans, 1998). Research on AP is relevant to RP, which has certain advantages for study. RP is more common and trainable than AP, and is well developed in almost all trained musicians. Learning to identify musical intervals is a primary goal of ear training methodologies, but little empirical work has been published.

Some evidence has emerged for both genetic and environmental components in RP. Genetic factors in musical pitch were observed in a twin-study: in a task identifying melodies with a mistuned interval, performance was more similar for identical twin pairs than for fraternal twin pairs; heritability estimates of pitch recognition were around .75 (Drayna, Manichaikul, de Lange, Snieder, & Spector, 2001). Pitch processing differences also emerged as a function of linguistic experience: tone-language speakers were more accurate at identifying speech tones than non-tone language speakers, but there was no difference between groups for just-noticeable-difference threshold for pitch (Bent, Bradlow, & Wright, 2006). Ethnicity effects in RP have not yet been explored despite intimations in this direction.

In the following three experiments, we investigated relative pitch learning among East Asian and non-Asian non-musicians in order to ascertain whether the observed ethnicity effects in AP extend into RP. Working with non-musicians is advantageous because it mitigates factors such as type of training. In addition to ethnicity, participants reported tone-language knowledge, musical training, musical environment and primary language in the home, and country of early childhood. Participants trained on various ascending musical intervals and were subsequently tested on interval recognition. Experiment 3 included an analogous "relative rhythm" task to test for motivational or general learning differences.

Experiment 1

Experiment 1 assessed pitch interval recognition for East Asian and non-Asian non-musicians after either active or passive training. The experiment consisted of a brief practice session, followed by approximately 25 minutes of training, and an interval-recognition test.

Methods

Participants Thirty-one Cornell undergraduates participated for course credit (23 women, 8 men; 11 East Asians, 20 non-Asians). The East Asian sample consisted of 8 Chinese, 2 Koreans, and 1 Filipino. Participants reported their tone-language knowledge on a 1 to 5 scale (1 = understanding but trouble speaking and 5 = fluency). Six East Asians reported tone-language knowledge: two reported 1s, two reported 3s, and two reported 5s. Participants were unfamiliar with relative pitch naming tasks. None were currently playing a musical instrument; they had received no formal ear training and had 5 years or less musical training (M = 2.9 yrs; non-Asians=2.5 yrs, East Asians=3.6 yrs; this difference was non-significant and musical training was included as a covariate).

Materials and Procedure The stimuli consisted of four ascending melodic intervals: major second (M2), major third (M3), perfect fourth (P4), and perfect fifth (P5). The intervals began with one of two tones, C4 or F#4. For example, the major second was played with the tones C4 and D4, or the tones F#4 and G#4. The two different reference pitches (starting tones) were used to limit an absolute pitch strategy, in which the absolute pitch height of the second tone could be used to recognize the interval. All pitch intervals consisted of MIDI tones produced via a MAX/MSP program on a Macintosh G4 computer and heard over AKG K141 headphones.

The experimenter first introduced the four different pitch intervals (M2, M3, P4, P5) and explained that the distance between the tones was important, not the absolute pitch height. In order to introduce the task, participants completed a short practice session identifying intervals generated by the computer. All tones lasted 500 ms and were separated by 250 ms of silence. Participants registered responses by mouse-clicking one of four boxes on the screen (labeled 2, 3, 4, and 5).

In the training phase, half the participants were randomly assigned to 'passive' training and half to 'active' training. In the 'passive' condition, they produced both the reference pitch and the interval tone by mouse-clicking the same button. In the 'active' condition, participants used a Roland Handsonic drum machine to produce the tones; they placed their right hand over five pads – the thumb played the reference pitch and the 2nd, 3rd, 4th, and 5th fingers produced the respective interval tone as indicated by the interval number (2-5) on the screen. Within the active and passive groups, half the participants heard only a piano timbre and half heard only oboe timbre throughout training. The training phase consisted of a total of 320 trials (4 intervals x 2 reference pitches x 40 repetitions).

The test phase consisted of 16 total intervals (4 intervals x 2 reference pitches x 2 timbres) presented 10 times each for a total of 160 trials. Half the test trials were played in an oboe timbre and half were played in a piano timbre; however, the timbre manipulation yielded no differences or interactions and will not be discussed further. The experiment was self-paced and lasted approximately 1 hour.

Results and Discussion

Interval identification data were analyzed in a 2 (ethnicity: East Asian/non-Asian) x 2 (training method: active/passive) between subjects analysis of covariance (ANCOVA) with prior musical training as a covariate. A main effect of ethnicity showed interval recognition was more accurate for East Asians (M = 62.2%) than non-Asians (M = 45.7%; means are adjusted for the years music covariate), $F(1, 26) = 7.9$, $p = .009$. The effect of active/passive training was marginally significant, with active training more effective than passive training, $F(1, 26) = 4.12$, $p = .053$, although this effect was much smaller than the ethnicity effect. There was no effect of prior musical training ($p = .14$). The ethnicity x training interaction was marginally significant, ($p = .07$), indicating that active training seemed to be more helpful for the East Asian group than the non-Asian group. The ethnicity effect was unplanned, thus random assignment to active/passive conditions did not take ethnicity into consideration: The passive condition included 5 East Asians (52.3% correct) and 11 non-Asians (41.1%), whereas active condition included 6 East Asians (76.6%) and 9 non-Asians (48.4%).

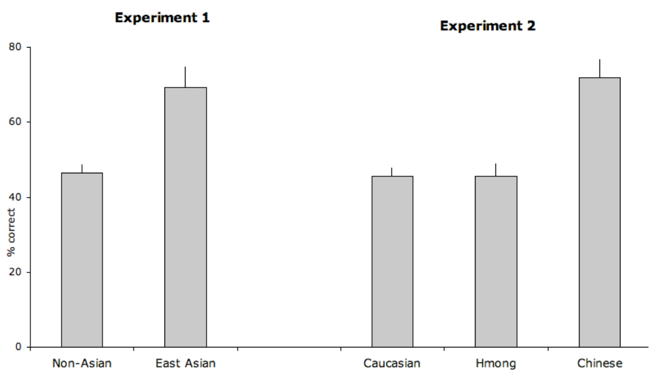

Figure 1: Pitch recognition by group for Exp. 1 and 2.

The next analyses consider the effect of tone-language experience. The performance of the East Asians participants who could at least understand a tone language ($M = 64.7\%$, n = 6), did not differ from the East Asians with no tone-language experience ($M = 66.3\%$, n = 5), $t(9) = .12$, $p > .91$. However, within the group who understand a tone language, identification performance tended to be highest among the fluent speakers (proficiency level 5, $M = 83.7\%$, $n = 2$; proficiency level 3, $M = 48.7\%$, $n = 2$; proficiency level 1, $M = 61.9\%$, $n = 2$). The very small numbers of participants in these groups make these results inconclusive, however. Finally, the East Asians with no tone-language experience outperformed the non-Asians, $t(23) = 2.8$, $p = .01$. Thus, ethnicity effects remain even when all participants do not understand a tone language.

The final analyses tested the effect of location of early childhood in the East Asian participants. The East Asians who grew up in East Asia ($M = 82.7\%$, n = 3) tended to outperform the East Asians who grew up in North America ($M = 59.1\%$, n = 8), t(9) = 1.90, $p = .09$. The East Asians who grew up in North America outperformed the non-Asians who grew up in North America ($M = 44.3\%$, n = 20), $t(26)=2.2$, $p = .038$. Thus, some effect of ethnicity remains even when all participants spent their childhoods in North America.

This first experiment found a substantial advantage for the East Asians in learning to identify pitch intervals. This suggests a link to the ethnicity effects in AP. If so, then it would seem that the difference found between ethnic groups is not limited to the more well-documented abilities to name pitches in isolation, but to some more general advantage in applying labels to musical pitches.

As to factors that might cause these differences to appear, the present study shows an effect of ethnicity even for East Asians who grew up in North America compared with non-Asians. An effect of ethnicity was found also for East Asians who reported no understanding of tone languages compared to non-Asians. A caveat here is that, although these East Asians do not understand a tone language, they may nonetheless have had greater exposure. Also, the small number of East Asian participants makes comparisons within this group inconclusive.

Experiment 2

Experiment 2 further examined the previously observed ethnicity effect and potential effects of tone language on melodic interval recognition. In order to assess the relative contributions of tone language and ethnicity in pitch recognition tasks, we compared the interval recognition performance of three groups: Chinese, native tone-language speakers from the East Asian group (Chinese/Japanese/Korean) previously showing pitch perception advantages; Hmong, also native tone-language speakers, but genetically distinct from that East Asian group (Wen et al., 2004); and Caucasians. Experiment 2 was a simplified version of Experiment 1. Stimuli consisted of three intervals rather than four, no timbral differences, and all participants trained in the active condition. Participants were high school non-musicians.

Methods

Participants Participants were 38 unpaid volunteers (20 females, 18 males) from secondary schools in China, Taiwan, and the United States. 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 (a tone language). Half of the Hmong sample were born in the U.S. and half were born in Thailand or Laos and immigrated to the U.S. (five before age 5, two at age 10); this did not affect performance. Participants were non-musicians with three years or less of musical training (means for Caucasians = 1.8 years, Hmong = .9 years, and Chinese = 1.2 years; *ns*) and had no formal ear training.

Materials and Procedure Experiment 2 consisted of three intervals from the pentatonic scale (M2, P4, P5) starting on one of two reference pitches (C4 and F#4). To avoid language labels, intervals were identified only by color: M2s were red, P4s green, and P5s blue. Tone timbre was a MIDI metallophone. The MIDI tones were presented via a MAX/MSP program on a Mac G4 laptop over circumaural headphones.

Participants were first briefed on the experimental structure and the task of recognizing pitch intervals. The Caucasians and Hmong students were instructed verbally from a script and the Chinese students received written instructions translated into Chinese (back-translated to English to ensure accuracy).

Participants briefly practiced the interval recognition task and responded via one of three keys demarcated by correspondingly colored stickers (a red sticker on the 'T' key (M2), green on the 'Y' key (P4), and blue on the 'U' key (P5)). The *training* phase consisted of 120 intervals (3 intervals x 2 reference pitches x 20 repetitions). 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, then the appropriate colored key for the higher, interval tone. Following training, participants performed the interval recognition test on the trained-on intervals. The test was 96 trials for the Caucasian and Hmong groups and reduced to 48 trials for the Chinese group due to time limitations.[1] The entire experiment lasted approximately 25 minutes for the Caucasian and Hmong groups and 20 minutes for the Chinese group.

Results and Discussion

A 3 (group: Chinese, Hmong, Caucasian) level between-subjects ANCOVA with previous musical training as a covariate revealed a highly significant group difference: the Chinese (M = 72.0%) outperformed the Caucasians (M = 45.5%) and Hmong (M = 45.5%), F (2,34) = 18.85, p < .001. There was no effect of previous musical training on the interval recognition scores, $F(1, 34) = 1.75$, $p = .20$.

The Chinese performance advantage for non-musicians in this relative pitch task parallels the previously established advantage in AP rates for highly trained Chinese musicians. Identical performance for Caucasian and the native tone-language speaking Hmong indicates that speaking a tone language does not necessarily produce better pitch interval recognition. The Chinese performance advantage is consistent with ethnicity and possibly environmental explanations for pitch perception advantages.

Experiment 3

Experiment 3 further investigated ethnicity effects in a similar relative pitch learning task, and included an analogous "relative rhythm" learning task (with time rather than pitch intervals) in order to control for possible motivational, memory, or general cognitive differences. For example, relative pitch tasks involve *context* or the *relation* between stimuli, and hence might favor the more context-sensitive East Asian cultures (e.g., Masuda & Nisbett, 2001). However, if groups performed differently in the pitch task, but not the rhythm task, one can infer that those group differences arose from differences in pitch processing, rather than motivational or other general cognitive differences.

[1] 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 second 48 trials.

Methods

Participants Sixty-five Cornell undergraduates participated for course credit or $8/hr. Participants were non-musicians with 3 years or less of musical training (M=1.2 years, SD=1.0). There were three groups: Caucasian (n = 30; musical training = .9 years); Chinese (n = 24; musical training = 1.4); and Korean (n = 11; musical training = 1.5 years; *ns* difference between groups). Participants reported their language experience on a 1 to 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 = .8). Primary language spoken at home was also reported. An additional thirteen participants participated in the experiment but were excluded; one due to corrupted data and twelve due to ethnicities that were not Caucasian, Chinese, or Korean.

Materials and Procedure The experiment consisted of two tasks counterbalanced in order: a pitch-interval learning task similar to Experiment 2 and an analogous rhythm-interval learning task. In the rhythm-interval task, participants learned to recognize different rhythmic patterns. The rhythm stimuli consisted of three rhythms identified by color (red, green, or blue) presented at one of two tempi (slow or fast), to ensure that participants learned the *relative* time interval and not the absolute times. The rhythms were presented in a MIDI woodblock timbre and consisted of equally spaced reference clicks (quarter notes) with an inter-onset interval of 600 ms in the slow tempo and 450 ms in the fast tempo. The three different rhythms resulted from inserting different subdivision clicks. The subdivisions occurred: (1) halfway between the reference clicks (a 1:1 subdivision); (2) two-thirds after the first reference click (a 2:1 subdivision); or (3) three-quarters after the reference click (a 3:1 subdivision); or in musical terms: (1) eighth note feel; (2) triplet feel; or (3) sixteenth note feel. There were seven clicks in each rhythmic interval: the first two served to set the tempo, followed by two iterations of the rhythmic interval.

The procedure for the rhythm and pitch portions were identical: the intervals were defined by the experimenter, followed by a short practice, a 96 trial training phase, and a 96 trial test. Each training phase lasted approximately 10 minutes. The color of the upcoming interval appeared on the screen and a spacebar press started the interval. The pitch-interval stimuli were the same as Experiment 2 — three intervals (M2, P4 or P5) and two reference pitches (C or F#). However, each stimuli presentation consisted of five tones rather than two to match the rhythm presentation. The reference pitch was first played to establish pitch context and was then followed by two repetitions of the interval. For example, the presentation of an M2 (red) beginning on C4 would be C C D C D. The experiment was self-paced and lasted approximately one hour.

Results and Discussion

Average percent correct for the pitch and rhythm tasks appears in Figure 2. Separate ANCOVAs on pitch and rhythm interval recognition examined ethnicity with previous musical training as a covariate. First, the *pitch* data: ethnicity again had a significant effect on pitch interval recognition. The Chinese (M = 71.1% correct) and Koreans (M = 76.6%) outperformed the Caucasians (M = 59.6%), (reported Ms with previous music covariate held at 1.2 years), $F(2, 61) = 6.42$, $p = .003$. There was no difference between the Chinese and Korean groups, $p > .3$. Unlike Experiments 1 and 2, previous musical training did have a significant effect, $F(1, 61) = 8.21$, $p < .01$.

The *rhythm* data, in contrast, yielded no significant difference between the Chinese (M = 67.5%), Korean (M = 66.1%), and Caucasian participants (M = 63.6%), $F(2, 61) = .5$, $p > .6$; nor did the rhythm test show an effect of prior musical training, $p > .4$. Since ethnicity differences between East Asians and Caucasians emerged in the pitch task, but not in the analogous rhythm task, we can more confidently conclude that the observed differences in pitch recognition reliably reflect differences in pitch recognition, rather than spurious effects of motivation, strategy or other cognitive differences.

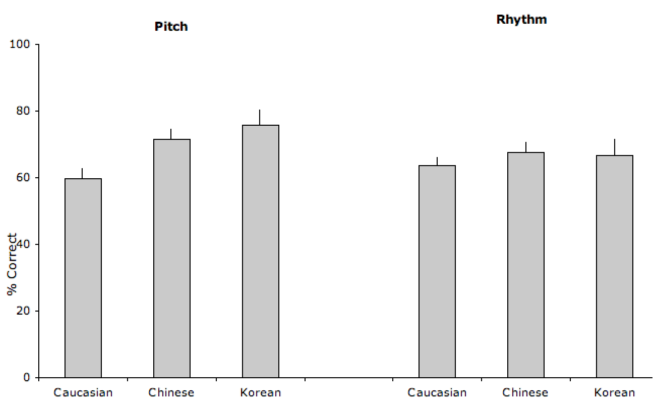

Figure 2: Average percent correct for pitch and rhythm portions for Caucasian, Chinese, and Korean participants.

Next, we examine the potential role of language on pitch interval recognition. Within the East Asian sample, no difference arose between the Chinese participants (all of whom had tone language experience) and the Korean participants (all Korean speakers). Some dialects of Korean are pitch accent languages, but the majority of our participants (and their parents) spoke standard South Korean, which does not have pitch accents (Sohn, 1999), thus the relatively high pitch performance for Koreans is not driven by pitch accent language. Additionally, the *degree* of tone-language fluency 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 the 9 participants with non-fluent tone-language experience (M = 80.4%), $p = .07$.

Finally, we observed no difference between the East Asians who grew up in East Asia (M = 77.6%, n = 15) and the East Asians who grew up in North America (M = 71.5%, n = 20), $p > .3$. Nor did the primary language spoken in the home have an effect, $ps > .6$.

Experiment 3 demonstrates an ethnicity effect in relative pitch, but not relative rhythm identification. This effect remains regardless of language experience.

General Discussion

The three studies reported here indicate an ethnicity effect in relative pitch learning: the East Asian samples (previously shown in other studies to possess higher rates of absolute pitch) better identified musical pitch intervals. Relative pitch performance was not affected by tone-language knowledge in any of the experiments. The amount of musical training yielded an effect in Experiment 3, but was not responsible for the observed ethnicity effects.

The observed ethnicity effects could be influenced, at least in part, by genetic differences. Genetic effects have previously been established in pitch perception abilities: identical twin pairs performed more similarly than fraternal twin pairs when identifying melodies with incorrect pitch (Drayna et al., 2001); AP aggregates in families even after controlling for shared environment (Baharloo et al., 1998); and higher rates of AP in East Asian populations (e.g. Chinese, Korean, and Japanese) at least suggest genetic predispositions (Gregersen et al., 2000; Zatorre, 2003). Dediu and Ladd (2007) recently proposed a link between specific genes and tone language distribution; the population frequencies of two derived haplotypes of the brain growth and development genes, ASPM and Microcephalin, correlate with whether that population speaks a tone language (rs ~ .5). The haplotypes could affect subtle organization of the cerebral cortex and lead to cognitive biases such as in low-level pitch perception that facilitate the acquisition of tone language. The authors propose that such a cognitive bias is very small and would only manifest itself in linguistic change over many generations.

The East Asian samples showing better pitch interval recognition have derived ASPM and Microcephalin frequencies consistent with the proposed cognitive bias (Evans et al., 2005; Mekel-Brobov et al., 2005). However, the Hmong (Miaozu) also have similar frequencies of these derived haplotypes, but showed no relative pitch perception advantage in our study. The lack of effect in the Hmong could reflect complex gene-environment interactions or could stem from uncontrolled factors. For example, although the Hmong sample consisted of fluent tone-language speakers with no known cognitive or auditory impairments, they were refugees; and refugees can have elevated rates of PTSD and depression (Ehntholt & Yule, 2006), which could in turn affect auditory processing (Metzger et al., 2002).

Another uncontrolled factor in the present study is intelligence. Some might propose that enhanced relative pitch identification in Asians could stem from the previously identified higher IQ scores in Asians (Dickens & Flynn, 2006) combined with the positive correlation between IQ and pitch discrimination (Acton & Schroeder, 2001). However, IQ is unlikely driving ethnicity effects here as the Asian IQ advantage is very small, if it exists at all (Flynn, 1991) and the correlation between IQ and pitch discrimination is also weak (r ~ .3; Acton & Schroeder, 2001). Evidence indicates that IQ positively correlates with temporal discrimination (Rammsayer & Brandler, 2007); thus if relative pitch effects appeared due to IQ in Experiment 3, concordant "relative rhythm" effects should also appear, but did not.

In summary, we establish an ethnicity effect in relative pitch identification in non-musicians that was previously seen only in highly trained musicians with absolute pitch. East Asians consistently outperformed others in relative pitch identification, regardless of tone language knowledge. This effect is consistent with genetic work on *ASPM* and *Microcephalin*, and opens up many research questions concerning the genetic and environmental contributions in pitch interval identification.

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