Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Journal of Experimental Child Psychology 100 (2008) 40–52
Journal of Experimental Child Psychology
www.elsevier.com/locate/jecp

Cross-cultural perspectives on pitch memory

Sandra E. Trehub [a], E. Glenn Schellenberg [a,*], Takayuki Nakata [b]

[a] *Department of Psychology, University of Toronto at Mississauga, Mississauga, Ontario, Canada L5L 1C6*
[b] *Department of Media Architecture, School of Systems Information Science, Future University–Hakodate, Hakodate, Hokkaido 041-8655, Japan*

Received 8 May 2007; revised 22 January 2008
Available online 5 March 2008

Abstract

We examined effects of age and culture on children's memory for the pitch level of familiar music. Canadian 9- and 10-year-olds distinguished the original pitch level of familiar television theme songs from foils that were pitch-shifted by one semitone, whereas 5- to 8-year-olds failed to do so (Experiment 1). In contrast, Japanese 5- and 6-year-olds distinguished the pitch-shifted foils from the originals, performing significantly better than same-age Canadian children (Experiment 2). Moreover, Japanese 6-year-olds were more accurate than their 5-year-old counterparts. These findings challenge the prevailing view of enhanced pitch memory during early life. We consider factors that may account for Japanese children's superior performance such as their use of a pitch accent language (Japanese) rather than a stress accent language (English) and their experience with musical pitch labels.

Keywords: Music cognition; Cognitive development; Music perception; Pitch memory; Cross-cultural development

Introduction

Recognizing or producing familiar music relies primarily on relative aspects of pitch and timing. As a result, listeners can identify familiar tunes played at widely different pitch levels and tempi or on different instruments provided that the pitch and timing relations

* Corresponding author. Fax: +1 905 569 4326.
E-mail address: g.schellenberg@utoronto.ca (E.G. Schellenberg).

0022-0965/$ - see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.jecp.2008.01.007

remain intact. The prevailing view is that long-term representations of music are relatively abstract or independent of absolute features (Burns, 1999; Krumhansl, 2000). Nevertheless, adults seem to retain both absolute and relational information about musical materials that are highly familiar or ecologically valid. For example, they sing well-known pop songs within two semitones of the pitch level of canonical versions (Levitin, 1994) and within 8% of the original tempo (Levitin & Cook, 1996). Comparable consistency is evident in repeated performances of familiar songs that have no canonical version (Halpern, 1989). Maternal singing is especially consistent, with repeated renditions of specific nursery songs varying by roughly a semitone in pitch level and 3% in tempo (Bergeson & Trehub, 2002).

Consistency in the pitch level of sung performances cannot be entirely attributable to motor memory or a restricted singing range (Halpern, 1989). Schellenberg and Trehub (2003) demonstrated that adults with little or no music training successfully distinguish theme music of familiar television shows from foils that have been shifted upward or downward in pitch by one or two semitones. Adults' failure to perform at above-chance levels with music from unfamiliar shows confirms that success with familiar music stems from pitch memory rather than pitch-shifting artifacts. This finding supports claims of automatic encoding and retention of surface details from ecologically valid music (Dowling, Tillmann, & Ayers, 2002), which enables adults to recognize or sing familiar songs at or near the original pitch level (Parncutt & Levitin, 2001).

The situation is far less clear for children. According to one school of thought, young children accord priority to absolute aspects of pitch, shifting to relational processing during the preschool period or shortly thereafter (Levitin & Rogers, 2005; Saffran, 2003; Saffran & Griepentrog, 2001; Takeuchi & Hulse, 1993). There are two sources of evidence for this view. The first involves infants' preferential processing of absolute cues after limited exposure (2 min) to isochronous sequences (i.e., equally timed notes) of pure tones (Saffran, 2003; Saffran & Griepentrog, 2001). This absolute processing bias is at odds, however, with solid evidence of relational processing of music during infancy (e.g., Plantinga & Trainor, 2005; for a review, see Trehub, 2003a). Perhaps infants accord priority to absolute pitch details for stimuli that lack the usual temporal and pitch patterning of music.

The second source of evidence for absolute pitch processing biases during early development comes from the tiny minority of individuals (1 in 1,500 or 1 in 10,000 according to Profita and Bidder (1988) or Bachem (1955), respectively) who have absolute pitch (AP), which enables them to identify or produce isolated pitches within the musical range (Takeuchi & Hulse, 1993; Ward, 1999). Because intensive music training by 6 or 7 years of age is the best predictor of AP, the presumption is that the early years involve enhanced attention to absolute cues (Chin, 2003; Deutsch, 2002; Levitin & Rogers, 2005; Miyazaki & Ogawa, 2006; Takeuchi & Hulse, 1993). Indeed, efforts to train participants to produce or recognize a single tone reveal better performance by young children than by adolescents or adults (Crozier, 1997; Russo, Windell, & Cuddy, 2003).

Although early music training increases the probability of AP, it does not guarantee it, raising the possibility of other facilitating factors such as genetic predispositions (Baharloo, Johnston, Service, Gitschier, & Freimer, 1998; Baharloo, Service, Risch, Gitschier, & Freimer, 2000; Deutsch, Henthorn, Marvin, & Xu, 2006; Gregersen, Kowalsky, Kohn, & Marvin, 2000) and early exposure to a tone language (Deutsch, 2002; Deutsch, Henthorn, & Dolson, 2004; Deutsch et al., 2006). The incidence of AP is much higher in populations of Asian ancestry (e.g., Chinese, Japanese, Korean) than of European ancestry (Deutsch et al., 2006; Gregersen, Kowalsky, Kohn, & Marvin, 1999; Gregersen et al., 2000). Nevertheless, genetic accounts of AP remain contentious because of the difficulty of disentangling genetic contributions from shared environment (Deutsch et al., 2006; Miyazaki & Ogawa, 2006). Indeed, when environmental differences are minimized, the Asian advantage in pitch memory tends to disappear (Gregersen, Kowalsky, & Li, 2007; Henthorn & Deutsch, 2007; Schellenberg & Trehub, 2008).

The tone language account is also problematic because of the elevated incidence of AP among native speakers of Korean and Japanese, which are pitch accent rather than tone languages (Zatorre, 2003). Tone languages have elaborate mappings between semantics and pitch (e.g., a phoneme sequence can have as many as five different meanings depending on its pitch patterning), whereas pitch accent languages have simpler distinctions (e.g., high vs. low) and relatively few words differ in pitch patterning alone. Still, in contrast to stress accent languages such as English, pitch accent languages could promote attention to pitch level, but to a lesser degree than do tone languages (Deutsch, 2006; Henthorn & Deutsch, 2007). This hypothesis may account for the high incidence of AP in cultures with tone languages (e.g., Chinese), the low incidence of AP in cultures with stress accent languages (e.g., English), and the intermediate incidence of AP in cultures with pitch accent languages (e.g., Japanese) (Gregersen et al., 2000). In any event, the relative rarity of AP and its restriction to individuals with early and prolonged music training imply that AP has limited application to questions of pitch memory in the general population.

Instead of absolute or relative pitch processing assuming priority at different phases of development (e.g., Levitin & Rogers, 2005; Takeuchi & Hulse, 1993), both modes of processing may be available throughout life, with their deployment depending on stimulus and task details (Saffran, Reeck, Niebuhr, & Wilson, 2005; Schellenberg & Trehub, 2003). For example, although 6-month-olds exhibit long-term memory for the relative pitch patterns of synthesized instrumental melodies but not their pitch level (Plantinga & Trainor, 2005), they remember the pitch level of expressively sung lullabies (Volkova, Trehub, & Schellenberg, 2006).

Age, musical experience, and nonlinguistic cultural differences could also influence the encoding and retention of absolute aspects of music. For example, cultural variations in the nature of musical exposure could affect pitch memory during childhood and beyond. Communal singing is widespread in child care and early education settings across cultures, but the activity often is implemented differently. In Japan, for example, early child educators provide piano accompaniment for children's singing, with the consequence that specific songs are sung at the same pitch level on different occasions. Moreover, Japanese educators label the starting pitch of each song with fixed note names such as *do* for C and *mi* for E. In fact, they frequently teach songs with note names first (e.g., *mi-re-do-re-mi-mi-mi*), subsequently adding the words (e.g., "Mary had a little lamb"). These pitch labels could enhance children's memory for specific pitches, just as labeling environmental sounds enhances adults' memory for those sounds (Bartlett, 1977; Bower & Holyoak, 1973). Labeling also enhances attention to labeled objects, attributes, and events. For example, naming objects enhances their visual salience for 12- and 18-month-olds (Baldwin & Markman, 1989). Similarly, toddlers accord greater attention to objects with known names than to those with unknown names (Schafer, Plunkett, & Harris, 1999). The implication is that verbal labels enrich the mental representations of objects and events, as Whorf (1956) proposed some years ago.

In the current investigation, we explored the effect of age and culture on children's memory for the pitch level of familiar music. In Experiment 1, we tested the memory of Canadian 5- to 10-year-olds for the pitch level of familiar music from their favorite television programs or movies or from pop recordings heard regularly. Superior performance by younger children in this sample would be consistent with the proposed shift from absolute to relative pitch processing (Deutsch, 2002; Saffran, 2003; Saffran & Griepentrog, 2001; Takeuchi & Hulse, 1993). In contrast, age-related improvement in pitch memory could reflect increasing domain-general and domain-specific knowledge, as is the case for many other skills. The absence of age differences would imply developmental stability in pitch memory (Schellenberg & Trehub, 2003; Trehub, 2003b; Volkova, Trehub, & Schellenberg, 2006) or possibly that age-related improvements in cognitive ability counteract a predisposition for absolute pitch processing during the early years of life.

In Experiment 2, we assessed Japanese 5- and 6-year-olds' memory for the pitch level of excerpts from familiar television theme songs. Because of Japanese children's experience with a pitch accent language and with pitch labels, they may accord greater attention to pitch level than do Canadian children. Gregersen and colleagues (2000, 2007) discounted the contribution of tone or pitch accent languages to AP acquisition. They argued instead that age of onset of music lessons and exposure to a "fixed do" system before 7 years of age account for differences in the incidence of AP across cultures. Most Japanese children in the current study were not receiving formal music training in the strict sense (i.e., lessons outside of school), but their in-school musical experience incorporated aspects of conventional music lessons. Moreover, in contrast to the Canadian children in the current study, Japanese children were exposed to a fixed do system in which names were linked to specific pitches. Accordingly, we predicted that Japanese children's memory for the pitch level of familiar music would be more accurate than that of same-age Canadian children.

Experiment 1

We recruited a sample of Canadian children who varied widely in age and exposure to music lessons. Our primary goal was to examine age-related changes in pitch memory. A secondary goal was to examine the impact of music training.

Method

Participants

The participants were 90 5- to 10-year-olds (57 girls and 33 boys) who were recruited from a suburban community near Toronto, Canada. There were 15 children in each of six age groups: 5-year-olds ($M = 64$ months, range = 60–69), 6-year-olds ($M = 79$ months, range = 74–83), 7-year-olds ($M = 87$ months, range = 84–91), 8-year-olds ($M = 101$ months, range = 96–106), 9-year-olds ($M = 115$ months, range = 109–119), and 10-year-olds ($M = 124$ months, range = 121–127). All of the children attended publicly funded schools and spoke English fluently. On average, children had 18 months of music lessons, but the distribution was positively skewed ($SD = 19$ months) with a median of 10 months and a mode of 0 months. Approximately 59% ($n = 53$) had taken some music lessons. Because AP is much more common among children who begin music lessons by 6 or 7 years of age, we explored the possibility of an association between early music lessons and pitch memory. Specifically, 19 of the children had early music lessons, which we defined as starting by 5.5 years of age to maximize statistical power.

Apparatus and stimuli

Stimulus presentation and response recording were controlled with customized software created with PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993) installed on an iMac computer. Children were tested in a sound-attenuating booth while wearing headphones (Sony Dynamic Stereo Headphones, model MDR-P1). The stimuli were more than 40 5-s musical excerpts from popular children's television shows (e.g., *Arthur, Scooby Doo, The Magic School Bus, Franklin, Dragon*), movies (e.g., *I'm a Believer* from *Shrek, Hakuna Matata* from *The Lion King*), and pop songs (e.g., *Oops I Did It Again, You Drive Me Crazy,* and *Baby One More Time* by Britney Spears, *Pinch Me* by Barenaked Ladies). Each excerpt was selected as most representative of its corresponding recording. In most cases, it was the first 5 s of the first chorus. Unlike Schellenberg and Trehub's (2003) study with adults that used instrumental recordings only, most of the excerpts in the current set contained vocals, typical of music composed primarily for child listeners.

Excerpts were normalized with digital sound-editing software (SoundEdit 16) so that maximum amplitude was constant across excerpts. Each excerpt was pitch-shifted upward and/or downward by one semitone using the pitch-shifting function of ProTools 5.0. When the pitch shift was in only one direction (upward or downward), the other direction was excluded because it was deemed to sound artificial. In addition, to minimize potential artifacts created by the pitch-shifting process, the original pitch excerpts were shifted upward in pitch by a half semitone and then downward in pitch by a half semitone so that the pitch-shifting process was identical in magnitude across conditions. All excerpts (original pitch or shifted) were stored as monaural CD-quality digital sound files.

Procedure

From our large set of musical recordings, children selected the songs they knew best so that we could choose four excerpts for the younger children (5- to 7-year-olds) and eight excerpts for the older children (8- to 10-year-olds). Only the older children had pop songs among their choices. For each child, half of the original pitch excerpts were paired with excerpts that were pitch-shifted upward (higher) and half were paired with those that were pitch-shifted downward (lower). On each trial, children heard two excerpts of the same recording presented in succession with 1 s of silence between excerpts. Their task was to identify whether the first or second excerpt was presented at the original or "correct" pitch (i.e., the one heard at home). Because the direction of the pitch shift always was the same for a particular excerpt (i.e., either upward or downward, not both upward and downward), children could not adopt a strategy of choosing the middle (correct) pitch over the course of the testing session.

The younger children had 8 trials. Pairs of excerpts from each of the four recordings were presented twice, with order of presentation (original–shifted or shifted–original) counterbalanced with direction of pitch shift. The older children had 16 trials (i.e., pairs of excerpts from each of 8 recordings presented twice) counterbalanced identically. Such counterbalancing ensured that consistently choosing the first (or second) excerpt, or the higher (or lower) excerpt, led to chance levels of performance. No feedback was provided, thereby preventing participants from learning which responses were correct over the course of the test session.

Before the test session began, there was a training phase to ensure that children understood the task. On each of eight trials, children heard two utterances: one in a normal female voice and the other distorted substantially by electronic means (e.g., backward, higher, faster). As in the test trials that followed, the two utterances were separated by 1 s of silence and children were asked to identify the "correct" voice by choosing the utterance heard first or second. Children who responded correctly on at least six of eight trials (97% of the sample) proceeded to the test trials. The other children (one 5-year-old, one 6-year-old, and one 7-year-old) repeated the training session. Each of these children obtained at least seven of eight correct responses on their second attempt.

Control study

Schellenberg and Trehub (2003) confirmed the absence of perceptible artifacts when they pitch-shifted instrumental music by two semitones by means of ProTools software. Pilot testing in our laboratory revealed, however, that the pitch-shifting process yielded subtle artifacts with speech samples. For example, adult listeners could distinguish "normal" speech excerpts from excerpts shifted by two semitones and, at times, by one semitone. To test whether pitch shifting generates similar artifacts in singing, we conducted a control study with 30 adults using four vocal excerpts from the current stimulus set that were highly familiar to children (as indicated by their selections) but were unfamiliar to adult participants. Half of the participants were tested with one-semitone pitch shifts (as with the children in the current study), and the other half were tested with two-semitone shifts. The procedure was identical to that of the current study except that (a) participants were informed of the pitch-shifting manipulation and (b) no training session was required to ensure that adults understood the instructions. On each of eight trials, adults were asked to listen carefully to the two excerpts and to identify which excerpt (first or second) was at the original pitch level (i.e., the level used on the corresponding television show). Performance was significantly better than chance (50% correct) in the two-semitone condition ($M = 71\%$), $t(14) = 5.23$, $p < .001$, but was at chance levels in the one-semitone condition ($M = 48\%$), $p = .513$. In short, pitch-shifting vocal recordings with ProTools created perceptible artifacts for two-semitone shifts but not for one-semitone shifts.

Results and discussion

Scores (correct responses) were converted to percentages to facilitate comparisons among age groups with different numbers of test trials. Preliminary analyses revealed that duration of music lessons was not associated with performance, $r = .04$, $N = 90$, $p = .698$. Independent samples t tests confirmed that performance did not differ between children with music lessons ($M = 57\%$) and those without music lessons ($M = 55\%$), $p = .595$. The difference between children who began music lessons early ($M = 61\%$) and those who did not ($M = 55\%$), although more substantial, was not statistically significant, $p = .167$.

Performance of each age group is shown in Fig. 1. The principal analyses involved comparisons of performance with chance levels (50%) for each age group, followed by between-group comparisons. Performance was at chance for 5- to 8-year-olds, $ps > .156$

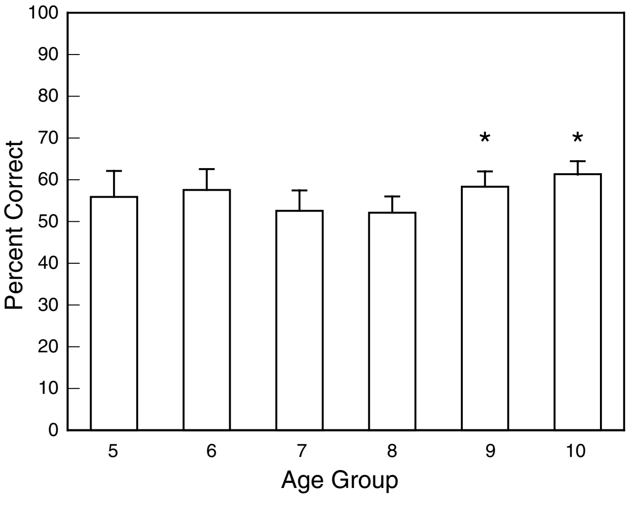

Fig. 1. Performance of Canadian children in Experiment 1. Error bars are standard errors. Asterisks indicate performance at above-chance levels.

(two-tailed). Only 9- and 10-year-olds performed above chance levels, $t(14) = 2.32$, $p = .036$, and $t(14) = 3.60$, $p = .003$, respectively. Nonetheless, a between-participants analysis of variance (ANOVA) revealed no effect of age, $F < 1$, and a more powerful test (i.e., of a linear trend) showed no age-related improvement or deterioration, $F < 1$. Moreover, the combined sample of children performed no differently ($M = 56.3\%$) from Schellenberg and Trehub's (2003) sample of adults ($M = 57.7\%$), $p = .611$.

Our results offer no support for the notion that pitch memory is enhanced during the early years of life or among those with formal music lessons. Despite the large age range in the current sample of children, there was no age-related decrement in performance as predicted by several scholars (e.g., Saffran, 2003; Takeuchi & Hulse, 1993). Suggestions of age-related improvement for the older children (i.e., above chance performance) did not yield a significant age effect. In fact, children's memory for the pitch level of familiar music was comparable to that of adults tested previously (Schellenberg & Trehub, 2003).

Experiment 2

In the second experiment, we sought to determine whether young Japanese children would remember the pitch level of familiar theme music more readily than would Canadian children of a similar age. We are not suggesting that young Japanese children have AP (i.e., the ability to recognize and reproduce musical pitches). Rather, we argue that they might recognize or reproduce the pitch level of songs (Parncutt & Levitin, 2001) more readily than do their Canadian counterparts. Young Japanese children might have comparable exposure to television, but it is likely that they would have less cumulative exposure to specific musical themes than do young Canadian children. In contrast to North America, where television programs feature the same theme songs for several years, Japanese children's programs typically change their theme music at 3- to 12-month intervals. In other words, our test of a Japanese advantage for the pitch memory of television theme music was very conservative. A secondary goal was to compare the relative accuracy of pitch memory for vocal and instrumental music. In principle, pitch memory for recordings with vocals could be facilitated by the presence of both vocal and nonvocal cues. There are indications, however, that young children have difficulty in ignoring the content of speech (Morton & Trehub, 2001) and musical lyrics (Morton & Trehub, 2007) even when instructed to attend solely to the prosody or the melody. It is possible, then, that verbal content could interfere with children's encoding and retention of the pitch level of music. Finally, as in Experiment 1, we also examined whether music training was associated with memory for pitch.

Method

Participants

The participants were 60 school-age children (36 girls and 24 boys) who were recruited from three different educational settings in Nagasaki, Japan: a junior kindergarten class ($n = 18$), a senior kindergarten class ($n = 19$), and a first grade class ($n = 23$). The sample consisted of 23 5-year-olds ($M = 65$ months, range = 59–71) and 37 6-year-olds ($M = 80$ months, range = 72–87). Information about children's extracurricular music training was obtained from a mail-in questionnaire that yielded complete responses (i.e., months of lessons along with age of onset) from 52 of 60 families. As in Experiment 1, duration of music lessons was positively skewed ($M = 6$ months, $SD = 13$) with a median and mode of 0. There were 16 children who had taken music lessons, 9 of whom began before 5.5 years of age.

Apparatus and stimuli

The experiment was computer controlled on a Macintosh PowerBook G3 using the software from Experiment 1 translated into Japanese. Children were tested in a quiet room. The stimuli were presented over loudspeakers (Yamaha, model YST-MS201) for the junior and senior kindergarten groups, and over lightweight headphones (Sony, model MDR-G51) for the first graders.

The stimuli were excerpts from 17 theme songs taken from 13 different children's television programs broadcast in Japan. For 4 programs, we selected two different recordings (e.g., different melody, different harmony) that were taken from musical themes that began and ended the programs. From each recording, one 5-s vocal excerpt was selected as most representative of the overall recording. For 11 of the 17 recordings, a second 5-s instrumental excerpt was also selected if it seemed equally representative of the recording. Hence, the stimulus set consisted of 26 different excerpts. Each excerpt was shifted in pitch (by means of ProTools 5.0) upward and downward by one semitone. Excerpts at the original pitch were also shifted upward and then downward by a half semitone.

Procedure

The procedure was identical to that of Experiment 1 with the following exceptions. Because pilot testing revealed that first graders had no difficulty in understanding the test procedure, only the junior and senior kindergarteners completed the training phase before proceeding to the test phase. The training phase was similar to that of Experiment 1 except that the original excerpts were spoken in Japanese. All but five of the children had at least six correct responses out of eight trials on their first attempt at identifying the correct recording when it was paired with a drastically altered counterpart. These five children reached this level of performance on their second attempt ($n = 2$) or third attempt ($n = 3$).

For the test session, children were asked to select at least four programs that they watched regularly. We asked for at least four programs because we sought two vocal and two instrumental excerpts for each child, but instrumental excerpts were not available for all programs. Some children's choices did not permit an even division of vocal and instrumental excerpts, so they had only one instrumental excerpt ($n = 5$) or none at all ($n = 1$). The specific direction of the pitch shift was assigned randomly to each excerpt, constrained so that for each child at least one of the excerpts was shifted upward and at least one was shifted downward.

Results and discussion

For each child, we calculated an overall percentage correct score as well as separate scores for the vocal and instrumental excerpts (Fig. 2). The overall scores were analyzed first. Preliminary analyses revealed that performance was not associated with duration of music lessons, $r = .10$, $N = 52$, $p = .483$. Children with music lessons performed no differently ($M = 69\%$) from those without music lessons ($M = 64\%$), $p = .330$, and children with early music lessons performed no differently ($M = 69\%$) from those without early music lessons ($M = 65\%$), $p = .521$. In contrast to Experiment 1, where same-age Cana-

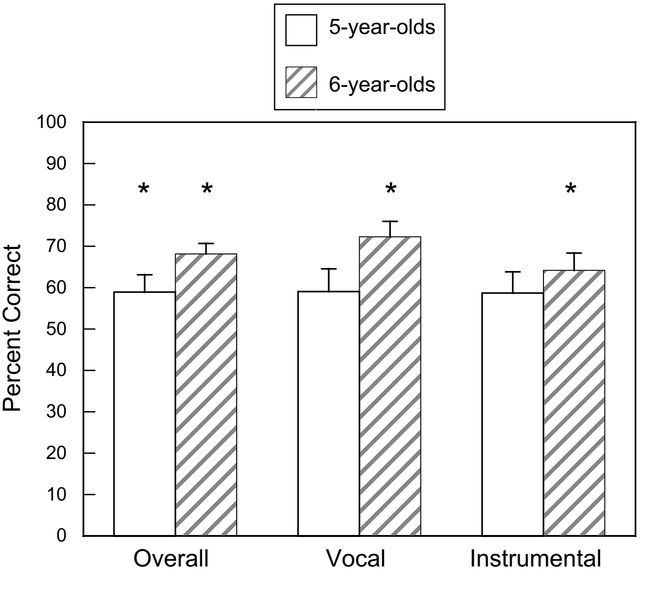

Fig. 2. Overall performance, performance on vocal excerpts, and performance on instrumental excerpts of Japanese children in Experiment 2. Error bars are standard errors. Asterisks indicate performance at above-chance levels.

dian children performed at chance levels in the one-semitone condition, Japanese 6-year-olds performed reliably better than chance ($M = 68\%$ correct), $t(36) = 7.20$, $p < .001$, as did 5-year-olds ($M = 59\%$), $t(22) = 2.13$, $p = .045$. The difference between the two age groups was significant, $t(58) = 2.01$, $p = .049$, with the older group performing 9% better than the younger group.

Separate examination of vocal and instrumental excerpts (Fig. 2) revealed that the 6-year-olds performed at above-chance levels on vocal excerpts ($M = 72\%$) and on instrumental excerpts ($M = 64\%$), $t(36) = 5.99$, $p < .001$, and $t(36) = 3.40$, $p = .002$, respectively. Because of greater variability, the 5-year-olds performed at chance levels on the vocal excerpts ($M = 59\%$), $p = .113$, and on the instrumental excerpts ($M = 59\%$), $p = .103$. A two-way mixed-design ANOVA, with one within-participants variable (vocal or instrumental excerpts) and one between-participants variable (age group), revealed a main effect of age group, $F(1, 58) = 4.14$, $p = .047$, with older children outperforming younger children. There was no main effect of excerpt type and no two-way interaction, Fs < 1. As with Experiment 1, the results provided no evidence of decreases in performance as a function of age. Instead, we found evidence of age-related improvement.

Comparisons of Japanese and Canadian children were accomplished by including all 60 children from the Japanese sample and 36 same-age children (i.e., those 87 months of age or younger) from the Canadian sample of Experiment 1. (The Canadian subsample had the same mean age as the Japanese sample, i.e., 6 years 2 months.) Japanese children ($M = 65\%$) achieved 10% greater accuracy than did same-age Canadian children ($M = 55\%$), a difference that was statistically significant, $t(94) = 2.39$, $p = .019$. In sum, the well-established Asian advantage in AP incidence (Deutsch et al., 2006; Gregersen et al., 1999, 2000) was also evident in our test of pitch memory.

General discussion

In the current investigation, we explored effects of age and culture on children's memory for the pitch level of familiar music. Canadian 9- and 10-year-olds distinguished the original pitch level of familiar music from foils that were pitch-shifted by one semitone. In general, the performance of 5- to 10-year-olds was similar to that of adults tested with familiar music from adult television programs (Schellenberg & Trehub, 2003). Indeed, neither age nor music training was associated with performance. In the sample of Japanese children, there were clear advantages on our task for 6-year-olds over 5-year-olds. Considered as a whole, these findings are inconsistent with the proposed priority for absolute pitch processing during early childhood (Saffran, 2003; Takeuchi & Hulse, 1993). Nonetheless, it is possible that age-related cognitive development obscured the hypothesized shift from absolute to relative pitch processing. In our view, it is more likely that the well-documented relation between early music training and AP (Levitin & Rogers, 2005; Miyazaki & Ogawa, 2006; Takeuchi & Hulse, 1993) stems from the relative ease of acquiring arbitrary labels (e.g., for objects, for note names) during early childhood (Crozier, 1997; Russo et al., 2003) rather than from fundamental differences in pitch processing or memory (Chin, 2003; Deutsch, 2002; Gregersen et al., 2007; Saffran, 2003).

Despite the likelihood that Japanese children received less exposure to the target music, they identified the original pitch level of the music more accurately than did their Canadian counterparts. In principle, Japanese children's experience with a pitch accent language could play a role, but the absence of tone-language effects for individuals of Asian heritage who are reared in North America (Gregersen et al., 2007; Schellenberg & Trehub, 2008) makes this interpretation unlikely. According to Gregersen and colleagues (2000, 2007), age of onset of music lessons and early exposure to a fixed do system make the principal contribution to AP acquisition. Although music lessons played no role in our Canadian or Japanese sample, early music lessons could make an enduring contribution to pitch memory for lessons that are sustained for many years. A second possibility is that early music training promotes modest improvement in pitch memory that would require a larger sample size and greater statistical power to become apparent.

We contend that Japanese children's experience with pitch labeling, beginning in kindergarten, facilitated greater depth of processing of pitch cues at the time of encoding (Craik & Lockhart, 1972) and greater long-term retention than would otherwise be the case. We are not suggesting that Japanese children knew all musical pitch labels. In general, the initial note of a musical piece identifies its key. Many adults who do not have AP can still recognize the musical key of familiar pieces (Levitin & Rogers, 2005; Schellenberg & Trehub, 2003), an ability that sometimes is called absolute tonality (Burns, 1999). The children's repertoire is likely to be characterized by a limited set of keys (e.g., those represented by the white keys on the piano) that would facilitate memory for key identity or overall pitch level. In any case, knowledge of pitch or key labels could lead to both verbal and sensory encoding of music, allowing listeners to reap the benefits of dual encoding (Paivio, 1986).

Verbal encoding confers advantages beyond the auditory domain. Adults who verbally describe photographs of complex scenes recognize the photographs more readily than do those who sketch the depicted scenes (Bartlett, Till, & Levy, 1980). Furthermore, adults' memory for colors and odors is enhanced by relevant knowledge of color and odor names (Brown & Lenneberg, 1954; Perkins & Cook, 1990; Schab, 1991).

Cultural differences in exposure to music may have both general cognitive and specific musical consequences. If Japanese children's exposure to music at school generates overall increases in music proficiency relative to same-age Canadian children, it may have implications for the processing of both nonmusical and musical stimuli. For example, musicians exhibit more faithful and more robust encoding of linguistic pitch (i.e., lexical tones) than do nonmusicians (Wong, Skoe, Russo, Dees, & Kraus, 2007). Musical ability or aptitude, as assessed by standardized tests, is also associated with enhanced phonological processing in a second language (Slevc & Miyake, 2006). Moreover, there is suggestive evidence that musical aptitude accelerates the acquisition of early literacy skills (Anvari, Trainor, Woodside, & Levy, 2002; Atterbury, 1985). Finally, it remains to be determined whether music exposure in Japanese kindergarten and first grade classes generates modest IQ gains like those resulting from extracurricular music lessons in North America (Schellenberg, 2004, 2006).

Acknowledgments

This work was funded by the Natural Sciences and Engineering Research Council of Canada. Jane Campbell and Yuki Higashikawa provided invaluable assistance with stimulus selection, recruiting, testing, and data entry.

References

Anvari, S. H., Trainor, L. J., Woodside, J., & Levy, B. A. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. *Journal of Experimental Child Psychology, 83*, 111–130.

Atterbury, B. W. (1985). Musical differences in learning-disabled and normal-achieving readers, aged seven, eight, and nine. *Psychology of Music, 13*, 114–123.

Bachem, A. (1955). Absolute pitch. *Journal of the Acoustical Society of America, 27*, 1180–1185.

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.

Baharloo, S., Service, S. K., Risch, N., Gitschier, J., & Freimer, N. B. (2000). Familial aggregation of absolute pitch. *American Journal of Human Genetics, 67*, 755–758.

Baldwin, D. A., & Markman, E. M. (1989). Establishing word–object relations: A first step. *Child Development, 60*, 381–398.

Bartlett, J. C. (1977). Remembering environmental sounds: The role of verbalization at input. *Memory & Cognition, 5*, 404–416.

Bartlett, J. C., Till, R. E., & Levy, J. C. (1980). Retrieval characteristics of complex pictures: Effects of verbal encoding. *Journal of Verbal Learning and Verbal Behavior, 19*, 430–449.

Bergeson, T. R., & Trehub, S. E. (2002). Absolute pitch and tempo in mothers' songs to infants. *Psychological Science, 13*, 72–75.

Bower, G. H., & Holyoak, K. (1973). Encoding and recognition memory for naturalistic sounds. *Journal of Experimental Psychology, 101*, 360–366.

Brown, R. W., & Lenneberg, E. H. (1954). A study in language and cognition. *Journal of Abnormal and Social Psychology, 49*, 454–462.

Burns, E. M. (1999). Intervals, scales, and tuning. In D. Deutsch (Ed.), *The psychology of music* (2nd ed., pp. 215–264). San Diego: Academic Press.

Chin, C. S. (2003). The development of absolute pitch: A theory concerning the roles of musical training at an early developmental age and individual cognitive style. *Psychology of Music, 31*, 155–171.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavior Research Methods, Instruments, & Computers, 25*, 257–271.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671–684.

Crozier, J. B. (1997). Absolute pitch: Practice makes perfect, the earlier the better. *Psychology of Music, 25*, 110–119.

Deutsch, D. (2002). The puzzle of absolute pitch. *Current Directions in Psychological Science, 11*, 200–204.

Deutsch, D. (2006). The enigma of absolute pitch. *Acoustics Today, 2*, 11–19.

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.

Dowling, W. J., Tillmann, B., & Ayers, D. F. (2002). Memory and the experience of hearing music. *Music Perception, 19*, 249–276.

Gregersen, P. K., Kowalsky, E., Kohn, N., & Marvin, E. W. (1999). Absolute pitch: Prevalence, ethnic variation, and estimation of the genetic component. *American Journal of Human Genetics, 65*, 911–913.

Gregersen, P. K., Kowalsky, E., Kohn, N., & Marvin, E. W. (2000). Early music education and predisposition to absolute pitch: Teasing apart genes and environment. *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 A, 143*, 104–105.

Halpern, A. R. (1989). Memory for the absolute pitch of familiar songs. *Memory & Cognition, 17*, 572–581.

Henthorn, T., & Deutsch, D. (2007). 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 A, 143*, 102–103.

Krumhansl, C. L. (2000). Rhythm and pitch in music cognition. *Psychological Bulletin, 126*, 159–179.

Levitin, D. J. (1994). Absolute memory for musical pitch: Evidence from the production of learned memories. *Perception & Psychophysics, 56*, 414–423.

Levitin, D. J., & Cook, P. R. (1996). Memory for musical tempo: Additional evidence that auditory memory is absolute. *Perception & Psychophysics, 58*, 927–935.

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

Miyazaki, K., & Ogawa, Y. (2006). Learning absolute pitch by children: A cross-sectional study. *Music Perception, 24*, 63–78.

Morton, J. B., & Trehub, S. E. (2001). Children's understanding of emotion in speech. *Child Development, 72*, 834–843.

Morton, J. B., & Trehub, S. E. (2007). Children's judgements of emotion in song. *Psychology of Music, 35*, 629–639.

Paivio, A. (1986). *Mental representations: A dual-coding approach*. New York: Oxford University Press.

Parncutt, R., & Levitin, D. J. (2001). Absolute pitch. In S. Sadie (Ed.), *The New Grove dictionary of music and musicians* (pp. 37–39). New York: St. Martin's.

Perkins, J., & Cook, N. M. (1990). Recognition and recall of odours: The effects of suppressing visual and verbal encoding processes. *British Journal of Psychology, 81*, 221–226.

Plantinga, J., & Trainor, L. J. (2005). Memory for melody: Infants use a relative pitch code. *Cognition, 98*, 1–11.

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

Russo, F. A., Windell, D. L., & Cuddy, L. L. (2003). Learning the special note: Evidence for a critical period for absolute pitch acquisition. *Music Perception, 21*, 119–127.

Saffran, J. R. (2003). Absolute pitch in infancy and adulthood: The role of tonal structure. *Developmental Science, 6*, 35–47.

Saffran, J. R., & Griepentrog, G. J. (2001). Absolute pitch in infant auditory learning: Evidence for developmental reorganization. *Developmental Psychology, 37*, 74–85.

Saffran, J. R., Reeck, K., Niebuhr, A., & Wilson, D. (2005). Changing the tune: The structure of the input affects infants' use of absolute and relative pitch. *Developmental Science, 8*, 1–7.

Schab, F. B. (1991). Odor memory: Taking stock. *Psychological Bulletin, 109*, 242–251.

Schafer, G., Plunkett, K., & Harris, P. (1999). What's in a name? Lexical knowledge drives infants' visual preferences in the absence of referential input. *Developmental Science, 2*, 187–194.

Schellenberg, E. G. (2004). Music lessons enhance IQ. *Psychological Science, 15*, 511–514.

Schellenberg, E. G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology, 98*, 457–468.

Schellenberg, E. G., & Trehub, S. E. (2003). Good pitch memory is widespread. *Psychological Science, 14*, 262–266.

Schellenberg, E. G., & Trehub, S. E. (2008). Is there an Asian advantage for pitch memory? *Music Perception, 25*, 241–252.

Slevc, L. R., & Miyake, A. (2006). Individual differences in second-language proficiency: Does musical ability matter? *Psychological Science, 17*, 675–681.

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

Trehub, S. E. (2003a). Absolute and relative pitch processing in tone learning tasks. *Developmental Science, 6*, 44–45.

Trehub, S. E. (2003b). Musical predispositions in infancy: An update. In I. Peretz & R. J. Zatorre (Eds.), *The cognitive neuroscience of music* (pp. 3–20). New York: Oxford University Press.

Volkova, A., Trehub, S. E., & Schellenberg, E. G. (2006). Infants' memory for musical performances. *Developmental Science, 9*, 583–589.

Ward, W. D. (1999). Absolute pitch. In D. Deutsch (Ed.), *The psychology of music* (2nd ed., pp. 265–298). San Diego: Academic Press.

Whorf, B. L. (1956). *Language, thought, and reality*. Cambridge, MA: MIT Press.

Wong, C. M., Skoe, E., Russo, N. M., Dees, T., & Kraus, N. (2007). Musical experience shapes human brainstem encoding of linguistic pitch patterns. *Nature Neuroscience, 10*, 420–422.

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