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Becoming musically enculturated: effects of music classes for infants on brain and behavior

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Musical enculturation is a complex, multifaceted process that includes the development of perceptual processing specialized for the pitch and rhythmic structures of the musical system in the culture, understanding of esthetic and expressive norms, and learning the pragmatic uses of music in different social situations. Here, we summarize the results of a study in which 6-month-old Western infants were randomly assigned to 6 months of either an active participatory music class or a class in which they experienced music passively while playing. Active music participation resulted in earlier enculturation to Western tonal pitch structure, larger and/or earlier brain responses to musical tones, and a more positive social trajectory. Furthermore, the data suggest that early exposure to cultural norms of musical expression leads to early preferences for those norms. We conclude that musical enculturation begins in infancy and that active participatory music making in a positive social setting accelerates enculturation.

Keywords: enculturation; music acquisition; brain development; EEG; learning; infancy; tonality; esthetics

Introduction

Music is a cornerstone of human culture, found in everyday life in all societies and used to mark important occasions such as weddings and funerals. The ability of music to engender a common emotion and engage people in cooperative social behavior likely explains why music is ubiquitous in religious rituals, sporting events, cooperative work engagement, and interactions between caregivers and infants.[1–9] Part of the power of music lies in the fact that it is generative; that is, it does not consist of a fixed set of vocal signals, but rather a structural framework in which an unlimited number of musical compositions are possible. Furthermore, although there are biological constraints that shape the space of possible musical structures,[10,11] the particular structures used vary from musical system to musical system, and even within a musical system, these structures evolve from generation to generation. Thus, for young infants, learning to become full participants in their culture necessarily involves becoming sensitive to, and specialized for, the particular musical system of that culture.

Enculturation takes place on many levels. Musical systems differ structurally in how they organize pitch space, the musical scales they use, whether and how they define harmony, and what rhythmic and metrical structures they employ. In this regard, many studies indicate that even Western adults with no formal musical training have become enculturated listeners through everyday exposure to Western music.[12–20] Musical systems also differ in terms of how musical esthetics and expressivity are conveyed; for example, timbral voice qualities considered pleasing in one culture may be aversive in another. Performance group structures also differ, from a predominance of solo to antiphonal to chorus styles.[21] Finally, there are cultural rules as to who performs what music when, including songs for males or females or children and special songs for religious leaders.[22]

The vast majority of developmental research on musical enculturation concerns infants and children learning Western tonal and rhythmic structure.[11,23–32] In this regard, Hannon and her colleagues have shown that young Western infants are

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able to process both simple and complex metrical structures found in music around the world, but become specialized for the simple metrical structures predominant in Western music by 12 months of age.[23,24,33] Similarly, in contrast to Western adults, young infants are not yet sensitive to Western tonal pitch structure, processing equally well wrong notes that go outside the key of a melody and wrong notes that are consistent with the key and implied harmony of a melody.[34] Interestingly, studies in preschool children suggest that music lessons accelerate musical acquisition as measured both behaviorally[35] and with brain imaging techniques such as electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI).[36–38] Little work has been done in the infancy period. However, one study suggests that metrical specialization can be slowed by exposure to foreign musical systems around 12 months of age.[33] There is also evidence that participation in Kindermusik classes for infants and parents can accelerate specialization for Western meters in seven-month-old infants.[39] In the pitch domain, one study indicates that controlled listening to melodies in either marimba or guitar timbre at four months of age strengthens brain responses to the exposed timbre,[40] but it remains an open question as to whether musical training in infancy can accelerate enculturation to Western tonality and Western esthetic values related to musical expression.

Experiment on the effects of active musical experience in infancy on enculturation to Western music

Gerry, Unrau, and Trainor investigated the effects of music classes for infants and parents on enculturation to Western music.[41] Their findings on enculturation to Western tonality and the social implications of this enculturation are summarized below. In the present paper, we also present new data from this large project on the effects of these classes on esthetic responses and brain development.

Study background

We hypothesized that musical enculturation takes place through social interaction and participation in music making. To test this idea, we randomly assigned infants at 6 months of age to participate for 6 months in one of two types of weekly hour-long music classes for infants and parents. A total of 38 infants completed the musical training, as defined by attending at least 75% of the classes. After this participation, we measured their sensitivity to Western tonality, their esthetic preferences, their brain responses to musical sounds, and their social development. We also measured brain responses and social development at the beginning of the classes. We did not expect to see sensitivity to Western tonality or esthetic preferences at 6 months of age, so these were only measured at 12 months. The classes took place at Ontario Early Years Centers, which are government-sponsored drop-in centers for preschool children and their families. In the active classes, a Suzuki-philosophy approach was used in which the teacher engaged parents and infants in a curriculum that focused on movement, singing, playing percussion instruments, and building a repertoire of lullabies and action songs.[42] The classes emphasized musical expression, listening in order to play a percussion instrument or sing at the correct time, repetition of the repertoire, and encouraging parents to develop an awareness of their infants' responses. Parents were encouraged to play a CD at home that included the songs learned in class. In the "passive classes," parents and infants listened to a rotation of CDs from the Baby Einstein (The Walt Disney Co., Burbank, CA) series while the teacher encouraged play and interaction at art, book, ball, block, and stacking cup play stations. These CDs consist of synthesized classical music, rendered without musical expression, but nonetheless, as the name indicates, marketed as a tool to help make your baby more intelligent. Parents were encouraged to take home a different Baby Einstein CD each week to listen to at home. Thus, the passive classes were matched as much as possible to the active classes in terms of amount of musical stimulation, motivation, and social interaction. Details concerning the classes can be found in Gerry *et al.*[41] The classes took place at two different centers, one in a lower socioeconomic status (SES) area and the other in a middle-class SES area, such that each center had one active and one passive class. Teachers of the classes were blind as to the content and hypotheses of the tests given to infants, and experimenters conducting the tests were blind as to whether each infant was in the group participating in passive or active classes.

Enculturation to Western tonality

As reported by Gerry and colleagues,[41] sensitivity to Western tonality was measured by examining infants' preferences for two versions of a sonatina by Thomas Atwood (1765–1838). The *tonal* version was presented in G major as written by Atwood. The *atonal* version had additional accidentals added, such that it alternated between G major and G-flat major every beat and therefore had no feeling of a tonal center. This modification maintained the rhythm, phrasing, and melodic contours of the original piece as well as the amount of sensory consonance (every chord maintained its identity, for example as major or minor, because the manipulation simply transposed the whole chord down by a semitone or not).

Infants' preferences for these two versions were measured in a head-turn preference procedure in which the experimenter sat across from the infant, who sat on his or her parent's lap. The parent and the experimenter wore headphones and listened to masking music so that they were unaware of what the infant was hearing and could not influence the results. The experimenter signaled to the computer through a button box to begin a trial when the infant was facing forward. The computer initiated a trial by flashing a light on one side of the infant, illuminating an interesting toy. When the infant looked at the toy, the light remained on and one of the two versions of the sonatina began playing. The light remained on and the music played until the infant looked away, signaling the end of the trial. The next trial was identical except that it occurred on the opposite side of the infant and involved the other version of the sonatina. Which version was played on the first trial and which version was played on which side were counterbalanced across infants. Trials of the two versions alternated until 20 trials had been completed. In this way, the infant controlled how long they listened to each version. The dependent measure of infants' tonality preference was the proportion of the total time listening (listening times to tonal plus atonal versions) spent listening to the tonal version.

The final sample consisted of 20 infants in the active classes group and 10 in the passive classes group. An additional 20 infants were tested in a no-training age-matched control group in order to verify the results in the passive classes group. Interestingly, a higher proportion of parents completed the active compared to passive training classes with their infants, measured by attending at least 75% of the classes. Furthermore, no infants in the active group, but four in the passive group, had to be eliminated for fussing during the preference procedure or producing anomalous data. For details see Gerry *et al.*[41] Analysis of the preference data indicated that the groups differed significantly and that those in the active classes group showed a preference for the tonal version, whereas those in the passive classes and no-training groups showed no significant preferences.[41]

These results clearly show that some sensitivity to Western tonality is possible by 12 months of age. Furthermore, they indicate that active musical participation involving social interaction between infants, their parents, and others in the group promotes earlier enculturation to the pitch structure of music.

Esthetic enculturation to Western classical music

Enculturation to stylistic norms of expressive performance is an important aspect of musical development, but one that has been little studied. There are many aspects of esthetics, and infant listeners have limited attention spans in which to be tested, so this first study could only scratch the surface of this question. We decided to test whether infants in the active and passive classes groups would show differential responding to musically expressive versus synthesized versions of a classical Western piece from the Romantic period, in which there is a large scope for expression during performance. Two versions of the opening section of Chopin's Waltz in A-flat, op. 69, No. 1, were used in this experiment (Fig. 1A). The first version was played in an expressive manner on acoustic piano by Dinu Lipatti, considered to be one of the world's greatest interpreters of Chopin. The second version was synthesized using Cakewalk in Midi Chorus timbre, with no timbral or dynamic variation, no expressive timing, and no velocity contour. Due to dynamic variation within the Lipatti performance, dynamics in both versions were normalized in order to obtain dynamic uniformity. Average tempo was matched between the two versions. These stimuli can be heard in the supporting information at

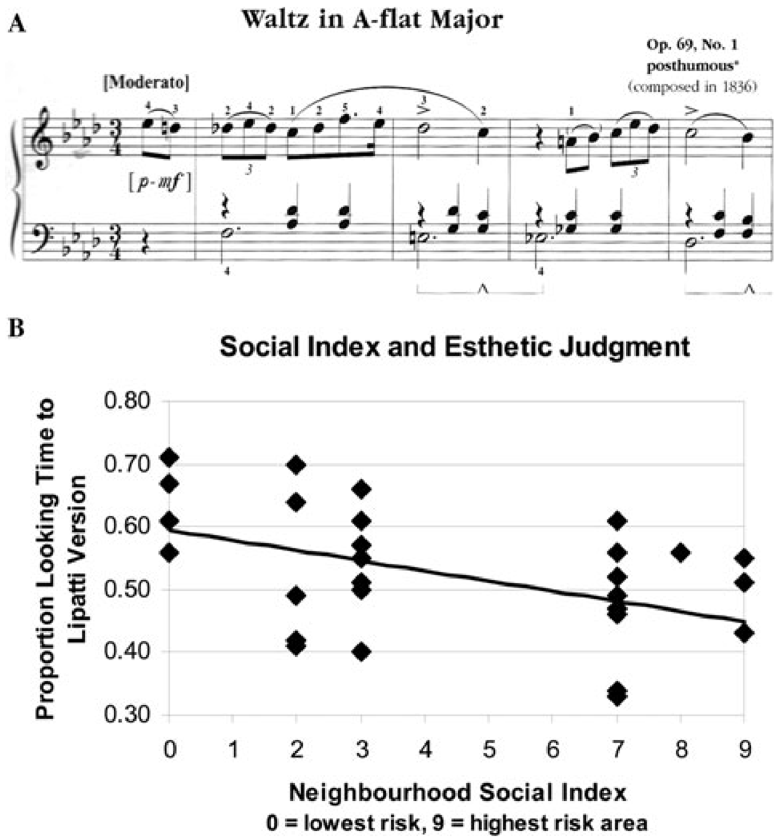

Figure 1. Relationship between esthetic preferences and SES vulnerability. (A) The opening of the Chopin Waltz in A-flat, op. 69, No. 1, from the Romantic period of the Western classical music repertoire. Two versions of the waltz were used, one performed by Dinu Lipatti on acoustic piano and the other synthesized with no dynamic variation and no expressive timing. The two versions can be heard in the supporting information at http://www.psychology.mcmaster.ca/ljt/estheticstimuli.htm. (B) Correlations between SES vulnerability and degree of each individual infant's preference for the Lipatti compared to the synthesized version. SES vulnerability is a composite score based on the area where the infant resides. It can be seen that lower SES vulnerability is associated with greater preference for the Dinu Lipatti version, consistent with greater exposure to acoustic classical music in higher-SES homes.

http://www.psychology.mcmaster.ca/ljt/estheticstimuli.htm.

Infants' preferences for the two versions were tested in the preferential-looking paradigm described in the last section. Each infant completed 20 trials. The sample had 20 infants from the active classes and 14 from the passive classes group. Of these, two infants did not complete the testing due to fussing or crying and two were eliminated as outliers (total looking time more than 2 SD from the mean), leaving a final sample of 20 infants from the active classes and 10 from the passive classes. A t-test with proportion listening time to the Lipatti version (time listening to Lipatti/time listening to Lipatti plus synthesized version) as the dependent measure revealed no significant difference between the groups ($P > 0.55$). Furthermore, a single-group t-test revealed that there was no significant preference for either version (not significantly different from 0.5, representing the expected value for chance performance, $P > 0.30$; mean proportion $= 0.52$, SD $= 0.10$). Thus, no evidence was found for an effect of active versus passive musical experience on esthetic preferences for two highly contrastive versions of a Chopin waltz at 12 months of age. This is perhaps not surprising as neither class type was exposed to expressive exemplars of this type from the Western classical corpus within the classes.

We conducted a further analysis based on SES vulnerability. A neighborhood social index (NSI) is available for the Hamilton, Ontario area.[43,44] It rates each area on nine subscales, with a total score of 0, representing lowest vulnerability, and 9 the highest vulnerability for young children. This score takes into account the percentage of unemployed residents, low-income families, income derived from government transfer payments, residents without high-school diplomas, recent immigrants, residents who do not speak English or French, residents who do not own their own home, resident mobility, and single-parent families (all compared to national averages). From the home address of each participating family, we obtained the SES vulnerability score for each infant. Classifying infants as low or high vulnerability according to the NSI scores resulted in 10/20 infants in the active classes and 4/10 infants in the passive classes being classified as residing in high-vulnerability neighborhoods. Interestingly, NSI scores were negatively correlated with preference for the expressive Lipatti version ($r = –0.48$, $n = 30$, $P = 0.008$; Fig. 1B), and this correlation remained significant for each group separately. Thus, infants from higher-SES neighborhoods tended to prefer the expressive Lipatti version.

While it is difficult to determine causality from correlational data, this result is consistent with higher-SES families exposing infants to more acoustic classical music in their homes compared to lower-SES families. If this interpretation is correct, it indicates that enculturation to esthetic norms of expression in musical performances begins early in development through exposure to exemplars from the musical culture.

Effects of musical enculturation on brain development

Musical training has been shown to affect brain development in preschool children,[36–38] but previous studies have not examined this question in infants. To determine whether participation in the active classes set infants on a different trajectory of brain development compared to participation in the passive classes, we measured EEG while infants listened to a repeating standard piano tone (C_5, 523 Hz) through a speaker (custom-built Westsun Jason Sound, Mississauga, Ontario, Canada) at 70 dB(A) over a noise floor of 29 dB(A) measured at the location of the infant's head. On 10% of repetitions (deviants), the pitch was changed by one semitone ($C\#_5$, 554 Hz), although responses to these trials are not reported (see below). The piano tones were 300 msec in duration with stimulus-onset asynchronies of 400 msec and infants were recorded for up to 20 min, as long as they did not fuss. Recordings were made at 6 months of age at the onset of the music classes and again at 12 months of age, at the end of the classes.

EEG was recorded at a sampling rate of 1,000 Hz from a 124-channel HydroCel GSN net (Electrical Geodesics, Eugene, OR) referenced to the vertex. The impedance of all electrodes was below 50 KΩ during the recording. EEG data were bandpass filtered between 2 and 18 Hz (roll-off = 12 dB/octave) using EEprobe software. The sampling rate was modified to 200 Hz in order to run the Artifact Blocking program in Matlab.[45,46] Recordings were rereferenced off-line using an average reference and then segmented into 500-msec epochs (–100 to 400 msec relative to stimulus onset) to create event-related potential (ERP) waveforms. Standard and deviant trials were averaged separately for each electrode for each infant at each age (6, 12 months). Standard trials immediately following deviant trials were excluded from the average. To increase signal-to-noise ratios, groups of electrodes were averaged together to form 10 scalp regions covering left and right frontal, central, parietal, occipital, and temporal regions (FL, FR, CL, CR, PL, PR, OL, OR, TL, TR), following He *et al.*[47] As the amplitude of the ERPs was almost flat at parietal regions, as expected from the scalp distribution of ERPs in response to sound,[48] these regions (PL and PR) were eliminated from further analysis. Unfortunately, the deviant waveforms were too noisy (there were too few trials) to analyze. The initial sample contained 24 infants who completed testing at both 6 months and 12 months. An additional three infants (two from the active and one from the passive classes) had to be eliminated because their data contained too few trials to analyze and/or their data contained too much movement artifact at one of the test sessions (6, 12 months), leaving a final sample of 14 infants from the active classes group and seven infants from the passive classes group.

As can be seen in Figure 2A, the ERPs to standards were dominated by a large positivity peaking around 175 msec at 6 months and 155 msec at 12 months after stimulus onset. This is consistent

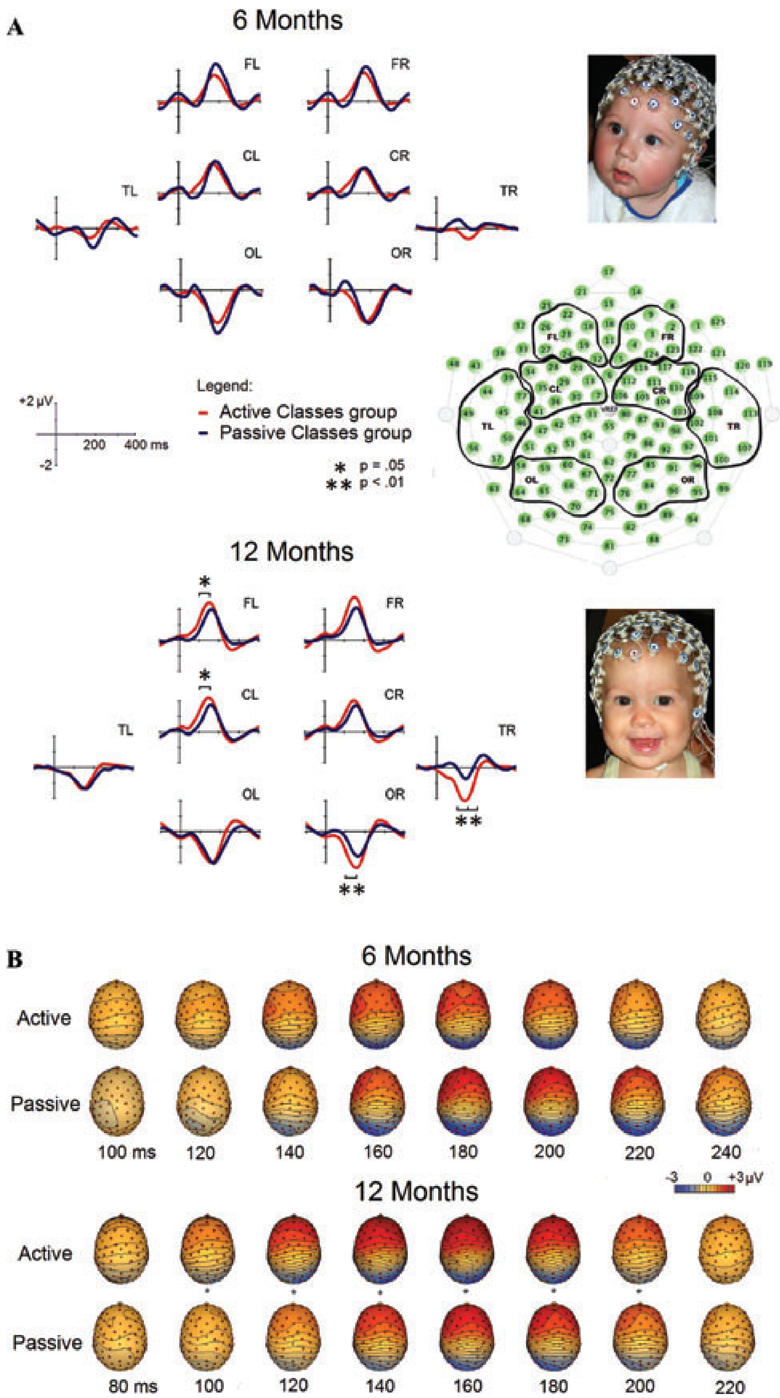

Figure 2. Comparison of ERP responses to a piano tone between infants in the active and passive classes groups. (A) Grand average ERP waveforms to standard piano tones comparing the results for infants in the active and passive classes groups at 6 months (upper) and 12 months (lower) of age. The *y*-axis represents the onset of the piano tone stimulus. Scalp regions at which the two groups differed significantly between 100 and 150 msec and between 150 and 200 msec after stimulus onset are shown. The electrodes included in the eight scalp regions used for analysis (following He *et al.*[47]) are shown to the right, with illustrations of infants in the 124-channel HydroCel GSN nets. (B) Topographic head maps for the active and passive classes groups at 6 and 12 months of age every 20 msec, illustrating the time course of the positivity across age and group.

with the previous ERP reports of infants' responses to piano tones (as reviewed by Trainor[49]). Topographic voltage maps were calculated every 20 msec so that the evolution of the amplitude and the spatial distribution of this component could be seen across age and type of training (Fig. 2B). The precise peak of the positivity was sometimes difficult to measure in individual infants at 6 and 12 months of age. Therefore, in order to analyze the differences between the active classes and passive classes groups, we computed mean amplitudes in two time windows, 100–150 msec and 150–200 msec after stimulus onset for each infant for each age for each region as the dependent measure. Because the number of infants was different in the two groups (14 and 7), the nonparametric Mann–Whitney U-test was used rather than an analysis of variance (ANOVA) approach.

At 6 months of age, before the training, the ERPs elicited by the piano tones were not significantly different between the active and passive classes groups in either the 100–150 msec or 150–200 msec time windows at any region (Fig. 2A). After 6 months of training, when infants were 12 months of age, infants in the active classes group showed a larger positivity between 100 and 150 msec compared to infants in the passive classes group in the left frontal (1.99 μV vs. 1.28 μV; $P = 0.05$) and left central (1.88 μV vs. 1.10 μV; $P = 0.05$) regions, and a larger negativity in the right occipital (–1.87 μV vs. –0.96 μV; $P = 0.007$) and right temporal (–1.85 μV vs. –0.40 μV; $P = 0.001$) regions. Between 150 and 200 msec, infants in the active classes group showed a larger negativity compared to infants in the passive classes group in the right temporal region (–1.46 μV vs. –0.25 μV; $P = 0.006$).

These results revealed no differences between ERP responses to piano tones between the active and passive classes groups before training began, but significantly different responses after 6 months of music classes. Although the latency difference is not possible to examine statistically, the plots in Figure 2 indicate that the large positive component might be both larger and earlier in the active classes group compared to passive classes group after the 6 months of musical training. This difference indicates that tone processing was more advanced for those in the active classes in that responses were faster and/or involved more synchronous neural firing. Because infants were randomly assigned to groups, the differences between the groups can be attributed to differences related to the training they received. Furthermore, although the sample size is relatively small, the fact that there were no differences at 6 months but robust differences at 12 months again suggests that the ERP differences were due to the differences in the music classes that the groups received. Although we cannot determine precisely which aspect of the active musical classes led to advanced brain development for musical processing, good candidates include active participation in music making, involvement of the parent in musical interaction with their infant, modeling of good singing by the teacher, routine and repetition of musical materials, and encouraging infants to attend to the music in a social setting.

Social consequences of musical enculturation

Because making music with other people leads to entrainment, social cooperation, and prosocial behavior in older children and adults,[1–7,9] Gerry *et al.*[41] hypothesized that infants in the active classes might show advanced social development compared to infants in the passive classes. They administered several subscales of the Infant Behavior Questionnaire (IBQ)[50,51] and indeed found that although infants in the active and passive classes showed no significant differences at 6 months of age, at 12 months, after 6 months of classes, those in the active classes showed less distress to limitations, less distress when confronted with novel stimuli, more smiling and laughter, and easier soothability compared to those in the passive classes.

The IBQ is a parent report measure, so it is not clear from these results whether the infants in the two groups were actually different, whether they were perceived to be different by their parents, or both. In a sense, it does not matter which interpretation is correct because it is clear that parents in the active classes developed better social interactions with their infants and rated their infants more positively compared to parents in the passive group. With social interaction, positive feelings on the part of the parent are likely to result in positive interactions with the infant, which likely lead to better outcomes for the infant. Reciprocally, more positive responses from infants likely lead to more positive responses from the parent, which again feed back to better outcomes for the infant. The important result is that the active classes led to more positive parent–infant social interaction compared to the passive classes.

Conclusions

Many different musical systems are used around the world with unique pitch and rhythmic structures, devices for expressive performance, and rules of pragmatic use. Enculturation involves the development of perceptual processing that is specialized for the particular pitch and rhythmic structures of the musical system used in the culture, familiarity with esthetic and expressive norms, and learning what music is used pragmatically in different social situations. Here, we explored the beginnings of some of these processes in Western infants by comparing the effects of 6 months of music classes beginning at 6 months of age that either emphasized active musical participation or passive exposure to synthesized music. The results indicate that active participation leads to earlier enculturation to tonal pitch structure. Furthermore, we found suggestive evidence that exposure to Western classical music leads to earlier sensitivity to esthetic norms for musical expression in this genre. Intriguingly, the social context of the musical experience appears to be crucial, such that infants in the active classes, in which parents and infants participated in active music making together, showed more positive social developmental trajectories compared to infants in the passive classes. Finally, the results indicate that differences between these two groups can also be measured at the brain level, with larger and/or earlier ERP responses to musical sounds in the active classes group compared to passive classes group evident after but not before participation in the classes. Previous studies in older children have indicated that musical lessons are associated with more advanced brain responses,[36–38] but the present study is the first to show effects of musical training on sound processing in the brain during the first year after birth.

In this initial study, there were a number of differences between the active classes and passive classes, so we cannot be sure as to which features of the active classes were most crucial for promoting musical enculturation. The most obvious candidate is active music making in a social context involving infants and parents. Other features of the active classes may have contributed as well, however, such as the use of live, expressive singing as modeled by the teacher and parents, the high degree of repetition that enabled parents to learn the songs and feel comfortable singing them at home with their infants, the more formal class routine that may have directed infants' attention to important features of the music, and the encouragement for parents to observe their infants' behaviors and progress over the course of the classes. In any case, the results clearly indicate that infants can benefit from participatory early musical classes and that musical enculturation begins in early infancy.

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Supporting information

Additional supporting information may be found in the online version of this article:

The stimuli used to test infants' understanding of norms of expression in Western classical music from the Romantic period. Dynamics in both versions below were normalized and average tempo was matched in order to obtain uniformity across the stimuli.

Sound example 1. Chopin's Waltz in A-flat, op. 69, no. 1, as played by Dinu Lipatti, considered to be one of the world's greatest interpreters of Chopin.

Sound example 2. Chopin's Waltz in A-flat, op. 69, no. 1, as synthesized using Cakewalk midi chorus timbre, with no timbral or dynamic variation, no expressive timing, and no velocity contour.

Conflicts of interest

The authors declare no conflicts of interest.

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