BRIEF REPORT

Musical training and language-related brain electrical activity in children

SYLVAIN MORENO and MIREILLE BESSON
Institut de Neurosciences Cognitives de la Méditerranée (INCM)FCNRS, Marseille, France

Abstract
This experiment aimed at testing whether 8 weeks of musical training affect the ability of 8-year-old children to detect pitch changes in language. Twenty non musician children listened to linguistic phrases that ended with prosodic ally congruous words or with weak or strong pitch incongruities. We recorded reaction times, error rates, and event-related brain potentials to the final words. Half of the children followed music training and the other half painting training, and all children were retested following training. For both groups, the weak incongruity was the most difficult to detect, but performance was not significantly different between groups. However, the amplitude of a late positive component was largest to strong incongruities and was reduced after training only in the music group. These results suggest that a relatively short exposure to pitch processing in music exerts some influence on pitch processing in language.

Descriptors:
Children, Musical training, Pitch processing, Language and music, ERPs

We recently tested the hypothesis that musical expertise influences some aspects of language processing such as prosody (Magne, Schon, & Besson, 2006; Scho¨ n, Magne, & Besson, 2004). Prosody can be defined at the phonological level as the pattern of stress and intonation in a spoken language and at the acoustic level by the same parameters that define the melodic aspects of music: pitch or fundamental frequency (F0), intensity, duration, and spectral characteristics. Based on these similarities, we reasoned that improved pitch perception in music, due to Musical training may facilitate pitch perception in language.
Thus, musicians may perceive pitch deviations better than no musicians not only in music but also in language. Short musical and linguistic phrases were auditory presented, and Participants were asked to decide whether the final words/notes were prosodic ally/melodically congruous or weakly or strongly Incongruous. Results with both adults and children showed that when the incongruity was the most difficult to detect (weak incongruity), musicians outperformed no musicians in both the music and the language tasks. We also examined the neural basis and time course of pitch processing using event-related brain potentials (ERPs). ERP analysis revealed interesting differences between adults and children and between music and language (Magne et al., 2006). Most importantly, positive components were elicited by the strong prosodic incongruities in both musician and non musician children, but only in musicians by the weak prosodic incongruity. Based on these results, the specific aim of the present experiment was to determine whether 8 weeks of musical training will allow non musician children to obtain effects similar to those of the musician children described above.

Methods

Participants

This project was conducted in an elementary school in Marseille (‘‘Ecole Gillibert’’) with the agreement of the Academy Inspector, the director of the school, and the teacher of each class. All parents gave informed consent for their children to participate in this project. Children were given presents at the end of each testing session to thank them for their participation and to maintain their motivation. Thirty-four French children with similar socioeconomic background (the French middle class; Laroque, 1968) participated in this project, which lasted for 14 weeks. Eight children served as pilot subjects, and 6 were excluded from final analysis.
Of the remaining 20 children (mean age: 8 years 6 months;
SD50.5), 10 followed music training (5 girls, 7 right-handed) and 10 painting training (4 girls, 8 right-handed). Their global school level, as tested by a general survey initiated by the French

This research was supported by a grant from the Human Frontier Science Program (HSFP #RGP0053) and by a grant from the Ministe` re de la jeunesse, de l’e´ ducation nationale et de la recherche (03 2 443) to Mireille Besson. Sylvain Moreno benefits from a doctoral fellowship from the same Ministry. We thank Mitsuko Aramaki, Monique Chiambretto, CyrilleMagne, Vanina Luigi, Marjorie Geva, and Daniele Scho¨ n for their precious help, the Machin’Art association, in particular Christian Napole´ oni, for their collaboration with the ‘‘musical garden,’’ and all the children who participated in the study. Address reprint requests to: Sylvain Moreno, INCMFCNRS, 31 Chemin Joseph Aiguier, 13402 Marseille, Cedex 20, France. E-mail:sylvain.moreno@incm.cnrs-mrs.fr.
Psychophysiology, 43 (2006), 287–291. Blackwell Publishing Inc. Printed in the USA. Copyright r 2006 Society for Psychophysiological Research
DOI: 10.1111/j.1469-8986.2006.00401.x 287

Ministry of Education for all 8-year-old children, was above average (i.e., mean54 on a 10-point scale; 1 is highest) and not significantly different between groups (Student test: po.74). None of the children, and none of their parents, had specific training in music or painting. Finally, children were from two different classes within the same school (in each group, 6 children came from class A and 4 from class B).

Stimuli

Stimuli comprised 72 French spoken declarative sentences taken from children’s books and ending with bisyllabic words (e.g., Un loup solitaire se faufile entre les troncs de la grande foreˆt; ‘‘A lonely wolf walked his way through the trees of the large forest’’; see Figure 1a). Sentences were spoken at a normal speech rate by a native French female speaker and were recorded in a soundproof room using a digital audiotape (sampling at 44.1 kHz). An equal number of sentences (24) were presented in each of three conditions: the final words were prosodically congruous, weakly incongruous (35% F0 increase), or strongly incongruous (120% F0 increase; see Figure 1a). F0 manipulations were performed using the software WinPitch (Martin, 1996). The mean duration of the sentences was 3.95 s (SD50.65).

Procedure

The experiment comprised three sessions. Session 1. Children were tested individually, in a session that lasted for about 2 h. Because children were only free on Wednesdays or on weekends, the first phase of the project lasted for approximately 3 weeks. The experiment comprised three blocks of 24 trials and began with a practice block. Children were asked to listen attentively, through headphones, to the sentences that were presented in a pseudorandom order and to decide, as quickly and as accurately as possible, by pressing one of two response keys, whether the pronunciation of the last word was normal or strange (i.e., something was wrong). The hand of response was counterbalanced across children.

Training.

Children were assigned either to themusic group or to the painting group, while ensuring that both groups were equivalent. The training period lasted for 8weeks, twice aweek for 40minutes in their school, with teachers specifically trained in music or painting/drawing.[1] Music training was based on a new technology: ‘‘The Musical Garden’’ (Conceptor C. Napoleoni): a 4 _ 4m carpet comprising pads of different colors connected to a computer.When the child walks on the different pads, different sounds are played depending upon the software in use. For this experiment, we only used synthesized sounds of the flute, piano, contrabass, and violin.

Figure 1. a: Examples of the linguistic stimuli and pitch changes used in the experiment. The speech signal is illustrated for the sentence: Un loup solitaire se faufile entre les troncs de la grande foreˆ t (literal translation: ‘‘A lonely wolf worked his way through the trees of the big forest’’). b: Comparison of the ERPs to the strong incongruities in the music and painting groups before (top panel) and after training (bottompanel). Data are presented for three representative electrodes. Time is on the abscissa (in milliseconds) and amplitude is on the ordinate (in microvolts). Negativity is up.

1. The music and painting teachers were specifically hired for this project.

Children were trained to perform finer and finer pitch discrimination by learning the different notes of the scale, themusical intervals, and different types of musical sequences.

The painting group served as a control for general developmental and cognitive stimulation effects. Because children moved from one pad to the other on the ‘‘Musical Garden,’’ it was necessary to control for motor aspects. Thus, children learned painting techniques based on the work of contemporary artists such as Pollock (1912–1956), Hantaı¨ (1922–today), and Rauschenberg (1925–), who used movement for their creations. Children learned how to mix pigments to make colors and to create works of art based on movement.

Session 2. As constraints were similar to Session 1, the third phase of the project also lasted for approximately 3 weeks.

A total of 20 children were again tested individually in a session that lasted for around 2 hours following the same procedure as in test 1.

ERP Recordings

EEG was recorded for 2200ms starting 150ms before stimulus onset, from 28 scalp electrodes, located at standard positions (International 10/20 system sites), and referenced to the left mastoid electrode. Impedances never exceeded 3 kO. The horizontal electrooculogram (EOG) was recorded from electrodes placed 1 cmto the left and right of the external canthi, and the vertical EOG from an electrode beneath the right eye, referenced to the left mastoid. The data were re-referenced offline to the algebraic average of the left and right mastoids. Trials containing ocular or movement artifacts or amplifier saturation were excluded from the analysis (8.2% on average). The EEG and EOGwere amplified by a SA Instrumentation amplifier with a bandpass of 0.01–30 Hz and were digitized at 250 Hz by a PC-compatible microcomputer (Compaq 486).

Data Analysis

RT and ERP were analyzed for correct responses only. Mean amplitude of the ERPs was computed in the 0–200-ms, 200– 700-ms, and 700–1200-ms latency windows. ANOVAs were used for all statistical tests, and p values were adjusted using the Greenhouse–Geisser epsilon correction for nonsphericity. Group (music vs. painting) was used as a between-subjects factor, and Sessions (2) and Congruity (3) as within-subject factors, together with Electrodes (4) for midline analyses and Hemisphere (2), Anterior-Posterior Dimension (3 regions of interest [ROIs]: fronto-central [F3, Fc5, Fc1; F4, Fc6, Fc2], temporal [C3, T3, Cp5; C4, T4, Cp6], and temporo-parietal [Cp1, T5, P3; Cp2, T6, P4]), and Electrodes (3 for each ROI) for lateral analysis. Tukey tests were used for post hoc comparisons. Data processing was conducted with the Brain Vision Analyser software (Version 01/04/2002; Brain Products, Gmbh).

Results

Behavioral Data Reaction times (RTs). Results showed no main effect of Group but significant main effects of Session, F(1,18)56.68, po.05, and Congruity, F(2,36)545.5, po.001. Children were faster after (1101ms) than before training (1178ms). Moreover, RTs were faster to strong (1060 ms) than to weak incongruities (1191ms; po.001) and congruous endings (1170 ms; po.001).

Finally, training shortened RTs to both congruous (before: 1203ms; after: 1136ms, po.05) and weak incongruities (before: 1252ms; after: 1128ms; po.001), but not to strong incongruities (before: 1080 ms; after: 1039ms; po.30; Session _ Congruity interaction: po.05). The Group _ Session _ Congruity was not significant, p4.86. Transformed percentage of errors. Results showed no main effect of Group but significant main effects of Session,
F(1,18)514.92, po.001, and Congruity, F(2,36)593.16, po.001. Children made fewer errors after (12.3%) than before training (19.1%) and to congruous endings (5.4%; po.001) and strong incongruities (2.5%; po.001) than to weak incongruities (39.3%). Finally, only in the weak incongruity condition did children make fewer errors after (32%) than before training (46.4%; po.001; Session _ Congruity interaction: po.01). The Group _ Session _ Congruity was not significant, p4.47.

Electrophysiological Data

No significant effects were found before 200ms. Within the 200–700-ms latency band, results at both midline and lateral electrodes showed a main effect of Congruity, F(2,36)527.74, po.001 and F(2,36)520.65, po.001, respectively: strong incongruities (midline: 9.77 mV and lateral: 6.87 mV) elicited larger positivity than weak incongruities (midline: 3.37 mV and lateral: 0.86 mV; po.001) and congruous endings (midline: 1.53 mVand lateral:_0.39 mV; po.001) that did not differ from each other, p4.60. At midline electrodes, the Congruity _ Electrodes interaction was significant, F(6,108)54.36, po.001, with the largest effects over parietal electrodes. Most importantly, both the Group _ Session _ ROI and the Congruity _ ROI interactions were significant at lateral electrodes, F(2,36)53.90, po.03 and F(4,72)513.63, po.001, respectively, and the Group _ Session _ Congruity _ ROI was almost significant, F(4,72)52.21, po.07.
To further track these interactions, separate ANOVAs were computed for each group. In the painting group, none of the interactions involving the Session and Congruity factors were significant, all p4.37. In contrast, in the music group, results at lateral sites showed that the Session _ Congruity _ ROI interaction was significant, F(4,36)52.87, po.03: strong incongruities elicited less positivity after, compared to before, training over parietal regions, po.002 (see Table 1 and Figure 1b).
None of the main effects or interaction were significant in the 700–1200-ms latency band, all p4.26.

Discussion

Children made significantly more errors to weak incongruities than to strong incongruities and congruous endings. This main effect of Congruity, found for both RTs and error rates, is in line with previous reports (Magne et al., 2006; Scho¨ n et al., 2004). Clearly the weak incongruity was the most difficult to detect. However, RTs were not different for congruous and weak incongruity endings. Taken together, these results seem to indicate that children had difficulties discriminating weak incongruities from congruous endings, and that, whenever they heard weak incongruities or congruous endings, they categorized both as congruous. Such a strategy would explain the high error rate to weak incongruity and the low error rate to congruous endings, together with similar RTs in both cases. Behavioral data also revealed a main effect of Session, with faster RTs and lower error rates after than before training. Musical training and language-related brain electrical activity 289
Clearly, the development of perceptive and cognitive abilities with age (children were around 3 months older in Test 2 than in Test 1) and familiarity effects with both the experimental setup and the sentence materials may explain why both groups performed better after than before training (Schellenberg, 2001).
Finally, and perhaps most importantly, the effects of Congruity and Session were not different across groups. Thus, 8 weeks of musical training with the ''Musical Garden'' were not sufficient for children to detect weak incongruities in language better than children in the painting group. However, before concluding on the lack of training effects with the ''Musical Garden,'' it is interesting to consider the ERP data. In both Sessions 1 and 2, ERPs data showed that strong incongruities elicited larger positivities, with a parietal distribution, than both weak incongruity and congruous endings in both groups of children. Late, parietally distributed positivities have been described in numerous experiments and are generally interpreted as reflecting the processing of surprising and taskrelevant events (for a review, see Donchin & Coles, 1988).
Because the strong incongruity corresponded to a 120% increase in pitch, it was certainly both obvious (all children detected it with high accuracy) and surprising.
Perhaps the most interesting finding of our study is that although strong incongruities elicited similar effects in both groups before training, the decrease in the amplitude of the late positivity was only found in the music group (see Figure 1).
Decreases in the amplitude of late positive components have typically been described when surprising events become less surprising with repetition (Rugg, 1990). Directly related to our findings, Faı¨ ta and Besson (1994) have shown that the repetition of wrong notes (out of the tonality) at the end of musical phrases is associated with a decrease in the amplitude of a late positivity. However, attributing the decrease in positivity found here solely to repetition effects is problematic because such effects would need to be long-lasting (sentences were repeated after an average of 3 months) and present in both groups. Because children in the

music group were specifically trained on pitch, it may be that pitch processing became more automatic (which may not be reflected by RTs or percent errors data because of ceiling effects).
Previous results by Klein, Coles, and Donchin (1984) have also shown that the better the subject's performance in an auditory discrimination task, the smaller the P300 elicited by rare auditory stimuli. Finally, results of several experiments using fMRI have shown that training is often associated with decreased activation (e.g., Tatsuno & Sakai, 2005).
The decrease in the amplitude of the late positivity to strong incongruity with music training was largest over parietal regions (see Figure 1). Although it remains difficult to ascertain the extent to which the ERP effects recorded at the scalp reflect the activity of brain structures directly underneath, it is nevertheless interesting to note that the frontal and temporo-parietal regions have been shown to be activated by both language and music processing. Recent brain imaging studies with children, using fMRI, have shown activations in the superior temporal gyrus and the inferior fronto-lateral cortex when children were asked to decide whether chord sequences ended regularly (tonic chord) or irregularly (Neapolitan chord; Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005) or to decide whether two musical phrases were same or different (Overy et al., 2004). Similar activations have been reported with linguistic stimuli in adults (e.g., De´ monet, Thierry,& Cardebat, 2005). Taken together, these results and the present ones showing that short-term musical training exerts some influence on pitch perception in language indicate that pitch processing may rely upon similar processes in music and speech (Anvari, Trainor, Woodside, & Levy, 2002; Besson & Scho¨ n, 2001). Whether these mechanisms are mainly perceptive or cognitive in nature remains a question for further research.
In conclusion, when pitch detection is easy, as when the change in pitch is large (strong incongruity), music training appears to decrease the amplitude of late positive components to strong incongruities, presumably by facilitating pitch detection and the automation of pitch processing. In contrast, when the pitch detection is difficult (weak incongruity), 8 weeks of musical training are not long enough to influence the pattern of brain waves and of behavioral data. Therefore, it will be important in further experiments to train children over longer periods, as has been done, for instance by Schellenberg (2004; 36 weeks) or Rauscher et al. (1997: 6–8 months).

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.
Besson, M., & Scho¨ n, D. (2001). Comparison between language and music. Annals of the New York Academy of Sciences, 930, 232–259.
De´ monet, J., Thierry, G., & Cardebat, D. (2005). Renewal of the neurophysiology of language: Functional neuroimaging. Physiological Review, 85, 49–95.
Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? Behavioural and Brain Sciences, 11, 355–372.
Fai¨ ta, F., & Besson, M. (1994). Electrophysiological index of musical expectancy: Is there a repetition effect on the event-related potentials associated with musical incongruities? In Proceedings of the Third International Conference for Music Perception and Cognition. Lie` ge, Location: Belgium. pp. 144–145.
Klein,M., Coles, M. G. H., & Donchin, E. (1984). People with absolute pitch process tones without producing P300. Science, 223, 1306–1309.
Koelsch, S., Fritz, T., Schulze, K., Alsop, D., & Schlaug, G. (2005).
Adults and children processing music: An fMRI study. NeuroImage, 25, 1068–1076.
Laroque, P. (1968). Les classes sociales. Paris: Presses Universitaires de France.

Table 1. Mean Amplitudes (in Microvolts) in the Three Experimental Conditions before and after Training

200–700 ms Parietal

	Strong		Weak		Congruous	
	Before	After	Before	After	Before	After
Music	14.5	9	6	5.8	0.8	4.5
Painting	13.5	13.3	4.4	5.3	0.9	2

Magne, C., Schon, D., & Besson, M. (2006). Musician children detect pitch violations in bothmusic and language better than non-musician children: Behavioral and electrophysiological approaches. Journal of Cognitive Neurosciences, 18, 199–211.
Martin, P. (1996). WinPitch: Un logiciel d'analyse temps re´ el de la fre´ quence fondamentale fonctionnant sous Windows In. Booktitle: Actes des XXIV Journe´es d'E´tude sur la Parole, 224–227.
Overy, K., Norton, A., Cronin, K., Gaab, N., Alsop, D., Winner, E., et al. (2004). After one year of musical training, young children show a left-hemispheric shift for melody processing. Neuroimage, 22, S53.
Rauscher, F. H., Shaw, G. L., Levine, L. J., Wright, E. L., Dennis, W. R., & Newcomb, R. (1997). Music training causes long-term enhancement of pre-school children's spatial–temporal reasoning. Neurological Research, 19, 2–8.
Rugg, M. D. (1990). Event-related brain potentials dissociate repetition effects of high- and low-frequency words. Memory and Cognition, 18, 367–379.
Schellenberg, E.G. (2001). Music and non-musical abilities. Annals of the New York Academy of Sciences, 930, 355–371.
Schellenberg, E. G. (2004). Music lessons enhance IQ. Psychological Science, 15, 511–514.
Scho¨ n,D.,Magne,C.,&Besson,M. (2004).Themusic of speech:Music facilitates pitch processing in language. Psychophysiology, 41, 341–349.
Tatsuno, Y., & Sakai, K. L. (2005). Language-related activations in the left prefrontal regions are differentially modulated by age, proficiency, and task demands. Journal of Neurosciences, 25, 1637–1644.
(Received October 6, 2005; Accepted March 16, 2006)