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Musical Aptitude and Foreign Language Learning Skills: Neural and Behavioural Evidence about Their Connections

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ABSTRACT

Perceiving music and language seems to depend upon subtle and accurate auditory processing skills. Could music and language also share common neural resources? Possible interaction between music and speech memory systems has not been ruled out. On the contrary, there is increasing evidence pointing out the accuracy at perceiving phonetic contrasts in native or foreign language of subjects with musical aptitude or musical training. The main focus of this study was to examine the relationship between musical aptitude and linguistic abilities, especially in terms of second language pronunciation skills. We examined 10-12-year-old elementary school children's ability to preattentively process musical features in music and speech stimuli. Sound processing accuracy was examined by means of event-related potential (ERP) recordings and behavioural measures. Those children with superior performance in foreign language production and musicality tests seem to show more pronounced sound-change-evoked activation in response to the music stimuli than subjects with less accurate linguistic skills. Our study provides further evidence for the claim that musical aptitude and linguistic skills are interconnected.

I. INTRODUCTION

Recent studies have provided preliminary evidence of the benefits of musical training on language processing (Schön et al. 2004, Magne et al. 2006, Moreno & Besson 2006, Slevc & Miyake 2006, Anvari et al. 2002). Since musical aptitude is associated with superior auditory discrimination of acoustic features, musicality may facilitate the learning of foreign language skills. Although it seems that musical aptitude has a facilitating effect in processing language (Milovanov 2004; Gilleece 2006), relatively little is known about the possible interaction between musical aptitude and second language learning.

Several studies show that subjects with musical aptitude have strong neural responses to musical sounds (Lang et al. 1990 for Seashore Pitch task; Tervaniemi et al. 1997 for Karma test; Schneider et al. 2002 and Seppänen et al. 2007 for Advanced Measures of Musical Audition, AMMA). Event-related potential (ERP) recordings can be used as an objective method in order to evaluate neural musical sound representations. In ERP recordings, electric potentials are measured on the scalp surface, and they are used to detect the activity of the brain. The method is noninvasive, painless and gives very accurate temporal information of the functioning of the auditory cortex.

Mismatch Negativity (MMN) is an ERP component. It can be used as an indicator of preattentive auditory processing skills, for instance, the ability to track changes in a continuous flow of auditory stimuli, such as pitch or duration. MMN offers a direct measure for the similarity of neural sound representations, without being contaminated by differences, for instance, in the attentional or motivational involvement of the subject (see e.g., Kujala et al., 2006).

II. THE AIMS OF THE STUDY

The relationship between musical aptitude and linguistic abilities, especially in terms of second language pronunciation skills, was examined. Taking into account the structural similarities between music and language, the hypothesis was that the participants with good foreign language pronunciation skills would represent musical sound features, namely pitch and duration, more readily in the attentive and preattentive levels of neurocognitive processing compared with those participants with less-advanced pronunciation skills.

III. METHOD

A. Participants

40 right-handed 10-12-year-old Finnish elementary school children formed two separate groups, an advanced pronunciation group and a less-advanced pronunciation group, based on English pronunciation test. The participants were asked to repeat 30 words containing such English phonemes that have no direct equivalents in Finnish after a native English speaker's model. The participants' repetitions were recored onto a tape. To ensure that all the children had an adequate amount of pretraining in pronunciation of English, they received an 8-week course of pronunciation training in English, including phonemic discrimination exercises. The cognitive capacity of the subjects was tested by WISC-III. The analysis of variance (ANOVA) confirmed that there were no significant group effects between the test groups in linguistic intelligence ($p>0.05$) or general intelligence ($p>0.05$). The performance IQ was better with children with advanced pronunciation skills [$F(1,38)= 8.12$, $p<0.05$]. All the participants had intact hearing and the musical background of the two test groups did not differ (see Milovanov et al., 2008).

B. Musical aptitude test

The Seashore musicality test was here chosen for this study since it is a valid and functional musical aptitude test with the longest traditions and is still commonly used. Importantly, it has percentile equivalents of raw scores for each subtest for

different age groups. The test measures the accuracy and threshold of auditory discrimination (Seashore et al. 1960; 2003). The test consists of Pitch, Loudness, Rhythm, Time, Timbre and Tonal memory tasks.

The original audio files, recorded from the Seashore LP record, were corrupted with both impulsive and broadband background noise. Due to the annoyance produced by the corrupted audio material, noise reduction via digital signal processing techniques was conducted in order to improve the test quality. First, audio de-clicking was applied: the algorithm based on autoregressive (AR) models presented by Esquef et al., (2000) was employed. The second step was audio de-hissing: the de-clicked signal was submitted to a standard Short-Time Spectral Attenuation (STSA) technique (Boll, 1979; Wolfe & Godsill, 2003; Hicks & Reid, 1996). Finally, a standard noise gate processing (Moorer & Berger, 1986; Hicks & Reid, 1996) was employed as a means to filter out the residual noise present in the intervals between the tone bursts. This procedure improved the Seashore test quality significantly.

C. Behavioural tests

The participants' ability to recognize difficult English phonemes for Finns was tested by means of a minimal pair listening discrimination test (i.e., words that differ only in one phoneme (thin-Finn-Finn). Moreover, exactly the same triads used in the first ERP-recording were implemented in a minimal pair listening discrimination test in order to see how the participants could behaviourally distinguish musical stimuli. Both tests were conducted twice, before and after the pronunciation course (see Milovanov et al., 2008 for full description of the behavioural tests).

D. ERP tests

Two ERP studies were carried out at the Centre for Cognitive Neuroscience laboratories, University of Turku. First, the accuracy of the auditory cortex in representing musical sounds [C-major triad, assigned here a name (C), and its two mistuned modifications ($C^{2\%}$) and ($C^{4\%}$)] was examined by means of ERP recordings in the MMN paradigm. In the mistuned stimuli, the major third was either 2% (one third semitone) or 4% (two thirds of a semitone) flat (Milovanov et al., 2008).

In the second ERP study, the neural encoding processes of the Finnish vowel /ö/ and musical stimuli (C4 violin tones) durations (standard 250ms, deviant 150ms) were investigated (Milovanov et al., in revision).

IV. RESULTS

Children with good linguistic skills had significantly better musical skills (72%) as measured by the Seashore musicality test than children with less accurate linguistic skills (54%). Individual Seashore subtests indicated that the participants with advanced pronunciation skills were superior to the participants with less-advanced pronunciation skills in pitch discrimination ability, timbre, sense of rhythm, and sense of tonality. The results in time or loudness subtests did not differ significantly between groups (Figure 1).

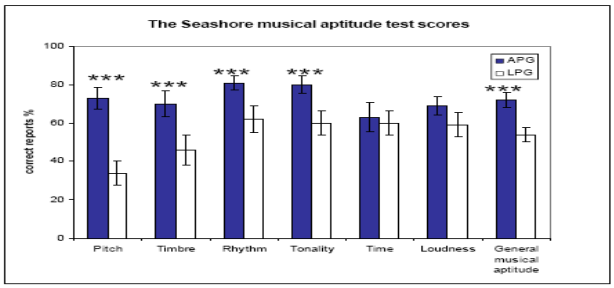

Figure 1. Percentage of correct reports (mean and SEM) from Seashore musical aptitude test. Significant mean differences between APG (= advanced pronunciation group) and LPG (=less-advanced pronunciation group) are shown by * with a significance level of p < 0.001 (figure after Milovanov et al., 2008).**

The participants performed the phonemic and chord discrimination test before and after the 8-week training period. The results of the phonemic and triad tests of the advanced pronunciation group did not differ significantly before or after the training. Nevertheless, the advanced pronunciation group outperformed the participants with less-advanced pronunciation skills in terms of a higher amount of correct answers and a smaller amount of mistakes in both music and phonemic discrimination tests. For the less-advanced pronunciation group, triad contrasts were more difficult than the phonemic contrasts both before and after the training. Both test groups marginally improved their phonemic discrimination skills after the training. Interestingly, the training period did not only develop the participants' linguistic skills but also strengthened the discrimination skills of musical sounds, especially in the participants with advanced pronunciation skills (Figure 2.) The results for the Seashore test and minimal pair discrimination tests are reported in detail in Milovanov et al., 2008.

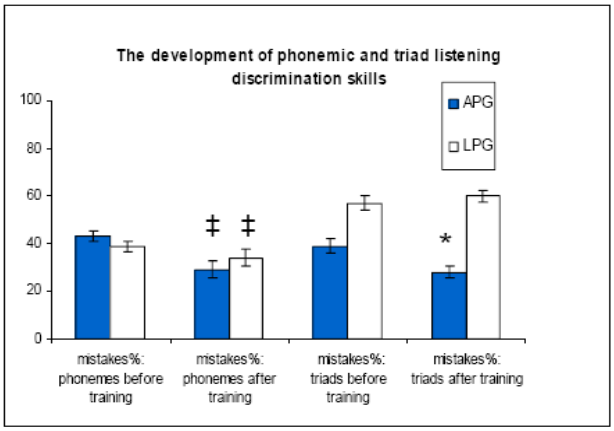

Figure 2. Percentage of errors (mean and SEM) from the phonemic and triad discrimination tests before and after the pronunciation training. Significant mean differences between (APG = advanced pronunciation group, LPG =less-advanced pronunciation group). A significant change between before and after training is marked by *(p<0.05). Additionally ‡denotes p <0.1 (figure after Milovanov et al., 2008).

The first ERP data accompany the results of the behavioural tests: children with good linguistic skills showed more pronounced sound-change-evoked activation with the triad stimuli than children with less accurate linguistic skills, especially when the mistuned stimuli was two thirds of a semitone flat (Figure 3). In addition to this, the advanced pronunciation group showed larger fronto-central MMN with the same C4% triad condition than the participants with less accurate pronunciation skills (Milovanov et al., 2008). The MMN lateralization pattern did not differ between the test conditions nor the test groups.

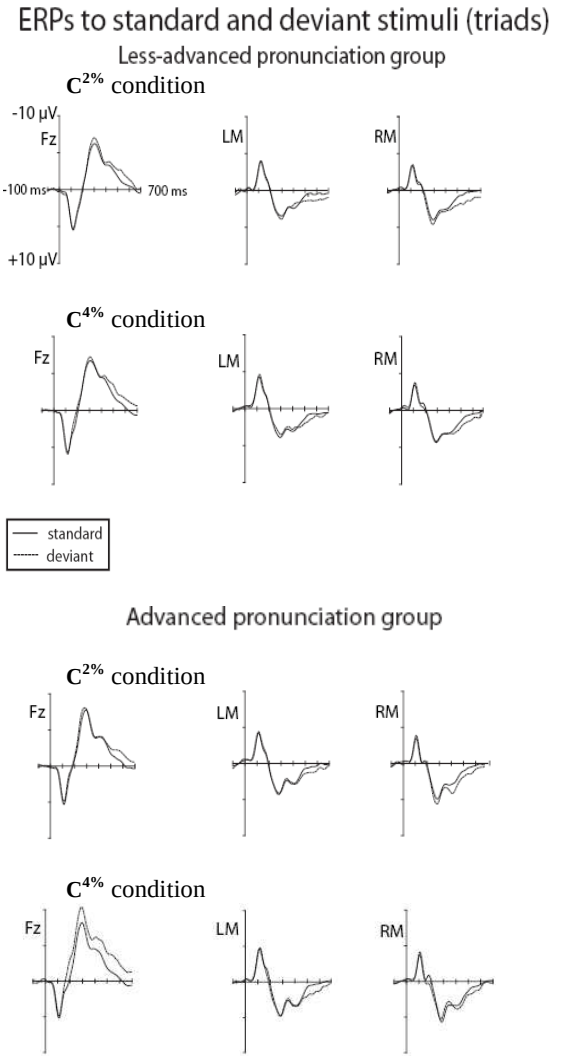

Figure 3. The standard (solid line) and deviant (dashed line) ERPs for both ($C^{2\%}$) and ($C^{4\%}$) conditions from the Fz, LM (left mastoid) and RM (right mastoid) electrodes (figure after Milovanov et al., 2008).

The second ERP study indicated that duration changes in musical sounds were more prominently and accurately processed than changes in speech sounds with both test groups (Figure 4). Only the advanced pronunciation group showed an MMN lateralization effect. Interestingly, stronger reactions were found in the right hemisphere, against the traditional brain lateralization models (Milovanov et al., in revision).

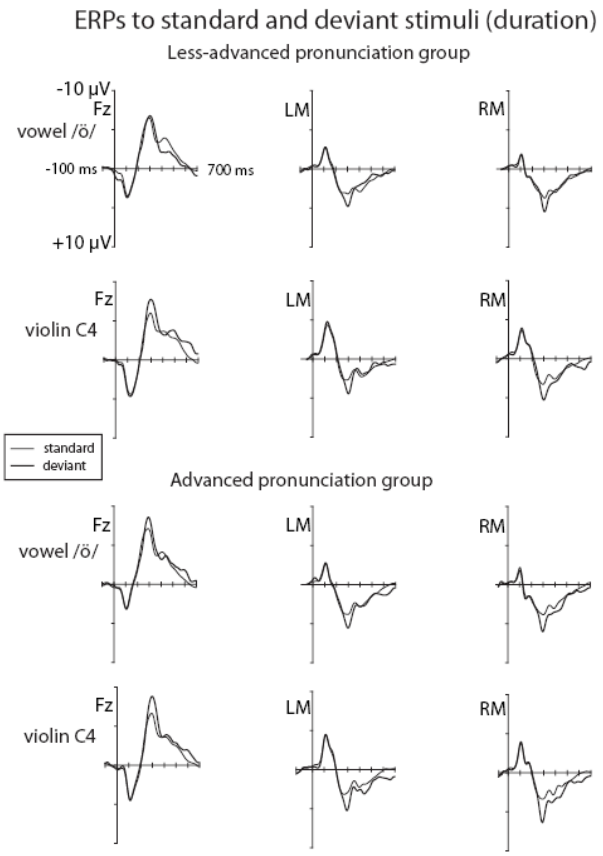

Figure 4. The standard (thin line, 250 ms) and deviant (bold line, 150 ms) ERPs in the vowel condition and violin condition at the Fz, LM (left mastoid) and RM (right mastoid) electrodes in the less-advanced pronunciation group (upper panel) and advanced pronunciation group (bottom panel) (figure after Milovanov et al., in revision).

V. CONCLUSION

The relationship between musical aptitude and linguistic abilities, especially in terms of second language pronunciation skills, was investigated. Moreover, the studies sought to reveal whether children with advanced second language pronunciation skills and higher general musical aptitude differed from children with less-advanced pronunciation skills and less musical aptitude in accuracy when preattentively processing mistuned triads and music / speech sound durations.

The results indicated that the greater the musical aptitude the participant possessed, the better their foreign language pronunciation skills were. The background variables, such as musical activities or performance in WISC-III, did not differ between the test groups. A significant relationship between

musical aptitude, English language pronunciation skills, chord discrimination ability, and sound-change-evoked brain activation in response to musical stimuli (durational differences and triad contrasts) was found.

The participants practised English phonemes by means of pronunciation and minimal pair listening discrimination tasks. Surprisingly, the training period had a positive effect on discriminating musical minimal pairs. This effect was seen especially in those participants with advanced pronunciation skills. The advanced pronunciation group had better results in both behavioural music and phonemic listening discrimination tests than the less-advanced pronunciation group.

Based on the present results, it is proposed that language skills, both in production and discrimination, are interconnected with perceptual musical skills. According to the present results, the general musical aptitude score and the other four independent subtests of the Seashore musical aptitude test (pitch, rhythm, timbre and tonal memory accuracy) resulted in statistically significant group differences in the favour of children with advanced second language pronunciation skills.

The subjects with advanced pronunciation skills and greater musical aptitude were able to preattentively process the duration difference when presented in the vowel and violin sounds more effectively then the less-advanced pronunciation group with less musical aptitude. Moreover, both triad changes evoked significant MMN responses in both participant groups, although without significant amplitude differences between the groups. Nonetheless, those participants with advanced pronunciation skills showed larger fronto-central MMN responses with the C4% triad condition than the participants with less accurate pronunciation skills. The results imply that musical and linguistic skills could partly be based on shared neural mechanisms.

It is proposed that the musical subjects are able to more efficiently process the musical features in both speech and language, both attentively and preattentively. Perhaps those participants with less-advanced pronunciation skills overlooked the musical components of language, while those participants with advanced pronunciation skills had found the key to successful foreign language pronunciation learning by also paying attention to the musical components of speech.

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REFERENCES

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

Boll, S. F. (1979). Suppression of Acoustic Noise in Speech Using Spectral Subtraction. *IEEE Transactions on Acoustics, Speech, and Signal Processing, ASSP-27 (2),* 113-120.

Esquef, P. A. A., Biscainho, L. W. P., Diniz, P. S. R., & Freeland, F. P., 2000. A Double-Threshold-Based Approach to Impulsive Noise Detection in Audio Signals. In *Proceedings of the X European Signal Processing Conference* (pp. 2041-2044), Vol. 4, EURASIP**,** Tampere, Finland.

Gilleece, L. (2006). *An Empirical Investigation of the Association between Musical Aptitude and Foreign Language Aptitude*. Doctoral thesis, Dublin: Trinity College.

Hicks, C., & Reid, G. (1996). *The Evolution of Broadband Noise Reduction Techniques.* The 6th Regional Australian Convention of the Audio Engineering Society, Melbourne, Australia (Preprint 4307).

Kujala, T., Lovio, R., Lepistö, T., Laasonen, M., & Näätänen, R. (2006). Evaluation of multi-attribute auditory discrimination in dyslexia with the mismatch negativity. *Clinical Neurophysiology, 117*, 885-893.

Lang, A.H., Nyrke, T., Ek, M., Aaltonen, O., Raimo I., & Näätänen, R. (1990). Pitch discrimination performance and auditory event-related potentials. In: C.H.M. Brunia, A.W.K. Gaillard, A. Kok, G. Mulder, & M.N. Verbaten (Eds.), *Psychophysiological Brain Research, vol. 1.* (pp. 294–298).:Tilburg, The Netherlands: Tilburg University Press.

Magne, C., Schön, D., & Besson, M. (2006). Musician Children Detect Pitch Violations in Both Music and Language Better than Nonmusician Children: Behavioral and Electrophysiological Approaches. *Neuropsychology, 17*, 439–450.

Milovanov R, Huotilainen M, Esquef P.A.A., Välimäki V. & Tervaniemi M. (in revision). The role of musical aptitude and language skills in preattentive duration processing in school-aged children. *Neuroscience Letters*.

Milovanov,R., Huotilainen, M., Välimäki, V., Esquef, P.A.A., & Tervaniemi, M. (2008). Musical aptitude and second language pronunciation skills in school-aged children: neural and behavioral evidence. *Brain Research, 1194*, 81-89.

Milovanov, R., Tervaniemi, M., & Gustafsson, M. (2004). The Impact of Musical Aptitude in Foreign Language Acquisition. In S.D. Lipscomb, R. Ashley, R.O. Gjerdingen & P. Webster (Eds.), *Proceedings of the 8th International Conference on Music Perception & Cognition (ICMPC8)* (pp. 717-718). Adelaide, Australia: Causal productions.

Moreno, S., & Besson, M. (2006). Musical training and language-related brain electrical activity in children. *Psychophysiology, 43* (3), 287-291.

Moorer, J. A. & Berger, M. (1986). Linear-Phase Bandsplitting: Theory and Applications. *Journal of the Audio Engineering Society 34* (3), 143-152.

Schneider, P., Scherg, M., Dosch, H., Specht, H., Gutschalk, A. & Rupp, A. (2002). Morphology of Heschl's gyrus reflects enhanced activation in the auditory cortex of musicians. *Nature Neuroscience, 5*, 688-694.

Schön, D., Magne, C., & Besson, M. (2004). The music of speech: Music training facilitates pitch processing in both music and language. *Psychophysiology, 41*, 341-349.

Seashore,C.E., Lewis, D., & Saetveit, J.G. Seashore Measures of Musical Talents (1960). Digitally remastered CD version by P. Esquef, Helsinki University of Technology, Finland, 2003.

Seppänen, M.S.A., Brattico, E. & Tervaniemi, M. (2007). Practice strategies in musicians modulate the neural processing and learning of sound-patterns. *Neurobiology of Learning and Memory, 87*, 236- 247.

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

Tervaniemi, M., Ilvonen, T., Karma, K., Alho, K., & Näätänen, R. (1997). The musical brain: brain waves reveal the neurophysiological basis of musicality in human participants. *Neuroscience Letters, 226*, 1-4.

Wolfe, P. J., & Godsill, S. J., (2003). Efficient Alternatives to the Ephraim and Malah Suppression Rule for Audio Signal Enhancement. *EURASIP Journal of Applied Signal Processing - Special Issue on Digital Audio for Multimedia Communications 10*, 1043-1051.