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Practice strategies of musicians modulate neural processing and the learning of sound-patterns

M. Seppänen [a,*], E. Brattico [a,b], M. Tervaniemi [a,b]

[a] *Cognitive Brain Research Unit, Department of Psychology, University of Helsinki, Finland*
[b] *Helsinki Brain Research Centre, Helsinki, Finland*

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Abstract

Previous studies suggest that pre-attentive auditory processing of musicians differs depending on the strategies used in music practicing and performance. This study aimed at systematically revealing whether there are differences in auditory processing between musicians preferring and not-preferring aural strategies such as improvising, playing by ear, and rehearsing by listening to records. Participants were assigned to aural and non-aural groups according to how much they employ aural strategies, as determined by a questionnaire. The change-related mismatch negativity (MMN) component of event-related brain potentials (ERPs) was used to probe pre-attentive neural discrimination of simple sound features and melody-like patterns. Further, the musicians' behavioral accuracy in sound perception was tested with a discrimination task and the AMMA musicality test. The data indicate that practice strategies do not affect musicians' pre-attentive neural discrimination of changes in simple sound features but do modulate the speed of neural discrimination of interval and contour changes within melody-like patterns. Moreover, while the aural and non-aural groups did not differ in their initial neural accuracy for discriminating melody-like patterns, they differed after a focused training session. A correlation between behavioral and neural measures was also obtained. Taken together, these results suggest that auditory processing of musicians who prefer aural practice strategies differs in melodic contour and interval processing and perceptual learning, rather than in simple sound processing, in comparison to musicians preferring other practice strategies.

Keywords: Auditory sensory memory; Auditory discrimination learning; Practice strategies; Musicians; Musicality; Auditory event-related potential; Mismatch negativity (MMN)

1. Introduction

When compared with non-musicians, enhanced auditory processing in musicians is indexed by increased amplitude and/or faster latency of several components of the auditory event-related potentials (ERPs) and magnetic fields, such as the N19m-P30m (Schneider et al., 2002), the electric and magnetic N1 (Pantev et al., 1998; Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Shahin, Bosnyak, Trainor, & Roberts, 2003; but, cf., Lütkenhöner, Seither-Preisler, & Seither, 2006), the electric and magnetic mismatch negativity (MMN) (Koelsch, Schröger, & Tervaniemi, 1999; Brattico, Näätänen, & Tervaniemi, 2001; Rüsseler, Altenmüller, Nager, Kohlmetz, & Münte, 2001; van Zuijen, Sussman, Winkler, Näätänen, & Tervaniemi, 2004; Vuust et al., 2005), the early right anterior negativity (ERAN) (Koelsch, Schmidt, & Kansok, 2002), the N2b (Koelsch et al., 1999; Tervaniemi, Just, Koelsch, Widmann, & Schröger, 2005), the P3a (Jongsma, Desain, & Honing, 2004), P3b (Koelsch et al., 1999; Paller, McCarthy, & Wood, 1992), and the P600 (Besson & Faïta, 1995).

Structural, changes related to music exposure can be seen in the specific brain regions which are involved in musical processing and skills (e.g., Schlaug, Jäncke, Huang, & Steinmetz, 1995; Gaser & Schlaug, 2003; Pantev et al., 2003b). For example, gray matter volume in music-related

* Corresponding author. Fax: +358 9 1912 9450.
E-mail address: miia.seppanen@helsinki.fi (M. Seppänen).

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brain areas was found to correlate positively with professional status in music: While professional musicians had the highest gray matter volume, amateur musicians had intermediate, and non-musicians the lowest gray matter volume in motor, auditory, and visuo-spatial brain regions (Gaser & Schlaug, 2003). In another study, musicians had 102% higher amplitudes and 130% larger gray matter volume of the primary auditory cortex in comparison to non-musicians (Schneider et al., 2002).

Musicians were also found to have enhanced pre-attentive sound processing with temporally and spectrally more complex sounds (and thus music-related) rather than with other kinds of stimuli when compared to non-musicians (e.g., Brattico et al., 2001; Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004; Koelsch et al., 1999). This finding was obtained by measuring the MMN elicited by a changed (or "deviant") tone in a sequence of repeated (or "standard") tones even when subjects are distracted from the sound stimulus (Näätänen, Tervaniemi, Sussman, Paavilainen, & Winkler, 2001). For example, an MMN involving slightly impure chords was elicited only in professional violinists but not in non-musicians (Koelsch et al., 1999). In contrast, no difference between groups was found when stimuli with high frequencies were used. The behavioral importance of detecting mistuning was further evidenced by the N2b and P3b to the mistuned chords during a condition of attentive discrimination and by the superior performance in the behavioral discrimination task by violinists compared with non-musicians.

Commonly, enhanced sound processing in musicians is interpreted as resulting from several years of experience in playing and listening music actively. These findings indicate that long-term memory can enhance even the early pre-attentive processing of sounds in experts when compared to novices. Such interpretation of the role of musical expertise for developing superior neural skills for sound processing is supported by evidence of learning-related changes in the brain that already can be seen functionally as enhanced neural processing in the short time span (for reviews see Pantev, Engelien, Candia, & Elbert, 2003a; Schlaug, 2003). For instance, the functional consequences of practice can be measured in the auditory cortex of non-musicians after frequency discrimination training sessions lasting only few hours or even a few minutes (Brattico, Tervaniemi, & Picton, 2003; Gottselig, Brandeis, Hofer-Tinguely, Borbély, & Achermann, 2004; Menning, Roberts, & Pantev, 2000; Näätänen, Schröger, Karakas, Tervaniemi, & Paavilainen, 1993; Pantev et al., 2003b). This implies that a general learning capacity of the auditory central system in the short-term might not differ between musicians and non-musicians, whereas the observed differences in auditory processing between groups might be caused by the contents and more advanced organization of long-term memory for sounds by musicians. There is, however, preliminary evidence that there are also differences in neural processing during sound discrimination learning among non-musicians. For example, in Näätänen et al. (1993) subjects differed in their neural and behavioral accuracy in detecting tone pattern deviants before training sessions and/or after training.

MMN findings further demonstrate that attention during perceptual learning is needed in acquiring neural abilities of automatic sound processing (Atienza, Cantero, & Dominguez-Marin, 2002; Näätänen et al., 1993; Tervaniemi, Rytkönen, Schröger, Ilmoniemi, & Näätänen, 2001). In addition to attention and given instructions (Näätänen et al., 1993), perceptual learning is also dependent on the difficulty of the to-be-learned stimuli. This was observed in an ERP study in which non-musicians were divided in two groups and trained to discriminate either the high- or the low-frequency patterns containing a pitch change (Gottselig et al., 2004). Deviant low-frequency patterns, easy to discriminate behaviorally, elicited a larger MMN even before discrimination training and were learned more efficiently than the difficult high-frequency deviants (as indexed by the MMN, which was not modulated by training).

In line with these results showing individual differences in perceptual learning, it was also tentatively shown that the learning of sound patterns is affected by the type of musical expertise. Musicians who did not use scores when practicing and playing (for example, jazz musicians, improvisers, and musicians who often played by ear) seemed to be more accurate in detecting contour changes (i.e., the patterns of ups and downs in the pitches of a melody) within randomly transposed melodic patterns after the attentive discrimination task when compared with a group including both musicians who often did use scores and with non-musicians (Tervaniemi et al., 2001). Superior detection was indexed as a higher hit rate in the behavioral discrimination task and as an enhanced MMN, measured under a passive condition following the discrimination training. Neural processing differences related to a particular aspect of musicianship were also found in other studies. For example, musicians have enhanced processing for sounds played with the timbre of their own main instrument (Pantev et al., 2001) and conductors show enhanced attention to spatially located sounds when compared to other musicians (Nager, Kohlmetz, Altenmüller, Rodriguez-Fornells, & Münte, 2003).

Individual differences in neural sound perception and behavioral discrimination skills might also relate to a potential or capacity to learn music, i.e., to musicality. Musicality (or musical aptitude) can be regarded as a physiologically based ability to discriminate changes in sounds or sound patterns. This view is supported by the finding that the individual variation in the ability to discriminate pitch changes between sound patterns in AMMA Tonal test correlated to the gray matter volume of the primary auditory cortex in musicians independently of their level of musical expertise (Schneider et al., 2002). Also there are functional relationships between musicality test score and pre-attentive neural sound processing (Lang et al., 1990; Schneider et al., 2002; Tervaniemi, Ilvonen, Karma, Alho, & Näätänen, 1997). Although not yet confirmed, musicality