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Musicianship facilitates the processing of Western music chords—An ERP and behavioral study

P. Virtala [a,*], M. Huotilainen [a,b], E. Partanen [a], M. Tervaniemi [a]

[a] Cognitive Brain Research Unit, Cognitive Science, Institute of Behavioural Sciences, University of Helsinki, P.O. Box 9, Helsinki 00014, Finland
[b] Finnish Institute of Occupational Health, Helsinki, Finland

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ABSTRACT

The present study addressed the effects of musicianship on neural and behavioral discrimination of Western music chords. In abstract oddball paradigms, minor chords and inverted major chords were presented in the context of major chords to musician and non-musician participants in a passive listening task (with EEG recordings) and in an active discrimination task. Both sinusoidal sounds and harmonically rich piano sounds were used. Musicians outperformed non-musicians in the discrimination task. Change-related mismatch negativity (MMN) was evoked to minor and inverted major chords in musicians only, and N1 amplitude was larger in musicians than non-musicians. While MMN was absent in non-musicians, both groups showed decreased N1 in response to minor compared to major chords. The results indicate that processing of complex musical stimuli is enhanced in musicians both behaviorally and neurally, but that major–minor chord categorization is present to some extent also in the absence of music training.

1. Introduction

Musicianship is associated with structural and functional differences in the brain when compared with non-musicians (see Münte, Altenmüller, and Jäncke (2002), Herholz and Zatorre (2012), and Moreno and Bidelman (2014)). According to evidence currently available, these differences can be attributed to the extensive training and not, for example, to innate differences between musicians and non-musicians. This evidence includes follow-up studies of children who begin instrument training (Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006; Hyde et al., 2009; Putkinen, Tervaniemi, Saarikivi, Ojala, & Huotilainen, 2014; Schlaug, Norton, Overy, & Winner, 2005), studies of non-musician adults demonstrating short-term training effects (Lappe, Herholz, Trainor, & Pantev, 2008; Draganova, Wollbrink, Schulz, Okamoto, & Pantev, 2009), and studies showing that in musicians, the extent of brain changes correlates with years of instrument training (Pantev et al., 1998).

In the auditory domain, enhanced gray matter volume and density are seen in the auditory cortices of musicians (Schneider et al., 2002; Sluming et al., 2002; Pantev et al., 1998; Gaser & Schlaug, 2003; Shahin, Bosnyak, Trainor, & Roberts, 2003; James et al., 2014). Together with these structural findings, changes in the auditory event-related potentials (ERPs) of the electroencephalogram (EEG) suggest expanded activation areas, larger number of neurons, greater synchronization, or faster connectivity in the brain of musicians. For example the N1 component that reflects basic auditory processing and is modified by physical stimulus features (Näätänen & Picton, 1987) shows enhanced amplitudes and/or shorter latencies in musicians compared to non-musicians (Pantev et al., 1998; Pantev, Roberts, Schulz, Engelien, & Ross, 2001b; Shahin et al., 2003; Kaganovich et al., 2013). Similarly, the mismatch negativity (MMN), an index of pre-attentive auditory discrimination (Näätänen, Gaillard, & Mäntysalo, 1978; Näätänen, Paavilainen, Rinne, & Alho, 2007), is modified by musicianship (Koelsch, Schröger, & Tervaniemi, 1999; Rüsseler, Altenmüller, Nager, Kohlmetz, & Münte, 2001; van Zuijen, Sussman, Winkler, Näätänen, & Tervaniemi, 2005). Enhanced ERPs are seen in musicians especially when the sounds are complex (Kaganovich et al. (2013); but for contrasting results see Nikjeh, Lister, and Frisch (2009)) or music-related (Pantev et al., 1998, 2001b, 2003; Pantev, Engelien, Candia, & Elbert, 2001a; Koelsch et al., 1999; Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004, 2005).

Despite their central role in Western music, the neural basis of Western music chord processing and the effects of musicianship on it have not been extensively studied (for previous evidence, see Koelsch et al. (1999), Brattico et al. (2009), and Tervaniemi, Sanneman, Nöyränen, Salonen, and Pihko (2011)). The present study is part of a large project established to systematically

* Corresponding author at: University of Helsinki, Institute of Behavioural Sciences, Cognitive Brain Research Unit, P.O. Box 9, FIN-00014 University of Helsinki, Finland. Tel.: +358 40 8446907.
E-mail address: paula.virtala@helsinki.fi (P. Virtala).

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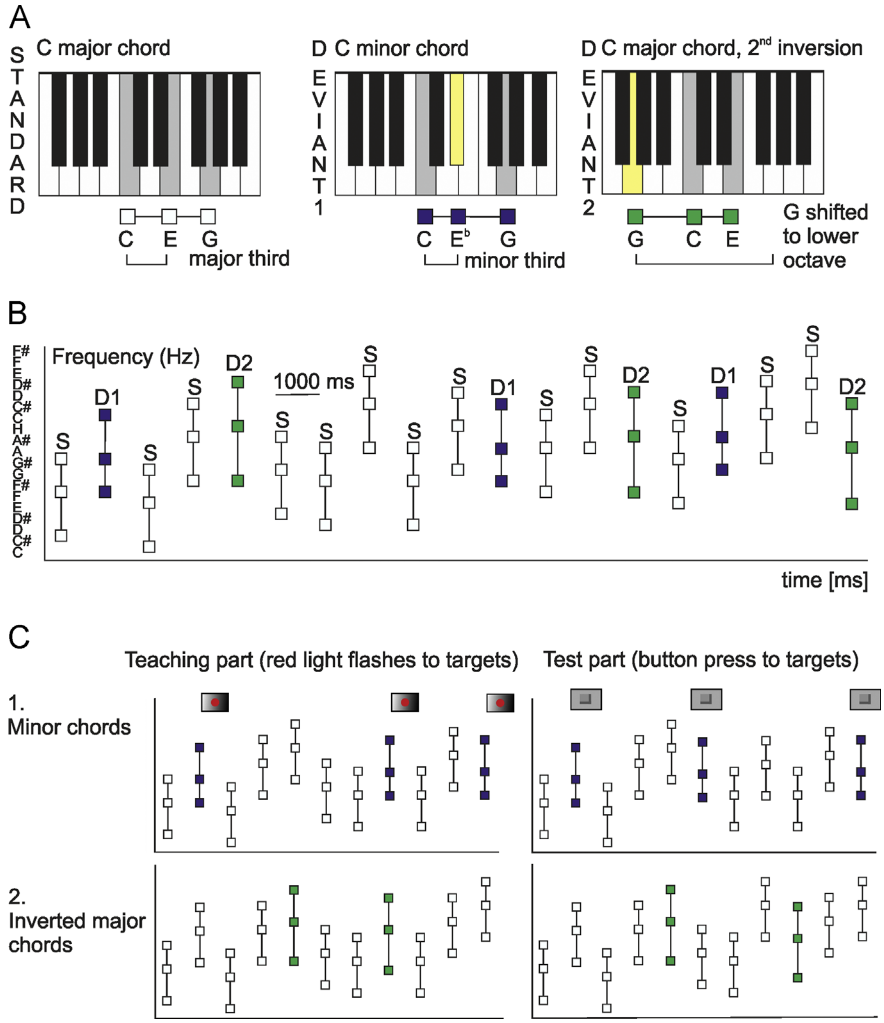

Fig. 1. A. Examples of the experimental stimuli in EEG paradigms and behavioral chord detection task. Chord types and their interval structures are illustrated with C-major (standard, major chord), C-minor (deviant, minor chord) and 2nd inversion of C-major (deviant, 2nd inversion of major chord) on a piano keyboard. B. EEG paradigm with major chords (white) transposed to 12 frequency levels presented as standards and minor chords (blue) and 2nd inversions of major chords (green) both transposed to 3 frequency levels presented as deviants. C. Behavioral chord detection task paradigms with major chords presented as standards and either minor chords or 2nd inversions of major chords presented as deviants.

investigate the effects of musicianship on the auditory cortical processing of Western music chords as reflected by the ERPs in participants at various age groups (adults, adolescents, and newborns; Virtala et al., 2011; Virtala, Huotilainen, Putkinen, Makkonen, & Tervaniemi, 2012, Virtala, Huotilainen, Partanen, Fellman, & Tervaniemi, 2013). The specific aim of the present study in this context was to first, investigate the effect of musical expertise on chord processing and, second, to improve the ecological validity of our paradigm by introducing harmonically rich piano sounds in addition to sinusoidal sounds to the participants. Additionally, for the first time, the behavioral detection of chord types and the relationship of ERPs to behavioral performance were studied.

Interval structure, the mutual relationships between a chord's notes, defines the chord's identity in music, making it for example a major or a minor chord (interval structures of major and minor chords are illustrated in Fig. 1A). Similarly, certain interval structures make the chords sound dissonant or mistuned. There is evidence that short-term training may lead to increased accuracy in behavioral discrimination of chords in non-musicians (Oechslin, Läge, & Vitouch, 2012), suggesting that explicit training can facilitate their processing. Neurally, there is evidence of musicians' superior processing of small frequency changes related to mistuning in chords, as reflected by enhanced MMNs (Koelsch et al., 1999). In a study by Brattico et al. (2009), musicians had larger MMN-responses than non-musicians to dissonant and mistuned chords in the context of A major chords. While MMN was also elicited by A minor chords in the context of A major chords, there was no difference between musicians and non-musicians in its strength, suggesting that even non-musicians are highly capable of major–minor categorization. In contrast, another study showed that MMNs to C minor chords in the context of C major chords were smaller in non-musicians than musicians or musically competent participants (Tervaniemi et al., 2011; for comparable music training effects in children see Putkinen et al., 2014). However, the aforementioned studies introduced single examples of major and minor chords in the paradigm. The obvious frequency differences between them could have elicited the MMNs even in the absence of mode differences (major vs. minor) between the standard and deviant stimuli. Thus, the questions whether non-musicians demonstrate pre-attentive neural discrimination of different chord types in general and major vs. minor chords in particular, and whether this neural discrimination is superior in musicians, were left open by previous work.

These questions were examined in prior work of the authors, together with the introduction of a new well-controlled MMN paradigm (Virtala et al., 2011, 2012, 2013). In the paradigm,