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Research paper

Musicians' edge: A comparison of auditory processing, cognitive abilities and statistical learning

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ABSTRACT

It has been hypothesized that musical expertise is associated with enhanced auditory processing and cognitive abilities. Recent research has examined the relationship between musicians' advantage and implicit statistical learning skills. In the present study, we assessed a variety of auditory processing skills, cognitive processing skills, and statistical learning (auditory and visual forms) in age-matched musicians (N = 17) and non-musicians (N = 18). Musicians had significantly better performance than non-musicians on frequency discrimination, and backward digit span. A key finding was that musicians had better auditory, but not visual, statistical learning than non-musicians. Performance on the statistical learning tasks was not correlated with performance on auditory and cognitive measures. Musicians' superior performance on auditory (but not visual) statistical learning suggests that musical expertise is associated with an enhanced ability to detect statistical regularities in auditory stimuli.

1. Introduction

Music is a quintessential multisensory activity and musical training involves engagement of multiple neural and cognitive resources. Musicians not only engage in auditory training due to many hours of listening and practising but also multimodal training involving reading and translation of complex symbolic notation into motor activity (Schlaug et al., 2005). Though it is difficult to differentiate abilities that prompt individuals to pursue music training from abilities that may result from music training, some cross-sectional studies comparing musicians with non-musician peers have shown that musicians perform better on certain auditory processing tasks (Fine and Moore, 1993; Micheyl et al., 2006; Zendel and Alain, 2012) and tasks of executive function (Bialystok and DePape, 2009; Zuk et al., 2014). In addition, neurophysiological and brain imaging studies have shown differences in the brain structure and function of musicians and non-musicians. For example, professional musicians have larger grey matter volume in primary motor and somatosensory areas, premotor areas, anterior superior parietal areas, and in the inferior temporal gyrus bilaterally (Gaser & Schlaug, 2003). The structural and functional changes associated with musical expertise are in line with an experience-dependent model of neuroplasticity (Münte et al., 2002). In summary, there is widespread interest in the musicians' advantage in various abilities. The current research was designed to explore whether auditory processing, cognitive processing, and implicit learning of statistical regularities – statistical learning – differ as a function of musical expertise.

1.1. Auditory processing and musical expertise

Some of the most widely investigated abilities associated with musical expertise pertain to auditory processing. Auditory processing is an umbrella term including spectral and temporal processing. Additionally, measures of temporal processing may include envelope processing and fine structure processing. The tests used to measure auditory processing include tests of frequency discrimination, discrimination of iterated rippled noise, detection of

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amplitude modulation, detection of gaps in noise, dichotic listening tests, and perception of speech in noise.

When considering the relationship between musical expertise and auditory processing, two issues come into play. First, as far as we are aware, no previous study has compared the performance of musicians and non-musicians on auditory processing tasks that address both spectral and temporal processing abilities. Second, the extent to which musical expertise is associated with superior performance on auditory processing tasks remains a controversial issue. On one hand, research has consistently shown that musicians have better frequency discrimination than non-musicians (Kishon-Rabin et al., 2001; Micheyl et al., 2006). On the other hand, contradictory evidence exists for musicians' superior auditory skills for gap detection (Ishii et al., 2006; Rammsayer and Altenmüller, 2006; Zendel and Alain, 2012), perception of speech in noise (Parbery-Clark et al., 2009; Ruggles et al., 2014), dichotic listening tests (Nelson et al., 2003; Špajdel et al., 2007), and other temporal processing skills (Iliadou et al., 2014; Ishii et al., 2006). Given these inconsistencies in the literature, we incorporated a comprehensive battery of auditory processing tasks in the current study.

1.2. Cognitive abilities and musical expertise

Musical expertise might be associated with some aspects of cognitive processing. For instance, it has been reported that adults and children who have undertaken music training have better working memory as measured through digit span and non-word span (Lee et al., 2007). Better performance on executive function measures such as verbal fluency, design fluency and backwards digit span for musicians has also been reported (Zuk et al., 2014). Still, there have been some ambivalent results as to whether or not musical expertise is associated with enhanced cognitive abilities. Using a large battery of tasks assessing cognitive skills such as verbal comprehension, word fluency, mental rotation, closure, perceptual speed, reasoning, and verbal memory, Brandler and Rammsayer (2003) found significant group differences in only two tasks – verbal memory and reasoning. Similar results were reported in another study where musicians were found to have better performance in only two out of the thirteen primary cognitive abilities tested – flexibility of closure and perceptual speed (Helmbold et al., 2005). Additionally, it is unclear whether enhancements are seen only in the auditory modality, such as in auditory attention tasks (Strait and Kraus, 2011), or also in the visual modality, such as divided visual attention tasks (Rodrigues et al., 2007). Given these gaps in the literature, we incorporated a battery of cognitive processing tasks in the current study including a task that assessed both visual and auditory attention.

1.3. Statistical learning and musical expertise

A growing area of interest is musicians' ability to learn statistical regularities implicitly, known as statistical learning (SL). SL was described in a seminal study by Saffran et al. (1996). They showed that participants are able to extract statistical regularities from a continuous stream of individually presented stimuli using information about transitional probabilities. SL has been shown in auditory (aSL) and visual (vSL) modalities. It is thought that SL ability may contribute to key mental activities including musical appreciation, object recognition, and language acquisition (Arciuli and von Koss Torkildsen, 2012; Rohrmeier and Rebuschat, 2012).

Similar to language, music is highly structured and listeners are able to extract regularities from music (François and Schön, 2010). Whilst being unaware of the complex patterns of music, it is possible to implicitly acquire musical knowledge and use this implicit knowledge to form expectancies, and extract regularities from continuous events. Heightened sensitivity to these statistical regularities in continuous speech or non-speech streams may be partly explained by the shared and overlapping cortical regions for music and language (OPERA hypothesis; Patel, 2010, 2011). It could also be argued that musical competence, which is acquired through repeated practise and exposure, primes and sharpens musicians' intuition for performing implicit learning tasks (Rohrmeier and Rebuschat, 2012). In addition, musicians have may have enhanced processing of auditory stimuli (for a detailed review see François and Schön, 2014). For these reasons, it is interesting to study SL in musicians.

Using neurophysiological measures such as electroencephalography and magnetoencephalography, musicians have been shown to have enhancements in neurophysiological indices (such as N100 or N400) in auditory tasks involving the extraction of distributional cues (François et al., 2014; François and Schön, 2011; Paraskevopoulos et al., 2012; Schön and François, 2011). To date, only two studies have demonstrated an advantage for adult musicians in aSL using behavioural indices (Shook et al., 2013 using morse code; Skoe et al., 2013 using tone doublets). A report of improved SL in a longitudinal study of 8- year old children learning music as opposed to a control painting group suggests that there may be a causal link between musical training and SL (François et al., 2013). Although musical expertise has been associated with improved skills in the visual domain, such as enhanced recognition of visual patterns, also known as design learning (Jakobson et al., 2008), an investigation of musicians' vSL has not been undertaken previously.

Any demonstrable musicians' advantage in SL raises further questions as to whether such an advantage is accompanied by advantages in auditory processing or other cognitive skills. Though not directly investigated, enhanced statistical learning of morse code in musicians was attributed to enhanced temporal encoding and/or cognitive skills in musicians (Shook et al., 2013). However, as far as we are aware, this has not been investigated empirically. We used an array of auditory processing tasks and cognitive processing tasks as well as measures of both auditory and visual SL to explore these questions.

1.4. The current study

The primary aims of this research were to ascertain whether musicians and non-musicians perform differently on: a) tests of auditory processing, b) tests of cognition, and c) tests of SL (aSL and vSL). We hypothesized that musical expertise would be associated with better performance on at least some of the auditory processing and cognition measures. We also hypothesized that musicians might outperform non-musicians with regard to aSL but we were not sure what to expect with regard to vSL. Moreover, we were unsure whether performance on SL tasks would be related to performance on the auditory and cognitive tasks.

2. Methods

2.1. Participants

Musicians were defined as adults who started to learn/practise music before the age of 9 years and had at least 10 years of music playing/singing experience. This criterion is based on previous studies with similar populations (Ruggles et al., 2014; Strait et al., 2010). All musicians reported that they still actively practised music. Non-musicians had less than 3 years of musical experience. Eighteen musicians (5 males) and 22 non-musicians (5 males) participated in the study. There was no significant difference in the ages of the musicians (Mdn = 28.0) and non-musicians