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Generality and specificity in the effects of musical expertise on perception and cognition

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ABSTRACT

Performing musicians invest thousands of hours becoming experts in a range of perceptual, attentional, and cognitive skills. The duration and intensity of musicians' training – far greater than that of most educational or rehabilitation programs – provides a useful model to test the extent to which skills acquired in one particular context (music) generalize to different domains. Here, we asked whether the instrument-specific and more instrument-general skills acquired during professional violinists' and pianists' training would generalize to superior performance on a wide range of analogous (largely non-musical) skills, when compared to closely matched non-musicians. Violinists and pianists outperformed non-musicians on fine-grained auditory psychophysical measures, but surprisingly did not differ from each other, despite the different demands of their instruments. Musician groups did differ on a tuning system perception task: violinists showed clearest biases towards the tuning system specific to their instrument, suggesting that long-term experience leads to selective perceptual benefits given a training-relevant context. However, we found only weak evidence of group differences in non-musical skills, with musicians differing marginally in one measure of sustained auditory attention, but not significantly on auditory scene analysis or multi-modal sequencing measures. Further, regression analyses showed that this sustained auditory attention metric predicted more variance in one auditory psychophysical measure than did musical expertise. Our findings suggest that specific musical expertise may yield distinct perceptual outcomes within contexts close to the area of training. Generalization of expertise to relevant cognitive domains may be less clear, particularly where the task context is non-musical.

1. Introduction

Perceptual and cognitive skills can be shaped and enhanced through our experience with the world (e.g., Goldstone, 1999; Palmeri & Gauthier, 2004). Pursuit of expertise in a given domain is a particularly striking example: groups as diverse as chess masters, physicians, athletes and musicians spend thousands of hours training and practicing, honing perceptual, cognitive and motor skills critical to success in their field (see Chi, 2006; Ericsson, 2006; Palmeri, Wong, & Gauthier, 2004, for review). Are expert-level perceptual and cognitive skills specific to the trained context? Could these skills also

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transfer to general or abstracted contexts, and might they also interact or influence each other?

Expert musicians are an ideal population for addressing these questions. Professional instrumentalists typically begin training very early in life and follow rigid practice regimens, often totaling 10,000+ h of lifetime practice by early adulthood (e.g., Ericsson, Krampe, & Tesch-Romer, 1993; Krampe & Ericsson, 1996). Critically, instrumentalists are faced with clear perceptual and cognitive demands. They must finely perceive and control their instrument's acoustic signal, sustain attention to their output, reproduce complex and variable sound sequences, and carefully analyze the output of other musicians. Importantly, the perceptual and performance demands faced by particular instrumentalists differ widely – for example, violinists must attend to and adjust intonation during performance, whereas pianists have no such control over intonation. If training demands drive perceptual and broader cognitive outcomes, then differences in these outcomes between particular instrumentalist groups can provide a useful means of accounting for specificity vs. transfer of skills (see Strait & Kraus, 2014). Moreover, the different demands faced by instrumentalist groups provide a testing ground to explore how finely honed auditory perception and top-down skills such as auditory attention might interact. Distinct instrumentalist groups with similar training extents also offer a way to control for differences in self-selection, motivation, or personality that can vary between musicians and non-musicians (see Corrigall, Schellenberg, & Misura, 2013; Herholz & Zatorre, 2012; Schellenberg, 2004).

Indeed, perceptual and cognitive outcomes associated with musical expertise have been studied extensively (see Kraus & Chandrasekaran, 2010; Strait & Kraus, 2011a, for review); yet many studies have examined perceptual and cognitive skills separately, with relatively small and/or heterogeneously trained samples. This is partly due to the difficulties of researching expert musician cohorts (e.g., recruitment, study time constraints, etc.) Few studies have investigated interactions between cognitive and perceptual outcomes relevant to musical training, or assessed predictive relationships between fine perceptual and higher cognitive skills such as attention (but see Parbery-Clark, Skoe, Lam, & Kraus, 2009; Strait, Kraus, Parbery-Clark, & Ashley, 2010). To our knowledge, no single study has examined the effects of expertise with one instrument vs. another on musically-relevant perceptual <u>and</u> cognitive performance; this would facilitate tests of experience-specific perceptual advantages alongside tests of cognitive outcomes that may relate to musical expertise, together with tests of perception–cognition interactions. As we show in a selective review of the extensive literature concerning perceptual and cognitive benefits related to musical expertise, relatively little research has measured both fine perceptual and broader cognitive outcomes in the same expert individuals. Thus, no study yet has explored whether musicians that train on different instruments might show differences in perceptual <u>and</u> cognitive skills that reflect some of the specific constraints of the instrument they play, or indeed whether those perceptual and cognitive skills might interact. The present study therefore aimed to address this gap in understanding (see Section 1.3).

1.1. Musicianship and auditory perception

A considerable body of research suggests that musicians tend to out-perform non-musicians in perceiving fine differences in a number of basic auditory properties, including frequency and/or pitch (Amir, Amir, & Kishon-Rabin, 2003; Kishon-Rabin, Amir, Vexler, & Zaltz, 2001; Koelsch, Schröger, & Tervaniemi, 1999; Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Nikjeh, Lister, & Frisch, 2009; Parbery-Clark, Skoe, Lam, et al., 2009; Spiegel & Watson, 1984), tone interval size (Siegel & Siegel, 1977; Zarate, Ritson, & Poeppel, 2012, 2013), temporal interval size (Cicchini, Arrighi, Cecchetti, Giusti, & Burr, 2012; Ehrlé & Samson, 2005; Rammsayer & Altenmüller, 2006), and timbre (Pitt, 1994). Below, we review evidence for lower-level and contextually-relevant perceptual advantages in differently trained musician cohorts.

1.1.1. Instrument- and musical-genre-specific effects on auditory perception

Expert musicians' fine-grained perceptual abilities may be driven – at least in part – by the demands of the kind of music they perform or the instrument they play. For instance, classically-trained musicians can discriminate finer differences in frequency compared to rock or jazz musicians (Kishon-Rabin et al., 2001; but see Vuust, Brattico, Seppänen, Näätänen, & Tervaniemi, 2012).[1] Percussionists reproduce temporal intervals less variably than string musicians and non-musicians (Cicchini et al., 2012); string musicians match frequency differences less variably than percussionists (Hoffman, Mürbe, Kuhlisch, & Pabst, 1997); and trained vocalists tend to sing pitches less variably than instrumentalists (Nikjeh et al., 2009). Relatedly, electro and magnetoencephalography (EEG & MEG) data indicate enhanced cortical responses in musicians to the timbre of the specific instrument they perform (vs. an instrument they do not), both in adults (Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Shahin, Bosnyak, Trainor, & Roberts, 2003) and children (Shahin, Roberts, Chau, Trainor, & Miller, 2008; Shahin, Roberts, & Trainor, 2004; Trainor, Shahin, & Roberts, 2003). Moreover, string and woodwind players – who constantly monitor and adjust the pitch they are producing – can discriminate frequency differences more finely than musicians who play fixed pitch instruments like piano (Micheyl et al., 2006; Spiegel & Watson, 1984).

Bowed string instruments like violin also differ from fixed-pitch instruments like piano in that string players make extensive use of vibrato – a periodic but non-sinusoidal oscillation in the frequency and amplitude of a given

[1] The difference between fixed and non-fixed pitch instrumentalists' perception of frequency may also have accounted for the genre effects reported by Kishon-Rabin et al. (2001) in that all but one of their 'contemporary' musicians played only fixed-pitch or fretted instruments, while all the 'classical' musicians played wind, brass, or string instruments where adjusting intonation is a crucial aspect of playing (see Micheyl et al., 2006, for discussion).