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Research report

Music training improves speech-in-noise perception: Longitudinal evidence from a community-based music program

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HIGHLIGHTS

- Longitudinal evidence of improved speech-in-noise perception with musical training.
- Random-assignment study assesses group instruction in established music program.
- Speech-in-noise perception improved in low-income, bilingual population.

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ABSTRACT

Music training may strengthen auditory skills that help children not only in musical performance but in everyday communication. Comparisons of musicians and non-musicians across the lifespan have provided some evidence for a "musician advantage" in understanding speech in noise, although reports have been mixed. Controlled longitudinal studies are essential to disentangle effects of training from pre-existing differences, and to determine how much music training is necessary to confer benefits. We followed a cohort of elementary school children for 2 years, assessing their ability to perceive speech in noise before and after musical training. After the initial assessment, participants were randomly assigned to one of two groups: one group began music training right away and completed 2 years of training, while the second group waited a year and then received 1 year of music training. Outcomes provide the first longitudinal evidence that speech-in-noise perception improves after 2 years of group music training. The children were enrolled in an established and successful community-based music program and followed the standard curriculum, therefore these findings provide an important link between laboratory-based research and real-world assessment of the impact of music training on everyday communication skills.

1. Introduction

Everyday communication rarely occurs in ideal conditions: from busy restaurants to noisy classrooms, the human auditory system is constantly faced with the challenge of picking out a meaningful signal from competing inputs. Understanding speech in noise not only presents an everyday communication challenge, it also provides an informative measure of auditory function under limiting conditions, since comprehension in noise requires the successful integration of cognitive, linguistic and sensory processing in response to novel incoming sounds. There is evidence that speech-in-noise perception can be improved with computer-based auditory training [1–3], and cross-sectional studies have indicated that auditory experts, specifically musicians, outperform age-matched peers in this task when matched for factors such as IQ

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and hearing thresholds [4–10], although recent studies attempting to replicate this advantage have reported mixed outcomes [11–13]. Further understanding of how this skill can be improved with training may provide important insights into the malleability of complex auditory processing, as well as informing educators and clinicians interested in the development of communication skills.

The extent to which the specific auditory skills developed through musical experience may transfer to non-musical domains is a matter of continuing debate [14–18], however numerous components of auditory processing that support the perception of speech in noise have been found to be strengthened in musicians, including syllable discrimination [19–21] and the processing of temporal speech cues [22–24], prosody [25], pitch [26–30] and melodic contour [31]. Further, musicians demonstrate enhanced auditory cognitive function such as working memory [32–34] and attention [6,35,36], as well as enhanced neural representation of speech when presented in acoustically-compromised conditions [6,8,9,37–40]. These findings are consistent with the theoretical framework proposed by Patel suggesting that music training promotes adaptive plasticity in speech-processing networks [41].

In the Parbery-Clark et al. (2009) study, which first reported the musician advantage, better speech perception was observed in both multi-talker babble and continuous speech-shaped noise [4]. The advantage in speech-shaped noise was observed specifically in the most challenging condition, where both speech and masker originated from the same source, and not in conditions where the speech and masker were spatially separated. Other studies aimed to differentiate the potential factors contributing to this observed advantage by using speech stimuli that were modified in various ways (e.g. whispered speech to reduce periodic content [12] or sine-wave vocoded speech to simulate perception through a cochlear implant [13]) and presented under a variety of different masking conditions (e.g. maskers varying in informational content [10,11]). Swaminathan et al. [10] replicated the musician advantage with co-located energetic masking, consistent with Parbery-Clark et al., and further identified that when the masker was intelligible, musicians showed a greater spatial release from masking than non-musicians [10]. Fuller et al. found that musicians outperformed non-musicians in one out of the eight masking conditions that were assessed, specifically the most challenging condition [13]. Zendel et al. found that French-speaking musicians performed better on a words-in-noise task than non-musicians, again in the most difficult listening condition, and this performance advantage was associated with more resilient cortical responses in noise [9]. However, neither Ruggles et al. (2014) nor Boebinger et al. (2015) replicated a musician advantage under any of their masking conditions [11,12], although Ruggles and colleagues observed a significant correlation between years of musical practice and performance on the same clinical measures of speech-in-noise perception that were assessed in the original study (i.e. HINT and QuickSIN).

There are a number of differences in methodology and participant characteristics that may have contributed to divergent outcomes. While all of the recent studies adopted similar musicianship inclusion criteria, there were some differences in average age of onset of training, which was lowest in the Parbery-Clark et al. [4] study (mean = 4.68 years). The Boebinger et al. (2015) study included participants across a much wider age range and did not perform audiometric screening, which raises concern about the possibility of noise exposure and undiagnosed hearing loss within the sample, especially within the musician group (e.g. several participants were reported to play drums).

The mixed outcomes highlight that the influence of musical expertise on speech perception in noise may vary according to the characteristics of the speech and masker, as well as the presentation conditions. Ruggles et al. (2014) is the only study that used the same speech-in-noise perception measures as the original Parbery-Clark et al. [4] study (i.e. HINT and QuickSIN), however Ruggles and colleagues administered the HINT (sentences in speech-shaped noise) with headphones (diotic), whereas Parbery-Clark et al. presented the test in sound field (binaural). Although the target and masker were co-located, musicians may still have gained a greater benefit in this more difficult condition by using binaural cues to improve the perception of acoustic details.

There have been divergent interpretations regarding the importance of cognitive vs. sensory factors: Interestingly, Ruggles et al. reported no significant correlation between speech-in-noise perception and IQ, and Parbery-Clark et al.'s outcomes were observed despite the lack of group differences in IQ, however Boebinger et al. reported that speech-in-noise performance is significantly predicted by non-verbal IQ. Fuller et al. [13] suggest that musician benefits are "mainly due to better processing of low-level acoustic cues" and not cognitive factors, while Boebinger et al. emphasize the importance of considering general cognitive abilities, given the relationship with IQ in their data. These mixed experimental outcomes also highlight some of the inherent limitations of cross-sectional comparisons and further demonstrate the importance of longitudinal assessments to determine the impact of musical training on speech-in-noise perception within individual subjects.

Research assessing the impact of musical skill on more general aspects of auditory and cognitive processing has also yielded mixed results, for example a recent study did not find any difference between musicians and non-musicians in multi-modal sequencing or auditory scene analysis, and the authors emphasize the importance of task context as a factor that may influence the transfer of musical skills to non-musical domains [18]. The complex processing demands of both speech and music may point to similarities that are important for transfer between these domains. As with spoken language, musical communication relies not only on the ability to detect and process specific acoustic cues, but on the ability to integrate these components into *meaningful* sounds through the engagement of cognitive, sensory and emotional brain circuitry. This integrated neural activation across multiple brain areas may help to explain why musical expertise has been associated with neural and perceptual advantages not only for music but for other forms of communication, such as speech [see 41 for review].

In this study we performed a longitudinal investigation of the effect of group music instruction on performance on a standard clinical measure of speech-in-noise perception. In contrast to previous studies in which music training regimens have been initiated by researchers specifically for the purposes of an experimental study, the present study uses a rigorous scientific approach to assess the impact of an established and successful music program, and therefore takes an important step in bridging the gap between laboratory and real-world application. All study participants received the standard curriculum of musical training provided by Harmony Project, a non-profit organization offering free music education to children in the gang reduction zones of Los Angeles. Harmony Project has provided music education to underserved children in the Los Angeles area for more than 10 years, garnering significant national acclaim as well as impressive musical and academic outcomes. We hypothesized that music training improves the ability to process novel soundscapes and extract meaningful information from competing auditory streams, and that this transfers to non-musical communication contexts. Specifically, we hypothesized that music training engages and strengthens neural circuitry that is important for speech perception, consistent with Patel's theoretical framework [41]. This is supported by cross-sectional evidence of enhanced neural encoding of speech in musically-trained children [21,42,43] as well as a small number of longitudinal studies showing effects of music training on speech processing