Musical experience offsets age-related delays in neural timing

Alexandra Parbery-Clarka,b, Samira Andersona,b, Emily Hittnera, Nina Krausa,b,c,d,e,*

a Auditory Neuroscience Laboratory, Northwestern University, Evanston, IL
b Communication Sciences, Northwestern University, Evanston, IL
c Institute for Neuroscience, Northwestern University Interdepartmental Neuroscience Program, Chicago, IL
d Departments of Neurobiology and Physiology, Northwestern University, Evanston, IL
e Department of Otolaryngology, Northwestern University, Chicago, IL

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Abstract
Aging disrupts neural timing, reducing the nervous system’s ability to precisely encode sound. Given that the neural representation of temporal features is strengthened with musical training in young adults, can musical training offset the negative impact of aging on neural processing? By comparing auditory brainstem timing in younger and older musicians and nonmusicians to a consonant-vowel speech sound /da/, we document a musician’s resilience to age-related delays in neural timing.

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1. Introduction
Along the auditory pathway, neurons respond to sound in a stimulus-synchronized manner, with subcortical structures displaying submillisecond temporal accuracy an order of magnitude greater than other sensory systems (Frisina, 2001; Walton, 2010; Wang, 2007). This subcortical precision is important for capturing fast-changing acoustic transitions, such as those that characterize speech. However, neural precision (Frisina and Walton, 2006) and auditory temporal processing (Grose et al., 2006; Strouse et al. 1998) decline with age, potentially contributing to the problems older adults report for speech comprehension (Frisina, 2010; Gordon-Salant and Fitzgibbons, 1993).

Growing evidence from young adults indicates that musical training improves the neural representation of key acoustic features important for speech perception, highlighting the effects of lifelong training on the brain (Kraus and Chandrasekaran, 2010). Here, we asked whether musical experience offsets the decline in neural precision that occurs during the natural aging process. To address this question, we examined subcortical speech-evoked responses in a group of younger (18–32 years) and older (45–65 years) normal-hearing musicians and nonmusicians. Given their extensive engagement with sound across their lifetimes, we hypothesized that older musicians demonstrate less age-related decline in subcortical temporal precision than older nonmusicians.

2. Methods
2.1. Subjects
Eighty-seven adults participated in this study: 50 younger participants (18–32 years, mean age: 23 ± 4 years) and 37 older participants (46–65 years, mean age 56 ± 5 years). All subjects had normal hearing (see Fig. 1, octave frequencies from 0.125 to 4 kHz bilaterally ± 20 dB HL, pure tone average ± 10 dB HL), were native English speakers, and did not report neurological or learning disorders, history of chemotherapy or ototoxic medication, major surgeries, or head trauma. All subjects had normal nonverbal IQ (younger: Test of Nonverbal Intelligence; older: Abbreviated Wechsler’s Adult Scale of Intelligence’s matrix reasoning subtest). Sub-
3. Results

To investigate neural timing, we identified peaks in the subcortical response generated by synchronous neural firing to the speech syllable [da] (Fig. 2A). Aging differentially delayed the neural response to the formant transition (30–70 ms, 4 peaks), the most complex and information-bearing portion of our stimulus, in musicians relative to nonmusicians [2Age × 2Musicianship multivariate analysis of variance (MANOVA); Interaction: F(1,83) = 2.659, p = 0.039 (Fig. 2E); Age: F(1,83) = 4.642, p = 0.002; Musicianship: F(1,83) = 6.016, p < 0.001]. Although younger and older musicians exhibited equivalent response timing for the formant transition (Fig. 2B) [F(1,83) = 1.434, p = 0.240], older nonmusicians demonstrated significantly later response timing relative to younger nonmusicians [F(1,83) = 4.304, p = 0.006 (Fig. 2C)]. Aging delayed the neural response to the onset (one peak) of sound in both groups.
equally [Interaction: \( F(1,83) = 0.867, p = 0.354 \); Age: \( F(1,83) = 40.045, p < 0.001 \); Musicianship: \( F(1,83) = 5.643, p = 0.02 \) [Fig. 2D]]. Aging did not affect the neural response to the vowel (70–170 ms, 10 peaks) [Interaction: \( F(1,83) = 0.813, p = 0.616 \); Age: \( F(1,83) = 0.757, p = 0.669 \); Musicianship: \( F(1,83) = 1.497, p = 0.158 \) [Fig. 2F]]. The main effect of musicianship observed for the neural response to the onset and the transition was driven solely by group differences in the older participants [Onset: Younger \( (F(1,83) = 1.530, p = 0.222) \); Older \( (F(1,83) = 3.739, p = 0.061) \); Transition: Younger \( (F(1,83) = 1.233, p = 0.311) \); Older: \( (F(1,83) = 6.206, p = 0.001) \)].

4. Discussion

In summary, our results show distinct effects of aging and musicianship on the neural mechanisms responsible for encoding the different components of a stimulus. Specifically, our findings indicate that aging negatively impacts the encoding of noise bursts (i.e. onset) and transient frequency sweeps (i.e. formant transition) but not stable frequency components (i.e. vowel). These outcomes are consistent with the demonstration that stop consonant perception is compromised in older adults, unlike vowel perception, which is minimally affected by age (Ohde and Abou-Khalil, 2001). We also show that although musicians and nonmusicians experience age-related delays in onset timing, the most vulnerable portion of the speech-evoked auditory brainstem response (Anderson et al., 2010; Cunningham et al., 2002), musical experience mitigates the effects of aging on the neural encoding of the formant transition.

That musical experience counteracts age-related delays in subcortical response timing to the formant transition reveals the biologically powerful impact of music on the aging nervous system, raising the question: through which neural mechanisms might musical experience be mediating...
this effect? Inhibitory processes are potential candidates given their critical role in shaping neural response patterns to temporally dynamic sounds like speech (Caspary et al., 2002; Simon et al. 2004). A reduction in inhibitory receptors occurs with age, fundamentally altering synaptic neurochemistry and compromising the nervous system’s ability to represent sound (Caspary et al., 2008). Auditory training in aging rodents bolsters compromised inhibitory processes, essentially reversing age-related deficits (Villers-Sidani et al., 2010). We posit, therefore, that lifelong musical experience is analogous to a long-term auditory training program, in that precise subcortical response timing is sustained through the maintenance of intricately balanced excitatory and inhibitory subcortical neural networks. Although our results speak to the positive effect of musical experience on the aging process, they also hold broader significance: musical experience protects against age-related degradation in neural timing, highlighting the modifiable nature of these declines. These findings should encourage future research into other forms of training that promote neural resilience across the lifespan.

Disclosure statements

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The data contained in this manuscript have not been previously published, have not been submitted elsewhere, and will not be submitted elsewhere while under consideration at Neurobiology of Aging.

The experimental protocol was reviewed and approved by Northwestern University’s Institutional Review Board. All subjects provided written informed consent according to principles set forth by Northwestern University’s Institutional Review Board.

All authors have reviewed the contents of the manuscript being submitted, approve of its contents, and validate the accuracy of the data.

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