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## New evidence of a rhythmic priming effect that enhances grammaticality judgments in children

Alexander Chern<sup>a,b,c,\*</sup>, Barbara Tillmann<sup>d</sup>, Chloe Vaughan<sup>a,e</sup>,  
Reyna L. Gordon<sup>b,c,f,\*</sup>

<sup>a</sup> Vanderbilt University School of Medicine, Nashville, TN 37212, USA

<sup>b</sup> Department of Otolaryngology, Vanderbilt University Medical Center, Nashville, TN 37212, USA

<sup>c</sup> Program for Music, Mind and Society at Vanderbilt, Nashville, TN 37212, USA

<sup>d</sup> Lyon Neuroscience Research Center, 69500 Bron, France

<sup>e</sup> Department of Hearing and Speech Sciences, Vanderbilt University School of Medicine, Nashville, TN 37212, USA

<sup>f</sup> Department of Psychology, Vanderbilt University, Nashville, TN 37212, USA

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### ABSTRACT

Musical rhythm and the grammatical structure of language share a surprising number of characteristics that may be intrinsically related in child development. The current study aimed to understand the potential influence of musical rhythmic priming on subsequent spoken grammar task performance in children with typical development who were native speakers of English. Participants (ages 5–8 years) listened to rhythmically regular and irregular musical sequences (within-participants design) followed by blocks of grammatically correct and incorrect sentences upon which they were asked to perform a grammaticality judgment task. Rhythmically regular musical sequences improved performance in grammaticality judgment compared with rhythmically irregular musical sequences. No such effect of rhythmic priming was found in two nonlinguistic control tasks, suggesting a neural overlap between rhythm processing and mechanisms recruited during grammar processing. These findings build on previous research investigating the effect of rhythmic priming by extending the paradigm to a different language, testing a younger population, and employing nonlanguage control tasks. These findings of an immediate influence of rhythm on grammar *states* (temporarily augmented grammaticality judgment performance) also converge with previous findings of associations between rhythm and grammar *traits* (stable generalized grammar abilities) in children. Taken

\* Corresponding authors at: Department of Otolaryngology, Vanderbilt University Medical Center, Nashville, TN 37212, USA.

E-mail addresses: [alexander.chern@vanderbilt.edu](mailto:alexander.chern@vanderbilt.edu) (A. Chern), [reyna.gordon@vanderbilt.edu](mailto:reyna.gordon@vanderbilt.edu) (R.L. Gordon).

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together, the results of this study provide additional evidence for shared neural processing for language and music and warrant future investigations of potentially beneficial effects of innovative musical material on language processing.

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## Introduction

Framed by a large literature showing associations between language and music skills in children, there is great interest in the possibility that one domain may affect the other via shared neural resources (Kraus & Slater, 2016). Sensitivity to musical features in particular has been hypothesized to be fundamental to early language and grammar acquisition (Brandt, Gebrian, & Slevc, 2012). Grammar, also called morpho-syntax, is the use of rules about how words change their form and combine with other words to make phrases and sentences that enable individuals to communicate with each other. Recent evidence suggests that children with enhanced rhythm perception ability tend to have better spoken grammar skills (Gordon, Shivers, et al., 2015) and children with grammatical deficits tend to have impaired rhythm (Cumming, Wilson, Leong, Colling, & Goswami, 2015). This shared variance could be explained in part by similarities in how rhythm and grammar employ hierarchical structures emerging from rule-based expectancies that unfold over time at multiple levels (Fitch & Martins, 2014) and, more generally, by shared brain mechanisms for temporal attention (Jones & Boltz, 1989), sequencing, and segmentation (Kotz, Schwartz, & Schmidt-Kassow, 2009). Other work has shown that these processes are highly relevant for many aspects of speech and language perception (Falk, Lanzilotti, & Schön, 2017; Grube, Cooper, & Griffiths, 2013), with grammatical task performance at the intersection between timing, rhythm, sequencing, and language (Kotz et al., 2009; Przybylski et al., 2013).

Several studies have explored potential shared neural resources for rhythm/timing and syntactic processing in adults using the event-related potential (ERP) method. For instance, altering temporal intervals between word onsets has shown that regular predictable presentation improves syntactic processing, reflected by an increase of the P600 ERP component (Schmidt-Kassow & Kotz, 2009). Interestingly, prior listening to rhythmically regular musical stimuli restored the (otherwise missing) P600 to grammatical (linguistic) violations in patients with basal ganglia lesions (Kotz, Gunter, & Wonneberger, 2005) and Parkinson's disease (Kotz & Gunter, 2015), thereby suggesting that rhythmic stimulation can improve detection of grammatical violations in subsequently presented sentences.

To evaluate potential benefits of rhythmic listening on subsequent syntactic processing in children with typical development (TD) and their peers struggling with language, Przybylski et al. (2013) tested native French-speaking children (ages 6–11 years) with TD, specific language impairment, and dyslexia. Performance on a grammaticality judgment task improved after listening to a rhythmically regular musical sequence (characterized by its strong metrical structure) compared with a rhythmically irregular (nonmetrical) musical sequence. Converging with data demonstrating relationships between rhythm and grammar traits in children (Gordon, Jacobs, Schuele, & McAuley, 2015; Gordon, Shivers, et al., 2015), these studies show that musical rhythm with a strong beat structure can influence language states (see also Bedoin, Brisseau, Molinier, Roch, & Tillmann, 2016; Bedoin et al., 2017).

This rhythmic priming effect (RPE), the positive influence of rhythmically regular musical stimulation on grammar task performance, has been reported in German (Kotz & Gunter, 2015; Kotz et al., 2005) and French native speakers (Bedoin et al., 2016, 2017; Przybylski et al., 2013), thereby covering the two rhythmic classes of stress-timed and syllable-timed languages (Lehiste, 1977; Lee & Todd, 2004; Arvaniti, 2009). Our aim was to test this RPE in children with TD who speak English (another example of a stress-timed language) given the prior evidence suggesting that RPE may be generalizable broadly across languages that have different isochrony patterns. In addition, work with native English speakers has shown the importance of the 2-Hz syllable rate in infant-directed speech

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