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Relationships between early literacy and nonlinguistic rhythmic processes in kindergarteners

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ABSTRACT

A growing number of studies report links between nonlinguistic rhythmic abilities and certain linguistic abilities, particularly phonological skills. The current study investigated the relationship between nonlinguistic rhythmic processing, phonological abilities, and early literacy abilities in kindergarteners. A distinctive aspect of the current work was the exploration of whether processing of different types of rhythmic patterns is differentially related to kindergarteners' phonological and reading-related abilities. Specifically, we examined the processing of metrical versus non-metrical rhythmic patterns, that is, patterns capable of being subdivided into equal temporal intervals or not (Povel & Essens, 1985). This is an important comparison because most music involves metrical sequences, in which rhythm often has an underlying temporal grid of isochronous units. In contrast, nonmetrical sequences are arguably more typical to speech rhythm, which is temporally structured but does *not* involve an underlying grid of equal temporal units. A rhythm discrimination app with metrical and nonmetrical patterns was administered to 74 kindergarteners in conjunction with cognitive and preliteracy measures. Findings support a relationship among rhythm perception, phonological awareness, and letter-sound knowledge (an essential precursor of reading). A mediation analysis revealed that the association between rhythm perception and letter-sound knowledge is mediated through phonological awareness. Furthermore, metrical perception accounted for unique variance in letter-sound

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knowledge above all other language and cognitive measures. These results point to a unique role for temporal regularity processing in the association between musical rhythm and literacy in young children.

Introduction

In research on cognitive relations between music and language, a topic of long-standing interest is the link between musical abilities (or training) and linguistic processes involved in reading. This issue has been investigated for more than 40 years (e.g., Hurwitz, Wolff, Bortnick, & Kokas, 1975) due in large part to its relevance to real-world issues such as finding new ways to enhance reading development. This is especially relevant for children struggling with language-based deficits such as developmental dyslexia. The significance of this topic for educational practice parallels its theoretical relevance to issues such as the modularity of language, that is, the extent to which the cognitive and neural mechanisms supporting language are domain specific versus shared with other domains such as instrumental (nonverbal) music (Patel, 2008a).

A central question that emerges is how *nonlinguistic* music processing, which uses nonverbal auditory and motor skills, can be related to reading, which involves mapping stored phonological and lexical representations onto visual representations. Several researchers suggest that one link may lie in the temporal processing of sound (e.g., Goswami, 2011; Lehongre, Ramus, Villiermet, Schwartz, & Giraud, 2011, chap. 3; Tallal & Gaab, 2006; Tierney & Kraus, 2013a). Reading acquisition depends heavily on phonological awareness (PA), that is, the ability to segment the seemingly continuous flow of speech into a sequence of perceptually discrete speech sounds, from words and syllables to phonemes. PA underlies the ability to blend phonemes and manipulate segmented speech sounds. These abilities, in turn, draw on auditory processes involved in analyzing the temporal structure of sound patterns. For example, distinctions between phonemes can involve very subtle timing cues (e.g., voice onset time differences between /b/ and /p/), and in some languages (e.g., English) syllable duration patterns are important in cueing stress (Greenberg, 2006), which in turn provides statistical cues to word boundaries (Cutler, 2012). Indeed, relations between linguistic stress sensitivity and reading abilities have been found in several studies (Holliman, Wood, & Sheehy, 2008, 2010; Whalley & Hansen, 2006; Wood, 2006).

Like speech, instrumental music also relies on fine timing distinctions and structured patterns of duration in complex sound sequences that unfold rapidly in time (Patel, 2008b). Thus, even though speech and instrumental music have many salient differences as acoustic patterns (Ding et al., 2017), a growing body of evidence suggests that some of the temporal processing mechanisms humans apply to these domains may be shared (see Kraus & Chandrasekaran, 2010, for one review). This could help to explain why links among musical temporal abilities, PA, and reading in children have been demonstrated in multiple studies (David, Wade-Woolley, Kirby, & Smithrim, 2007; Flaugnacco et al., 2014; Holliman et al., 2010; Whalley & Hansen, 2006). For example, Moritz, Sasha, Papadelis, Thomson, and Wolf (2012) found that the nonlinguistic rhythmic abilities of kindergarteners (their ability to reproduce or discriminate short rhythmic patterns made with bongo drum sounds) predicted their phonological and reading abilities in second grade even when partial correlation was used to control for overall cognitive ability (see also David et al., 2007). In other studies, nonlinguistic rhythmic processing deficits in children with dyslexia were reported, with the severity of these deficits predicting variance in phonological and reading abilities (e.g., Flaugnacco et al., 2014; Goswami, Huss, Mead, Fosker, & Verney, 2013). Importantly, longitudinal studies demonstrated positive impact of rhythmic training on phonological processing and reading both with typically developing children (e.g., Rautenberg, 2015) and with struggling readers (e.g., Bhide, Power, & Goswami, 2013; Flaugnacco et al., 2014). Yet not all studies have found such relations (Anvari, Trainor, Woodside, &