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A cross-cultural comparison of tonal synchrony and pitch imitation in the vocal dialogs of Belgian Flemish-speaking and Mexican Spanish-speaking mother–infant dyads

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ABSTRACT

This study reports a cross-cultural comparison of the vocal pitch patterns of 15 Mexican Spanish-speaking and 15 Belgian Flemish-speaking dyads, recorded during 5 min of free-play in a laboratory setting. Both cultures have a tradition of dyadic face-to-face interaction but differ in language origins (i.e., Romanic versus Germanic). In total, 374 Mexican and 558 Flemish vocal exchanges were identified, analyzed and compared for their incidence of tonal synchrony (harmonic/pentatonic series), non-tonal synchrony (with/without imitations) and pitch and/or interval imitations. The main findings revealed that dyads in both cultures rely on tonal synchrony using similar pitch ratios and timing patterns. However, there were significant differences in the infants' vocal pitch imitation behavior. Additional video-analyzes on the contingency patterns involved in pitch imitation showed a cross-cultural difference in the maternal selective reinforcement of pitch imitation. The results are interpreted with regard to linguistic, developmental and cultural aspects and the 'musilanguage' model.

1. A cross-cultural comparison of tonal synchrony in the vocal dialogs of Belgian Flemish-speaking and Mexican Spanish-speaking mother–infant dyads

The nature of vocal exchanges between adults and infants has been a topic of interest for several decades. Many studies have highlighted specific features of the infant-directed (ID) speech of mothers, revealing a unique and simplified language (Ferguson, 1977) characterized by raised and variable pitch use (Fernald, 1989; Fernald & Simon, 1984; Fernald et al., 1989; Papoušek, Papoušek, & Symmes, 1991) with lengthened vowels and pauses (Albin & Echols, 1996; Fernald & Simon, 1984; Fernald et al., 1989) as well as special "baby words" (Ferguson, 1977). Except for some controversial observations in cultures with a non-Western social structure (e.g., Mayan Yucatec in Gaskins, 1999; Mayans in Pye, 1986; Kaluli/Papua New

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Guinea and Samoan/Pacific Islands in Ochs & Schieffelin, 1984), these typical prosodic properties of ID speech are reportedly widespread in various languages (e.g., Bolinger, 1978; Ferguson, 1978), such as American English (Fernald et al., 1989; Stern, Spieker, Bamett, & MacKain, 1983), British English (Fernald & Morikawa, 1993; Fernald et al., 1989), Japanese (Fernald & Morikawa, 1993; Fernald et al., 1989), German (Fernald & Simon, 1984), Mandarin Chinese (Grieser & Kuhl, 1988), French (Fernald et al., 1989) and Italian (Fernald et al., 1989). However, some small differences have been found as well. For instance, mothers appear to use less raised pitch talk with their infants in British English than in American English (Shute & Wheldall, 1995), in Tai than in Australian English (Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002) and in Japanese than in other American-European languages (Fernald et al., 1989).

In the literature, three functions of ID speech are recurrently mentioned: the obtainment or maintenance of infants' attention (; Fernald & Simon, 1984; Pegg, Werker, & Mac Leod, 1992), the communication of affective information (Fernald, 1989, 1992; Trainor, Caren, Austin, & Desjardins, 2000) and the facilitation of language acquisition (Fernald & Mazzie, 1991). Until the age of 9 months (Newman & Hussain, 2006), infants seem to prefer ID speech over adult-directed (AD) speech (Cooper & Aslin, 1989; Fernald, 1985; Pegg et al., 1992). This preference has also been hypothesized to be universal rather than language or culture specific (e.g., Fernald, 1993; Werker, Pegg, & McLeod, 1994), and an increasing number of studies have suggested that it is not particularly the exaggerated pitch tone that attracts the infant but rather the positive affective melody (Kitamura and Burnham, 1998 in Kitamura et al., 2002; Trainor et al., 2000) or the musical quality (Malloch & Trevarthen, 2008) of the mother's voice.

This growing interest in the musical characteristics of mothers' speech has resulted in a series of acoustic studies that not only focused on ID speech but also examined the vocal co-construction between mothers and infants, highlighting the importance of specific micro-aspects such as pitch (Malloch, 1999/2000; Van Puyvelde et al., 2010), timbre (Malloch, 1999/2000), prosodic contours (Gratier & Devouche, 2011), rhythm (Schögler, 1998) and timing (Gratier, 2003; Malloch, 1999/2000) in the formation of a shared lived experience. These attempts to pinpoint spontaneous proto-musical processes in the interpersonal connection between mothers and infants have revealed new concepts, such as spontaneous musicality (Malloch & Trevarthen, 2008), tonal synchrony (Van Puyvelde et al., 2010, 2013) and shared feelings of belonging (Gratier, 2008). All of these studies have in common that they highlighted specific proto-musical micro-aspects that are suggested to play a role in the interpersonal world of the early vocal communication between mothers and infants. In one of these studies (Van Puyvelde et al., 2010), it was demonstrated that Belgian mothers and infants in a Flemish-speaking population regularly engage into brief periods of mutual vocalizing during which they adapt their vocal utterances alternately to one another in such a way that their pitches become tonally related or synchronized. Additionally, during tonal synchrony, the authors observed a ubiquity of consonant or simple frequency ratios (i.e., a sound combination that is pleasant to listen to; see below) aligned with the harmonic or pentatonic series. A harmonic series is a natural acoustical phenomenon that refers to the internal mathematical structure of the partial spectral components or so-called harmonics that are present in each pitch of a musical or vocal sound (see Fig. 1). Every single tone that we perceive is actually a complex sound that consists of a fundamental frequency (F0 or harmonic number 1, h1 in Fig. 1) and a series of harmonics (h2-16 in Fig. 1). Together, they blend with the F0/h1, giving the impression of a single tone. The F0/h1 and its octaviations can be considered "the tonal center" of a harmonic series (Van Puyvelde et al., 2010). The other harmonics (h2-16) form fixed mathematical frequency ratios[1] in relation to this tonal center, i.e., 2:1, 5:3, 5:4, 7:4, 9:8, 11:8, 13:8, and 15:8 (see Fig. 1). The simpler the frequency ratio between two tones is, the more consonant these tones are perceived. For example, the 2:1 ratio is the most simple frequency ratio, followed by the 5:3 and 5:4 ratios. These simple frequency ratios are rated by naïve and trained listeners as more pleasant than the more complex frequency ratios of 7:4, 9:8, 11:8, 13:8, and 15:8 (e.g., McDermott, Lehr, & Oxenham, 2010). A pentatonic series is a five-tone series system deduced from the harmonic series and consists of only 3:2 ratios (Meyer, 1956; Van Puyvelde et al., 2010). A pentatonic series thus contains no complex frequency ratios and is cross-culturally perceived as consonant and relaxing (Kennedy, 1994; Sadie, 1980). During tonal synchrony, the pitches of mothers and infants are aligned to those of a harmonic series. Mothers and infants share a tonal center (F0/h1) to which their other uttered pitches are related in the same way that the harmonics are related to their F0/h1, i.e., primarily by consonant or simple frequency ratios and a smaller number of complex frequency ratios (Van Puyvelde et al., 2010) (see Fig. 1).

These pitch ratio principles that characterize the harmonic series are the base of several music systems that are widespread across cultures (Kennedy, 1994; Meyer, 1956; Sadie, 1980; Van Puyvelde et al., 2010) and are therefore considered musical predispositions (Trehub, 2001). Moreover, new research suggested that these preferences or predispositions are not unique to humans and may be biologically defined (Doolittle, Gingrasb, Endresc, & Fitch, 2014). Doolittle et al. showed that the pitches produced during a song of the hermit thrush (*Catharus guttatus*) are also related by simple frequency ratio intervals derived from the harmonic series. The authors (Doolittle et al.) concluded that certain aspects of human music scales—and, thus, early human vocal communication—may be partially based on shared biological principles. Further research into tonal synchrony is consistent with this idea, showing that tonal synchrony is related to mother–infant social-affective (Van Puyvelde et al., 2013) and physiological (Van Puyvelde et al., 2014) co-regulation. Moreover, these findings suggest that early vocal communication between mothers and infants is embedded in a multimodal communication system that serves

[1] When considering ≥2 tones, their pitches are related by a frequency ratio. For instance, the frequency ratio of two tones with a pitch of 220 and 440 Hz is 2:1 or the doubling.