LINGUISTIC EXPERIENCE AND UNIVERSAL DESIGN OF THE AUDITORY SYSTEM IN SPEECH RHYTHM PERCEPTION: IMPLICATIONS FOR SPEECH EVOLUTION

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1. Abstract

The existing literature is consistent with two plausible and reasonable hypotheses: Either (a) linguistic experience (primarily, one's native language) shapes rhythm processing, or (b) prosody in general (and rhythmic structures in particular) in natural languages is shaped by the general design of the auditory system, cognitive mechanisms, and neural physiology. On the one hand, rhythm perception is essential for speech processing and for language acquisition in infancy (Langus et al., 2018). Rhythmic patterns differ between languages (Gervain et al., 2008; Ramus & Mehler, 1999; White & Mattys, 2007) and thus individauls may differ in their experience with different rhythms. Non-native (Polyanskaya et al., 2017; Tajima et al., 1997) or pathological (Kent et al., 1989) rhythm affects speech accentedness and comprehensibility. These observations suggest that rhythmic patterns in speech might be processed via the phonological filter of the native language. In the other hand, rhythm perception relies on a fundamental design of mammalian auditory system (Gitza, 2011; Greenberg & Ainsworth, 2004; Hickok et al., 2015; Howard & Poeppel, 2012) that underlies rhythm discrimination by animals (Tincoff et al., 2005; Toro et al., 2003) and pre-linguistic babies (Nazzi & Ramus, 2003; Ramus et al., 1999). This mechanism is not unique to humans and is shared by all people irrespective of their native language. We performed multiple experiments to

pit these two hypotheses, both logically coherent and plausible according to prior empirical evidence, against one another.

We asked participants to listen to two continuous acoustic sequences and to determine whether their rhythms were the same or different (AX discrimination). Participants were native speakers of four languages with different rhythmic properties (Spanish and French – regular rhythm; English and German – irregular rhythm), to understand whether the predominant rhythmic patterns of a native language affect sensitivity, bias and reaction time (RT) in detecting rhythmic changes in linguistic (Experiment 2) and in non-linguistic (Experiments 1 and 2) acoustic sequences. We examined sensitivity and bias measures, as well as RTs. We also computed Bayes factors in order to assess the effect of native language.

All listeners performed better (i.e., responded faster and manifested higher sensitivity and accuracy) when detecting the presence or absence of a rhythm change when the first stimulus in an AX test pair exhibited regular rhythm than when the first stimulus exhibited irregular rhythm. This result pattern was observed both on linguistic and non-linguistic stimuli and was not modulated by the native language of the participant.

We conclude that rhythmic cognition is based on general auditory and cognitive mechanisms and are not modulated by linguistic experience and are shared by all mammals. We suggest that the mechanisms are related to vocal learning, beat induction, and rhythmic entrainment (the ability to coordinate motor output with sensory input). The ability to discriminate rhythmic patterns in not only pre-requisite of speech development in ontogenesis, but also underlied speech emergence in phylogenesis of the homo genera. Irregular rhythmic patterns are marked, in a sense that any communicative system that exhibits irregular rhythm also exhibits regular rhythmic patterns, while there are communicative systems that only exhibit regular rhythms. Also, regular speech rhythms are more typologically common across languages, and the same markedness relations can be applied to speech rhythms.Regular rhythms allow better coupling between the acoustic and neural oscillations and facilitate processing of the auditory input. Thus, switching from regular to irregular rhythm can be explained by expanding the repertoir of meanings to be expressed by prosodic means and facilitate the transition to the referentiality of the signals.

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