NEURAL SIGNATURES OF PROSODIC PROCESSING

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1. Introduction

Generating complex meaning from continuous speech requires the neural mapping of this incoming signal onto syntactic structure. In the evolution of language, prosody might have been integral in facilitating this mapping in the human brain – essentially providing a physical nexus to the abstract (Kreiner & Eviatar, 2014). Support for the possible phylogenetic significance of prosody comes from research on human ontogeny: Infants use a range of prosodic cues to infer different aspects of language in a process called prosodic bootstrapping (Hawthorne & Gerken, 2014). In trying to elucidate this mapping in adults, we refer to cortical oscillations as the biophysical infrastructure that might be suited to enabling the transformation from the physical to the abstract (Ding & Simon, 2014; Giraud & Poeppel, 2012; Meyer, 2018; Murphy, 2020). More precisely, cortical oscillations are hypothesized to synchronize with the speech signal – a process referred to as speech tracking. However, the extent to which this is functionally relevant for continuous speech processing and which prosodic features serve as driving forces is still not fully understood.

2. Methods

We therefore sought to better understand the dynamics of speech tracking and the extent to which it is modulated by prosodic features. To this end, we conducted an EEG experiment with a sample of native Swiss German speakers (N = 26). Participants listened to spoken sentences manipulated in terms of their rhythm and intonation. Roughly the first half of a sentence could either follow a predictable regular or an unpredictable irregular rhythm. The second half then either confirmed these predictions or violated them. Additionally, sentences either had a natural or pitch-flattened intonation contour. To test whether these manipulations were perceptually relevant, sentences were embedded in noise. We expected the quality of speech tracking to be influenced by the prosodic features of speech and this relationship between speech signal and brain signal to predict speech perception. To test these hypotheses, we calculated generalized linear mixed models. Specifically, we assessed the phase-locking value (Lachaux et al., 1999) as an indication of speech tracking and percentage of correctly identified syllables in noise as a perceptual marker.

3. Results

Results showed that the brain is sensitive even to slight variations in rhythmic (ir)regularity. Cortical oscillations in the theta range (3.5–4.7 Hz) were able to track the speech signal more faithfully when the rhythm was regular compared to irregular. However, the predictability of this rhythm did not seem to influence speech tracking: Neither the violation of a predictable rhythm nor the continuation of an unpredictable rhythm caused a reduction in the PLV. In contrast to rhythm, theta oscillations were less sensitive to intonation as evidenced by the equally high PLV values in either intonation condition.

4. Discussion

Continuous speech tracking was differentially influenced by the prosodic features of speech. A regular rhythm — as compared to an irregular rhythm — facilitated the brain’s ability to phase-align with speech in the theta range. These findings are in accordance with studies showing advantages in evoked potentials and perception afforded by rhythmic regularity in auditory stimuli (Abecasis et al., 2005) as well as speech (Bohn et al., 2013; Roncaglia-Denissen et al., 2013). Underlying this facilitation is presumably an evolutionarily rooted connection between the speech motor system, auditory perceptual system, and neural infrastructure (Giraud & Poeppel, 2012; Poeppel & Assaneo, 2020; Strauss & Schwartz, 2017). As such, rhythm may have evolved to take on the role of an endogenous tool, structuring speech input and optimizing sensory processing. Intonation, on the other hand, was not related to differences in speech tracking. Given this non-existent effect, it appears that these two prosodic features and their respective functions are dissociable in and dissociated by the brain and thus might have also had different evolutionary trajectories. Along these lines, intonation may come into play for more strictly high-level linguistic operations such as syntactic parsing or disambiguation (Marslen-Wilson et al., 1992; Selkirk, 2011).

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