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Title:
Interaural Coupling and Synchronization of Two Active Ears

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Abstract:
To a first order, the vertebrate inner ear can be considered active and "self-contained" in that the key elements for auditory transduction are coupled together and mechanically isolated within the bony labyrinth of the inner ear. A salient manifestation is the idiosyncratic nature of human spontaneous otoacoustic emissions (SOAEs), which effectively provide a unique acoustic "fingerprint" for a given ear. Aside from efferent innervation in tetrapods, non-mammalian classes exhibit acoustic interaural coupling (i.e., a contiguous internal airspace between tympanic membranes). Such is believed important in some species for improved azimuthal sound localization (e.g., Christensen-Dalsgaard, 2011) as the coupling allows for the two ears to effectively act as a "pressure difference receiver" (e.g., Fletcher & Thwaites, 1979). Unlike humans, SOAE activity from both ears of a lizard generally exhibit strikingly similar spectral features (e.g., comparable peak frequencies). Furthermore, recent results reporting temporal SOAE correlations between ears for the gecko (Roongthumskul & Hudspeth, 2017) suggest the two active ears mechanically synchronize with one another. We sought to further explore this provocative notion using a two-pronged empirical approach in a lizard model (Anolis carolinensis) that displays robust SOAE activity. First, we attempted to measure SOAE activity via the mouth. The hypothesis was that if acoustic crosstalk occurs between the two ears to drive synchronized SOAE activity, than such should be apparent in the oral cavity (which appears to be connected to the interaural airspace). We were readily able to observe "SOAEs" in the oral cavity, which shared highly similar spectral features with the spectra measured from each ear at the external meatus. Evoked emissions could also be readily detected orally. Second, to better characterize the acoustic pathway for crosstalk between ears, we examined middle ear morphology and the interaural space by means of both gross dissection and microCT. We found a clear airborne pathway between the two ears and with the oral cavity. Preliminary results indicate features of ossicular coupling between the tympanic membrane and oval window that may contribute to how inner-ear-generated sound appears in the interaural/oral space. Taken together, these data support the hypothesis that acoustic coupling can cause the two ears to effectively synchronize biomechanically. This notion may have profound implications for the role of "coupling" between active elements (e.g., determining more precisely the relevant forces acting upon a given hair cell) and functional features such as sound localization in non-mammalian tetrapods.