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Prolonged development of auditory skills: A role for perceptual anchoring?

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ABSTRACT

Many auditory skills continue to develop beyond infancy and even into adolescence, but the factors underlying this prolonged development remain poorly understood. Of interest here is the contribution of on-line statistical learning of stimulus repetitions (anchoring) to the development of auditory spectral and temporal discrimination, as well as the potential contributions of auditory attention and working memory. Children, aged 6–13 years, as well as adults (age range: 21–33 years) were tested on auditory frequency and duration discrimination. Each type of discrimination was measured in two conditions (XAB and XXXAB) designed to afford different levels of anchoring by varying the number of repetitions of a standard stimulus (X) prior to the presentation of the test tone (A or B) in each trial. Auditory attention and working memory were also assessed. Whereas duration and frequency discrimination in either condition did not reach adult level prior to 11 years of age, the magnitude of the anchoring effect was similar across ages. These data suggest that perceptual anchoring matures prior to the attainment of adult-like discrimination thresholds. Likewise, neither attention nor working memory could account for the observed developmental trajectories. That auditory discrimination and anchoring follow dissociable developmental trajectories suggests that different factors might contribute to the development of each. We therefore conclude that although anchoring might be necessary for attaining good auditory discrimination, it does not account for the prolonged development of auditory frequency and duration discrimination in school-aged children.

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1. Introduction

An intriguing facet of human auditory perception is that the performance of many auditory tasks develops along a protracted trajectory. This is so despite the relatively early maturation of the anatomical structures that support auditory sensory processing (i.e., processes associated with the encoding and analysis of acoustic structure; Werner, 2007). One explanation of this apparent discrepancy is that non-sensory factors (e.g., attention, working memory) associated with the performance of the psychophysical tasks – used to estimate conscious perception and that take longer to mature – are responsible for the prolonged developmental trajectories of various auditory skills (Moore, Ferguson, Halliday, & Riley, 2008; Werner, 2007). Despite its obvious appeal, this idea has received little experimental corroboration.

Of interest in the present work is the potential contribution of anchoring, an implicit process that allows individuals to benefit from stimulus repetitions during the performance of psychophysical tasks (Banai & Ahissar, 2006; Banai, Fisher, & Ganot, 2012; Banai & Yifat, 2011; Creelman & Macmillan, 1979; Harris, 1948; Nahum, Daikhin, Lubin, Cohen, & Ahissar, 2010). Specifically, we are interested in the development of auditory frequency and duration discrimination, as previous reports indicate that adult-like discrimination performance is not attained prior to 10 years of age (Elfenbein, Small, & Davis, 1993; Moore, Cowan, Riley, Edmondson-Jones, & Ferguson, 2011) and that non-sensory factors are probably involved in this prolonged development (Moore et al., 2008; Wightman & Allen, 1992).

Frequency discrimination in school-aged children and adolescents has been investigated in several studies (Banai & Ahissar, 2006; Halliday, Taylor, Edmondson-Jones, & Moore, 2008; Jensen & Neff, 1993; Moore et al., 2008, 2011; Sutcliffe & Bishop, 2005; Thompson, Cranford, & Hoyer, 1999). Despite methodological differences across studies, they are consistent in showing that frequency discrimination (a) is far from mature by school entry and continues to develop during the primary school years, perhaps even beyond; (b) varies widely across children within an age group; and (c) strongly depends on the exact nature of the psychophysical paradigm used during testing. Low-level auditory sensory processing seems mature by school entry (Johnson, Nicol, Zecker, & Kraus, 2008; Werner, 2007). A plausible interpretation of those findings, therefore, is that non-sensory factors associated with the assessment procedure, such as attention or working memory, contribute to this prolonged development, since both improve with age (Coch, Sanders, & Neville, 2005; Gomes, Duff, Barnhardt, Barrett, & Ritter, 2007; Lane & Pearson, 1982; Rueda et al., 2004). For example, several groups used indices of performance consistency to quantify the ability of children to sustain attention (Allen, Wightman, Kistler, & Dolan, 1989; Dawes & Bishop, 2008; Moore et al., 2008; Wightman, Allen, Dolan, Kistler, & Jamieson, 1989). Performance variability while executing the psychophysical task was the measure of consistency, with less variable (or more consistent) scores interpreted as an indication of good attention. Although performance consistency during frequency discrimination was found to improve with age (Moore et al., 2008), the attentional demands of the task were not manipulated experimentally. Therefore, it is not clear whether attention indeed drives the development of frequency discrimination or whether both attention and discrimination simply improve with age. As for the development of duration discrimination, to our knowledge this has been investigated in two published studies only (Elfenbein et al., 1993; Jensen & Neff, 1993), both showing development during the primary-school years.

Anchoring is a factor found to strongly influence frequency discrimination in adults (Creelman & Macmillan, 1979; Harris, 1948; Nahum et al., 2010), adolescents (Banai & Ahissar, 2006) and preschool children (Banai & Yifat, 2011), as well as duration discrimination in adults (Banai et al., 2012). Anchoring can be defined operationally as an on-line, implicit statistical learning process that allows listeners to extract simple regularities (e.g., repetitions) from on-going stimulus sequences. Both frequency and duration discrimination are more sensitive when assessed under test paradigms in which a consistent reference stimulus is repeated throughout testing than in the absence of such a reference because the across-trial repetition of the reference creates a stable anchor. Anchoring has been shown to facilitate performance across perceptual, reading, naming and memory tasks (Banai & Yifat, 2012; Oganian & Ahissar, 2012). It therefore appears that anchoring is a simple and rapid learning process rather than a sensory process. We have shown that anchoring benefitted frequency discrimination even in