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Research report

Accentuate or repeat? Brain signatures of developmental periods in infant word recognition

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ABSTRACT

Language acquisition has long been discussed as an interaction between biological preconditions and environmental input. This general interaction seems particularly salient in lexical acquisition, where infants are already able to detect unknown words in sentences at 7 months of age, guided by phonological and statistical information in the speech input. While this information results from the linguistic structure of a given language, infants also exploit situational information, such as speakers' additional word accentuation and word repetition. The current study investigated the developmental trajectory of infants' sensitivity to these two situational input cues in word recognition. Testing infants at 6, 9, and 12 months of age, we hypothesized that different age groups are differentially sensitive to accentuation and repetition. In a familiarization–test paradigm, event-related brain potentials (ERPs) revealed age-related differences in infants' word recognition as a function of situational input cues: at 6 months infants only recognized previously accentuated words, at 9 months both accentuation and repetition played a role, while at 12 months only repetition was effective. These developmental changes are suggested to result from infants' advancing linguistic experience and parallel auditory cortex maturation. Our data indicate very narrow and specific input-sensitive periods in infant word recognition, with accentuation being effective prior to repetition.

1. Introduction

Language acquisition requires the mapping of relevant sound sequences to potential referents in the environment. For segmenting those sound sequences from the ongoing speech stream that correspond to words, preverbal infants can hardly rely on lexical–semantic knowledge; instead they need to generate lexical candidates bottom-up from acoustic and distributional features of the speech input. To complicate matters further, most infant-directed speech consists of multi-word utterances for which pauses, which are the most salient acoustic cues, do not reliably signal word boundaries (Cutler & Butterfield, 1990; Van de Weijer, 1998). Yet, infants start to detect their first words early during the first year of life, supported by neurobiological preconditions for language learning and environmental input factors.

Infants take their first steps in language learning using brain structures in which the major language-relevant regions are already in place, but the fiber bundles connecting these regions are not yet fully mature (Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002; Perani et al., 2011; Pujol et al., 2006). At birth, newborns engage their temporal cortex to differentiate

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forward from backward speech (Peña et al., 2003), and prosodic speech from speech without prosody (Perani et al., 2011). As precursors of word segmentation, newborns were shown to involve temporal and left frontal (LF) areas to recognize sound sequences containing immediate repetitions (Gervain, Macagno, Cogoi, Peña, & Mehler, 2008), and to recruit their right frontal (RF) area to support recognition of pseudoword sounds (Benavides-Varela et al., 2011).

Behaviorally, infants have been found to first segment natural speech at the age of 4.5–6 months, detecting highly frequent words, such as *mommy* and their own name, in continuous speech (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Mandel, Jusczyk, & Pisoni, 1995). This early ability is not only facilitated by the word's familiarity, but also its acoustic prominence resulting from the typical use in isolation. In contrast to known words, infants start to segment unknown bisyllabic words at around 7.5 months (Jusczyk & Aslin, 1995; Jusczyk, Houston, & Newsome, 1999; Kooijman, Hagoort, & Cutler, 2005; Polka & Sundara, 2012). When words are not canonically stressed on the first syllable in stress-timed languages, segmentation only occurs at around 10 months of age (Jusczyk et al., 1999; Kooijman, Hagoort, & Cutler, 2009). Thus, particular speech-inherent features, in this case rhythmic-prosodic information, guide infants' speech segmentation (Kooijman et al., 2009; Thiessen & Saffran, 2007). Infants were not only found to utilize native-language-specific speech characteristics (e.g., Friederici & Wessels, 1993; Mattys & Jusczyk, 2001; Thiessen & Saffran, 2007), but also statistical relations and distributional input properties (Saffran, Aslin, & Newport, 1996, Saffran, Newport, & Aslin, 1996).

These different speech-input characteristics supporting speech segmentation seem to follow different developmental trajectories; infants have been shown to use different segmentation strategies across their first year of life (Johnson & Jusczyk, 2001; Johnson & Seidl, 2009; Thiessen & Saffran, 2003). For example, Mattys, Jusczyk, Luce, and Morgan (1999) studied infants' differential weighting of segmentation cues and found an early advantage of rhythmic-prosodic over phonotactic information. The prosodic-bootstrapping account (Gleitman & Wanner, 1982) suggests that prosodic information is one of the first cues used for the perception of language structure (Christophe, Dupoux, Bertoncini, & Mehler, 1994; Jusczyk et al., 1999). Although other segmentation cues become progressively more important along the developmental course, and several cues work in concert by the end of the first year (Christiansen, Allen, & Seidenberg, 1998; Morgan & Saffran, 1995), rhythmic-prosodic information still determines infants' segmentation abilities at 11 months (Johnson & Seidl, 2009).

In addition to these speech-inherent input characteristics that are context-independent, there are situational input characteristics, because speakers adapt their speech style when interacting with infants. Predominantly, adults use enhanced prosodic features in infant-directed speech, as has been demonstrated for mothers and fathers across languages (Fernald et al., 1989). Not only do these situational adjustments serve emotional and communicative functions, but also infants exploit them in acquiring their native language (see Cristia, 2013; Soderstrom, 2007). However, infants' preference for prosodic speech modifications is not uniform across infancy (Hayashi, Tamekawa, & Kiritani, 2001; Newman & Hussain, 2006), and adults' use of particular speech modifications appears to be dependent on infants' age (Kitamura & Burnham, 2003; Stern, Spieker, Barnett, & MacKain, 1983). Thus, studies on both infant perception and the environmental input suggest developmental differences in the role of situational speech-input cues for language acquisition. For lexical acquisition, it has been shown that caregivers naturally apply accentuation of words and repetition when teaching infants new words (Aslin, Woodward, LaMendola, & Bever, 1996; Bernstein Ratner, 1996; Fernald & Mazzie, 1991; Fernald & Morikawa, 1993) and infants utilize speakers' prosodic enhancements to segment speech (Bortfeld & Morgan, 2010; Thiessen, Hill, & Saffran, 2005). However, a systematic evaluation of when during infancy particular situational speech-input cues aid word segmentation and recognition is still missing.

Regarding the underlying neural mechanisms of infant word segmentation, Kooijman et al. (2005) and Kooijman, Junge, Johnson, Hagoort, and Cutler (2013) observed word familiarity effects in the event-related brain potential (ERP) that varied in polarity with infants' age. While at 10 months of age, infants showed a negativity in response to familiar words, as compared to new words; 7-month-olds displayed either a negative or positive familiarity effect in their ERPs. These data suggest a developmental transition from a positive to a negative ERP familiarity effect in infant word segmentation at around 7 months of age, with the latter indicating a more mature process (Kooijman et al., 2005, 2013). The reasoning behind the more mature negative ERP effect is based on the general observation of a positivity–negativity transition with increasing age during infancy, similarly found for auditory discrimination (He, Hotson, & Trainor, 2007; Mueller, Friederici, & Männel, 2012). Furthermore, the fact that infants' negative word recognition response in the ERP, but not the positive response, is related to children's later lexicon (Kooijman et al., 2013), suggests different underlying processes. Thus, the positivity–negativity transition in the ERP markers of infant word segmentation across age most likely follows from infants' advancing linguistic experience and parallel brain plasticity. With respect to infants' linguistic experience, relevant sound sequences that correspond to words may draw infants' attention towards different stimulus features and trigger the formation of phonological, lexical, and semantic representations (see Swingley, 2008). Additionally, the way infants respond to words in fluent speech might be influenced by infants' advancing vocal abilities between 6 and 8 months (Oller, 2000), because infants' production inventory has been shown to shape their word perception (DePaolis, Vihman, & Keren-Portnoy, 2011). Regarding brain plasticity, myelination and neurogenesis of the auditory cortex undergo tremendous changes at around 6 months of age (Moore & Guan, 2001; Moore & Linthicum, 2007), that is, immediately prior to the emergence of infants' positive-going word recognition response. These changes exert a particular influence on the latency and polarity of early sensory-driven ERP components (see Eggermont & Moore, 2012), and may also determine the polarity of infants' word recognition responses.