Cognition 155 (2016) 57–66

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Original Articles

The phonetic landscape in infant consonant perception is an uneven terrain

Youngja Nam, Linda Polka *

School of Communication Sciences and Disorders, McGill University, 2001 McGill College Avenue, 8th Floor, Montreal, Quebec H3A 1G1, Canada
Centre for Research on Brain, Language & Music, 2001 McGill College Avenue, 8th Floor, Montreal, Quebec H3A 1G1, Canada

ARTICLE INFO

Article history:
Received 13 April 2015
Revised 2 June 2016
Accepted 13 June 2016

Keywords:
Infant speech perception
Perceptual bias
Consonants
Natural Referent Vowel framework
Asymmetry

ABSTRACT

Previous research revealing universal biases in infant vowel perception forms the basis of the Natural Referent Vowel (NRV) framework (Polka & Bohn, 2011). To explore the feasibility of extending this framework to consonant manner perception, we investigated perception of the stop vs. fricative consonant contrast /b/-/v/ to test the hypothesis that young infants will display a perceptual bias grounded in the acoustic-phonetic properties of these sounds. We examined perception of stop-initial /bas/ and fricative-initial /vas/ syllables in English-learning and French-learning 5- to 6-month-olds. The /b/ and /v/ sounds distinguish words in English and French but have different distributional patterns; in spoken English /b/ occurs more frequently than /v/ whereas in spoken French /v/ occurs more frequently than /b/. A perceptual bias favoring /b/ over /v/ emerged in two experiments. In Experiment 1, a directional asymmetry was observed in discrimination; infants noticed when /vas/ changed to /bas/ but not when /bas/ changed to /vas/. In Experiment 2, a robust listening preference favoring stop-initial /bas/ was evident in responses from the same infants. This is the first study to show a perceptual bias related to consonant manner and to directly measure a consonant perception bias within the same infants. These data encourage further efforts to extend the NRV principles to perception of consonant manner. These findings indicate that we need to reform our view of infant speech perception to accommodate the fact that both discrimination abilities and biases shape speech perception during infancy.

1. Introduction

Research over several decades shows that young infants are universal perceivers, born with the ability to discriminate virtually any phonetic contrast that languages use (Saffran, Werker, & Werner, 2006). In recent years, there has been increasing evidence that young infants also display some language-universal phonetic biases. These findings enrich our understanding of the infant's initial perceptual capacities. Although infant perception affords access to a detailed phonetic landscape with all or most relevant categories, there appears to be an irregular terrain in which some phonetic categories are more perceptually prominent than others.

Most of the work fueling this enriched view has emerged from research on infant vowel perception. Many studies show that infant discrimination of a vowel change presented in one direction is significantly better compared to when the same change is presented in the reverse direction (for reviews, see Polka & Bohn, 2003, 2011). In young infants, these directional asymmetries are independent of language experience and follow a common pattern – within the traditional vowel space, discrimination is easier when the direction of change is from a central to a more peripheral vowel. Polka and Bohn proposed that these asymmetries arise because infant perception is biased favoring vowels that occupy the most extreme positions in the traditional articulatory/acoustic vowel space (defined by the first and second formant frequencies). There is currently a high level of interest in perceptual asymmetries and increasing evidence that vowel perception is biased at least in the early months of infancy (e.g., Pons, Albareda-Castellot, & Sebastián-Gallés, 2012) and in adult perception of non-native contrasts as well (e.g., Tyler, Best, Faber, & Levitt, 2014).

To integrate and explain these vowel perception findings, Polka and Bohn (2011) proposed the Natural Referent Vowel (NRV) framework. According to NRV, vowel perception asymmetries reflect a universal perceptual bias that is grounded in

* Corresponding author at: School of Communication Sciences and Disorders, McGill University, 2001 McGill College Avenue, 8th Floor, Montreal, Quebec H3A 1G1, Canada.
E-mail addresses: young.nam@mail.mcgill.ca (Y. Nam), Linda.polka@mcgill.ca (L. Polka).

http://dx.doi.org/10.1016/j.cognition.2016.06.005
0010-0277/

acoustic-phonetic properties. When adjacent vowel formants move closer together, energy is focused into a narrower spectral region creating a spectral bump or prominence. This focalization of spectral energy occurs in tandem with changes in vocal tract constriction (in a graded fashion) as you move from the center to the corners of the traditional vowel space. Following Schwartz, Abry, Boë, Ménard, and Vallée (2005), Polka and Bohn (2011) proposed that this formant convergence (or focalization) is the acoustic-phonetic pattern behind vowel perception biases. Thus, vowels that are more focal are *natural referents* due to their salient acoustic and articulatory properties which make them easier to detect and to hold in memory. These properties bias perception and give rise to directional asymmetries in discrimination tasks.

At a broad conceptual level, the NRV should also make predictions for consonants along dimensions with comparable auditory-articulatory properties. No previous work has specifically tested these NRV-based predictions, but several studies document directional asymmetries in consonant perception, which have been explained in diverse ways. For example, Kuhl, Stevens, Hayashi, Deguchi, Kiritani, and Iverson (2006) observed directional asymmetries in discrimination of /r/-/l/ by both English-learning and Japanese-learning infants. These findings point to a language-independent effect given that /r-l/ is a native contrast in English but not in Japanese. The authors suggest that discriminating the /ra/ to /la/ change may be more difficult because the /a/ vowel interferes (via forward masking) with the formant transitions for /la/ more than for /ra/.

Tsuji, Mazuka, Cristia, and Fikkert (2015) reported another consonant discrimination asymmetry that also points to a language-independent effect. Using a habituation paradigm, they tested Dutch-learning and Japanese-learning 4- to 6-month-olds' discrimination of /ompa/ and /onta/; these non-word stimuli contain contrasting native consonants in both languages. Infants habituated to /ompa/ (with labial consonants) noticed the change to /onta/ but infants habituated to /onta/ (with coronal consonants) did not notice the change to /ompa/ (see also Dijkstra & Fikkert, 2011). It is well documented that infants begin to perceptually tune into native consonant categories between 6 and 12 months (e.g., Kuhl, 1992, 1994; Polka & Werker, 1994; Werker & Tees, 1984). Thus, this finding shows that perception of coronal-labial consonant place is asymmetric before attunement to native language phonetics or phonotactics is underway. Even so, early attunement would not explain the asymmetric findings reported by Tsuji et al. (2015) because coronal consonants occur more frequently than labials in Dutch whereas the reverse pattern is found in Japanese.

Finally, Segal, Hejli-Assi, and Kishon-Rabin (2016) observed asymmetric discrimination of the non-native /b-p/ voicing contrast by older (10–12 months) but not younger (4–6 months) infants acquiring Arabic, which has a /b/ category but no /p/ category. The older Arabic infants discriminated a /p/ to /b/ change but not a /b/ to /p/ change; this pattern reveals greater sensitivity to a voicing change in the non-prototypic to prototypic direction compared to the reverse direction, consistent with the Native Language Magnet (NLM) model proposed by Kuhl (1991). No directional effect was evident in younger or older Hebrew-learning infants who experience /b/-/p/ as a native contrast. Thus, these data also suggest an effect of native language attunement. Miller and Eimas (1996) also found directional asymmetries in discrimination of within-category voice onset time (VOT) variants of English stops in English-learning 3- to 4-month-olds. Although these data are also consistent with the NLM model, it is unclear whether this asymmetry reveals a language-specific or language-independent pattern because only English infants were tested.

To summarize, a few prior studies reveal directional asymmetries in infant consonant perception and support different interpretations. Crucially, no previous work has assessed the possibility that asymmetries arise from differences in the perceptual strength of different sound categories. In this study, we firstly extend documented discrimination asymmetries to a new consonant contrast and secondly demonstrate a listening preference for one of the categories. This listening preference shows both that infants can discriminate in such cases, and that the perception field is not level.

To advance this theoretical position, we bring new data to bear on perceptual asymmetries in consonant perception and explore the feasibility of extending the principles of the NRV framework to consonants. As a first step, we focus on infant perception of consonant manner of articulation, specifically the stop-fricative contrast, /b/ vs. /v/. We propose that young infants will display a perceptual bias favoring stop over fricative consonants and that this bias is a natural consequence of acoustic-phonetic patterns generated by stop and fricative consonant production. These predictions are motivated by prior research, which is reviewed below.

Stop consonants are produced by creating a rapid and complete oral closure, which causes a buildup of intra-oral air pressure, followed by an abrupt release of the closure which is accompanied by a brief burst of the maintained air (e.g., Ladefoged, 1993). This rapid closure/release gesture causes a sharp, abrupt shift in signal amplitude, which is a prominent landmark in the speech signal (e.g., Stevens & Keyser, 1989). Fricatives are produced by forcing air through a narrow constriction in the vocal tract causing a turbulent airflow that generates an audible noise. Fricative production also creates a shift in signal amplitude but the shift is smaller and slower than in stop production (e.g., Reetz & Jongman, 2011; Repp, Liberman, Eccardt, & Pesetsky, 1978). Stop consonants are found in all languages and they are strongly favored over fricatives in phonemic inventories across languages of the world (Maddieson, 1984). Stops, being easier to produce, also appear earlier than fricatives and are often substituted for fricatives in early word production, e.g., an English child might say "**b**egetable" for "**v**egetable".

Perception studies conducted with adults reveal directional asymmetries in discrimination of stop-fricative contrasts consistent with the claim that stops are more salient than fricatives. For example, Tsushima, Shiraki, Yoshida, and Sasaki (2003, 2005) observed directional asymmetries in Japanese listeners' discrimination of the non-native English /ba/-/va/ in a variety of AX discrimination tasks. In this work, the /v/ to /b/ direction of change was consistently easier compared to the reverse direction, revealing a bias favoring stop consonant /b/. A similar pattern was reported by Zhang, Imada, Kawakatsu, and Kuhl (2006); their measures of brain activity using magnetoencephalography (MEG) showed that both native English and non-native Japanese listeners were more sensitive to stop /ba/ deviants amidst fricative /va/ stimuli than the other way around. Recently, Nam (2015) examined discrimination of eight stop-fricative contrasts (6 from English; 2 from Persian) by adult native speakers of English, French and Korean. In this research, directional asymmetries were observed for almost every non-native contrast and also for one native stop-fricative contrast. As in prior studies, discrimination was easier in the fricative to stop direction, indicating a stop bias.

Directional asymmetries involving stop-fricative contrasts have not been investigated in infants. However, asymmetries are reported in research exploring early word recognition and word learning abilities in toddlers who are in the 2nd year of life. Altvater-Mackensen and Fikkert (2010) reported an asymmetry when they tested Dutch-learning 14-month-olds in the switch task using the minimal-pair non-words /paap/ and /faap/, which feature the native Dutch /p-f/ contrast. The switch task is a standard procedure for assessing associative word learning by measuring the ability to map a novel spoken label with a novel visual object