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Research Article

Accounting for variability in North American English /ɹ/: Evidence from children's articulation

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ABSTRACT

This acoustic and articulatory pilot study examines the North American English /ɹ/ productions of English-speaking children during acquisition, and compares their early- and later-stage productions with /ɹ/ allophony patterns reported in previous studies with adults. Ultrasound imaging is used to investigate the articulatory behavior of four children, aged 3–6 years, during production of familiar lexical items containing prevocalic, post-vocalic, and syllabic /ɹ/. Shape analysis of the tongue is conducted using a technique that is highly robust against rotational and translational differences from token to token. Participants exhibited behaviors that are consistent with adults' in previous studies, showing both intra- and inter-speaker variability, and similar patterns of allophony based on syllable position, consonant place of articulation, and vowel quality. For three participants, variable behavior occurred prevocalically, in contexts where adults tend to exhibit the greatest amount of allophonic variation. Variable behavior during acquisition of an articulatorily complex speech sound provides a plausible explanation for the variability that has been previously reported with adults. If a child's dominant strategy for reaching adult-like targets proves ineffective in certain contexts, that may motivate exploratory behavior that could lead to a stable alternative strategy in those contexts over time. Participants' later-stage productions mirror allophony patterns observed with adults in previous studies. The current research adds to the literature on children's articulatory behavior during acquisition, and to the body of accumulated knowledge on North American English /ɹ/.

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1. Introduction

This acoustic and articulatory pilot study examines the North American English /ɹ/ productions of four English-speaking children during acquisition and compares their early production strategies with /ɹ/ allophony patterns observed in previous studies with adults. North American English /ɹ/ is of interest in adult populations because it exhibits acoustic stability (e.g. low F3) despite considerable articulatory variability both within and between speakers (Delattre & Freeman, 1968; Guenther et al., 1999; Mielke, Baker, & Archangeli, 2010, 2016; Westbury, Hashi, & Lindstrom, 1998). In children, /ɹ/ is often one of the last sounds to be acquired (Sander, 1972; Smit, 1993), especially in prevocalic position (McGowan, Nittrouer, & Manning, 2004; Smit, Hand, Freilinger, Bernthal, & Bird, 1990; Stoel-Gammon, 1985). Tiede, Boyce, Espy-Wilson, and Gracco (2011) have suggested that children might attempt different vocal tract configurations during an "exploratory period" (p. 65) in acquisition, particularly in contexts where the articulatory demands are greater. Variable behavior during acquisition of an articulatorily complex speech sound provides a plausible explanation for the /ɹ/ allophony patterns observed in previous studies with adults.

The current research uses ultrasound imaging to investigate the articulatory behavior of four English-speaking children, aged 3–6 years, during production of familiar lexical items containing /ɹ/. Children's early-stage /ɹ/ productions are examined and compared with their later-stage productions. Shape analysis of the tongue is conducted using a technique that is highly robust against rotational and translational differences from token to token (Ménard, Aubin, Thibeault, & Richard, 2012). Children's variable behavior is interpreted in reference to previously published work on tongue shapes used by adults when producing /ɹ/. Findings suggest that adult variability may emerge in childhood during an exploratory period in acquisition, as proposed by Tiede et al. (2011). Not only do participants exhibit behaviors that are consistent with adults' in previous studies (e.g. Mielke et al., 2010, 2016; Westbury et al., 1998), they also

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demonstrate variable behavior in contexts where they have not yet acquired adult-like /ɹ/, and where adults tend to show the greatest amount of allophony (Mielke et al., 2010, 2016). While there is a growing body of literature on articulatory variability in adult production of /ɹ/ (see Mielke et al., 2016), and on /ɹ/ production in children experiencing phonological delay (e.g. Adler-Bock, Bernhardt, Gick, & Bacsfalvi, 2007; Bacsfalvi, 2010; Bernhardt, Gick, Bacsfalvi, & Adler-Bock, 2005; Davidson, Klein, & Grigos, 2007; Klein, McAllister Byun, Davidson, & Grigos, 2013; McAllister Byun & Hitchcock, 2012; McAllister Byun, Hitchcock, & Swartz, 2014), there remains virtually no articulatory data on children's production of /ɹ/ during typical development. This research makes a small contribution to the literature on children's articulation of this speech sound, and to the body of accumulated knowledge on North American English /ɹ/.

2. Background

North American English /ɹ/ is an approximant speech sound that is often one of the last to be acquired by children (Sander, 1972; Smit, 1993), particularly in prevocalic position (McGowan et al., 2004; Smit et al., 1990; Stoel-Gammon, 1985). Its articulation involves two points of lingual constriction, in the pharyngeal space and along the palate, and (frequently) a third point of constriction at the lips, making it an articulatorily complex sound (Delattre & Freeman, 1968; Gick, 1999). Studies with adults show considerable inter- and intra-speaker articulatory variability during production (Delattre & Freeman, 1968; Mielke et al., 2016; Westbury et al., 1998). As illustrated in the /ɹ/ taxonomy presented in Fig. 1 (Delattre & Freeman, 1968), adults use different tongue shapes to produce /ɹ/, ranging from bunched postures with the tongue tip pointing down, to more retroflex postures with the tongue tip pointing up. Indeed, the bunched (tip-down) vs. retroflex (tip-up) distinction has remained an important one (Derrick & Gick, 2011; Hagiwara, 1995; Mielke, Baker, & Archangeli, 2016; Stavness, Gick, Derrick, & Fels, 2012), and while some speakers use exclusively one tongue shape across contexts, others employ different tongue shapes in different contexts (Mielke et al., 2016). Despite this articulatory variability both within and between speakers, /ɹ/ exhibits a strong degree of acoustic stability (Delattre & Freeman, 1968).

2.1. Acoustics of adult /ɹ/

One of the earliest acoustic studies of North American English /ɹ/ was conducted by Lehiste (1962), who performed a spectrographic analysis of the /ɹ/ productions of five Midwestern American speakers. Participants produced 135 target words, and midpoint formant values (F1–F3) were collected for each. Lehiste found that, even across a range of contexts, allophones of /ɹ/ had enough features in common to describe them as “phonetically similar” (p. 109). These common features included a low third formant and a relatively small difference in frequency between F2 and F3.

In a larger-scale acoustic and articulatory examination of /ɹ/, Delattre and Freeman (1968) used cineradiography and magnetic tape recording to capture the /ɹ/ productions of 46 men and women living in different regions of the United States. They proposed eight tongue shapes (Fig. 1) to describe the various articulatory strategies employed by participants during production of 32 common English words containing /ɹ/. Acoustically, the study confirmed what had already been attested (Delattre, 1951; Lehiste, 1962; Potter, Kopp, & Kopp, 1947): that low F3 serves as an important acoustic characteristic of /ɹ/. Unlike Lehiste (1962), however, who had speculated that acoustic similarities may be due to retroflexion, Delattre and Freeman found that the F1, F2, and F3 frequencies of /ɹ/ s produced with bunched vs. retroflex tongue shapes were not significantly different from one another.

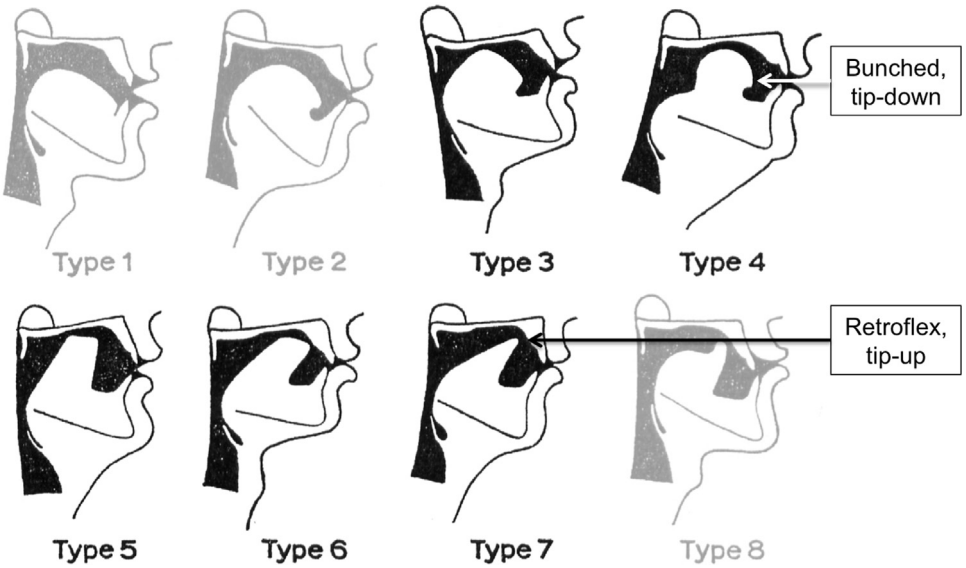

Fig. 1. Adapted from Delattre and Freeman (1968) /ɹ/ taxonomy (p. 41, images have been rotated to be rightward facing); types 4 and 7 illustrate the classic bunched/retroflex distinction (types 1, 2, and 8 represent shapes observed in non-rhotic varieties of English).

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