



## Infants' recognition of foreign-accented words: Flexible yet precise signal-to-word mapping strategies

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### ARTICLE INFO

#### Keywords:

Infant speech perception  
Spoken language processing  
Word recognition  
Foreign accents  
Phonological specificity

### ABSTRACT

To develop adult-like communication skills, children need to learn to converse not only with individuals from their local community, but also with second-language learners who might have foreign accents. Here, we ask when infants can recognize foreign-accented word forms, and what the cognitive underpinnings are that enable children to map such surface forms onto established lexical representations. In line with reports using regional accents, Canadian-English learners recognize words forms in a foreign French accent by 18 months of age, indicating that the developmental trajectory of coping with foreign accents is not always more protracted than that of regional accents. Moreover, mispronounced versions of known words appear to be treated as nonwords, suggesting that children do not accept all phonemic substitutions when listening to foreign-accented speech. Thus, infants' word form recognition is simultaneously flexible and at least somewhat specific, allowing them to cope with accents relatively efficiently from early on.

### Introduction

Children acquire their mother tongue with tremendous speed and efficiency. A key aspect of this process concerns the development of the ability to map the surface forms of words onto their underlying representations. This is not always an easy feat. The pronunciation of a given word can differ tremendously across utterances of the same speaker, and even more so across different speakers, especially if those speakers have different language backgrounds. In order to efficiently recognize words across situations and speakers, children thus need to be flexible in their signal-to-word mappings. That is, they need to allow for acoustic-phonetic deviation at the word form level<sup>1</sup> when mapping word tokens onto their stored representations. At the same time, words in a given language often differ only minimally from other words in that language. Consequently, to avoid confusion, children's word identification mechanism needs to be precise enough to exclude phonological neighbors. Here, we examine when and how infants learn to strike this fine balance of being both flexible and precise in their word recognition abilities.

By the time they reach their first birthday, infants typically produce their first words. The foundation of this ability is, however, established many months earlier. Parental report scores indicate, for instance, that

as early as eight months of age, children understand a few dozen words on average (Dale & Fenson, 1996; Frank, Braginsky, Yurovsky, & Marchman, 2017). Experimental studies testing young infants' early word recognition abilities confirm this observation. That is, six- to nine-month-olds have been found to correctly identify the referent of at least a few highly frequent words upon hearing the word's label (Bergelson & Swingley, 2012; Parise & Csibra, 2012; Tincoff & Jusczyk, 1999; Tincoff & Jusczyk, 2012). Interestingly, these findings hold despite the tremendous amount of variability in the realization of words across speakers that children come across in their daily lives. This suggests that children's early word recognition skills are fairly robust to variation in the input, a finding corroborated by infant word learning studies. Specifically, such studies reveal that although acoustic differences in the realization of words between training and test can hinder the recognition of these items (Houston & Jusczyk, 2000; Singh, 2008; Singh, Morgan, & White, 2004), word forms produced by a novel speaker can sometimes still be recognized (Houston & Jusczyk, 2000; Johnson, Seidl, & Tyler, 2014; Singh, Nestor, & Bortfeld, 2008; Van Heugten & Johnson, 2012; also see Jusczyk, Pisoni, & Mullennix, 1992; Kuhl, 1979; Polka, Masapollo, & Ménard, 2014 for similar findings regarding variability in vowels and syllables). Thus, despite the additional processing cost induced by between-speaker differences, under the right

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<sup>1</sup> In line with our focus on infants' recognition of the *phonological form* of words (rather than their comprehension of the referent of words), we use the term *word form* (rather than *word*) throughout this paper when referring to the sound patterns of lexical entries.

circumstances, young children *can* cope with acoustic-phonetic deviation in the pronunciation of words.

In all of the studies described above, however, the acoustic-phonetic discrepancies between learning tokens (whether at home or in the lab) and test items were limited to changes in speaker gender, pitch, or affect. Such differences, while acoustically salient, are lexically irrelevant in English. This raises the question of how children cope with discrepancies in the pronunciation of words due to differences in speakers' language backgrounds. Imagine, for instance, a scenario where an infant's typical language input consists of English spoken by her North American English-speaking family and friends. When learning the word *bath*, she may hear various people say *bath* [bæθ]. Although these individuals all differ in terms of their vocal tract configurations, their speaking style, and their speech rate (hence causing the exact acoustic-phonetic realizations to be different across all tokens), these speakers do converge in that they all produce all three segments of the word *bath* in a phonetically similar fashion. At some point during the first or second year of life, however, the child may start daycare, where one of her daycare providers may speak with a British English accent. Much like any of the other people the child has listened to in the past, this speaker diverges from other speakers in terms of vocal tract and speech rate, but on top of that, this novel speaker also differs in accent, hence pronouncing *bath* as [ba:θ], using a different vowel. As a result, the infant listener will need to work out that even though the vowel has changed, the British English pronunciation [ba:θ] maps onto the same referent as [bæθ]. Possessing such ability to comprehend words in the face of acoustic-phonetic deviation can be of great importance when interacting with someone who speaks with an accent, either in the everyday home or school environment or at testing facilities (e.g., accented teachers or speech-language pathologists). When do infants start contending with accents they have never heard before? And what are the potential mechanisms underlying this ability?

In recent years, research examining the developmental trajectory of unfamiliar accent comprehension has revealed that infants are able to recognize words produced by a novel speaker of their own local accent before they can recognize words produced in accents that have never been heard before. For instance, using a preferential listening procedure, American English-learning 15-month-olds have been shown to listen longer to lists containing familiar word forms than to lists containing unfamiliar word forms when these words are pronounced in an (American) accent matching their input. In line with previous research using a similar methodology (Hallé & De Boysson-Bardies, 1994; Swingley, 2005; Vihman, Nakai, DePaolis, & Hallé, 2004), such a preference for familiar over unfamiliar word forms can be taken to indicate children's recognition of the familiar items. However, when the very same high- and low-frequency word lists were produced in a Jamaican accent, an accent unfamiliar to these American children, no such preference was observed. In fact, it was not until 19 months that American English-learners displayed a high-frequency word preference when the speaker had a Jamaican accent. Taken together, these findings suggest that 19- but not 15-month-olds are able to contend with unfamiliar accents (Best, Tyler, Gooding, Orlando, & Quann, 2009). This developmental path, from initial difficulty to later competence in coping with unfamiliar accents, has since been replicated across accents. For instance, results comparable to those with American English learning infants described above were obtained with Canadian English learners listening to either a Canadian or an Australian speaker. That is, while 15-month-old Canadian English-learning infants recognized word forms pronounced in their own Canadian accent, they did not appear to succeed in the task until 22 months of age when the Canadian speaker was replaced by someone with an Australian accent (Van Heugten & Johnson, 2014).

A similar developmental trajectory has also been observed in studies using the Preferential Looking Procedure (Mulak, Best, Tyler, Kitamura, & Irwin, 2013; Van Heugten, Krieger, & Johnson, 2015). In this procedure, children's eye movements are recorded as they are presented

with two objects depicted on a screen, and hear one of the two images labeled. A greater proportion of looks to the named target than to the unrelated image is thought to be indicative of successful word comprehension. Thus, unlike preferential listening tasks that test infants' *recognition* of the phonological form of words and that do not necessarily require access to the semantic component of words (though see Delle Luche, Durrant, Floccia, & Plunkett, 2014; Willits, Wojcik, Seidenberg, & Saffran, 2013 for evidence suggesting that infants do access the meaning of words in tasks highly similar to the procedure used here), the Preferential Looking Procedure is referential in nature and examines infants' *understanding* of words. Despite these differences in tasks, however, the observed developmental patterns are remarkably similar, thus reinforcing the idea that both paradigms can be used complementarily to study infants' ability to contend with accents. Taken together, the combination of findings to date suggests that children learn to recognize familiar words in unfamiliar accents sometime in the months before their second birthday (Best et al., 2009; Mulak et al., 2013; Van der Feest & Johnson, 2016; Van Heugten & Johnson, 2014; Van Heugten & Johnson, 2016; Van Heugten et al., 2015; White & Aslin, 2011), potentially as a result of the dramatic increase in vocabulary size around that time (Mulak et al., 2013; Van Heugten et al., 2015).

One caveat to this timeline of learning to cope with unfamiliar accents is that the findings establishing this developmental trajectory are dominated by research using *regional* accents. But what if the daycare provider in the example above was not a British English speaker but rather someone who had a different native language and spoke English with a strong French, Vietnamese, or Slavic accent? Encountering foreign-accented individuals is a very common scenario in many metropolitan areas such as New York, Miami, Toronto, Paris, or London, where a large proportion of the inhabitants are foreign-born, but also in parts of the world where different language communities co-exist or live in near proximity. Findings showing that 15-month-old English learners can cope with a Jamaican or Australian accent do not necessarily imply that they are also able to similarly accommodate foreign-accented English speakers. It would thus be useful to know whether the ability to cope with *foreign*-accented speech would follow a trajectory similar to that to cope with regional accents.

While recent research has started to use foreign accents when testing young children's word recognition abilities, this work has mainly been conducted testing participants who are much older than the infants tested in the work described earlier (Bent, 2014; Bent & Atagi, 2015; Bent & Atagi, 2017). Studies testing younger children's linguistic skills in the face of foreign accents have furthermore predominantly used tasks where children first have to learn novel words (Schmale, Cristia, & Seidl, 2012; Schmale, Cristia, Seidl, & Johnson, 2010; Schmale, Hollich, & Seidl, 2011; Schmale & Seidl, 2009; Schmale, Seidl, & Cristia, 2015). Although such work has put forward interesting results, directly comparing these studies to studies using regional accents is hard, as recognizing familiar versus newly-learned words are not necessarily equal in terms of task demands. For instance, recognizing familiarized word forms across surface-level acoustic-phonetic changes tends to be easier for words that routinely occur in the input (e.g., *mommy*) than for items that are likely never heard in the home setting (e.g., *Ghana*; Singh et al., 2008), perhaps due to reduced frequency of exposure (potentially leading to less stable representations; Barton, 1976; Fennell & Werker, 2003; Metsala, 1999) or reduced experience with item-specific variability (potentially leading to less flexible representations; Graf Estes & Lew-Williams, 2015; Rost & McMurray, 2009; Singh et al., 2008). Thus, to compare linguistic processing in the face of regional and foreign accents more directly, we here test children's recognition of familiar word forms in an unfamiliar, foreign accent using a task we have previously used to test children's recognition of familiar words in an unfamiliar, regional accent (Van Heugten & Johnson, 2014). This allows us to examine whether the recognition of foreign-accented word forms may be delayed compared to

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