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Exposure to multiple accents supports infants' understanding of novel accents

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ABSTRACT

Accented speech poses a challenge for listeners, particularly those with limited knowledge of their language. In a series of studies, we explored the possibility that experience with variability, specifically the variability provided by multiple accents, would facilitate infants' comprehension of speech produced with an unfamiliar accent. 15- and 18-month-old American-English learning infants were exposed to brief passages of multi-talker speech and subsequently tested on their ability to distinguish between real, familiar words and nonsense words, produced in either their native accent or an unfamiliar (British) accent. Exposure passages were produced in a familiar (American) accent, a single unfamiliar (British) accent or a variety of novel accents (Australian, Southern, Indian). While 15-month-olds successfully recognized real words spoken in a familiar accent, they never demonstrated comprehension of English words produced in the unfamiliar accent. 18-month-olds also failed to recognize English words spoken in the unfamiliar accent after exposure to the familiar or single unfamiliar accent. However, they succeeded after exposure to multiple unfamiliar accents, suggesting that as they get older, infants are better able to exploit the cues provided by variable speech. Increased variability across multiple dimensions can be advantageous for young listeners.

1. Introduction

For listeners of all ages, it can be challenging to understand speakers with unfamiliar accents. Adult listeners process speech produced with an unknown accent more slowly than familiar-accented speech (e.g., Adank, Evans, Stuart-Smith, & Scotti, 2009; Cristià et al., 2012; Schmid & Yeni-Komshian, 1999), and less proficient language users have even more difficulty comprehending unfamiliar accents (e.g., Nathan & Wells, 2001; Nathan, Wells, & Donlan, 1998; Newton & Ridgway, 2015; Schmale, Hollich, & Seidl, 2011; Van Heugten, Krieger, & Johnson, 2015). Infants are particularly hindered by novel accents (e.g., Best, Tyler, Gooding, Orlando, & Quann, 2009; Mulak, Best, Tyler, Kitamura, & Irwin, 2013; Van Heugten & Johnson, 2014).

Fortunately, this difficulty is not insurmountable. With experience, infants learn to overcome the differences between a new accent and their native accent (e.g., Mulak et al., 2013; Schmale et al., 2011; Van Heugten & Johnson, 2014; Van Heugten et al., 2015). For example, 15-month-olds recognize familiar words produced in an unfamiliar accent given appropriate support (Van Heugten & Johnson, 2014). Canadian English-learning infants were tested on their comprehension of an unfamiliar Australian accent. As in prior studies, infants at this age initially failed to recognize the difference between real words and nonsense words produced in a novel accent. However, if infants first heard a familiar story read by the same Australian speaker, they subsequently recognized the Australian-accented words. Crucially, success only occurred when infants were already familiar with the story prior to the study. Thus, increased familiarity with both the speaker and context facilitated infants' ability to contend with an unfamiliar accent.

In addition to familiarity, other aspects of listening experience can help listeners cope with accented speech. Exposure to multiple speakers helps both adults and toddlers adapt to new accents (e.g., Bradlow & Bent, 2008; Clopper & Pisoni, 2004; Schmale, Seidl, & Cristià, 2015; Sumner, 2011). It has been suggested that variability draws attention to relevant dimensions and allows listeners to learn what distinctions are likely to matter (e.g., Baese-Berk, Bradlow, & Wright, 2013; Lively, Logan, & Pisoni, 1993; Nygaard & Pisoni, 1998; Sumner, 2011). McMurray and colleagues have emphasized the role that variability plays in infant speech

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perception, even when the variability is provided in a seemingly irrelevant dimension (e.g., Apfelbaum & McMurray, 2011; Rost & McMurray, 2009, 2010; Toscano & McMurray, 2010). Infants struggle to disregard irrelevant dimensions in speech; for example, they may be distracted by talker-specific information (e.g., Graf Estes & Lew-Williams, 2015; Houston & Jusczyk, 2000; Singh, Morgan, & White, 2004). Like adults, infants benefit from variability, and hearing many different speakers can allow infants to ignore indexical information and boost their language learning (Graf Estes & Lew-Williams, 2015; Rost & McMurray, 2009).

While these studies demonstrate that speaker variability is important, speakers are not the only potential source of variability that infants might exploit. Exposure to different accents could also highlight the distinctions that are likely to be meaningful. Both real life and lab-based experience with different accents change the cues that adults use in speech perception (e.g., Evans & Iverson, 2004; Idemaru & Holt, 2012; Scott & Cutler, 1984; Sumner & Samuel, 2009). In fact, exposure to multiple accents facilitates adults' comprehension of speech produced with a novel accent more than exposure to multiple speakers of a single unfamiliar accent (Baese-Berk et al., 2013; Bradlow & Bent, 2008). The effect of experience with multiple accents has not yet been explored with infants. Prior research has shown that after experience with a single novel accent, infants can adapt to that particular accent, but do not generalize to other accents (e.g., White & Aslin, 2011). Given that variability in other dimensions is advantageous for infants, the current studies were designed to test the hypothesis that exposure to multiple novel accents improves infants' ability to comprehend words produced in a different unfamiliar accent.

We exposed infants to multi-talker passages and tested their performance in a word recognition task closely modeled on the earlier study by Van Heugten and Johnson (2014). Across studies, we varied the accents in the exposure and test phases in order to manipulate potentially informative features in the input. Given that experience with multiple speakers can change infants' speech perception, we wanted to ensure that any facilitation observed in our studies was not simply due to experience with multiple talkers. We therefore included a condition where infants heard multiple talkers with a single unfamiliar accent. Based on studies with older infants, we expected this experience might also be advantageous relative to exposure to a single speaker (Schmale, Cristia, & Seidl, 2012; Schmale et al., 2015). However, we expected the additional variability present in multiple accents would be even more helpful in allowing infants to demonstrate comprehension of accented speech.

All studies used an adaptation of the paradigm developed by Van Heugten and Johnson (2014). During the exposure phase, infants heard a passage of child-directed speech produced by three different speakers; the accents of those speakers varied across studies. Infants were then tested on their ability to recognize words produced in either a Familiar (American) accent or Unfamiliar (British) accent. On each trial, infants heard lists of either English words or phonotactically legal non-words. We used the Headturn Preference Procedure to assess their ability to differentiate between the two types of lists. Our goal was to determine which aspects of variability enhance infants' ability to process words spoken in an unfamiliar accent.

2. Study 1

Study 1 was designed to replicate prior findings suggesting that 15-month-old infants recognize familiar words produced in their own accent, but not an unfamiliar accent (Van Heugten & Johnson, 2014), using a new population (American-English-learning infants) and a new target accent (British English). In Study 1, all infants were exposed to the Familiar (American)-accented passage. Half the infants were then tested with materials spoken in the Familiar accent, while the other half were tested with materials spoken in the Unfamiliar (British) accent. Because the exposure passage provided no new accent information, we expected that as in past studies, 15-month-olds would recognize familiar words only when they were produced in the Familiar American accent and not when they were produced in the Unfamiliar British accent.

2.1. Method

2.1.1. Participants

Participants in Study 1 were 32 full-term infants (15 female) from monolingual English-speaking homes in the Midwestern United States, ranging in age from 14.3 to 15.7 months (mean: 15.1 months). The sample size was based on the study by Van Heugten and Johnson (2014). Half the infants heard the Familiar accent during the test phase, while the other half heard the Unfamiliar accent. None of the infants were reported to have hearing problems or exposure to British accents. Ten additional infants were tested but excluded because of fussiness (n = 1), stopping early (n = 2), parental interference (n = 1), or inattentiveness (n = 6).

2.1.2. Stimuli

2.1.2.1. Exposure stimuli. Exposure stimuli consisted of a short passage of infant-directed speech, recorded by three different female native English speakers from the same region as the infants. The passage was drawn from a children's book and did not contain any of the words used in the test phase. Each speaker read the story in child-directed speech, and the exposure passage was created by combining stanzas from each speaker such that they alternated throughout the reading. There were 13 stanzas, and the entire passage lasted approximately two minutes.

2.1.2.2. Test stimuli. All test stimuli were recorded by two female native English speakers. One speaker had a Familiar (American) accent, and the other spoke with an Unfamiliar (British) accent. The Familiar-accented speaker was from the same region as the exposure speakers (and infants). The Unfamiliar-accented speaker was from London and had lived in the United States for less than a year.

The test stimuli consisted of lists of Words and Non-words, taken from the materials used by Van Heugten and Johnson (2014). The Words were real English words that are highly familiar to infants of this age (e.g., *mommy*, *kitty*), while the Non-words were unfamiliar sound sequences, constructed using the same phonemes as the Words (e.g., *mitty*, *koth*). There were 12 tokens of each type. Each token was recorded in isolation, and all test items were edited to match in intensity and duration (750 ms). These items were then combined into lists where monosyllabic and disyllabic items alternated. There were eight different lists (four lists of Words, four of Non-words), and in each list, the 12 items were shuffled and then repeated. There were 700 ms of silence between items; each list was 34.8 s in duration.

2.1.3. Procedure

Infants sat on a parent's lap in a sound-attenuated booth with video monitors on three sides while the parent listened to music over headphones to prevent them from influencing infants' behavior. During the Exposure phase, infants listened to the Familiar exposure passage while viewing images from the storybook on the center monitor to maintain their interest.

After Exposure, infants participated in a brief training phase to familiarize them with the contingency between the side stimulus

and their own looking behavior. Each trial began with an interesting video on the center monitor. Once the infant looked to the center, a visual stimulus played on one of the side monitors. When the infant looked to that side, music played from that side of the booth until the infant had looked away for one second or 30 s elapsed. A trained coder, unaware of what the infant was hearing, coded the infant's looking behavior using custom software.

Immediately following the practice phase, the test phase began. The test phase was identical to the practice phase, except that instead of music, infants heard lists of either Words or Non-words on each trial. There were four blocks, each of which included four test trials (twice as many as in Van Heugten and Johnson (2014) because we wanted to ensure that we had enough trials to find a stable effect). On half the trials, infants heard lists of Words, while on the other half they heard lists of Non-words. On each trial, the list played until the infant looked away for one second or the full duration of the list (34.8 s) elapsed.

2.2. Results & discussion

Our first analysis focused on infants who were tested on the Familiar test materials. Because our test phase was twice as long as that of Van Heugten and Johnson (2014), we wanted to know if the increased number of trials would cause infants to lose interest. We performed an ANOVA to test whether looking time changed across the four test blocks. One participant did not contribute data for the fourth block, and for the remaining 15 infants, the effect of block was significant [$F(3, 42) = 3.81$, $p = 0.02$, $\eta_p^2 = 0.214$]. Subsequent pairwise analyses, using Tukey's HSD to correct for multiple comparisons, revealed that by the fourth block, infants' overall looking time was significantly shorter than in the first block [3.4 s shorter, $p = 0.007$]. When we removed the fourth block, there was no longer a significant effect of block, and all participants contributed data [$F(2, 30) = 2.45$, $p = 0.10$]. Therefore, we focused our analyses in this and all subsequent studies on only the first three test blocks (12 trials).

The main analysis tested whether infants demonstrated a preference for Words over Non-words. Using a two-tailed planned paired samples *t*-test, we found that infants tested on the Familiar-Accented Test materials looked significantly longer on trials with lists of Words (8.9 s) than Non-words (6.0 s) [$t(15) = 2.88$, $p = 0.01$, Cohen's $d = 0.72$, see Fig. 1]. Fourteen of the 16 infants demonstrated a preference for Words. Consistent with earlier studies, 15-month-old American-English-learning infants preferred to listen to real, familiar words over nonsense words when stimuli were produced in a familiar accent.

Infants tested on the Unfamiliar British accent, however, showed no significant difference in their looking times for lists of Words (8.0 s) versus Non-words (7.7 s) [$t(15) = 0.42$, $p = 0.68$]. Ten of the 16 infants listened longer to Words. Following exposure to familiar-accented speech, infants recognized familiar words spoken in their own, but not an unknown, accent. Thus, Study 1 replicated prior research demonstrating that infants at this age struggle to comprehend accented speech. Our subsequent studies tested whether increased variability during the exposure phase might help infants overcome this difficulty.

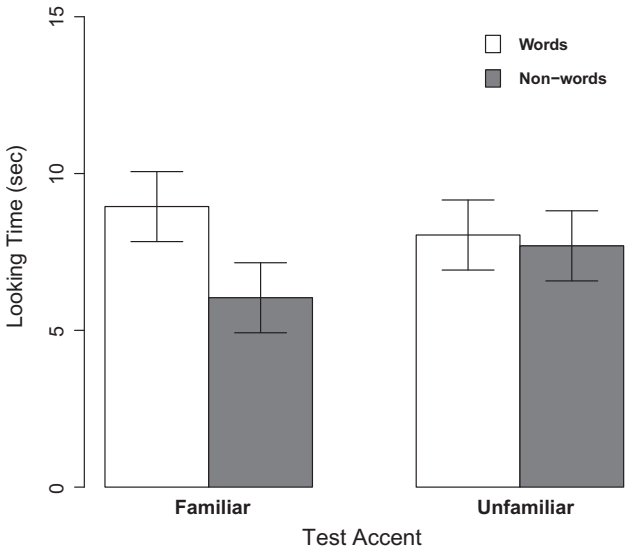

Fig. 1. 15-month-old infants' mean looking times to lists of Words and Non-words in Study 1. Error bars represent standard errors of the mean.

3. Study 2

Our next study was designed to determine whether exposure to variable speech would facilitate infants' recognition of familiar words spoken in an unfamiliar accent. All infants in this study were tested on the Unfamiliar-accented (British) test materials. In the Exposure phase, we explored two possible sources of variability: multiple accents and multiple talkers. In the *Mixed Novel Accent* condition, infants heard the exposure passage produced by three different speakers, each with a unique unfamiliar accent – and all different from the test accent (British English). In the *Single Novel Accent* condition, the passage was produced by three different speakers, all using the target British accent. Experience with a particular accent can improve toddlers' recognition of accented words (Schmale et al., 2012), suggesting that this experience might allow infants to recognize the familiar words. However, adults who hear multiple accents, rather than a single unfamiliar accent, later show better comprehension of a novel accent (Baese-Berk et al., 2013), suggesting additional variability could help infants ignore irrelevant differences between the Familiar and Unfamiliar accented speech. We therefore predicted we would see the best performance after exposure to the Mixed Novel Accent materials, because these materials included two sources of variability: multiple accents and multiple speakers.

3.1. Method

3.1.1. Participants

Study 2 included 32 additional infants (18 female, mean age: 15.1 months, range: 14.6–15.7 months) from the same population as Study 1. Half the infants heard the Mixed Novel Accent during exposure; the other half heard the Single Novel Accent. None of the participants were reported to have exposure to any of the accents included in the stimuli. Thirteen additional infants were tested but excluded due to fussiness (n = 6), inattentiveness (n = 5), or equipment malfunction (n = 2).

3.1.2. Stimuli

3.1.2.1. Exposure stimuli. Two new exposure passages were created for Study 2. All materials were produced by female native English speakers using the same text as in Study 1, but the accents of the speakers varied. The Mixed Novel Accent passage was produced by three speakers, each with a different native English accent. One speaker was from Australia, one was from India, and one was from the American South. The Single Novel Accent passage was produced by three different speakers of British English. All speakers had spent at least their first 18 years in the environment of their native accent. As with the Familiar exposure materials, the new exposure stimuli were created by combining individual

sentences from the three speakers into a single two-minute passage for each condition.

3.1.2.2. Test stimuli. Test stimuli were the Unfamiliar (British) materials used in Study 1. The speaker who produced these stimuli did not produce any of the exposure stimuli.

3.1.3. Procedure

The procedure for Study 2 was identical to that of Study 1. Based on Study 1, our analyses only included the first three blocks of testing.

3.2. Results & discussion

Infants in Study 2 failed to demonstrate a preference for lists of Words or Non-words in either the Mixed Accent exposure condition [Words: 7.7 s, Non-words: 8.2 s, $t(15) = 0.57$, $p = 0.58$], or the Single Novel Accent condition [Words: 8.9 s, Non-words: 7.0, $t(15) = 1.24$, $p = 0.23$]. See Fig. 2. Eight of the 16 infants demonstrated a preference for Words in the Mixed Accent condition, and 11 of the 16 infants in the Single Novel Accent condition preferred the lists of Words. Therefore, in Study 2, we found no evidence that infants recognized familiar words produced in an unknown accent.

Contrary to our hypothesis, increased variability did not facilitate 15-month-olds' comprehension of Unfamiliar-accented items. It could be that 15-month-olds failed to recognize familiar words, even after variable experience, because their representations of these lexical items were too shallow or not broad enough to withstand the unfamiliar pronunciation (e.g., Best et al., 2009; Van Heugten & Johnson, 2014). Infants with smaller vocabularies have greater difficulty understanding accented speech (Van Heugten et al., 2015), suggesting weaker language skills increase the challenge presented by novel accents. Another possibility, not mutually exclusive, is that 15-month-olds lack sufficient experience with language to be able to take advantage of the cues in variable speech. As infants gain experience, they may improve their ability to determine which dimensions of speech are important in a given situation (e.g., May & Werker, 2014; Stager & Werker, 1997) and thus may be better able to ignore the irrelevant features of accented speech. We designed Study 3 to examine these issues with older infants.

4. Study 3

In Study 3, we tested 18-month-old infants on the materials from Studies 1 and 2. Though these infants were just a few months older than the participants in Studies 1 and 2, they have had more experience with language and may also have more robust memory and attention skills, as well as stronger representations of familiar words. Therefore, we expected that they might be able to exploit the cues provided by variable speech. Infants heard one of the three multi-talker exposure passages (Familiar, Mixed, or Single Novel accent). All infants were tested on the Unfamiliar British-accented test materials. We predicted that like younger infants, 18-month-olds would struggle to recognize familiar words produced in a novel accent following exposure to the Familiar-accented passage. Unlike the younger infants, however, we expected that after exposure to the variability provided by the Mixed condition, they would be able to demonstrate understanding of the Unfamiliar-accented speech. We also thought it was possible that exposure to multiple speakers of a Single Novel accent would facilitate comprehension, but less than exposure to the Mixed condition, which contained two sources of variability.

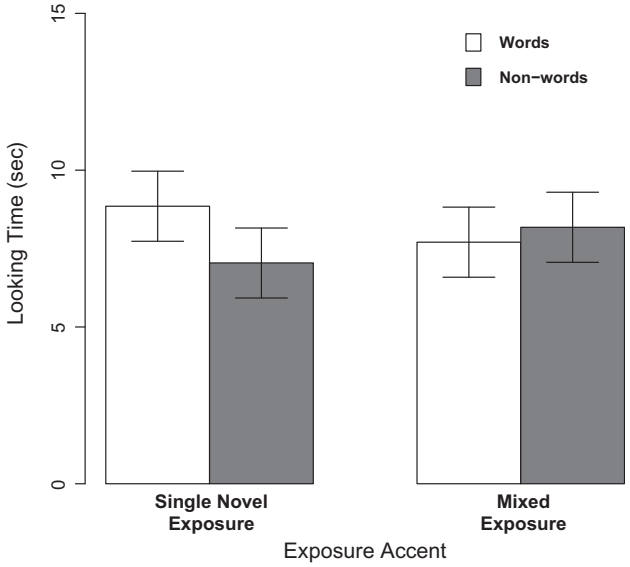

Fig. 2. 15-month-old infants' mean looking time to lists of Words and Non-words in Study 2. Error bars represent standard errors of the mean.

4.1. Method

4.1.1. Participants

Study 3 included 72[2] 18-month-old infants (35 female, mean age: 18.3 months, range: 17.4–19.3 months). Infants were assigned to one of three conditions (Familiar, Mixed, or Single Novel accent), with 24 infants in each condition. None of the infants had significant exposure to accented speech or reported any hearing difficulties. Twenty-nine additional infants were tested but excluded due to fussiness (n = 14), inattentiveness (n = 10), parental interference (n = 1), equipment malfunction (n = 3), or experimenter error (n = 1).

4.1.2. Stimuli & procedure

The stimuli were the same as in Studies 1 and 2. All infants were tested on the Unfamiliar British-accented test lists, and they were exposed to one of the three exposure passages: Familiar, Mixed Novel Accent, or Single Novel Accent. The procedure was identical to Studies 1 and 2.

4.2. Results & discussion

Like younger infants in Study 1, 18-month-old infants failed to differentiate lists of Words from Non-words after exposure to Familiar-accented materials [Words: 8.3 s, Non-words: 8.1 s, $t(23) = 0.27$, $p = 0.79$], with 11 of the 24 infants listening longer to Words (see Fig. 3). They were also unsuccessful after exposure to the Single Novel Accent [Words: 8.4 s, Non-words, 7.1 s, $t(23) = 1.58$, $p = 0.13$], with 15 of the 24 infants listening longer to Words. However, unlike the younger infants, 18-month-olds in the Mixed Novel Accent condition listened significantly longer to Words than Non-words [Words: 9.0 s, Non-words: 6.8 s, $t(23) = 2.96$, $p = 0.007$, Cohen's $d = 0.60$]. Sixteen of the 24 infants preferred the lists of Words, suggesting exposure to the more variable Mixed exposure passage allowed them to recognize the familiar words. Exposure to multiple accents, but not a single target accent,

[2] The sample sizes in Studies 1 and 2 were based on the prior study by Van Heugten and Johnson (2014). However, because we found that even with increased variability, the accented speech was still challenging for infants, we wanted to increase our power in Study 3. We thus increased our sample size by 50% to 24 infants per condition, which would give us 0.9 power to detect an effect size similar to Study 1 (Cohen's $d = 0.72$).

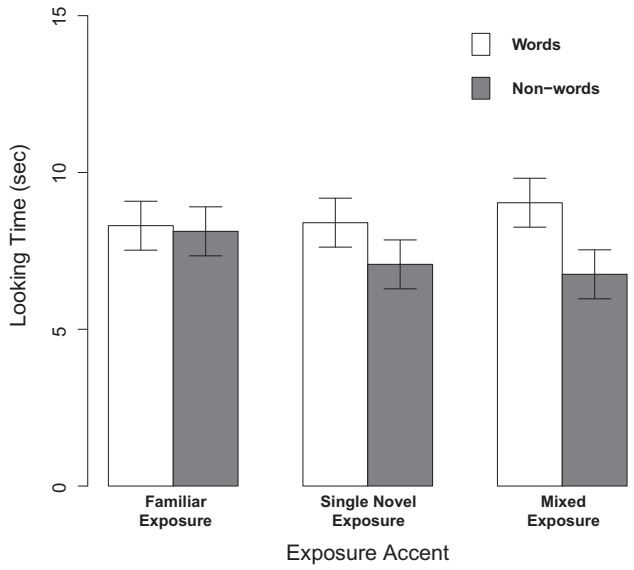

Fig. 3. 18-month-olds' mean looking times to lists of Words and Non-words. Error bars represent standard errors of the mean.

allowed 18-month-old infants to recognize familiar words produced in an unfamiliar accent.

5. General discussion

In Study 1, we replicated and extended prior findings suggesting that at 15 months, infants struggle to process accented speech. Infants differentiated between lists of familiar words and non-words only when those words were produced in the infants' native accent and not when they were produced in an unfamiliar British accent. In Study 2, increased variability did not facilitate 15-month-olds' comprehension of accented speech. In Study 3, we tested slightly older infants. At 18 months, infants could successfully discriminate between words and non-words produced in an unfamiliar accent after experience with multiple accents, but not multiple speakers of a single accent, suggesting that not all experience is equally advantageous. This is particularly striking because the infants exposed to multiple accents received no exposure to the target accent, and yet succeeded at comprehending words produced in the target accent, whereas the infants exposed to a single accent received exposure to the target accent, and yet failed at comprehending words produced in the target accent.

Infants' failure to recognize familiar words spoken with unfamiliar accents provides additional evidence that inexperienced listeners have difficulty identifying the most important features in speech (e.g., Singh et al., 2004). As infants are first learning words, their representations of words may be over- or under-specified (e.g., Van Heugten & Johnson, 2014), making it difficult for them to contend with accented forms that deviate from their prior experience. Even at 18 months, infants were initially unable to ignore the irrelevant differences between British and American English. Furthermore, experience with multiple speakers of a target accent did not allow either older or younger infants to overcome this difficulty, even though adults and even toddlers show improvements in their comprehension of unfamiliar accents after similar experience (Bradlow & Bent, 2008; Schmale et al., 2012). This surprising result suggests that the variability provided by multiple talkers with a single accent was not effective in helping infants adapt to novel pronunciations. The greater variability that occurred when there were multiple accents present, however, facilitated older infants' recognition of the familiar words. This suggests that increased variability along multiple dimensions helps listeners determine which cues are most important and which are less critical to the current context (e.g., Sommers & Barcroft, 2006; Toscano & McMurray, 2010).

In this particular study, we manipulated variability by including speakers with very distinct accents. It is possible that we could have similarly boosted infants' performance by providing variability along a different dimension, such as including speakers of different ages or genders. If infants successfully demonstrated comprehension of accented speech following exposure to these sources of variability, their behavior would be consistent with the view that hearing more variable speech can lead infants to accommodate a broader range of word forms within their lexical representations (Schmale et al., 2015). Alternatively, it is also possible that variability in indexical properties alone would not suffice, and that infants also needed exposure to the phonological variability inherent in the different accents in order to succeed in this task. Future studies will adjudicate between these competing possibilities.

Interestingly, in the current studies, only older infants exploited the additional variability. It could be that older infants were more successful because they had better knowledge of English overall. Best and colleagues suggest that infants' understanding that not all phonetic changes are meaningful develops as their vocabularies grow (Best et al., 2009; Mulak et al., 2013). Younger infants, who know fewer words, may not have this understanding. In addition, infants' representations of the individual words may not have been not robust enough to withstand the difference in pronunciation that comes from accented speech (Van Heugten & Johnson, 2014), so even with variable experience, they could not recognize the familiar words. Another possibility is that the older infants had more advanced cognitive skills that allowed them to take advantage of the information provided by multi-accent exposure. The ability to ignore irrelevant information in speech has been linked to domain-general cognitive skills (e.g., Conboy, Sommerville, & Kuhl, 2008; Lalonde & Werker, 1995), so enhanced memory or attention could have made the task easier. Finally, while none of the infants in this study were reported to have had experience with accented speech, older infants have nevertheless encountered more speakers who may speak differently. Experience with different languages influences bilingual infants' language discrimination abilities (Byers-Heinlein & Fennell, 2014; Petitto et al., 2012), demonstrating that variable experience can change infants' perception of new linguistic stimuli. It also possible that a combination of these factors helped older infants recognize familiar words.

The process of discovering which features of speech can be ignored is not trivial. Though unfamiliar-accented words have the same referents as familiar-accented words, in some contexts, accent may be relevant. For example, young children use accent as a social cue (Kinzler, Corriveau, & Harris, 2011; Wagner, Clopper, & Pate, 2014). Listeners' prior experiences also continue to influence their perception of novel accents. Even as adults, participants who have lived in a greater variety of places are better able to identify regional dialects (Clopper & Pisoni, 2007), demonstrating how exposure to different speakers can change listeners' sensitivity to phonological information. Throughout development, infants gain experience and expertise with language that allow them to contend with challenges such as accented speech. As listeners navigate their environments, they refine their ability to tune their attention appropriately and learn to use the information available to determine which distinctions are most likely to be important.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2017.05.031.

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