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

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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.

Keywords: infant speech perception, spoken language processing, word recognition, foreign accents, phonological specificity

Flexible but precise signal-to-word mapping strategies in infancy: Evidence from foreign-
accented word recognition

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 level¹ 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;

¹In 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.

Parise & Csibra, 2012; Tincoff & Jusczyk, 1999, 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 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, 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, 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, & Cristia, 2015; Schmale & Seidl, 2009). 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 the recognition of regionally-accented words. Moreover, by testing the specificity of word recognition in the face of a foreign accent, we can also compare potential strategies invoked for identifying words in regional and foreign accents.

There are several reasons for why children's ability to recognize foreign-accented word forms may lag behind their ability to recognize regionally-accented word forms. First, it has been argued that the deviations between the listener's own accent and the accent of the speaker tend to be more consistent for regional than for foreign accents (see Floccia, Goslin, Girard, &

Konopczynski, 2006; Goslin, Duffy, & Floccia, 2012 for a discussion). That is, although the target realization of a particular segment may differ depending on the regional variant at hand, native speakers are typically very adept at producing phonemes in a consistent fashion. By contrast, although second language learners might have the same target realization of a particular segment as native speakers, within-speaker variability has been argued to be somewhat more pronounced (Baese-Berk & Morrill, 2015; Wade, Jongman, & Sereno, 2007). For this reason, the pronunciation of foreign-accented speech may be less systematic than the pronunciation of regionally-accented speech. This, in turn, may make it harder for infants (and other listeners) to retrieve the underlying representation for a foreign-accented than for a regionally-accented word. A second reason to expect potential differences between regional and foreign accents has its basis in metalinguistic judgments performed by young language learners. According to such judgments, 5- to 7-year-old children are generally better at detecting unfamiliar foreign than unfamiliar regional accents (Floccia, Butler, Girard, & Goslin, 2009; Girard, Floccia, & Goslin, 2008; Wagner, Clopper, & Pate, 2014). It seems plausible that detecting accents at such a young age is associated with increased difficulty of understanding the speaker. If this were the case, then it would follow that foreign accents are more challenging to process than regional accents during the preschool years and such differences may have their origin in early infancy. A final argument for expected differences between regional and foreign accents concerns findings from the adult speech perception literature. In particular, some studies have observed differences in the adaptation to regional and foreign accents, with regional accents being easier to accommodate than foreign accents (Floccia et al., 2006; Goslin et al., 2012; Floccia, Butler, Goslin, & Ellis, 2009). One might expect to find similar (or perhaps even more enhanced) differences in the degree of processing difficulty for regional versus foreign accents at earlier

ages. By first establishing when infants' ability to cope with foreign-accented speakers develops, we can see whether the timeline of recognizing foreign-accented word forms lags behind that of recognizing regionally-accented word forms or whether the ability to accommodate regional and foreign accents develops at similar rates.

While testing children's ability to recognize foreign-accented word forms will enable us to construct the developmental trajectory of coping with foreign accents, it does not address the second question we set out to answer at the beginning of this paper, namely how the mechanisms underlying language processing may change when listening to an accented speaker. Clearly, in order to accommodate accented speakers –whose pronunciations diverge from the child's standard– flexibility in signal-to word-mapping strategies is essential. But how is this flexibility organized? Some have proposed that in the face of a foreign accent, infants recognize accented words by loosening their criteria for what counts as an acceptable pronunciation, allowing them to recognize accented words without much exposure (Schmale et al., 2012, 2015). This, however, could come at the cost of becoming relatively insensitive to subtle mispronunciations of familiar words spoken in foreign accents. Such insensitivity could lead to the activation of spurious lexical candidates, likely slowing word processing and as such reducing efficiency. Others, by contrast, have put forward the idea that children cope with accent variation by forming more precise between-accent mappings, potentially in a lexically-guided fashion (cf. Van Heugten & Johnson, 2014; White & Aslin, 2011). According to this view, infants and toddlers might be able to use top-down word form knowledge to work out the specific mapping between their own native accent and the unfamiliar foreign accent. Instead of generally lowering the acceptability criteria, this latter proposal thus involves the marking (or learning) of specific directional shifts. Any mispronunciations that do not align with such shifts should hence be

detected.² Prior work has found evidence for both mechanisms, albeit under different conditions. Specifically, evidence for general expansion has been found in cases where young children learn new words in foreign-accented speech (Schmale et al., 2012, 2015), whereas evidence for perceptual tuning comes mainly from work testing effects of children's exposure to familiar words spoken in regional accents (Van der Feest & Johnson, 2016; Van Heugten & Johnson, 2014) or in (artificial) accents consistently employing a single segment change (White & Aslin, 2011). Thus, it is currently unclear whether it is the type of accent or the type of task (or perhaps an unexplored third factor) that determines which mechanism is used when. Further clarification of the prerequisites for each of these mechanisms to come into effect is crucial to advance theories of speech perception and word recognition in young infants.

For this reason, the current study examines whether operations of general expansion and lexically-guided tuning are exploited when listening to a foreign-accented speaker pronouncing known words. In particular, to determine whether infants simply relax their acceptability criteria for word recognition in the face of a foreign accent, we examine the specificity of foreign-accented word form recognition. A vast body of work exploring infant word recognition has established that in the face of a native-accented speaker, children are better at recognizing correctly produced words than words realized with a (single) mispronounced segment (e.g., Mani & Plunkett, 2007, 2010; Swingley, 2005; Swingley & Aslin, 2000; White & Morgan, 2008). Put differently, mismatches between the child's spoken language input and their word form representations partially obstruct word recognition. This implies that children's early lexical representations contain fine-grained phonological detail. But to what extent do infants rely on this phonological detail when listening to a foreign-accented speaker? By comparing infants'

²Note that in order for this mechanism to work, it is not strictly necessary for any semantic content to be accessed. That is, once a sound pattern activates a word form representation, phonological information from the stored template could help fine-tune the mapping between the unfamiliar and the native accent.

interest in mispronounced versions of words in a foreign accent to their interest in intact versions of these accented words, we can determine whether young language learners pick up on the segmental difference between the two tokens. If their threshold for word form recognition is not uniformly lowered, any mispronunciation that cannot be explained by the foreign accent should be detected. Such results would align nicely with theories of perceptual tuning. If, by contrast, children simply increase their acceptance of deviation, they may fail to detect such mispronunciations. Findings like these would align better with theories of general expansion.

The goal of this paper is two-fold. First, in Experiment 1, we examine when Canadian English-learning infants begin recognizing familiar word forms produced in an unfamiliar foreign accent. All items were thus produced by a native French speaker who was fluent in English, but had a marked French accent. To determine when this ability first emerges, we tested three age groups: 15-, 18-, and 22-month-olds. Second, after establishing when Canadian English learning infants learn to recognize French-accented word forms, we examined, in Experiments 2 and 3, children's sensitivity to phonological detail when listening to the French-accented speaker. By using mispronounced versions of the known words from Experiment 1, we can determine the lexical status of mispronounced word forms, thus allowing us to pit the theories of general expansion and lexically-guided tuning for familiar word recognition in foreign accents.

Experiment 1

Experiment 1 tests Canadian English-learning 15-, 18-, and 22-month-olds' ability to recognize French-accented word forms. Using the Headturn Preference Procedure, infants listen to lists of known (e.g., *bottle*, *kiss*) and lists of nonsense words (e.g., *bocky*, *lath*) words, both produced by a French-accented speaker. As is typical in studies using this paradigm, a preference for known over nonsense words will be taken as evidence for children's recognition of word

forms (Hallé & De Boysson-Bardies, 1994; Swingley, 2005; Vihman et al., 2004), and hence, their capacity to cope with the accent at hand (Best et al., 2009; Van Heugten & Johnson, 2014). Of particular interest is at what age infants might start displaying this preference.

Method

Participants.

The final sample of participants consisted of 48 typically developing English-learning infants from the Greater Toronto Area, reportedly free of hearing issues or recent ear infections. All infants grew up in monolingual English-speaking households (defined as a minimum of 90% exposure to English), where at least one parent spoke with a North-American accent.³ In addition, a detailed language questionnaire administered to the caregiver(s) at the end of the lab visit confirmed that none of the infants had had any substantial exposure to either French or French-accented English. Note that only ~1% of the Toronto population speaks French as their home language, as established by the 2011 Canadian census, so this excluded very few children from their participation in this study. Participants belonged to one of three age groups, containing sixteen infants each: 15-month-olds in Experiment 1a (age range: 434-479 days; 10 boys), 18-month-olds in Experiment 1b (age range: 532-567 days; 8 boys), and 22-month-olds in Experiment 1c (age range: 659-693 days; 10 boys). An additional 15 infants (4 in Experiment 1a, 3 in Experiment 1b, and 8 in Experiment 1c) were tested, but excluded prior to data analyses due to extreme fussiness (10), parental interference (1), falling asleep (1), and not meeting the criteria for participation (3). All participating infants received a certificate and a small gift as a token of appreciation.

³Although recruitment was constrained to monolingual English-learning infants with at least one parent who spoke in a North American accent, most of our participants came from families where both parents spoke in a North American accent. Across all 144 participants in Experiments 1-3, only 11 reportedly had a parent who spoke in an accent other than North-American English (e.g., Jamaican-accented or New Zealand-accented English).

Stimuli.

A total of eight word lists were created. Four word lists contained words understood by the majority of 15-month-old infants, with an average word comprehension rate of 78% (range: 61%-99%) reported in the Wordbank Item Trajectories for American-English learning children (Frank et al., 2017). We refer to these lists as the known word lists. The remaining four lists, labeled the nonsense word lists, contained a combination of low-frequency words unfamiliar to young infants and phonotactically legal nonsense words of English (see Table 1 for known and nonsense words along with their broad transcriptions and the supplemental files for audio samples). Note that the two lists were matched on phonotactic probabilities. That is, neither positional segment probability (known words: .181 on average; nonsense words: .180 on average) nor biphone probability (known words: .009 on average; nonsense words: .008 on average), as measured by the Phonotactic Probability Calculator (Vitevitch & Luce, 2004), differed between the two types of word lists.

To prevent potential confounds due to spontaneous preferences for certain speech sounds, the two types of words were roughly matched in phonemes. The presentation of known and nonsense words within each list was modeled after previous work from our lab (Van Heugten & Johnson, 2014). Known word lists contained all fourteen known words and nonsense word lists contained all fourteen nonsense words. On each trial, mono- and bisyllabic (nonsense) words alternated, and all items were repeated twice. The order of the known and nonsense words within each list varied across word lists, but the same eight trials were used for all infants.

Our materials were recorded by a native French speaker originally from the east of France, but who had lived in Paris for approximately four years by the time of the recordings. She had started to learn English in a classroom setting at age 11, and had been using English on a

daily basis in the seven years prior to recording. She was thus fluent in English, but had a pronounced French accent, as judged by native English listeners. The speaker recorded each of the known and nonsense words in a moderate infant-directed fashion. Known and nonsense words were matched in terms of word length and average pitch level of the stressed vowel. The known words were on average 669 ms long and the nonsense words 674 ms. The average pitch of the vowel was 430 Hz for the known words and 439 Hz for the nonsense words. Words and nonsense words were equated for loudness and interspersed with silences of approximately 750 ms. All lists lasted 39.62 s.

Procedure.

Infants were tested individually using a variant of the Headturn Preference Procedure that involved, on separate trials, the presentation of lists of known and nonsense words (see Swingley, 2005; Van Heugten & Johnson, 2014 for similar use of this paradigm). Children sat on their caregivers' lap facing the center panel of a three-sided pegboard set-up placed in a double-walled sound-attenuated IAC test booth. A red light was mounted at infants' eye level on the front panel and a blue light was mounted on each of the side panels. Above the red light on the front panel, a small hole accommodated the use of a video camera that captured the child's looking behavior during the study. Loudspeakers were positioned near each of the blue lights on the side, directly behind the pegboard. Once an infant was seated, the experimenter started the study. First, the infant's attention was drawn towards the flashing front light. Upon center orientation, this light was extinguished and one of the sidelights started to flash. Once infants oriented toward this sidelight, one of the lists was presented from the associated loudspeaker. The list continued to play either until the infant looked away for two consecutive seconds or until the maximum trial length of 39.62 s was reached. Infants' looking behavior was coded in real

time by a trained experimenter, who was located outside the booth and who could hence not hear the word lists. Our custom-made computer program automatically computed children's orientation time to the light for each trial by subtracting any time the child did not orient toward the flashing light from the overall duration of the trial. This resulting orientation measure was used as the dependent variable in our analyses. Four presentation orders were created, each with the restriction that there could be no more than two known or two nonsense word trials in a row. Presentation side was randomized, but no more than two consecutive trials could be played from the same side. No familiarization phase was included. To avoid parental interference, accompanying parents were naïve to the experimental predictions and wore closed headphones playing masking music mixed with several layers of experimental stimuli. The experiment ended when all eight trials had been presented. This lasted approximately 2-3 minutes.

Results and Discussion

Infants' orientation time to lists of known and nonsense words was plotted for each of the three age groups (see Figure 1). A 2 x 3 Analysis of Variance (ANOVA) containing the data of Experiments 1a, 1b, and 1c with word status (known vs. nonsense word) as a within-participant factor and age group (15- vs. 18- vs. 22-month-olds) as a between-participant factor revealed a main effect of word status ($F(1,45) = 10.304; p = 0.002; \eta_p^2 = .186$), indicating that infants preferred to listen to known over nonsense words. No other main effects or interactions were observed.

To determine whether this preference for known over nonsense words was driven by the older age group(s) only, planned comparisons were conducted separately for all three age groups. On average, the 15-month-old infants tested in Experiment 1a listened to the known word lists for 11.57 s and to the nonsense words for 10.96 s. To compare the orientation time toward

known and nonsense words, a two-tailed paired-samples *t*-test was conducted. This analysis indicated that the listening times in the two conditions did not differ significantly from one another ($t(15) = .429$; $p = .674$; mean difference = 0.61 s, 95% CI [-2.43, 3.66]). Thus, in line with previous studies presenting 15-month-olds with known and nonsense words in unfamiliar accents (Best et al., 2009; Van Heugten & Johnson, 2014), we do not find evidence that Canadian English-learning infants this age recognize the French-accented versions of words.

By contrast, the 18-month-olds in Experiment 1b did display a preference for known over nonsense words. Infants listened to the known word lists for an average of 13.07 s and to the nonsense words for an average of 8.85 s. A two-tailed paired-samples *t*-test indicated that this preference for known over nonsense words is statistically significant ($t(15) = 2.615$; $p = .020$; mean difference = 4.22 s, 95% CI [.78, 7.66]), suggesting that by 18 months of age, Canadian English-learning children are able to recognize familiar words in a foreign French accent.

A similar pattern of results also held for the 22-month-olds. Infants in Experiment 1c listened to known words for 16.08 s on average and to nonsense words for an average of 12.10 s. This preference for known over nonsense words is statistically significant, as revealed by the same two-tailed paired-samples *t*-test used in Experiment 1a and 1b ($t(15) = 2.339$; $p = .034$; mean difference = 3.99 s, 95% CI [.35, 7.62]). Thus, much like the 18-month-olds tested in Experiment 1b, our Canadian English-learning 22-month-olds are capable of recognizing known word forms in a foreign French accent.

Taken together, these analyses reveal that by 18 months of age, infants are capable of coping with unfamiliar accents, at least in listening-only tasks such as the present one. Although the observed preference for known over nonsense words did not differ statistically from the looking pattern obtained from the 15-month-olds, a more conservative comparison, taking into

account only the data from the 15-month-olds indicated that this younger age group on its own did not display such an early capacity for coping with unfamiliar accents. Thus, although the current data do not provide us with evidence of a clear developmental shift between 15 and 18 months, we can conclude that 18- and 22-month-olds recognize foreign-accented word forms. As such, this replicates prior work using regional accents where infants were found to be able to recognize regionally-accented words sometime around 19 months of age (Best et al., 2009; Mulak et al., 2013). It also reveals that, at the very least, in the absence of any context, foreign accents are not by definition more challenging to cope with for infants than regional accents. These findings are in line with the idea that infants' abilities to recognize accented words become robust well before age two.

Experiment 2

While 18- and 22-month-olds' preference for known over nonsense words established the time course of infants' ability to cope with our French-accented speaker, it does not speak to the strategies children employed during word form recognition. In Experiment 2, we thus turn to examine the mechanisms underlying the ability to contend with foreign-accented speakers. Recall that one proposal put forward in the literature involves infants loosening their criteria for what counts as an acceptable pronunciation of a word when listening to foreign-accented speech (Schmale et al., 2012, 2015). An alternative hypothesis is that infants cope with accent deviation by forming signal-to-word mappings that are specific to the accent at hand (Van der Feest & Johnson, 2016; Van Heugten & Johnson, 2014; White & Aslin, 2011). Note that support for the former has primarily been observed in the case of word learning studies in foreign-accented speech (Schmale et al., 2012, 2010, 2015; Schmale & Seidl, 2009), whereas evidence for the latter in the case came from studies using familiar words in regionally- (or artificially-)accented

speech (Van der Feest & Johnson, 2016; Van Heugten & Johnson, 2014; White & Aslin, 2011).

But would this discrepancy in strategy be due to the accent type, due to the status of the words used in the task, or due to another (unexplored) difference between these two lines of studies?

The use of mispronunciations in the current experiment allows us to determine children's word specificity when listening to familiar word forms in foreign-accented speech. That is, according to the former, but not the latter proposal, infants should be relatively insensitive to

mispronunciations of familiar words spoken in unfamiliar accents. Vowel mispronunciations rather than consonant mispronunciations were used, as vocalic changes have consistently been

shown to affect word identification in native-accented speech, whereas only some consonant feature changes affect word recognition early on in life (Mani & Plunkett, 2010; also see

Durrant, Delle Luche, Cattani, & Floccia, 2015 for converging findings with children growing up in multidialectal households).

Thus, in Experiment 2, we compare Canadian 18- and 22-month-old infants' interest in known word forms (e.g. *bottle*, *kiss*) to their interest in mispronounced versions of these items (e.g. *bittle*, *koss*). A preference for known over mispronounced words would suggest that children make use of phonological detail during the recognition of accented words. This, in turn, would mean that even when listening to foreign-accented speech, children may, at least in certain situations, be creating signal-to-word mappings on the fly rather than becoming tolerant of all vowel changes. By contrast, the absence of such a preference may be indicative of the use of less phonological precision. This would be in line with accounts of category broadening in foreign-accented word recognition.

Method

Participants.

48 typically developing English-learning infants from the Greater Toronto Area were tested in Experiment 2. Half were tested in Experiment 2a (18-month-olds, age range: 536-562 days; 12 boys) and the other half were tested in Experiment 2b (22-month-olds, age range: 655-692 days; 11 boys). Much like in Experiment 1, none of the parents reported any hearing issues or recent ear infections and none of the infants had had substantial exposure to either French or French-accented English. An additional 16 infants (5 in Experiment 2a and 11 in Experiment 2b) were tested, but were excluded prior to data analyses due to extreme fussiness (12), parental interference (1), experimenter error (1), and not meeting the criteria for participation (2). As before, all infants received a certificate and a small gift as a token of appreciation.

Stimuli.

Experiment 2 used the same real word lists created in Experiment 1. Infants' interest in these word lists was pitted against their interest in lists of mispronounced words. To this end, the same native French speaker recorded mispronounced versions of all known words used in Experiment 1. All mispronunciations involved vowel changes in the stressed syllable. For each mispronunciation, vowels were altered in at least two of the following dimensions: vowel backness, vowel height, vowel roundness, vowel tenseness, and diphthongization (see Table 1 for the mispronounced items and their broad transcriptions and the supplemental files for audio samples). Vowel changes were unsystematic with respect to the direction of the vowel shift. Note that in the few cases where these mispronunciations resulted in real words (*wetter*, *hoot*, *luck*, *show*), these words are of such low frequency in infant-directed speech that 18- and 22-month-olds would not typically be familiar to them. In fact, only *wet* and *show* appear on the

MacArthur-Bates Communicative Development Inventories: Words and Sentences form and according to parental report both items are produced by less than 25% of North American 18-month-olds. As in Experiment 1, phonotactic probabilities did not differ between the two lists, neither on the positional segment probability measure (known and mispronounced words: .181 on average), nor on the biphone probability measure (known words: .009 on average; mispronounced words: .010 on average). The order of the 14 items varied across word lists, but the same eight trials were used for all infants.

To ensure that the accented speaker produced the items as naturally as possible, she was instructed to pronounce the items as a rhyme of a word that differed in onset only (e.g., *boss* for *koss*, *neck* for *seck*). Known and mispronounced words were matched for word length and average pitch level of the stressed vowel. The novel mispronounced words lasted 678 ms on average and had an average pitch level of 442 Hz on the vowel (compared to an average length of 669 ms and an average pitch of the vowel of 430 Hz for the known words). Much like the known and nonsense words in Experiment 1, the mispronounced words were equated for loudness and interspersed with silences of approximately 750 ms. All words were repeated twice, for a total of 39.62 s for all word lists.

Procedure.

The procedure was identical to that in Experiment 1.

Results and Discussion

Infants' interest in known and mispronounced words was plotted for infants in Experiment 2a and 2b (see Figure 2). To determine whether infants differentiated between the two types of word lists, a 2 x 2 ANOVA with word status (known vs. mispronounced words) as a within-participant factor and age group (18- vs. 22-month-olds) as a between-participant factor

was conducted. This revealed a main effect of word status ($F(1,46) = 9.098; p = 0.004; \eta_p^2 = .165$), indicative of a preference for known over mispronounced words. No other main effects or interactions were observed. Thus, much like infants presented with mispronunciations in their own native accent (Swingley, 2005; Vihman et al., 2004), infants presented with mispronounced words in a foreign accent are affected by the phonemic change.

To ensure that this pattern of results could not be attributed to only one of the two age groups, planned comparisons were conducted for each age group separately. Infants in Experiment 2a listened to the known word lists for an average of 14.09 s and to the nonsense words for an average of 10.68 s. A two-tailed paired-samples *t*-test showed that the listening time for words was indeed longer than that for mispronounced words ($t(23) = 2.159; p = .042$; mean difference = 3.41 s, 95% CI [0.14, 6.68]). Thus, the preference for known over mispronounced words was present by as early as 18 months. Moreover, this effect was stable over time. Specifically, in Experiment 2b, 22-month-olds' orientation time to known words was, on average, 14.91 s while their orientation time to mispronounced words was, on average, 11.72 s. A two-tailed paired-samples *t*-test conducted on these data revealed that listening times to the stimuli in these two conditions differed significantly from one another ($t(23) = 2.107; p = .046$; mean difference = 3.18 s, 95% CI [0.06, 6.32]).

These results indicate that even in this more stringent test case, where children were presented with lists of known words and lists of closely matched mispronounced versions of these tokens, infants differentiate between the two types of test trials. In other words, infants not only prefer to listen to known over nonsense words in foreign-accented speech, they also display a preference for phonologically intact words over single vowel mispronunciations, suggesting that not all vowel deviations become irrelevant when listening to accented speech. While these

findings suggest that infants treat mispronounced versions of words produced in foreign-accented speech differently from phonologically correctly pronounced words, these data do not directly speak to the exact status of these mispronounced word forms in relationship to word forms in the infant lexicon. That is, while phonologically intact words may be considered to be more word-like than mispronounced words, it is unclear to what extent mispronunciations lead to any activation of the target word form at all. On the one hand, infant listeners may consider these mispronounced tokens to be relatively small deviations from the real words and these items may, as such, be considered as partial evidence of the associated target word. On the other hand, our mispronunciations may be judged to be drastically different from the target word forms and may essentially be ranked at the same level as nonsense words. Thus, to tease apart these two possibilities, a third experiment was conducted, pitting the mispronounced tokens created in Experiment 2 against the nonsense words from Experiment 1.

Experiment 3

Experiment 3 was designed to establish the status of the mispronounced tokens during word form recognition in the foreign French accent. To address this question, children were presented with lists of mispronounced words and lists of nonsense words. If infants prefer to listen to the mispronounced words over the nonsense words, this may indicate that infants' word form recognition is negatively affected by phonological changes in foreign-accented words, but that such changes may not be sufficient to completely reject these items as words. Mispronunciations would, in other words, fall somewhere in between the two extremes on the lexical status continuum. By contrast, if children do not distinguish between mispronounced and nonsense words, this may indicate that phonological changes to a foreign-accented word essentially changes the status of the lexical item into a nonsense word, much like

mispronunciations can be considered to be nonword-like when pronounced in the home accent. Note that studies using the Headturn Preference Procedure to examine infants' word form recognition in the native accent have, in some cases, found evidence for the activation of mispronounced words (Hallé & de Boysson-Bardies, 1996; Swingley, 2005; Vihman et al., 2004). This renders it unlikely that any potential lack of an effect in this experiment may be due to young children's inability to activate word forms in cases where mispronounced words are uttered in the absence of a referent.

Method

Participants.

A total of 48 typically developing English-learning infants from the Greater Toronto Area were tested. Similar to Experiment 2, half were tested in Experiment 3a (18-month-olds, age range: 534-565 days; 12 boys) and half were tested in Experiment 3b (22-month-olds, age range: 565-585 days; 10 boys). As before, none of the parents reported any hearing issues or recent ear infections and none of the infants had had any substantial exposure to either French or to French-accented English. An additional 8 infants (4 in Experiment 3a and 4 in Experiment 3b) were tested, but were excluded prior to data analyses due to extreme fussiness (5), parental interference (1), and not meeting the criteria for participation (2). All infants received a certificate and a small gift for their participation.

Stimuli

The eight word lists used in this study consisted of the four lists containing mispronounced tokens used in Experiment 2, as well as the four nonsense word lists from Experiment 1. Phonotactic probabilities did not differ between the two lists (positional segment probability: .181 on average for mispronounced words vs. .180 on average for nonsense words;

biphone probability: .010 for mispronounced words vs. .008 for nonsense words). In addition, the tokens in the two types of lists were matched for word length (678 ms on average for mispronounced words and 674 ms on average for nonsense words) and average pitch level of the stressed vowel of (442 Hz for mispronounced words and 439 Hz for nonsense words on the vowel).

Procedure.

The procedure was identical to that in Experiments 1 and 2.

Results and Discussion

Infants' average listening times on trials containing mispronounced words and trials containing nonsense words was plotted for infants in Experiment 3a and 3b (see Figure 3). Similar to Experiment 2, a 2 x 2 ANOVA was conducted with word status (mispronounced vs. nonsense words) as a within-participant factor and age group (18- vs. 22-month-olds) as a between-participant factor. Unlike Experiment 2, however, no statistically significant main effects or interactions were observed. Thus, infants did not differentiate between French-accented mispronounced and nonsense words in this task.

To determine whether both age groups, on their own, failed to display a preference for either type of word list, planned comparisons were conducted for each experiment. 18-month-olds in Experiment 3a listened to the mispronounced tokens for an average of 13.69 s and to the nonsense words for an average of 12.76 s. A two-tailed paired-samples *t*-test revealed that the average listening time for mispronounced words indeed did not differ from that for nonsense words ($t(23) = .527$; $p = .603$; mean difference = .93 s, 95% CI [-2.73, 4.59]). The same was true for the older age group, who listened, on average, to mispronounced words for 12.60 s and to nonsense words for 10.94 s. The two-tailed paired-samples *t*-test conducted on these data

confirmed that listening times to the stimuli in these two conditions did not differ significantly from one another ($t(23) = 1.096$; $p = .285$; mean difference = 1.66 s, 95% CI [-1.47, 4.79]).

These data indicate that neither age group of infants shows a preference for mispronounced over nonsense words, thus reinforcing the notion that mispronounced versions of foreign-accented known words do not differ categorically from foreign-accented nonsense words in the young child's mind. At least when infants are tested in a listening-only task and when vowel mispronunciations involve a 2-feature change, children appear to treat mispronunciations and nonsense words alike. It is thus unlikely that many of the cases in which the phonological substitutions resulted in real words (i.e. *wetter*, *hoot*, *luck*, *show*), these items were recognized as such by the infants. Taken together, these data support the hypothesis that young infants make use of fairly specific phonological detail during foreign-accented word form recognition.

General Discussion

The pronunciation of words varies tremendously between accents and differences between native and foreign accents can be particularly marked. Yet, achieving adult-like competency in their communication skills requires children to learn to interact with foreign-accented speakers. Here, we began to explore the timeline for recognizing familiar words in foreign accents. In Experiment 1, Canadian infants listened to known and nonsense words produced by a French-accented speaker. Infants displayed a preference for known over nonsense words at 18 and 22 months of age, but not at 15 months of age. Thus, we conclude that by 18 months of age, children are capable of accommodating at least some foreign accents. Experiments 2 and 3 then examined the mechanisms underlying this early capacity. In particular, by pitting infants' interest in mispronounced words against their interest in intact words (Experiment 2) and nonsense words (Experiment 3), we examined to what extent Canadian

English-learning infants broaden their categories when listening to a French-accented speaker. While infants were found to listen longer to known than to mispronounced words, their listening times for mispronounced and nonsense words did not differ. Thus, in line with theories of lexically-guided perceptual tuning, vowel changes negatively impact word form recognition in the presence of a foreign accent. This suggests that children do not always simply become tolerant of all vowel deviations when listening to accented speech. Instead, our results are consistent with the view that in the absence of a referent, mispronounced words are treated as nonsense words, even when spoken in a foreign accent.

What do these findings reveal about the mechanism underlying the processing of foreign-accented word forms? Recall that previous work examining children's ability to cope with accents has provided evidence both for general, undirected broadening of phonemic categories (Schmale et al., 2012, 2015) and for accent-specific shifts in the sound-to-representation mappings (Van der Feest & Johnson, 2016; Van Heugten & Johnson, 2014; White & Aslin, 2011). The exact conditions, however, required for each of these mechanisms have not yet been established. Here, we thus raised questions regarding the specificity with which infants recognize *familiar* words in *foreign* accents. Our results show that even though infants are flexible in that they can recognize known words in foreign accents, they are specific in that they do not treat mispronounced versions of such accented words as the equivalent of familiar words. That is, in line with the idea of infants having achieved phonological constancy (Best et al., 2009), infants continue to rely on phonological detail during word form recognition, even when faced with an accented speaker. Thus, much like exposure to regional accents results in phonologically specific shifts in infants' mappings, accent-inconsistent deviations are not ignored when listening to foreign-accented speech. Given that the known word lists provide infants with as many as 14

familiar word forms, the first presentation of a known word list might have been sufficient for children in this task to quickly start deducing at least some signal-to-word mappings specific to this French accent. This, in turn, might have allowed them to distinguish between phonologically intact words and mispronounced versions of these words. While this does not exclude the possibility of general category loosening playing a role under some conditions (e.g., in the absence of lexical access or prior to the deduction of consistent surface-to-representation mappings), the amount of (consistent, likely lexical) exposure necessary to induce accent-specific mappings is minimal, given that the entire experiment lasted under three minutes.

The hypothesis that infants tune in to the French accent as a function of lexically-guided feedback rests on the assumption that their preference for words over nonsense and mispronounced words indicates recognition of the word forms in the known word list. That is, in line with the rationale behind studies using a preferential listening task to test infants' word form recognition in either their native or in an unfamiliar accent (e.g., Best et al., 2009; Hallé & De Boysson-Bardies, 1994; Hallé & de Boysson-Bardies, 1996; Swingley, 2005; Van Heugten & Johnson, 2014; Vihman et al., 2004), language learners are thought to listen longer to the known words because (the phonological forms of) at least some of the items in the list have been accessed. But might there be an alternative explanation for this preference, not grounded in lexical access? One possibility, for instance, may be that the infants in our study preferred to listen to the known word lists because of potential differences in the segmental or prosodic composition of the items (cf. Jusczyk, Cutler, & Redanz, 1993; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; Jusczyk & Luce, 1994). While this would not undermine the finding that infants can cope with foreign accents early in life, it might question whether lexically-guided adaptation would be the mechanism driving adaptation. However, such an

explanation seems unlikely given that our stimuli were carefully balanced in respect to phonotactic probabilities, syllable length, duration, and pitch. Nonetheless, future work systematically manipulating these statistics in accented speech could help us better understand whether these factors carry the same weight in accented speech as they do in native speech.

There is one potentially important factor that we have yet to consider: the severity of the mispronunciations. Recall that all vowel mispronunciations incorporated in the current study involved changes in at least two, but sometimes three or even four of the vowel features (instantiated as vowel backness, vowel height, vowel roundness, vowel tenseness, and diphthongization). With vowels differing on more than just a single feature, the intact and mispronounced vowel tokens were clearly acoustically, phonetically, and phonologically different. While these relatively large changes assured us that the mispronunciations could not be mistaken for the French-accented speaker's typical pronunciation of the target word, it is unclear whether the use of smaller discrepancies, perhaps differing in just a single feature, would lead to the same pattern of results. For instance, it is possible that while infants detect severe mispronunciations, interchanging similar-sounding vowels might be noticed to a lesser extent. If this were the case, then infants may recognize both [hæt] and [hɛt] as referring to *hat*, but may fail to recognize [hɒt] as referring to the same referent. Future studies, possibly manipulating the direction (Weatherhead & White, 2016; White & Aslin, 2011) and systematicity of the changes, could begin testing this hypothesis. Note, however, that even when listening to a native speaker, subtle mispronunciations do not categorically prevent word recognition (Creel, 2012; Mani, Coleman, & Plunkett, 2008; Mani & Plunkett, 2011; Swingley, 2016; White & Morgan, 2008). Should infants thus accept or tolerate some relatively small mispronunciations this would not directly imply a general broadening strategy for coping with accented words. As a result, the

boundary between general expansion and perceptual tuning strategies are somewhat blurred. Determining the minimum mispronunciation severity necessary to tease apart the two mechanisms will therefore be challenging. Nonetheless, regardless of any outcome in this matter, our current findings suggest that there are clear restrictions on what counts as an acceptable pronunciation of a known word, even in foreign-accented speech.

Our finding showing that 18- and 22-month-olds recognize foreign-accented word tokens, but fail to accept tokens in which a vowel has been changed suggests that children this age are highly sensitive to the difference between accents and mispronunciations. This may lead one to wonder how children determine whether a deviation from the word's pronunciation in the child's own accent is accent-induced or whether it is due to a mispronunciation. This question is particularly relevant given that the current study used lists of words, potentially limiting the number of factors that could differentiate the two types of deviation. One potential cue that might guide infants into the right direction would be prosodic differences. Although prosody might have less of an effect in isolated words than in sentences, certain differences in prosodic features can still be observed across accents at the word level. As an example, our French-accented speaker, being a native speaker of a syllable-timed language where stress is non-contrastive, may have produced the bisyllabic words used in the study with a somewhat different rhythmic pattern than a typical native English speaker. A second difference between foreign-accented and mispronounced words might have to do with the overall amount of segmental deviations. By definition, a mispronunciation (at least in this task) only affects a single segment, whereas a foreign accent potentially affects the realization of many more segments. Third, while mispronunciations always lead to a phonemic change, deviations invoked by foreign accents can sometimes be smaller in nature. In particular, instead of creating full segmental changes, it is

possible for accented speakers to slightly shift the category center (or distribution) in phonetic space. Accent-induced acoustic-phonetic discrepancies between the observed word form and its underlying representation may thus be smaller than those between mispronunciations and representation. And finally, over time, infants may come to realize that while accented speakers pronounce words differently than native Canadian speakers, the mispronounced phonemes from mispronounced words are not unpronounceable by the speaker. Specifically, a mispronunciation of [hu:t] for [hæt] might not appear to be strictly necessary given that the speaker can pronounce the original vowel [æ], as is observable in other mispronounced items (e.g., [kæki]) as well as in the correctly pronounced versions from the known word lists. Sensitivity to one or more of these factors highlighting the differences between mispronunciations and foreign accents may help children maintain their attention to phonological detail, all the while allowing for flexibility in establishing the signal-to-word mappings.

This is, of course, not to say that the observed flexibility by 18-22 months of age allows children to recognize all known word forms in any accent. Whether or not children recognize a specific accented token will largely depend on the task (e.g., procedures, cognitive demands, word familiarity, presentation of words in sentences or in isolation, use of images vs. auditory-only; see Van Heugten & Johnson, 2016 for a discussion). But even within a given task, accented word recognition will likely largely depend both on the accent and on the language background of the test population used. Children's ability to recognize words produced by our French-accented English speaker in this task does not imply that children tested in the current task can contend with all foreign accents (or even a more heavily accented native French speaker speaking English). Ideally, accent strength would be easily quantifiable. Unfortunately, this is not the case. It can be extremely challenging to measure the perceptual difference of an

unfamiliar accent from a child's native accent spoken at home. And even if this *would* be quantifiable for adults, there is no guarantee that an adult ranking would directly transfer to children's perception of accents or that accentedness correlates with intelligibility (Munro & Derwing, 1995). In addition, it is conceivable that even though our Canadian English infants can cope with a French accent by 18 months, English-learning infants raised hearing another accent or raised with routine exposure to a mixture of accents might need less (or more) time to learn to recognize familiar word forms in unfamiliar foreign accents (see Buckler, Oczak-Arsic, Siddiqui, & Johnson, 2017; Floccia, Delle Luche, Durrant, Butler, & Goslin, 2012; Van Heugten & Johnson, 2017 for evidence suggesting that exposure to accent variability in the home environment affects word recognition). Nonetheless, although the current paper uses only a single speaker and a relatively homogeneous group of participants, it does reveal that the time course of infants' ability to recognize familiar words in foreign accents is not categorically delayed compared to infants' ability to cope with native accents (cf. Best et al., 2009; Van Heugten & Johnson, 2014). In addition, the presentation of a foreign-accented speaker does not lead infants to fully relax their phonological criteria for word access. Thus, it is possible that contending with regionally-accented speakers is not qualitatively different from contending with foreign-accented speakers and that similar mechanisms may be employed to accommodate both types of accent. Further experiments could clarify whether this hypothesis would hold in the case of other speakers and accents.

In sum, the current paper established the developmental trajectory underlying infants' ability to contend with unfamiliar foreign accents and examined the strategies used to recognize word forms produced by a foreign-accented speaker. Although recognizing accented words is, without a doubt, challenging early in life (Best et al., 2009; Mulak et al., 2013; Van Heugten &

Johnson, 2014, 2016; Van Heugten et al., 2015; White & Aslin, 2011), infants –at least in the months preceding their second birthday– are equipped with the basic cognitive machinery to accommodate such variability, regardless of whether the accent is regional or foreign. This can be of great use when communicating with individuals from other linguistic backgrounds, whether this be in the home environment or at testing facilities. In line with accounts of lexically-guided perceptual tuning, foreign-accented word recognition is furthermore sufficiently precise to detect mispronunciations, and, at least in the absence of a clear referent, to treat such mispronounced items like nonsense words. Taken together, these findings suggest that infants’ word form recognition is simultaneously flexible and specific.

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References

- Baese-Berk, M. M., & Morrill, T. H. (2015). Speaking rate consistency in native and non-native speakers of English. *The Journal of the Acoustical Society of America*, *138*(3), EL223-EL228. <https://doi.org/10.1121/1.4929622>
- Barton, D. (1976). Phonemic discrimination and the knowledge of words in children under 3 years. *Papers and Reports on Child Language Development*, *11*, 61–68.
- Bent, T. (2014). Children's perception of foreign-accented words. *Journal of Child Language*, *41*(6), 1334–1355. <https://doi.org/10.1017/S0305000913000457>
- Bent, T., & Atagi, E. (2015). Children's perception of nonnative-accented sentences in noise and quiet. *The Journal of the Acoustical Society of America*, *138*(6), 3985–3993. <https://doi.org/10.1121/1.4938228>
- Bent, T., & Atagi, E. (2017). Perception of nonnative-accented sentences by 5-to 8-year-olds and adults: The role of phonological processing skills. *Language and Speech*, *60*(1), 110–122. <https://doi.org/10.1177/0023830916645374>
- Bergelson, E., & Swingle, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences*, *109*(9), 3253–3258. <https://doi.org/10.1073/pnas.1113380109>
- Best, C. T., Tyler, M. D., Gooding, T. N., Orlando, C. B., & Quann, C. A. (2009). Development of phonological constancy: Toddlers' perception of native- and Jamaican-accented words. *Psychological Science*, *20*(5), 539–542. <https://doi.org/10.1111/j.1467-9280.2009.02327.x>

- Buckler, H., Oczak-Arsic, S., Siddiqui, N., & Johnson, E. K. (2017). Input matters: Speed of word recognition in 2-year-olds exposed to multiple accents. *Journal of Experimental Child Psychology, 164*, 87–100. <https://doi.org/10.1016/j.jecp.2017.06.017>
- Creel, S. C. (2012). Phonological similarity and mutual exclusivity: On-line recognition of atypical pronunciations in 3–5-year-olds. *Developmental Science, 15*(5), 697–713. <https://doi.org/10.1111/j.1467-7687.2012.01173.x>
- Dale, P. S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers, 28*(1), 125–127. <https://doi.org/10.3758/BF03203646>
- Delle Luche, C., Durrant, S., Floccia, C., & Plunkett, K. (2014). Implicit meaning in 18-month-old toddlers. *Developmental Science, 17*(6), 948–955. <https://doi.org/10.1111/desc.12164>
- Durrant, S., Delle Luche, C., Cattani, A., & Floccia, C. (2015). Monodialectal and multidialectal infants' representation of familiar words. *Journal of Child Language, 42*(2), 447–465. <https://doi.org/10.1017/S0305000914000063>
- Fennell, C. T., & Werker, J. F. (2003). Early word learners' ability to access phonetic detail in well-known words. *Language and Speech, 46*(2–3), 245–264. <https://doi.org/10.1177/00238309030460020901>
- Floccia, C., Butler, J., Girard, F., & Goslin, J. (2009). Categorization of regional and foreign accent in 5- to 7-year-old British children. *International Journal of Behavioral Development, 33*(4), 366–375. <https://doi.org/10.1177/0165025409103871>
- Floccia, C., Butler, J., Goslin, J., & Ellis, L. (2009). Regional and foreign accent processing in English: Can listeners adapt? *Journal of Psycholinguistic Research, 38*(4), 379–412. <https://doi.org/10.1007/s10936-008-9097-8>

Floccia, C., Delle Luche, C., Durrant, S., Butler, J., & Goslin, J. (2012). Parent or community:

Where do 20-month-olds exposed to two accents acquire their representation of words?

Cognition, *124*(1), 95–100. <https://doi.org/10.1016/j.cognition.2012.03.011>

Floccia, C., Goslin, J., Girard, F., & Konopczynski, G. (2006). Does a regional accent perturb

speech processing? *Journal of Experimental Psychology: Human Perception and*

Performance, *32*(5), 1276–1293. <https://doi.org/10.1037/0096-1523.32.5.1276>

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open

repository for developmental vocabulary data. *Journal of Child Language*, *44*(3), 677–

694. <https://doi.org/10.1017/S0305000916000209>

Girard, F., Floccia, C., & Goslin, J. (2008). Perception and awareness of accents in young

children. *British Journal of Developmental Psychology*, *26*(3), 409–433.

<https://doi.org/10.1348/026151007X251712>

Goslin, J., Duffy, H., & Floccia, C. (2012). An ERP investigation of regional and foreign accent processing. *Brain and Language*, *122*(2), 92–102.

<https://doi.org/10.1016/j.bandl.2012.04.017>

Graf Estes, K., & Lew-Williams, C. (2015). Listening through voices: Infant statistical word

segmentation across multiple speakers. *Developmental Psychology*, *51*(11), 1517–1528.

<https://doi.org/10.1037/a0039725>

Hallé, P. A., & De Boysson-Bardies, B. (1994). Emergence of an early receptive lexicon:

Infants' recognition of words. *Infant Behavior and Development*, *17*(2), 119–129.

[https://doi.org/10.1016/0163-6383\(94\)90047-7](https://doi.org/10.1016/0163-6383(94)90047-7)

- Hallé, P. A., & de Boysson-Bardies, B. (1996). The format of representation of recognized words in infants' early receptive lexicon. *Infant Behavior and Development, 19*(4), 463–481.
[https://doi.org/10.1016/S0163-6383\(96\)90007-7](https://doi.org/10.1016/S0163-6383(96)90007-7)
- Houston, D. M., & Jusczyk, P. W. (2000). The role of talker-specific information in word segmentation by infants. *Journal of Experimental Psychology: Human Perception and Performance, 26*(5), 1570–1582. <https://doi.org/10.1037/0096-1523.26.5.1570>
- Johnson, E. K., Seidl, A., & Tyler, M. D. (2014). The edge factor in early word segmentation: utterance-level prosody enables word form extraction by 6-month-olds. *PloS One, 9*(1), e83546. <https://doi.org/10.1371/journal.pone.0083546>
- Jusczyk, P. W., Cutler, A., & Redanz, N. J. (1993). Infants' preference for the predominant stress patterns of English words. *Child Development, 64*(3), 675–687.
<https://doi.org/10.1111/j.1467-8624.1993.tb02935.x>
- Jusczyk, P. W., Friederici, A. D., Wessels, J. M., Svenkerud, V. Y., & Jusczyk, A. M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language, 32*(3), 402–420.
- Jusczyk, P. W., & Luce, P. A. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language, 33*(5), 630–645.
- Jusczyk, P. W., Pisoni, D. B., & Mullennix, J. (1992). Some consequences of stimulus variability on speech processing by 2-month-old infants. *Cognition, 43*(3), 253–291.
[https://doi.org/10.1016/0010-0277\(92\)90014-9](https://doi.org/10.1016/0010-0277(92)90014-9)
- Kuhl, P. K. (1979). Speech perception in early infancy: Perceptual constancy for spectrally dissimilar vowel categories. *The Journal of the Acoustical Society of America, 66*(6), 1668–1679. <https://doi.org/10.1121/1.383639>

- Mani, N., Coleman, J., & Plunkett, K. (2008). Phonological specificity of vowel contrasts at 18-months. *Language and Speech, 51*(1–2), 3–21.
<https://doi.org/10.1177/00238309080510010201>
- Mani, N., & Plunkett, K. (2007). Phonological specificity of vowels and consonants in early lexical representations. *Journal of Memory and Language, 57*(2), 252–272.
<https://doi.org/10.1016/j.jml.2007.03.005>
- Mani, N., & Plunkett, K. (2010). Twelve-month-olds know their cups from their keps and tups. *Infancy, 15*(5), 445–470. <https://doi.org/10.1111/j.1532-7078.2009.00027.x>
- Mani, N., & Plunkett, K. (2011). Does size matter? Subsegmental cues to vowel mispronunciation detection. *Journal of Child Language, 38*(3), 606–627.
<https://doi.org/10.1017/S0305000910000243>
- Metsala, J. L. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. *Journal of Educational Psychology, 91*(1), 3–19.
<https://doi.org/10.1037/0022-0663.91.1.3>
- Mulak, K. E., Best, C. T., Tyler, M. D., Kitamura, C., & Irwin, J. R. (2013). Development of phonological constancy: 19-month-olds, but not 15-month-olds, identify words in a non-native regional accent. *Child Development, 84*(6), 2064–2078.
<https://doi.org/10.1111/cdev.12087>
- Munro, M. J., & Derwing, T. M. (1995). Foreign accent, comprehensibility, and intelligibility in the speech of second language learners. *Language Learning, 45*(1), 73–97.
<https://doi.org/10.1111/j.1467-1770.1995.tb00963.x>

Parise, E., & Csibra, G. (2012). Electrophysiological evidence for the understanding of maternal speech by 9-month-old infants. *Psychological Science*, 728–733.

<https://doi.org/10.1177/0956797612438734>

Polka, L., Masapollo, M., & Ménard, L. (2014). Who's talking now? Infants' perception of vowels with infant vocal properties. *Psychological Science*, 0956797614533571.

<https://doi.org/10.1177/0956797614533571>

Rost, G. C., & McMurray, B. (2009). Speaker variability augments phonological processing in early word learning. *Developmental Science*, 12(2), 339–349.

<https://doi.org/10.1111/j.1467-7687.2008.00786.x>

Schmale, R., Cristia, A., & Seidl, A. (2012). Toddlers recognize words in an unfamiliar accent after brief exposure. *Developmental Science*, 15(6), 732–738.

<https://doi.org/10.1111/j.1467-7687.2012.01175.x>

Schmale, R., Cristià, A., Seidl, A., & Johnson, E. K. (2010). Developmental changes in infants' ability to cope with dialect variation in word recognition. *Infancy*, 15(6), 650–662.

<https://doi.org/10.1111/j.1532-7078.2010.00032.x>

Schmale, R., Hollich, G., & Seidl, A. (2011). Contending with foreign accent in early word learning. *Journal of Child Language*, 38(5), 1096–1108.

<https://doi.org/10.1017/S0305000910000619>

Schmale, R., & Seidl, A. (2009). Accommodating variability in voice and foreign accent: Flexibility of early word representations. *Developmental Science*, 12(4), 583–601.

<https://doi.org/10.1111/j.1467-7687.2009.00809.x>

- Schmale, R., Seidl, A., & Cristia, A. (2015). Mechanisms underlying accent accommodation in early word learning: Evidence for general expansion. *Developmental Science, 18*(4), 664–670. <https://doi.org/10.1111/desc.12244>
- Singh, L. (2008). Influences of high and low variability on infant word recognition. *Cognition, 106*(2), 833–870. <https://doi.org/10.1016/j.cognition.2007.05.002>
- Singh, L., Morgan, J. L., & White, K. S. (2004). Preference and processing: The role of speech affect in early spoken word recognition. *Journal of Memory and Language, 51*(2), 173–189. <https://doi.org/10.1016/j.jml.2004.04.004>
- Singh, L., Nestor, S. S., & Bortfeld, H. (2008). Overcoming the effects of variation in infant speech segmentation: Influences of word familiarity. *Infancy, 13*(1), 57–74. <https://doi.org/10.1080/15250000701779386>
- Swingley, D. (2005). 11-month-olds' knowledge of how familiar words sound. *Developmental Science, 8*(5), 432–443. <https://doi.org/10.1111/j.1467-7687.2005.00432.x>
- Swingley, D. (2016). Two-year-olds interpret novel phonological neighbors as familiar words. *Developmental Psychology, 52*(7), 1011–1023. <https://doi.org/10.1037/dev0000114>
- Swingley, D., & Aslin, R. N. (2000). Spoken word recognition and lexical representation in very young children. *Cognition, 76*(2), 147–166. [https://doi.org/10.1016/S0010-0277\(00\)00081-0](https://doi.org/10.1016/S0010-0277(00)00081-0)
- Tincoff, R., & Jusczyk, P. W. (1999). Some beginnings of word comprehension in 6-month-olds. *Psychological Science, 10*(2), 172–175. <https://doi.org/10.1111/1467-9280.00127>
- Tincoff, R., & Jusczyk, P. W. (2012). Six-month-olds comprehend words that refer to parts of the body. *Infancy, 17*(4), 432–444. <https://doi.org/10.1111/j.1532-7078.2011.00084.x>

- Van der Feest, S. V. H., & Johnson, E. K. (2016). Input-driven differences in toddlers' perception of a disappearing phonological contrast. *Language Acquisition, 23*(2), 89–111. <https://doi.org/10.1080/10489223.2015.1047096>
- Van Heugten, M., & Johnson, E. K. (2012). Infants exposed to fluent natural speech succeed at cross-gender word recognition. *Journal of Speech, Language and Hearing Research, 55*(2), 554–560. [https://doi.org/10.1044/1092-4388\(2011/10-0347\)](https://doi.org/10.1044/1092-4388(2011/10-0347))
- Van Heugten, M., & Johnson, E. K. (2014). Learning to contend with accents in infancy: Benefits of brief speaker exposure. *Journal of Experimental Psychology: General, 143*(1), 340–350. <https://doi.org/10.1037/a0032192>
- Van Heugten, M., & Johnson, E. K. (2016). Toddlers' word recognition in an unfamiliar regional accent: The role of local sentence context and prior accent exposure. *Language and Speech, 59*(3), 353–363. <https://doi.org/10.1177/0023830915600471>
- Van Heugten, M., & Johnson, E. K. (2017). Input matters: Multi-accent language exposure affects word form recognition in infancy. *Journal of the Acoustical Society of America: Express Letters, 42*(2), EL196-EL200. <https://doi.org/10.1121/1.4997604>
- Van Heugten, M., Krieger, D. R., & Johnson, E. K. (2015). The developmental trajectory of toddlers' comprehension of unfamiliar regional accents. *Language Learning and Development, 11*(1), 41–65. <https://doi.org/10.1080/15475441.2013.879636>
- Vihman, M. M., Nakai, S., DePaolis, R. A., & Hallé, P. (2004). The role of accentual pattern in early lexical representation. *Journal of Memory and Language, 50*(3), 336–353. <https://doi.org/10.1016/j.jml.2003.11.004>

- Vitevitch, M. S., & Luce, P. A. (2004). A web-based interface to calculate phonotactic probability for words and nonwords in English. *Behavior Research Methods, Instruments, & Computers : A Journal of the Psychonomic Society, Inc*, *36*(3), 481–487.
- Wade, T., Jongman, A., & Sereno, J. (2007). Effects of acoustic variability in the perceptual learning of non-native-accented speech sounds. *Phonetica*, *64*(2–3), 122–144.
<https://doi.org/10.1159/0000107913>
- Wagner, L., Clopper, C. G., & Pate, J. K. (2014). Children’s perception of dialect variation. *Journal of Child Language*, *41*(5), 1062–1084.
<https://doi.org/10.1017/S0305000913000330>
- Weatherhead, D., & White, K. S. (2016). He says potato, she says potahto: Young infants track talker-specific accents. *Language Learning and Development*, *12*(1), 92–103.
<https://doi.org/10.1080/15475441.2015.1024835>
- White, K. S., & Aslin, R. N. (2011). Adaptation to novel accents by toddlers. *Developmental Science*, *14*(2), 372–384. <https://doi.org/10.1111/j.1467-7687.2010.00986.x>
- White, K. S., & Morgan, J. L. (2008). Sub-segmental detail in early lexical representations. *Journal of Memory and Language*, *59*(1), 114–132.
<https://doi.org/10.1016/j.jml.2008.03.001>
- Willits, J. A., Wojcik, E. H., Seidenberg, M. S., & Saffran, J. R. (2013). Toddlers activate lexical semantic knowledge in the absence of visual referents: Evidence from auditory priming. *Infancy*, *18*(6), 1053–1075. <https://doi.org/10.1111/infa.12026>

Table 1

Items used and their broad transcriptions in Canadian English.

Words (Experiments 1 and 2)	Mispronounced words (Experiments 2 and 3)	Nonwords (Experiments 1 and 3)
bottle ba:tɫ	bittle bitɫ	bocky bɑ:ki
bye bye baɪbaɪ	bay bye beɪbaɪ	hooky hʊki
cookie kʊki	cackie kækɪ	kai kai kaɪkaɪ
ducky dʌki	dookie dʊki	mottle mɑ:tɫ
hello hɛloʊ	holo hoʊloʊ	mubber mʌbʊ
mommy mɑ:mi	mimmy mɪmi	shammy ʃæmi
water wɑ:tə	wetter wɛtə	willow wɪloʊ
bath bæθ	both bɑ:θ	belk bɛlk
hat hæʔ	hoot hu:t	bot bɑ:t
kiss kɪs	koss kɑ:s	coo ku:
look lʊk	luck lʌk	doss dɑ:s
milk mɪlk	mulk mʌlk	hick hɪk
shoe ʃu:	show ʃoʊ	lath læθ
sock sɑ:k	seck sɛk	sook sʊk

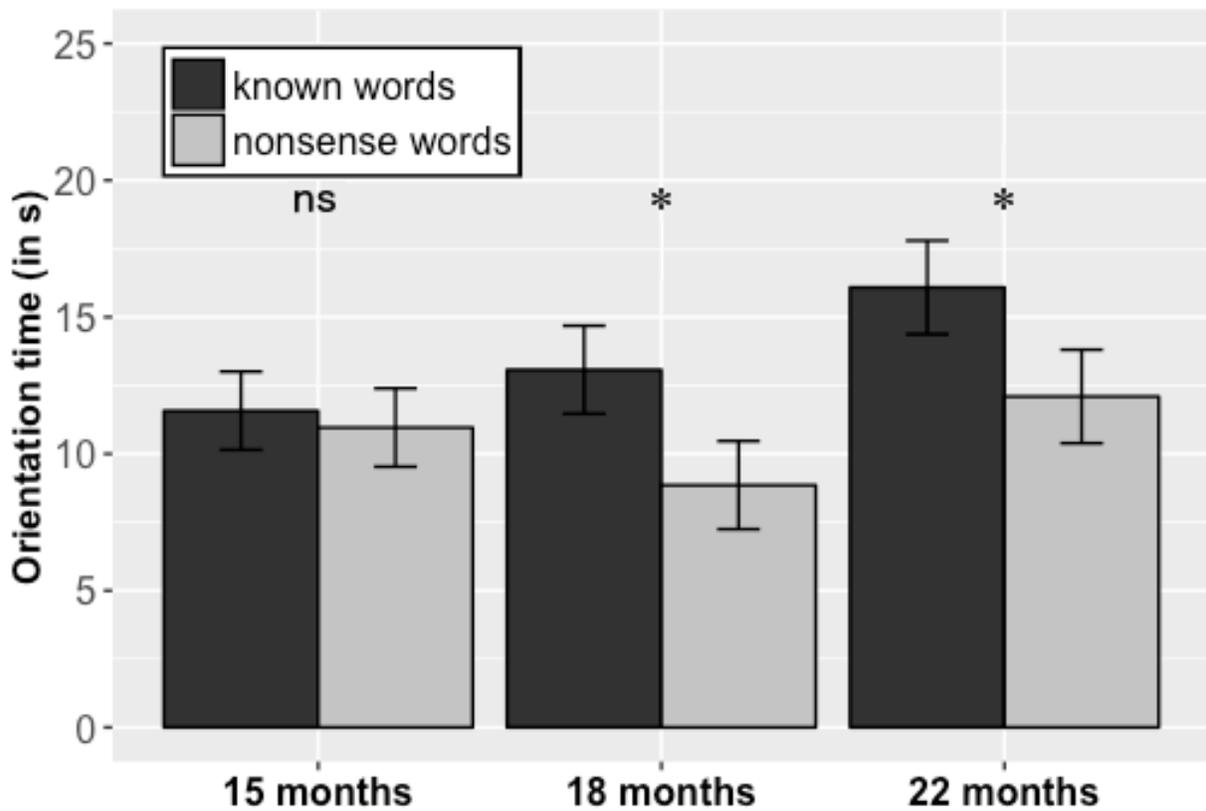


Figure 1. Orientation time in seconds (error bars indicate standard errors of the mean difference scores) to known and nonsense words in an unfamiliar French accent in Experiment 1a (15-month-olds), 1b (18-month-olds), and 1c (22-month-olds).

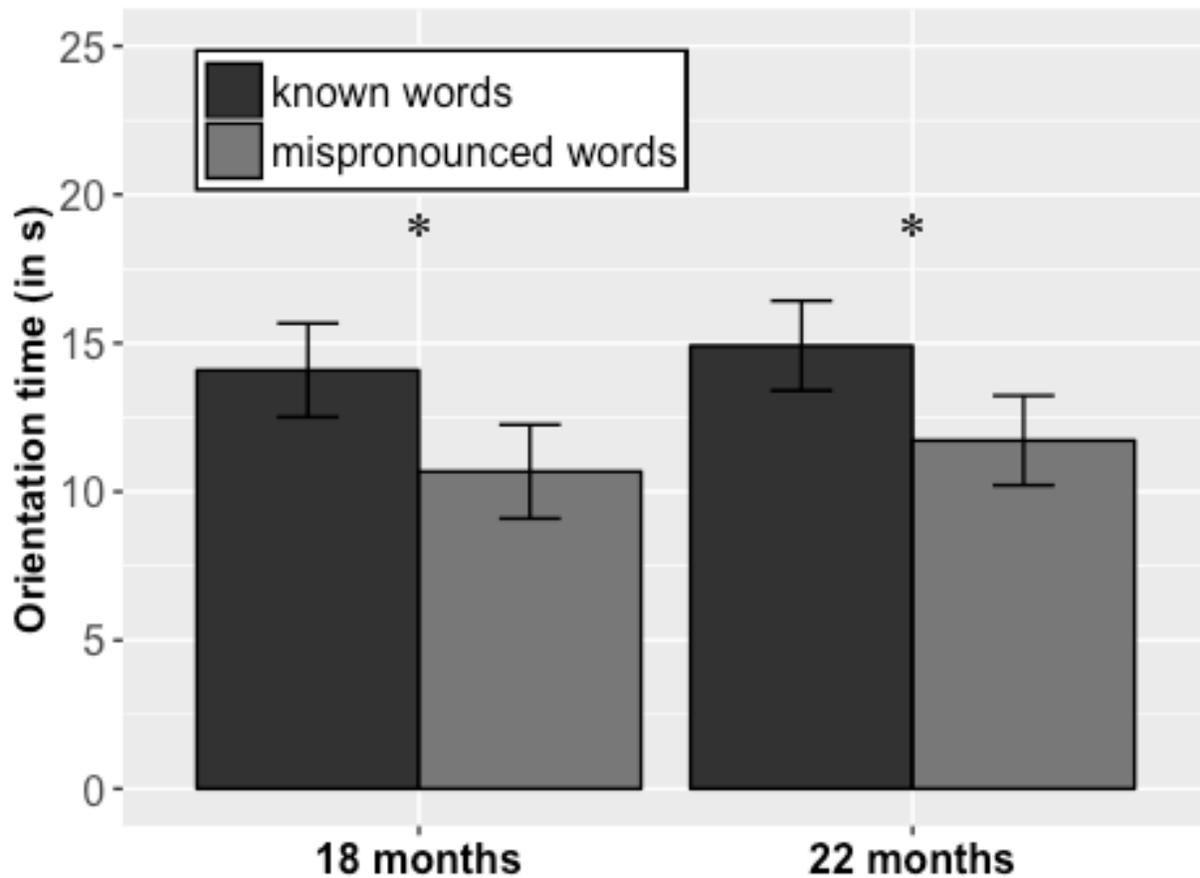


Figure 2. Orientation time in seconds (error bars indicate standard errors of the mean difference scores) to known and mispronounced words in an unfamiliar French accent in Experiment 2a (18-month-olds), and 2b (22-month-olds).

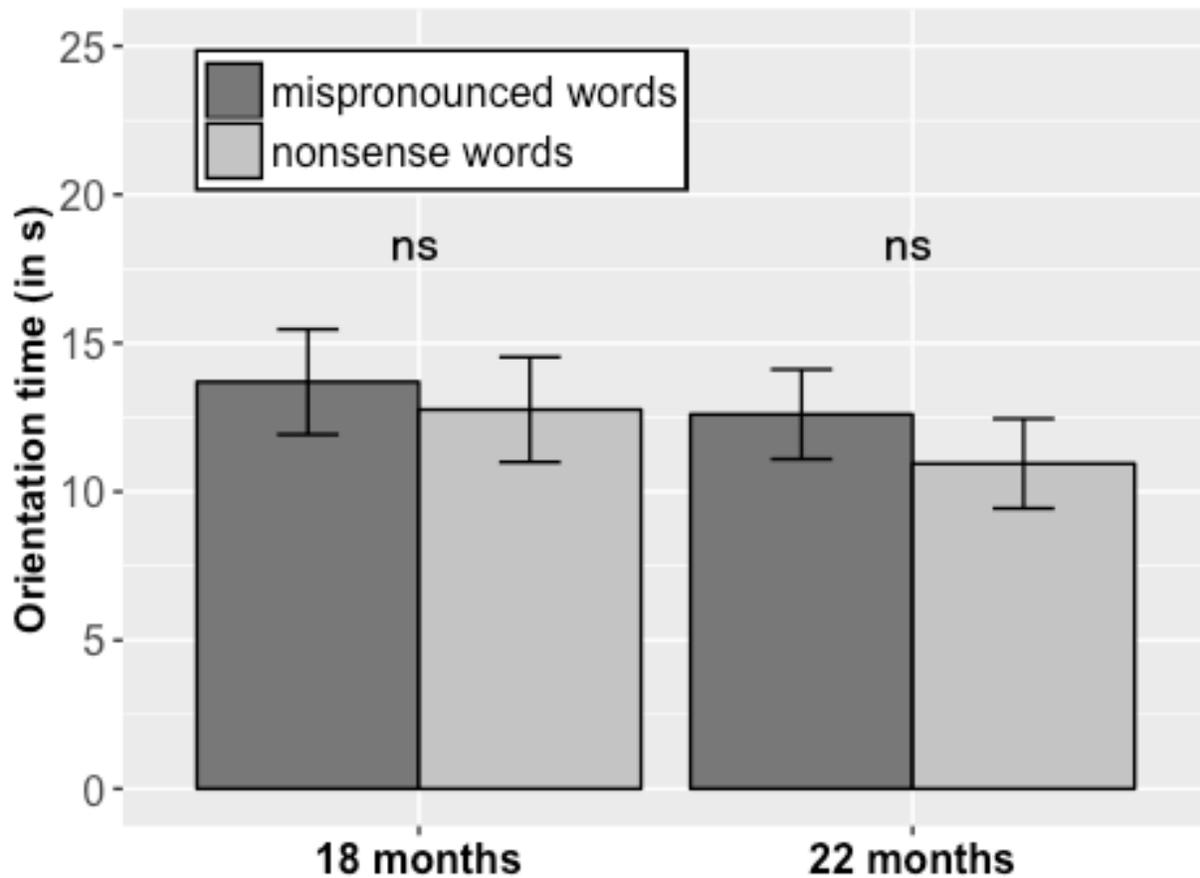


Figure 3. Orientation time in seconds (error bars indicate standard errors of the mean difference scores) to mispronounced and nonsense words in an unfamiliar French accent in Experiment 3a (18-month-olds), and 3b (22-month-olds).