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Abstract

Successful word recognition requires that listeners attend to differences that are phonemic in that language while also remaining flexible to the variation introduced by different voices and accents. Previous work has demonstrated that American-English-learning 19-month-olds are able to balance these demands: although one-off one-feature mispronunciations typically disrupt English-learning toddlers' lexical access, they no longer do after toddlers are exposed to a novel accent in which these changes occur systematically (White & Aslin, 2011; White & Daub, 2021). The flexibility to deal with different types of variation may not be the same for toddlers learning different first languages, however, as language structure shapes early phonological biases. We examined French-learning 19-month-olds' sensitivity and adaptation to a novel accent that shifted either the standard pronunciation of /a/ from [a] to [ɛ] (Experiment 1) or the standard pronunciation of /p/ from [p] to [t] (Experiment 2). In Experiment 1, French-learning toddlers recognized words with /a/ produced as [ɛ], regardless of whether they were previously exposed to an accent that contained this vowel shift or not. In Experiment 2, toddlers did not recognize words with /p/ pronounced as [t] at test unless they were first familiarized with an accent that contained this consonant shift. These findings are consistent with evidence that French-learning toddlers privilege consonants over vowels in lexical processing. Together with previous work, these results demonstrate both differences and similarities in how French- and English-learning children treat variation, in line with their language-specific phonological biases.

Keywords: familiar word recognition; accent adaptation; consonant bias; lexical processing; mispronunciation sensitivity

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The speech signal contains significant variation, introduced by speaker differences such as vocal-tract length, and within-speaker differences, such as affect and register. Despite this variation, by their first birthday infants have made considerable progress in acquiring the phonological categories of their first language, as they show increased sensitivity to the types of changes that signal a difference in word identity (e.g. Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005) and decreased sensitivity to some contrasts not used in their first language (e.g., Werker & Tees, 1984; Best, McRoberts, & Sithole, 1988; Kuhl et al., 1992; Polka & Werker, 1994; Rivera-Gaxiola et al., 2005). Infants as young as 12 months apply their knowledge of phonological categories during word recognition, showing sensitivity to mispronunciations of familiar words (e.g. Mani & Plunkett, 2010; see Von Holzen & Bergmann, 2021 for a meta-analysis). Yet, they do not always do so. Even when children have learned the phonological categories of their first language, the properties of the first language may bias them to be more sensitive to certain kinds of changes over others. For example, Dutch- and English-learning infants and toddlers are more sensitive to changes from labial consonants to coronal consonants than vice versa (Fennell & Waxman, 2010; van der Feest & Fikkert, 2015). Toddlers exposed to Japanese, however, show equivalent sensitivity to both types of changes (Tsuji, Mazuka, Cristia, & Fikkert, 2015). These different patterns may be due to language-specific differences in the properties of the early lexicon.

In the current study, we focus on a different kind of phonological bias, known as the consonant bias. Nespor, Peña, and Mehler (2003) described a “division of labor” between consonants and vowels, with consonants playing a more important role in lexical processing and vowels playing a more important role in grammatical and prosodic processing. The consonant bias describes a preference for consonant over vowel information in determining the identity of a word, and has been found in adult speakers of many different language backgrounds during lexical processing (for a review of languages tested thus far, see Nazzi & Cutler, 2018), with the exception of tonal languages (such as Cantonese or Mandarin; Gómez, Mok, Ordin, Mehler, & Nespor, 2018; Poltrock, Chen, Kwok, Cheung, & Nazzi, 2018; Wiener, 2020; Wiener & Turnbull, 2016). The factors that lead to this bias are still under debate, and are likely to be numerous and include both phonological and lexical factors. For example, at the phonological level, it might be due to the fact that consonants are processed more categorically than vowels (Fry, Abramson, Eimas, & Liberman, 1962). Also, consonants are often more numerous than vowels across languages, which may lead to more within-category variability in the production of vowels compared to consonants, with the amount of variability depending on language-specific inventories and other phonological properties such as lexical stress or lexical tones (Lindblom, 1986; see also Johnson, Ladefoged, & Lindau, 1993; Costa, Cutler, & Sebastián-Gallés, 1998; Hauser, 2019). At the lexical level, it has been shown, at least for French, that consonants are more informative than vowels in distinguishing and identifying words within the lexicon (Keidel, Jenison, Kluender, & Seidenberg, 2007; Nazzi & New, 2007).

However, there is cross-linguistic variability in whether and when the consonant bias emerges. Work so far shows no consonant bias in children learning languages such as Danish (Højen & Nazzi, 2016), Hebrew (Segal, Keren-Portnoy, & Vihman, 2020), or Cantonese (Chen et al., 2021). English-learning infants and toddlers show similar sensitivity to consonant and vowel mispronunciations (Delle Luche, Floccia, Granjon, & Nazzi, 2017; Mani & Plunkett, 2007, 2010; Swingley, 2016) and only demonstrate a consonant bias at older ages (Floccia, Nazzi, Luche, Poltrock, & Goslin, 2014; Nazzi et al., 2009). In contrast, French-learning infants demonstrate a consistent consonant bias from the second half of the first year of life onward (Nishibayashi & Nazzi, 2016; Poltrock & Nazzi, 2015; Von Holzen & Nazzi, 2020; Von Holzen, Nishibayashi, & Nazzi, 2018). Although the reasons for these cross-linguistic differences remains to be specified more precisely, they are thought to be shaped by differences in the acoustic-phonetic (Floccia et al., 2014) or lexical properties of the first language (Keidel et al., 2007), or more likely a combination of both (Poltrock & Nazzi, 2015; see also Nazzi, Poltrock, & Von Holzen, 2016). These and other cross-linguistic comparisons (see Nazzi et al., 2016) serve to highlight the role that the characteristics of the first language may have in the development of phonological biases.

Studies investigating the consonant bias with children examine how lexical processing is interrupted by changes to consonant or vowel information. This can be examined in recognition at the word form level (e.g. Bouchon, Floccia, Fux, Adda-Decker, & Nazzi, 2015; Nishibayashi & Nazzi, 2016; Poltrock & Nazzi, 2015), in mapping new labels to unfamiliar objects (e.g. Nazzi, 2005), and in accessing the meanings of familiar words (e.g. Mani & Plunkett, 2007, 2010; Swingley, 2016; Wewalaarachchi, Wong, & Singh, 2017; Zesiger & Jöhr, 2011). Our study focuses on the latter, familiar word recognition, as it queries both children's phonological representations for familiar words as well as how alterations to the word form in the input (e.g. segmental changes to the word form) impact access to the lexical entry. In tests of familiar word recognition using the Intermodal Preferential Looking Paradigm (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Golinkoff, Ma, Song, & Hirsh-Pasek, 2013) looking to a target (vs. a distractor) object is compared between trials where children are presented with a correct pronunciation vs. a mispronunciation of the target object label. This paradigm is sensitive to the degree to which children's processing is interrupted (Mani & Plunkett, 2011; White & Morgan, 2008), yielding measures of both sensitivity to mispronunciations (differences between the two pronunciation types in target looking) and recognition (whether target looking is above chance level).

When tested on both vowel and consonant mispronunciations, English- (Mani & Plunkett, 2007, 2010; Swingley, 2016) and English-Mandarin learning infants and toddlers

(Wewalaarachchi et al., 2017) show similar sensitivity to the two types of changes, while French-learning toddlers have been found to show sensitivity to consonant, but not vowel mispronunciations (Zesiger & Jöhr, 2011). Compared to correct pronunciations, 14-month-old French-learning toddlers showed reduced looking to the target object when a consonant in the second syllable was mispronounced. However, for consonant mispronunciations in the first syllable and vowel mispronunciations in both the first and second syllables, looking to the target did not differ from looking for correct pronunciations. Zesiger and Jöhr (2011) conclude that French-learning toddlers show a bias for consonant information during familiar word recognition, albeit one that is specific to certain word positions, potentially due to the fact that French has phrase-final stress. However, upon closer examination, it is not clear that the absence of a penalty for some mispronunciation types in that study was due to children being insensitive to those mispronunciations. In fact, there was little evidence that toddlers recognized even the correct pronunciations of those words, as their target looks did not exceed chance. Because even correct pronunciations were not recognized, it is not possible to determine on the basis of this study whether French toddlers show asymmetries in their sensitivity to vowels and consonants during familiar word recognition.

The first aim of the present study is, therefore, to investigate French-learning toddlers' sensitivity to consonant and vowel mispronunciations during familiar word recognition. Although clear evidence for a consonant bias during familiar word recognition in French-learning infants is lacking, a greater sensitivity to or a preference for consonantal information has been found in French-learning infants as young as 8 months (Nishibayashi & Nazzi, 2016; Von Holzen et al., 2018) and it has been observed consistently from infancy to childhood in other tasks (Poltrock and Nazzi (2015); Von Holzen and Nazzi (2020); Nazzi (2005); Havy and Nazzi (2009); Nazzi et al. (2009); Havy, Bertoncini, and Nazzi (2011); Havy, Serres, and Nazzi (2014)). Based on this evidence, one could expect French-learning toddlers to show sensitivity to a consonant mispronunciation but a reduced or even a lack of sensitivity to a vowel mispronunciation.

That said, in some contexts, pronunciation changes do not signal a change in word identity. Speakers with different first languages or dialects may produce words in ways that are phonemically different from a listener's language variety. For example, whereas Parisian French speakers produce the word 'spoon' as *cuillère* ([kɥi.jɛʁ]), a speaker of Acadian French would say *tchuillère* ([tʃɥi.jɛʁ]). This sort of natural variation poses a significant challenge to the word recognition system. Although some research suggests that toddlers can recognize words across different language varieties by 19 months (Best, Tyler, Gooding, Orlando, & Quann, 2009; Mulak, Best, Tyler, Kitamura, & Irwin, 2014), other research suggests that toddlers require more experience with their first language to overcome the challenge imposed by such variations (Floccia, Delle Luche, Durrant, Butler, & Goslin, 2012; Heugten, Krieger, & Johnson, n.d.; Schmale, Hollich, & Seidl, 2011). In addition to experience with their first language, brief exposure to a particular accent variant can alter children's treatment of phonological variation (Schmale, Cristia, & Seidl, 2012; White & Aslin, 2011). White and Aslin (2011) familiarized a group of 19-month-old English-learning toddlers with a novel accent that shifted the pronunciation of the vowel /a/ from [a] to [æ] in familiar words (e.g., dog-dag), while a second group of toddlers was familiarized with the standard pronunciations. Toddlers were then tested on their recognition of familiar words pronounced using the standard and shifted pronunciations (a classic mispronunciation task). Only the toddlers who were familiarized with words containing the target vowel shifts showed recognition of these words during the test phase. Importantly, they also recognized new items with the same shift, showing an ability to adapt to and generalize learned changes in the input after only a brief exposure. Using a similar paradigm, White and Daub (2021) found that English-learning toddlers also adapt to a novel accent that shifts a consonant in familiar words (e.g. book-dook).

The second aim of this study is to examine adaptation patterns for novel accents[1] that shift either a vowel or a consonant in children learning French, a language in which the processing of consonant and vowel information at the lexical level has been found to differ. If a toddler's native language influences their sensitivity to consonant and vowel changes in familiar words, it may also impact their ability to adapt when these changes are presented as systematic shifts. English-learning toddlers are sensitive to both vowel and consonant mispronunciations in familiar word recognition (Mani & Plunkett, 2007, 2010), but with brief exposure can adapt to shifts of both types (White & Aslin, 2011; White & Daub, 2021). French-learning toddlers, on the other hand, have thus far shown evidence of sensitivity to only consonant, but not vowel, mispronunciations during familiar word recognition (Zesiger & Jöhr, 2011). Considering the important role that consonants play in lexical processing, and the increased weight French-learning toddlers' give to consonants' during processing, it is possible that they may not adapt to a novel accent that shifts a consonant after only a brief exposure. This would highlight the role that native language phonological biases may play in the ability to adapt to phonological variation. Or, similar to English-learning toddlers, French-learning toddlers may be able to adapt to and even generalize consonantal variation to new items after brief exposure. Alternatively, toddlers may do something in between these two alternatives, accepting shifted pronunciations in items they have been familiarized with, but not generalizing to new items.

Present Study

In our study, we investigate how toddlers initially respond to vowel (Experiment 1) and consonant (Experiment 2) shifts (mispronunciations) in familiar words and whether brief, systematic exposure to such shifts can lead to adaptation and generalization to new items. In the paradigm employed here, word recognition is reflected by a significant

[1] We acknowledge that natural accent variation is more complex than the shifts used here. However, following on previous work using artificial accents (e.g., White & Aslin, 2011; Maye, Aslin, & Tanenhaus, 2008), we refer to the presence of a systematic shift across multiple lexical items as an accent, and an unsystematic/one-off shift as a mispronunciation.

increase in looking at the target following the presentation of the target word. Sensitivity to phonological changes is reflected by a reduction in the size of this increase for shifted compared to correct pronunciations. Toddlers in the present experiments either received no exposure to the systematically shifted phoneme prior to test (Control Groups) or did receive exposure to the systematically shifted phoneme prior to test (Accent Groups). Additionally, this exposure only presented half of the test words (labeled items), allowing for a test of whether toddlers in the Accent Groups generalize the shifted pronunciation to new instances (unlabeled items). In the Control Groups, we expect sensitivity to consonant shifts, but a reduced or even a lack of sensitivity to vowel shifts, as predicted by previous evidence for a consonant bias in French-learning toddlers. Therefore, we predict that toddlers will show reduced looking at the target for consonant shifts (and perhaps no recognition of these shifted words at all), whereas we predict that they will not show the same penalty for vowel shifts. If toddlers in the Control Group do show the predicted lack of sensitivity to vowel shifts, we expect that toddlers who were previously exposed to this vowel shift (Accent Group) will likewise be unaffected by vowel shifts. When toddlers have prior exposure to a novel accent (Accent Group) shifting a consonant, however, there are several possible outcomes. French-learning toddlers, like English-learning toddlers, may adapt to such changes, despite their typical sensitivity to consonants. In this case, we would expect no difference in target looks between correct pronunciations and consonant shift pronunciations, as well as successful recognition of consonant shifted pronunciations. If native phonological biases play a role in adaptation to phonological changes, however, we may find that French-learning toddlers, who have been found to rely more exclusively on consonantal information compared to children learning other languages, are unable to adapt to a consonant change. This could be reflected by a complete lack of recognition of consonant-shifted words or reduced recognition in comparison to correctly pronounced words, even after previous exposure to the accent. Finally, children may show adaptation to shifted pronunciations in words they have been briefly exposed to, but not generalize this adaptation to new items. If so, we would expect recognition of previously labeled consonant shift pronunciations and no difference with correct pronunciations, but a lack of recognition for previously unlabeled consonant shift pronunciations and reduced recognition in comparison to correctly pronounced words.

Experiment 1: Vowel Shift Accent

We use a modification of the procedure used by White and Aslin (2011) to examine French-learning 18- to 20-month-old toddlers' adaptation to a novel accent that involves a vowel shift. During an Exposure Phase, half of the toddlers were exposed to pronunciations of familiar words that shifted the vowel [a] to [ɛ], a phonemic change in French (Accent Group), while the other half heard standard pronunciations (Control Group). The choice of this contrast was constrained by the words toddlers are likely to know at this age, based on CDI data (Kern, 2003). The Exposure Phase was followed by a Test Phase, where word recognition was assessed in response to both shifted and standard pronunciations. For toddlers in the Control Group, for whom the shifted pronunciations at test are essentially mispronunciations of the correct, standard forms, a reduction in word recognition for shifted pronunciations would indicate sensitivity to the shifted phoneme. However, based on the evidence that young French-learning children are tolerant of vowel changes (Zesiger & Jöhr, 2011; see also Nazzi et al., 2016), we expected toddlers in the Control Group to not show a reduction in word recognition for words containing shifted vowels in the Test Phase. Given the predicted insensitivity to the vowel shift in the Control Group, we likewise predicted that toddlers in the Accent Group would recognize the words undergoing a vowel shift.

Methods

Participants. Forty-five 18-20-month-old toddlers were included in the final sample (mean age = 578.34 days, age range = 550 - 613 days, 17 females, 28 males). Twenty-two toddlers were tested in the Control group and 23 were tested in the Accent group. All participants were healthy, full-term French-learning monolinguals, with no reports of cognitive, visual, or hearing impairment, recruited from the Paris metropolitan area through birth lists. The socio-economic status of families participating in studies in this laboratory is typically upper-middle class[2]. All toddlers included in the final sample were exposed to the local, Parisian accent a majority of the time. Families were compensated by a participation diploma with their child's picture. The study was conducted in accordance with the Declaration of Helsinki, and the Ethics Committee of CERES (N$\circ$2011-14, 18 October 2011) approved the protocol; parents gave written informed consent. An additional 16 participants were tested but not included in the final sample due to fussiness or refusing to wear the target sticker on their forehead (9), parental interference (2), exposure to a non-Parisian French accent (1), and not providing enough trials to be included in the analysis (4; details below).

Stimuli. We chose stimuli using a similar procedure as in White and Aslin (2011), but with several changes to adapt to the French language. The stimuli of White and Aslin (2011) were five monosyllabic words and one bisyllabic word, with the target vowel occurring on the first, stressed syllable. The young French toddler's lexicon has few monosyllabic words to choose from, and not enough monosyllabic words which contain the same vowel. We chose the target vowel /a/, a low central, unrounded vowel, as it occurs frequently in words reported as comprehended by at least 50% of French-learning 16-month-olds (Kern, 2003). We chose words such that the position of the vowel /a/ varied across words, occurring twice in monosyllabic words, twice in the final syllables of bisyllabic words, and twice in the initial syllables of bisyllabic words. In addition to ensuring the generalizability of effects across syllable positions, this also made the position of the target vowel comparable with that of the target consonant in Experiment 2. Six highly familiar, and highly picturable words were chosen to serve as the familiar word

[2] Although this sample is not representative of families from all socio-economic situations, we have no hypothesis regarding whether population bias through families' self-initiated participation would influence these results.

stimuli: *chat* ‘cat’, *table* ‘table’, *cheval* ‘horse’, *fromage* ‘cheese’, *ballon* ‘balloon’, and *gateau* ‘cookie’. For each standard pronunciation of /a/ with the correct [a] vowel, a shifted pronunciation was produced where this vowel was shifted to [ɛ], a mid-front, unrounded vowel. Shifted words were pseudowords or words not included on the list of familiar words in the French Communicative Developmental Inventory: Words and Gestures for ages 16-30 months (Kern, 2003).

A female speaker of Parisian French recorded the stimuli in a sound attenuating booth, using a mild infant-directed register. Stimuli were recorded at a sampling rate of 44,100 Hz and later analyzed and edited using Praat (Boersma & Weenink, 2016). For the stimuli presented in the Exposure Phase, word tokens were produced in isolation. Three tokens were selected for the standard and shifted versions of the words. Tokens of “*regarde*” (‘look’) and “*coucou*” (‘peek-a-boo’) were also recorded, to be played in lieu of some item labels during the Exposure Phase (unlabeled items, see Experimental Design). For the stimuli presented in the Test Phase, word tokens were produced with two carrier phrases (“*Où est le/la X*” – ‘Where is the X’; “*Tu vois le/la X*” – ‘You see the X’). For each of the two types of carrier phrases presented in the Test Phase, one token containing the standard and one containing the shifted pronunciation were selected. As expected, shifted vowels had lower F1 and higher F2 than the standard vowels (Table 1). Durations of the target words containing the standard and shifted vowels were similar.

Representative digital photographs were chosen for the visual stimuli. As in previous studies (e.g., White & Morgan, 2008) each familiar object was paired with an unfamiliar object for the test trials, presenting an alternative referent for children to map the shifted pronunciations to. The six unfamiliar objects were real objects, similar in visual complexity to the familiar items: ‘paint roller’, ‘megaphone’, ‘euphonium’, ‘papaya’, ‘pump’, and ‘tool’. These objects were chosen as their names were not included in the lists of familiar words on the infant or toddler versions of the French CDI (Kern, 2003; Kern & Géraldine, 2003).

Parents were also given a short vocabulary questionnaire to ensure toddlers were familiar with the chosen familiar stimuli. Images were resized and pictured centrally on a 562 x 750 pixel white background. For the Exposure Phase, we created 1 second long videos for each familiar object where the image loomed (first incrementally decreased to 50%, then increased back to 100% of its regular size) using the package resizeimage (Tissier, 2017) in Python (Python Core Team, 2015). The same photographs of the familiar objects were used in the Exposure and Test Phases.

Experimental Design. The experimental design was the same as in White and Aslin (2011), and consisted of an Exposure Phase followed by a Test Phase. In the Exposure Phase, a series of three animated displays were presented, each containing four familiar objects. The chosen six familiar objects were presented equally often across the three displays (in randomized positions in the array). After an initial two second period of silence, one of the objects was labeled (e.g., "*cheval!*" – 'horse!') while the looming video of the object played to highlight the relationship between the label and the object. Looming of objects in the display occurred every two seconds, to a total of ten looming events per display: two objects (labeled items) loomed four times each and were accompanied by labels, while the other two objects each loomed once and were not labeled (unlabeled items). These unlabeled items were instead accompanied by *regarde!* or *coucou!* and were not labeled at any point in the Exposure Phase. Half of the toddlers heard the objects table, horse, and balloon labeled in the Exposure Phase, with the objects cat, cheese, and cake unlabeled. For the other half of toddlers, the reverse was true. The unlabeled/labeled distinction allowed for a test of generalization in the Test Phase (see below). The unlabeled items were included in the Exposure displays to ensure that they were visually familiar to the toddlers at test (without providing evidence for how the talker would produce these unlabeled items). The pronunciation of the labeled items heard during the Exposure Phase depended on whether the toddler was assigned to the Control or Accent group. Toddlers in the Control group heard the object labels pronounced using the standard vowel (e.g., "*cheval*") while toddlers in the Accent group heard them pronounced using the shifted vowel (e.g., "*chevel*").

The Exposure phase was followed by the Test phase. Test displays were one familiar target object paired with one unfamiliar, distractor object. Half of the familiar target objects had been labeled during the Exposure Phase (labeled), while the other half had not been labeled (unlabeled), allowing for a test of generalization to new items. Target-distractor pairings were the same for all toddlers. Each test trial began with a pre-naming phase, where the two objects were presented side-by-side in silence to establish baseline looking preferences, followed by a sentence, which instructed the toddler to look at the target object using one of the two carrier phrases (*Où est le/la X* – 'Where is the X'; *Tu vois le/la X* – 'You see the X'). The onset of the carrier phrase was timed such that the onset of the target label was always at 3000 ms. Following the onset of the target word, the display remained on the screen for the remainder of the trial, for a total trial time of six seconds. Figure 1 presents a schematic of an individual trial.

The Test Phase consisted of a total of 24 test trials, four per target-distractor pair. The target word was presented using the standard pronunciation in twelve trials and using the shifted pronunciation in the other twelve. Thus, the label for each familiar target object was heard twice with the standard pronunciation (once per sentence frame) and twice with the shifted pronunciation (once per sentence frame). The Test Phase comprised two test blocks of 12 trials each. Within each test block, every target object was named once with the standard and once with the shifted pronunciation, both using the same sentence frame and side of presentation (reversed for the second block). Half of the target objects were presented in each sentence frame during each test block. The order of presentation was randomized using the pseudorandom package (Mathôt, 2016) for Python (Python Core Team, 2015), with the constraint that the target object could not appear on the same side and the same sentence frame could not occur in more than three trials in a row.

Procedure. During the experiment, each toddler sat on their caregiver's lap inside a sound-attenuated booth. The caregiver was given noise-attenuating headphones which played instrumental music mixed with a woman speaking in order to mask the audio stimuli. Caregiver and toddler were seated approximately 60 cm in front of an Eyelink 1000 remote eye-tracker mounted below a BenQ computer display monitor (53 cm x 30 cm) which was attached to a movable arm. Two speakers were located on a table below the movable arm. A large black curtain occluded everything in front of the caregiver and toddler such that only the computer monitor and eye-tracker were visible. Speech stimuli were played at 70 dB. Visual stimuli were presented using the open-source experimental software Open Sesame (Mathôt, Schreij, & Theeuwes, 2012). The experiment was controlled using a Mac Mini. While the caregiver and toddler entered the booth, an animated children's cartoon was played on the screen. The purpose of the cartoon was to focus the attention of the toddler on the display monitor while the experimenter adjusted the eye tracker/monitor movable arm to ensure good track-ability. The eye-tracker automatically detected the target sticker on the participant's forehead to accommodate for movements of head and eye position relative to the camera. A five-point calibration and validation of toddler looking was used.

After calibration, the experiment began, first with the Exposure phase, followed by the Test phase. Each display or trial was followed by a white screen and an attention-getter image (baby, bear, or star) displayed with laughing baby sounds. Once the participant fixated the attention getter, the laughing baby sounds stopped and a central fixation correction was manually applied. This ensured that toddlers refocused their attention on the screen after each trial and updated the calibration in the event that their position in front of the eye-tracker had shifted. Exposure and Test trials were launched automatically after each attention-getter/fixation correction sequence. After completing the experiment, caregivers completed a short vocabulary questionnaire, which included the familiar items, to indicate their children's comprehension and production of the stimuli.

Data pre-processing. Eye-movements were recorded by the Eyelink eye-tracker every 2 ms (500 Hz) and were exported to a text readable format using the eyelinker package (Barthelme, 2016) for R (R Core Team, 2018). Only fixations defined by the automatic Eyelink algorithm that were at least two data points or 4 ms in length were included in the analysis (Quinn, Doran, Reiss, & Hoffman, 2009). With the aid of the R package eyetrackingR (Dink & Ferguson, 2015), we calculated the proportion of time toddlers spent looking at the target image during the Test Phase (Proportion of Target Looking, PTL = T/(T + D)). Samples not directed at the target or distractor were coded as missing. To ensure that toddlers were attentive, we removed trials where the eye-tracker was unable to track the eyes for more than 50% of the trial (Chen et al., 2021). This removed 19.17% of trials. As in previous work (e.g., Mani & Plunkett, 2011; White & Morgan, 2008), only those trials where toddlers fixated the target and the distractor at least once during the pre-naming phase (before target word onset at 3000 ms) were included in the analysis. This removed 6.30% of trials. To be included in the final analysis, toddlers had to contribute at least two trials of different words for each of the conditions. This removed 4 toddlers. The final sample of toddlers contributed 818 trials.

Analysis. Average PTL was computed for the time in the trial before the target word was heard (pre-naming phase; 0-3000 ms) as well as after the target word was heard (post-naming phase; 3300-6000 ms). A delay of 300 ms was used in the post-naming phase to account for the amount of time needed for children's eyes to move in response to auditory stimuli (Canfield et al., 1997). For each trial, the mean PTL for the pre-naming phase was subtracted from the mean PTL for the post-naming phase to create the PTL-change measure, our dependent variable. Values above 0 indicate increased looking to the target in the post-naming phase, while values below 0 indicate increased looking to the distractor.

We computed a series of linear mixed-effects models (lme4, Bates, Maechler, Bolker, & Walker, 2015; lmerTest Kuznetsova, Brockhoff, & Christensen, 2017) in the statistical program R (R Core Team, 2018) to predict toddlers' PTL-change. The first model[3] assessed how the fixed effects Pronunciation Type (standard, shifted), Group (Control, Accent), and Word Type (labeled, unlabeled) influenced PTL-change (PTL-change ~ Pronunciation Type * Group * Word Type). Subsequent models focused on specific hypotheses using nested contrasts, thus reducing both the required number of estimated parameters and subsequent comparisons (Abelson & Prentice, 1997; Schad, Vasishth, Hohenstein, & Kliegl, 2020). The second model examined sensitivity to the shifted vowel separately in the Control and Accent Groups, focusing first on recognition as a function of pronunciation, and therefore collapsing across Word Type. We predicted no difference in PTL-change between standard and shifted pronunciations for either group and therefore expected no significant effects in this model. This model included the effect of Pronunciation Type nested within Group (PTL-change ~ Group / Pronunciation Type). The third model also examined sensitivity to the shifted vowel separately in the Control and Accent Groups, but additionally separated by whether toddlers had been exposed to the word form in the Exposure Phase (labeled) or not (unlabeled). We again predicted no difference in PTL-change between labeled and unlabeled words for either pronunciation for either group, expecting no significant effects in this model. This model included the effect of Pronunciation Type nested within Word Type, nested within Group (PTL-change ~ Group / Word Type / Pronunciation Type). Levels of all categorical variables were centered and the intercept in the resulting models represented the grand mean. For each model, the maximum feasible model, including random effects structure, was determined using the R package buildmer (Voeten, 2021; see also Barr, Levy, Scheepers, & Tily, 2014). To evaluate recognition in the conditions of interest, we used the R package emmeans (Lenth, 2019) to calculate their estimated marginal means and test whether they were greater than the chance value of 0 using one-sample t-tests. We predicted recognition

[3] The first model was included for the purpose of comparability with previous literature that has not used a nested contrasts approach.

regardless of Group, Word Type, or Pronunciation. Figures were created using the ggplot2 package (Wickham, 2009).

Results

Figure 2 plots PTL-change for Pronunciation, Group, and Word Type. The first model tested the interaction of Pronunciation, Group, and Word Type and included individual participant intercepts. The full results of this model can be found in Table A1 in Appendix A. The model results yielded a significant intercept ($\beta = 0.09$, 95% CI [0.06, 0.11], $t(808) = 6.62$, $p < .001$, $\eta^2 p = 0.05$), indicating that PTL-change was above the chance value of zero and indicating overall recognition of the test words. No other effects were significant.

The second model tested whether PTL-change was different between the standard and shifted pronunciations separately for the Accent and Control Groups and included individual participant intercepts. The full results of this model can be found in Table A2 in Appendix A. The difference between standard and shifted pronunciations was not significant for either the Control Group or the Accent Group. One-sample t-tests revealed that baseline-corrected PTL was above chance for standard and shifted pronunciations for toddlers in both the Control and Accent Group (Table 2). Toddlers showed recognition of both the standard and shifted pronunciations, regardless of whether they were briefly exposed to the shifted pronunciations in the Exposure Phase or not.

The third model tested whether PTL-change was different between the standard and shifted pronunciations separately for each Word Type (labeled, unlabeled) within the Accent and Control Groups. Individual participant intercepts were included. The full results of this model can be found in Table A3 in Appendix A. The difference between standard and shifted pronunciations was not significant for labeled or unlabeled words for either the Control Group or for the Accent Group. One-sample t-tests revealed that

PTL-change was above chance in 7 out of 8 conditions (Table 2). The only exception was the Control Group for unlabeled, shifted pronunciations. Other than this exception, toddlers showed recognition of both the standard and shifted pronunciations, regardless of Group and Word Type.

Summary

Experiment 1 revealed no difference in our PTL-change measure between standard and shifted pronunciations, regardless of Group and Word Type, suggesting a lack of sensitivity to the vowel shift tested in this Experiment ([a] – [ɛ]). If toddlers in the Control group are not sensitive to this vowel shift, then there is little room for adaptation in toddlers in the Accent group who were systematically exposed to the vowel shift. However, toddlers in the Control Group did not recognize shifted pronunciations of the words they had not heard during the Exposure Phase, while toddlers in the Accent Group did. This indicates that toddlers in the Accent group may have had a small advantage in recognizing shifted pronunciations in at least a subset of the tested words.

Experiment 2: Consonant Shift Accent

The results of the first experiment showed a lack of sensitivity to vowel shifts in French-learning 19-month-olds: there was no difference in PTL-change between standard and shifted pronunciations, regardless of whether toddlers had been familiarized with the shifted (Accent Group) or standard (Control Group) pronunciations. This is in line with previous evidence showing a lack of sensitivity to vowel mispronunciations in French-learning children (Zesiger & Jöhr, 2011). In the second experiment, we use a similar approach to test whether, in contrast, French-learning toddlers are sensitive to a consonant shift from [p] to [t] (Control Group) and, if they are, whether they can adapt to this shift after brief exposure (Accent Group) and generalize to new words. Given previous evidence that French-learning children are more sensitive to consonant compared to vowel information, we predicted that toddlers in the Control Group would show better recognition of target words in the Test Phase when they were pronounced using the standard compared to shifted pronunciations. If this is the case, then the pattern of results for toddlers in the Accent Group will allow us to adjudicate between several possibilities. Toddlers, regardless of their language experience, may demonstrate the ability to adjust rapidly to new linguistic environments. If this is the case, we would expect toddlers in the Accent Group to adapt to consonant shifts and generalize to new items, showing recognition of these shifted pronunciations and a lack of a difference in their recognition between standard and shifted pronunciations, regardless of whether they previously heard the shifted pronunciation (labeled items) or not (unlabeled items). However, brief exposure that suffices for adaptation to vowel and consonant shifts in English-learning toddlers may not suffice for French toddlers' adaptation to a consonant shift. If so, we would then expect toddlers in the two groups (Accent and Control) to pattern similarly in showing a recognition penalty for the shifted pronunciations of both previously heard items and new items. Finally, a third possibility is that toddlers may exhibit adaptation for items they have previously heard produced using a shifted consonant, but not yet generalize this to new items.

Methods

Participants. Forty-six 18-20-month-old toddlers were included in the final sample (mean age = 579.20 days, age range = 537 - 613 days, 21 females, 25 males). Twenty-four toddlers were tested in the Control group and 22 were tested in the Accent group. Recruitment was the same as Experiment 1. An additional 15 participants were tested but not included in the final sample due to fussiness or refusing to wear the target sticker on their forehead (6), exposure to a non-Parisian French accent (1), and not providing enough trials to be included in the analysis (8; details below).

Stimuli. The consonant /p/, a voiceless bilabial stop, was chosen as it occurs frequently in words reported as comprehended by at least 50% of French-learning

16-month-olds (Kern & Géraldine, 2003). To ensure similarity with Experiment 1, the target consonant /p/ appeared in different positions across the 6 chosen words, occurring twice in monosyllabic words, twice in the final syllables of bisyllabic words, and twice in the initial syllables of bisyllabic words. Six highly familiar, and highly picturable words were chosen to serve as the familiar word stimuli: *pain* ‘bread’, *porte* ‘door’, *canapé* ‘couch’, *lapin* ‘rabbit’, *poubelle* ‘garbage can’, and *poussette* ‘stroller’. For each standard pronunciation with the correct [p] consonant, a shifted pronunciation was produced where this consonant was shifted to [t], a voiceless laminal denti-alveolar stop consonant. Shifted words were pseudowords or words not included on the list of familiar words in the French Communicative Developmental Inventory: Words and Gestures for ages 16-30 months (Kern, 2003). Durations of the target words containing the standard and shifted consonants were similar (Table 3).

Experimental Design. The structures of the Exposure and Test Phases were identical to Experiment 1.

Procedure. The Procedure was identical to Experiment 1.

Data pre-processing. Data pre-processing was identical to Experiment 1. To ensure that toddlers were attentive, we removed trials where the eye-tracker was unable to track the eyes for more than 50% of the trial (Chen et al., 2021). This removed 21.64% of trials. Only those trials where toddlers fixated the target and the distractor at least once during the pre-naming phase (before target word onset at 3000 ms) were included in the analysis. This removed 7.68% of trials. To be included in the final analysis, toddlers had to contribute at least two trials of different words for each of the conditions. This removed 4 toddlers. The final sample of toddlers contributed 769 trials.

Analysis. The analysis of eye-movements was identical to Experiment 1 and the three models were built using a similar approach, but with different predictions for the second and third models and for the tests of recognition. The second model examined sensitivity to the shifted consonant separately in the Control and Accent Groups. We predicted sensitivity to consonant shifts for toddlers in the Control Group and therefore expected their PTL-change to be greater for standard compared to shifted pronunciations. If toddlers can adapt to consonant shifts after brief exposure, then there should be no difference in PTL-change between standard and shifted pronunciations for toddlers in the Accent Group. The third model examined sensitivity to the shifted vowel separately in the Control and Accent Groups, and additionally separated by Word Type: whether toddlers had been exposed to the word form in the Exposure Phase (labeled) or not (unlabeled). We again predicted sensitivity to consonant shifts for toddlers in the Control Group, regardless of Word Type. If toddlers in the Accent Group not only adapt to consonant shifts after brief exposure but also generalize this shift to new items, then PTL-change should show no difference between shifted and standard pronunciations and this should be the case for both labeled and unlabeled words. If they do not generalize, however, then PTL-change should be greater for standard, unlabeled compared to shifted, unlabeled pronunciations. In terms of whether words are recognized at above chance levels, we expect toddlers to show recognition of standard pronunciations regardless of their Group or Word Type. If toddlers are sensitive to the consonant shift then we may also find a lack of recognition for shifted pronunciations.

Results

Figure 3 plots PTL-change for Pronunciation, Group, and Word Type. The first model tested the interaction of Pronunciation, Group, and Word Type and included individual participant and item intercepts. The full results of this model can be found in Table B1 in Appendix B. The model results yielded a significant intercept ($\beta = 0.09$, 95% CI [0.04, 0.13], $t(767) = 4.00$, $p < .001$, $\eta^2 p = 0.02$), indicating that PTL-change was above the chance value of zero and indicating overall recognition. The effect of Pronunciation Type was also significant ($\beta = 0.05$, 95% CI [0.03, 0.07], $t(767) = 3.98$, $p < .001$, $\eta^2 p = 0.02$), indicating that PTL-change was greater for standard (EMM = 0.14, SE

= 0.03, 95% *CI* = [0.08, 0.19]) compared to shifted pronunciations (EMM = 0.04, SE = 0.03, 95% *CI* = [-0.02, 0.09]). No other effects were significant.

The second model tested whether PTL-change was different between the standard and shifted pronunciations separately for the Accent and Control Groups and included individual participant and item intercepts. The full results of this model can be found in Table B2 in Appendix B. The difference between standard and shifted pronunciations was significant for the Control Group (β = 0.06, 95% CI [0.03, 0.10], t(771) = 3.74, p < .001, $\eta^2 p$ = 0.02) but marginal in the Accent Group (β = 0.04, 95% CI [-1.75e-04, 0.07], t(771) = 1.95, p = 0.051, $\eta^2 p$ = 0.00). Toddlers in the Control Group had higher PTL-change scores for standard (EMM = 0.14, SE = 0.03, 95% *CI* = [0.07, 0.21]) compared to shifted pronunciations (EMM = 0.01, SE = 0.03, 95% *CI* = [-0.06, 0.08]). One-sample t-tests revealed that PTL-change was above chance for standard pronunciations for toddlers in both groups as well as for shifted pronunciations in the Accent Group, but not the Control Group (Table 4). Therefore, only toddlers who heard the consonant shift during Exposure showed recognition of words pronounced with this shifted consonant in the Test Phase.

The third model tested whether PTL-change was different between the standard and shifted pronunciations separately for each Word Type (labeled, unlabeled) within the Accent and Control Groups and included individual participant intercepts. The full results of this model can be found in Table B3 in Appendix B. The difference between standard and shifted pronunciations was significant for the Control Group for words both labeled (β = 0.06, 95% CI [0.01, 0.11], t(767) = 2.42, p = 0.015, $\eta^2 p$ = 0.01) and unlabeled in the Exposure Phase (β = 0.07, 95% CI [0.02, 0.12], t(767) = 2.87, p = 0.004, $\eta^2 p$ = 0.01), but not for the Accent Group (labeled: β = 0.04, 95% CI [-0.01, 0.09], t(767) = 1.47, p = 0.141, $\eta^2 p$ = 0.00; unlabeled: β = 0.03, 95% CI [-0.02, 0.08], t(767) = 1.29, p = 0.196, $\eta^2 p$ = 0.00). One-sample t-tests revealed that PTL-change was above chance for standard, but not shifted, pronunciations for toddlers in both groups for both labeled and unlabeled words (Table 4). Although only toddlers in the Control Group showed a difference in their treatment of standard and shifted words, neither group showed recognition of words produced with the shifted pronunciation in this analysis.

Summary. The results of Experiment 2 revealed that toddlers in the Control Group showed significantly greater increases in looking to the target in response to standard compared to shifted pronunciations, and no recognition of the shifted pronunciations, suggesting sensitivity to the consonant shift. Toddlers in the Accent Group showed no difference between standard and shifted pronunciations, suggesting that brief exposure to a novel accent that shifts a consonant results in adaptation to that accent. However, toddlers in the Accent Group may have only weakly recognized the shifted pronunciation, as the change in target looking was not significantly above chance for shifted pronunciations when labeled and unlabeled words were considered separately.

General Discussion

In two experiments, we examined French-learning toddlers' initial sensitivity to vowel (Experiment 1) or consonant (Experiment 2) changes in familiar words and their ability to adapt to a novel accent that systematically shifts these sounds. The motivation for studying both consonant and vowel processing was the consonant bias, a phonological bias found across adult speakers of many different languages (e.g. Nazzi & Cutler, 2018), but the developmental emergence of which varies for infants learning different native languages (e.g. Nazzi et al., 2016).

We found, first, that French-learning toddlers were sensitive to consonant, but not vowel shifts. Critical to this evaluation was the performance of toddlers in the Control groups. Overall, toddlers in Experiment 1 showed no difference in their recognition of standard and shifted vowel pronunciations, demonstrating that French-learning toddlers are not disrupted by a shift from [a] to [ɛ] in familiar words. However, toddlers in the Control Group did not show recognition in response to shifted pronunciations of words that were unlabeled in the Exposure Phase, indicating that their recognition may have been impacted by the vowel shift Nonetheless, this was not statistically different than their response to standard pronunciations, suggesting that overall, toddlers in the Control Group were not sensitive to the vowel change. In Experiment 2, toddlers in the Control Group had a greater increase in target looking in response to standard pronunciations than in response to shifted pronunciations, showing sensitivity to the consonant shift from [p] to [t]. In addition, significant recognition was found for standard, but not shifted pronunciations, providing further evidence that toddlers were sensitive to the consonant shift.

Our evidence showing that French-learning toddlers are sensitive to consonant but not vowel mispronunciations in familiar word recognition supports the previous, albeit tentative, results of Zesiger and Jöhr (2011) and is consistent with the large body of evidence demonstrating a consonant bias for French-learning children in word segmentation (Nishibayashi & Nazzi, 2016; Von Holzen et al., 2018), word form recognition (Poltrock & Nazzi, 2015; Von Holzen & Nazzi, 2020), and word learning (Havy et al., 2011, 2014; Havy & Nazzi, 2009; Nazzi, 2005; Nazzi et al., 2009). This asymmetry is likely language specific, as sensitivity to consonant and vowel mispronunciations has been found to take a different developmental trajectory depending on the first language being learned (for reviews see Nazzi & Cutler, 2018; Nazzi et al., 2016). For example, English-learning children show similar sensitivity to consonant and vowel mispronunciations until the age of 30 months (Delle Luche et al., 2017; Floccia et al., 2014; Mani & Plunkett, 2007, 2010; Nazzi et al., 2009). Differences in the acoustic/phonetic (Bouchon et al., 2015; Floccia et al., 2014) or lexical (Keidel et al., 2007) properties of the language being learned have been proposed to influence the weight children give to consonants and vowels in lexical processing. English, for example, includes several phenomena which may encourage the use of vowels in lexical processing, such as vocalic reduction, lexical stress, and the distinction between tense and lax vowels (Burzio, 2007), whereas French lacks these properties. Future studies are needed to determine exactly what properties drive these cross-linguistic differences in processing.

Our study finds that French-learning toddlers tolerate a vowel shift in familiar words that is phonemic in their native language. This stands in contrast to evidence from English-learning children, who show sensitivity to both one-off consonant and vowel mispronunciations (Mani & Plunkett, 2007, 2010; Swingley, 2016) and also sensitivity to systematically shifted consonants and vowels when they have not previously been exposed to the shifts (White & Aslin, 2011; White & Daub, 2021). By necessity, some aspects of our study differ from this previous work with English-learning toddlers. With respect to the stimuli, we sought to keep the vowel shift as similar as possible to that of White and Aslin (2011), but we were constrained by the phonology of French as well as the composition of the early French lexicon. One difference across studies was in the location of the shift in the target words. In the present study, the shifted phoneme appeared in both the initial and final syllables of the target words, whereas White and Aslin (2011) shifted only vowels in the initial syllable. Although some research suggests that young children are equally sensitive to mispronunciations of onset- and coda consonants (Nazzi & Bertoncini, 2009; Swingley, 2009, but see 2005), it is not clear whether vowel mispronunciations are detected equally well across positions. A second difference between the studies involves the extent of the phonological shift. The contrast tested by White and Aslin (2011) was a 1-feature change in height, whereas the contrast tested in the current study was a 2-feature change, in both height and backness. English-learning toddlers are sensitive to such graded differences in feature similarity in vowels (Mani & Plunkett, 2011). If generalizable to French, toddlers in the present study should have shown more, rather than less, sensitivity to the 2-feature vowel changes used here. Nonetheless, future studies, especially with French-learning children, should test other vowel contrasts to determine whether the lack of sensitivity found in the current study is generalizable across contrasts. Note, however, that the larger literature on the early consonant-bias in French shows sensitivity to many consonant contrasts, and a lack of sensitivity to many vowel contrasts, including multiple-feature ones (Nazzi, 2005).

Our second research question addressed toddlers' adaptation to these types of phonological shifts Critical to the evaluation of this question was the performance of toddlers in the Accent Groups. For vowel shifts in Experiment 1, considering the lack of sensitivity to the shifted vowel pronunciation found in toddlers tested in the Control Group, it is rather unsurprising that toddlers in the Accent Group performed similarly, showing no difference in recognition of standard and shifted vowel pronunciations. However, in the case of consonant shifts in Experiment 2, there was more evidence for exposure-driven adaptation. Toddlers in the Accent Group, but not the Control Group, showed no difference in recognition between standard and shifted pronunciations, suggesting that exposure to the shifted pronunciations in the Exposure Phase led toddlers to adapt to this altered pronunciation. Our results extend previous evidence of adaptation to vowel and consonant shifts in toddlers learning English (White & Aslin, 2011; White & Daub, 2021) to toddlers learning French.

Note, however, that the adaptation demonstrated in Experiment 2 appears to have been weaker than that observed previously by White and Aslin (2011). In particular, toddlers in the Accent Group did not show recognition of words produced with a shifted pronunciation when labeled and unlabeled words were considered separately. Although non-significant, there was also a marginal difference in the Accent Group between standard and shifted pronunciations. Taken together, these results suggest that although toddlers did adapt to the consonant shift, this adaptation likely did not rise to the level of toddlers treating these shifted pronunciations as equivalent to standard pronunciations. Importantly, the lack of recognition of unlabeled words produced with a shifted pronunciation may also indicate that toddlers in the Accent Group did not generalize to new lexical items. Perhaps with more extended exposure to the shifted pronunciation, such as the extended exposure given adults by Maye et al. (2008), toddlers may show increased acceptance of shifted consonant pronunciations and generalize this acceptance to new instances. Future studies could determine the amount of exposure French-learning toddlers require to show more robust adaptation.

Flexibility in the face of variability is essential for responding to changes in the environment. Recall our earlier example of the consonant shift between Acadian and Parisian French speakers. Our results suggest that at first encounter, a Parisian French-learning toddler will indeed struggle to understand what an Acadian speaker is referring to when the label for an object differs by a consonant. But, brief exposure to such a shift should reduce this difficulty in the future. Importantly, brief exposure does not reduce toddlers' recognition of words produced in their standard pronunciations. Recognition of standard pronunciations remains robust, even as the system learns the new variants.

Conclusion

In a pair of experiments, we examined French-learning 18-20-month-olds' sensitivity and adaptation to vowel and consonant shifts in the recognition of familiar words. We demonstrate, first, that in line with evidence of cross-linguistic differences in the emergence of the consonant bias, toddlers were sensitive to consonant, but not vowel mispronunciations of familiar words. Second, we find that toddlers showed adaptation after exposure to a novel accent that systematically shifts the consonant, but that they do not necessarily generalize this shift to new lexical items. Taken together, our results show that children's sensitivity to phonological changes in familiar words is shaped by their native language. However, the ability to adapt to such phonological changes may be less affected by language background.

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Table 1

A summary of the means and standard deviations (in parenthesis) of duration values in milliseconds and F1 and F2 values in Hz for the stimuli used in Experiment 1.

Phase	Pronunciation	Duration	F1	F2
Exposure Phase	Accent	662.48 (152.25)	764.94 (51.12)	2230.61 (119.36)
	Control	640.15 (140.01)	893.58 (53.19)	1889.57 (158.14)
Test Phase	shifted	452.41 (120.37)	813.83 (135.19)	2215.35 (160.26)
	standard	459.39 (124.55)	923.2 (142.45)	1909.76 (137.29)

Table 2

Posthoc tests comparing the nested effects in models 2 and 3 to the chance value of 0.

Model	Group	Word Type	Pronunciation	EMM	SE	t-ratio	p-value	Cohen's d
Model 2	Accent		Standard	0.105	0.026	4.072	<0.001	0.675
			Shifted	0.087	0.026	3.382	<0.001	0.548
	Control		Standard	0.099	0.026	3.816	<0.001	0.626
			Shifted	0.062	0.026	2.377	0.0094	0.396
Model 3	Accent	Labeled	Standard	0.096	0.035	2.753	0.0031	0.282
			Shifted	0.075	0.035	2.158	0.0158	0.221
	Control		Standard	0.099	0.036	2.783	0.0028	0.280
			Shifted	0.078	0.035	2.204	0.0141	0.226
	Accent	Unlabeled	Standard	0.113	0.036	3.177	<0.001	0.314
			Shifted	0.101	0.036	2.775	0.0029	0.268
	Control		Standard	0.100	0.036	2.767	0.0030	0.272
			Shifted	0.045	0.036	1.244	0.1072	0.124

Table 3

A summary of the means and standard deviations (in parenthesis) of duration values in milliseconds for the stimuli used in Experiment 2.

Phase	Pronunciation	Duration
Exposure Phase	Accent	627.74 (143.06)
	Control	631.39 (143.76)
Test Phase	shifted	436.46 (127.69)
	standard	449.28 (135)

Table 4

Posthoc tests comparing the nested effects in models 2 and 3 to the chance value of 0.

Model	Group	Word Type	Pronunciation	EMM	SE	t-ratio	p-value	Cohen's d
Model 2	Accent		Standard	0.135	0.035	3.891	<0.001	1.121
			Shifted	0.063	0.035	1.802	0.0389	0.512
	Control		Standard	0.141	0.033	4.291	<0.001	1.355
			Shifted	0.012	0.034	0.363	0.3590	0.110
Model 3	Accent	Labeled	Standard	0.136	0.043	3.145	0.0011	0.592
			Shifted	0.058	0.045	1.297	0.0985	0.227
	Control		Standard	0.128	0.041	3.166	0.0010	0.657
			Shifted	0.010	0.042	0.250	0.4015	0.049
	Accent	Unlabeled	Standard	0.134	0.044	3.060	0.0014	0.562
			Shifted	0.067	0.043	1.568	0.0598	0.299
	Control		Standard	0.153	0.041	3.753	<0.001	0.770
			Shifted	0.014	0.042	0.333	0.3699	0.066

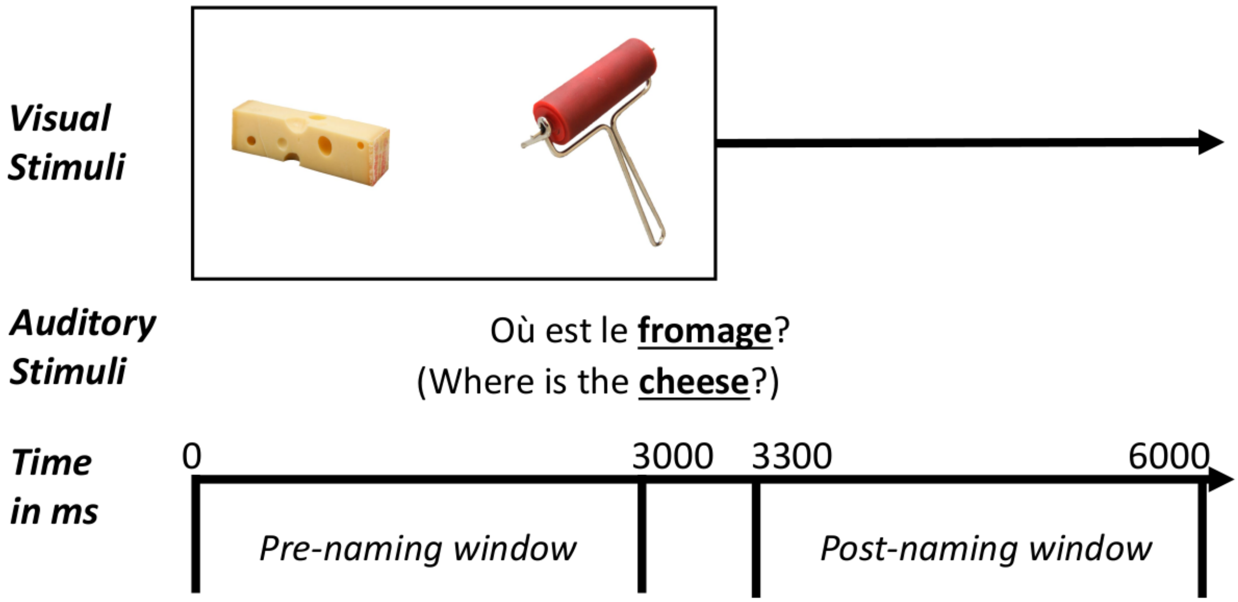

Figure 1. Schematic of the trial structure with stimulus examples. In the actual experiment, images were in color.

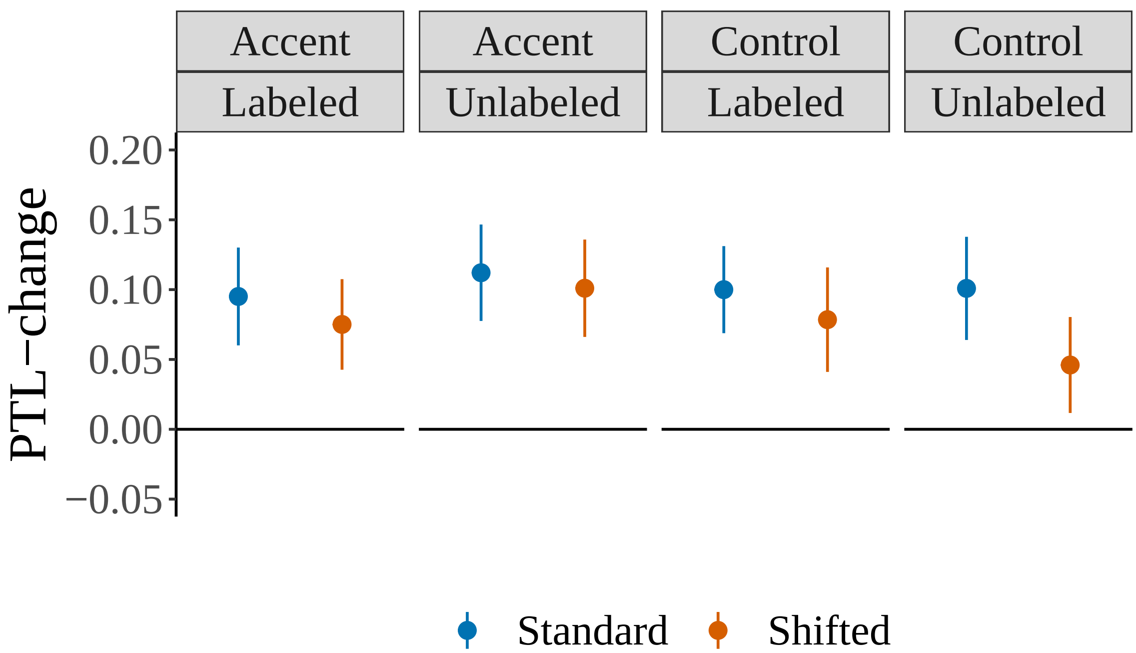

Figure 2. Mean PTL-change with standard error for Experiment 1, which tested the vowel change accent, comparing Pronunciation Type (standard, shifted), Group (Control, Accent), and Word Type (labeled, unlabeled). Values above 0 indicate increased looking to the target.

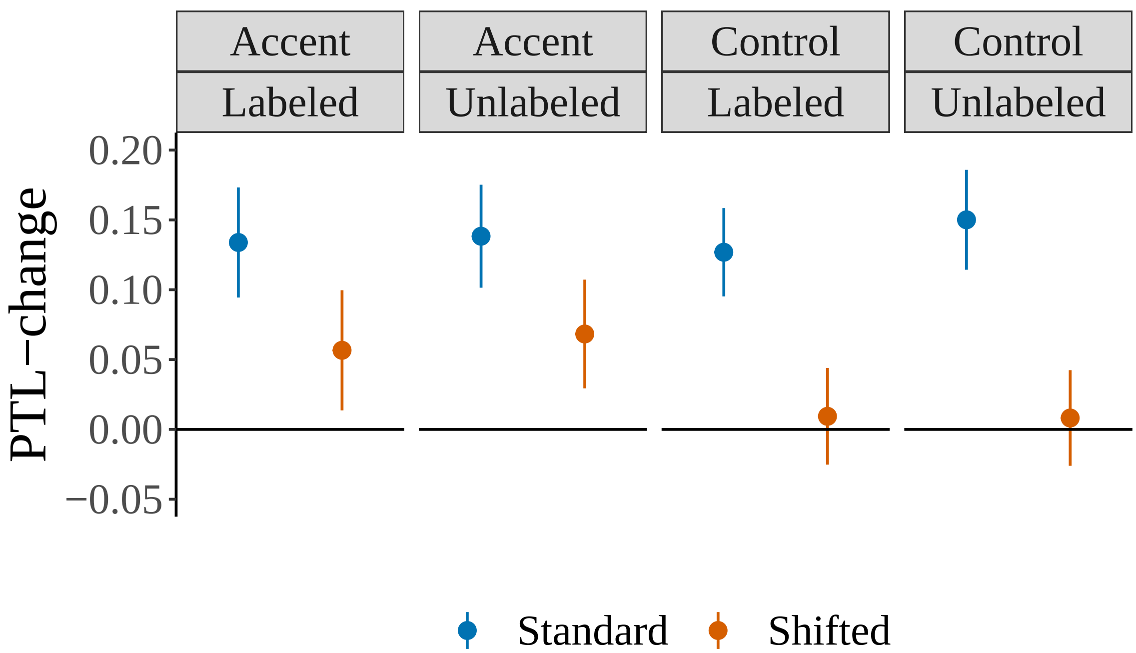

Figure 3. Mean PTL-change with standard error for Experiment 2, which tested the consonant change accent, comparing Pronunciation Type (standard, shifted), Group (Control, Accent), and Word Type (labeled, unlabeled). Values above 0 indicate increased looking to the target.