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Early Word Recognition in Sentence Context: French and English 24-Month-Olds' Sensitivity to Sentence-Medial Mispronunciations and Assimilations

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Recent work has shown that young children can use fine phonetic detail during the recognition of isolated and sentence-final words from early in

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lexical development. The present study investigates 24-month-olds' word recognition in sentence-medial position in two experiments using an Intermodal Preferential Looking paradigm. In Experiment 1, French toddlers detect word-final voicing mispronunciations (e.g., *bu**z*** [by**z**] for *bu**s*** [by**s**] "bus"), and they compensate for native voicing assimilations (e.g., *bu**z** **d**evant toi* [bu**zd**əvɑ̃twa] "bus in front of you") in the middle of sentences. Similarly, English toddlers detect word-final voicing mispronunciations (e.g., *shee**b*** for *shee**p***) in Experiment 2, but they do not compensate for illicit voicing assimilations (e.g., *shee**b** **th**ere*). Thus, French and English 24-month-olds can take into account fine phonetic detail even if words are presented in the middle of sentences, and French toddlers show language-specific compensation abilities for pronunciation variation caused by native voicing assimilation.

Over the last decade, research has revealed that infants' early lexical representations contain rich phonetic detail. From 12-months of age, infants show sensitivity to mispronunciations of familiar words in numerous studies analyzing their looking behavior. Infants look less at a picture of a familiar object upon hearing a subtle mispronunciation of the label for this object (e.g., *vaby* instead of *baby*; e.g., Swingley & Aslin, 2000; Bailey & Plunkett, 2002; White & Morgan, 2008), even if the substitution occurs word-finally (Swingley, 2009). Similarly, sensitivity to mispronunciations has been documented by 14 months of age in electrophysiological studies (Duta, Styles, & Plunkett, 2012; Mani, Mills, & Plunkett, 2012). Infants can also encode fine phonetic distinctions when learning novel words from the age of 14 months (Ballem & Plunkett, 2005; Havy & Nazzi, 2009; Mani & Plunkett, 2008; Yoshida, Fennell, Swingley, & Werker, 2009), including in word-final position (Nazzi & Bertoncini, 2009).

To date, mispronunciation studies have presented infants with words in isolation or in sentence-final position. Yet, comprehension of fluent speech necessarily involves recognizing words in the middle of sentences. In *Can you put the car in the box?*, for instance, three of the most crucial words for the interpretation of the sentence—*you, put* and *car*—occur in the middle of the utterance. A number of studies have investigated infants' detection of words in fluent speech. In a head-turn preference study, Jusczyk and Aslin (1995) demonstrated that 7½-month-old infants can detect familiar words (e.g., *cup, dog*) in fluent speech and that they can distinguish them from subtle mispronunciations (i.e., *tup, bawg*), even if these mispronunciations occur word-finally (Tincoff & Jusczyk, 1996). Using a similar paradigm, Seidl and Johnson (2006) examined the effect of sentence position on infants' word detection and found that 8-month-old infants detected words more readily in fluent speech if they occurred at the beginning or the end of the sentences than if they occurred in sentence-medial position. They suggest that this may be due to the reduced acoustic salience of words in sentence-medial position.

Other studies have gone beyond word detection and investigated toddlers' comprehension of words in different linguistic contexts. These studies document a processing advantage for words in sentence-final position over words in isolation, both in tasks examining recognition of familiar words (Fernald & Hurtado, 2006) and in novel word-learning tasks (Fennell & Waxman, 2010). In contrast, words in sentence-medial position seem to be disadvantaged: Plunkett (2005) demonstrated that although both 17- and 24-month-old infants recognize familiar words in sentence-medial position, the younger infants showed an advantage for words in isolation over sentence-medial words, suggesting that the latter are more difficult to process early on. This study further explores the impact of word recognition in continuous speech by examining infants' sensitivity to mispronunciations in sentence-medial position, to assess the level of phonetic detail that young learners use when recognizing sentence-medial words in fluent speech.

In addition to the processing difficulties for medial words mentioned above, certain phonological properties can make their recognition even harder. Vowel-initial words, for instance, are harder to detect in sentences for young English-learning infants than consonant-initial words (Mattys & Jusczyk, 2001; Nazzi, Dilley, Jusczyk, Shattuck-Hunagel, & Jusczyk, 2005; Seidl & Johnson, 2006). Furthermore, word-form realizations in sentences can deviate from standard forms used in isolation due to phonological processes inducing sound changes at word junctures (Newton & Wells, 2002). For instance, many languages have one or more processes of assimilation, leading phonological features of one sound to spread to a neighboring sound. In English, the place of articulation of the alveolar consonants *t*, *d,* and *n* can be adapted to that of a following labial (*p*, *b*, *m*) or velar (*k*, *g*) consonant. For example, the word *te**n*** can be pronounced as *te**m*** in the phrase *te**m*** ***p**ounds*. Although there is individual variation with respect to the frequency and the degree to which this place assimilation is applied—some speakers produce partial assimilations that yield ambiguous segments—native speakers of English regularly produce strong instances of assimilations that can lead to lexical ambiguities (Ellis & Hardcastle, 2002; Gaskell & Snoeren, 2008). For instance, a phrase like *ma**p*** ***m**aker* can be interpreted either as a standard pronunciation of *ma**p*** ***m**aker* or as an assimilated version of *ma**t*** ***m**aker*. Despite such ambiguity, adult listeners exploit rapid, implicit, and automatic compensation mechanisms to cope with such variability during lexical access, as shown by priming experiments where correct (e.g., *lea**m*** ***b**acon*) but not incorrect assimilations (e.g., *lea**m*** *game*) facilitate the subsequent recognition of a target word (i.e., *lean*, Marslen-Wilson, Nix, & Gaskell, 1995).

Languages differ with respect to which sounds and features can be affected by assimilations (for a review, see Cho, 1999). In French, for instance, voicing rather than place of articulation spreads through assimilation. Word-final voiceless consonants such as *s* can become voiced (i.e., *z*) when followed by certain voiced consonants such as *v*, changing, for instance, the word *bus* ([by**s**], "bus") to *buz* ([by**z**]) in the phrase *buzvert* [by**zv**ɛʁ] ("green bus"), and vice versa for word-final voiced consonants becoming voiceless when followed by a voiceless consonant. French adults show similar compensation effects in priming experiments for voicing assimilation (Snoeren, Ségui, & Hallé, 2008) as English listeners do for place assimilation. While adults show sensitivity to assimilations that do not occur in their native language (Korean place assimilation in English listeners: Gow & Im, 2004; Hungarian liquid assimilation in Dutch listeners: Mitterer, Csépe, & Blomert, 2006a; Mitterer, Csépe, Honbolygo, & Blomert, 2006b), compensation effects for native assimilations are significantly larger than for non-native assimilations in tasks involving lexical access (Darcy, Ramus, Christophe, Kinzler, & Dupoux, 2009; Mitterer, Csépe, & Blomert, 2006a). This demonstrates that adults' perception of assimilations relies at least in part on language-specific processes.

Few studies have investigated how the processing of assimilations develops during language acquisition. Adult-like performance for native place assimilation has been reported for English 7-year-olds (Marshall, Ramus, & van der Lely, 2011) and Dutch 8-year-olds (Blomert, Mitterer, & Paffen, 2004). However, assimilations appear much earlier in children's own productions, with first instances being documented at 2; 4 years and adult-like use of English place assimilation from 2; 10 years in a single case study of a British boy (Newton & Wells, 2002). Skoruppa, Mani, and Peperkamp (2013) investigated the perceptual processing of assimilations in children of roughly the same age, that is, 2; 5–3; 0 years. Using a forced-choice picture-pointing task, they tested whether English toddlers interpret word forms in which a final alveolar is pronounced as labial (e.g., *pe**m*** for *pe**n***) as an assimilated label for a corresponding familiar object (here: a pen) or as a label for an unfamiliar object (e.g., an astrolabe). Children were first familiarized with both objects and their labels (e.g., *pen* for the pen and *pem* for the astrolabe) and then asked to point to one of them. They pointed to the familiar object more often when the request sentence contained the labial form (e.g., *pem*) in a context where English place assimilation could occur (i.e., before a labial, such as in the sentence *Can you find the pe**m** **p**lease?*) than when it was presented in a context where assimilation could not occur (i.e., before a nonlabial, such as in the sentence *Can you find the pe**m** **d**ear?*). Thus, English toddlers compensated for native place assimilation, taking into account the context in which this process applies. Likewise, French toddlers were found to compensate for native voice assimilation but not for a hypothetical place assimilation process that does not apply in French. The authors concluded that processing of assimilations is influenced by language experience already by 3 years of age.

These results raise the question of how even younger children process assimilations. Hence, this study focuses on 24-month-olds' sensitivity for sentence-medial voicing mispronunciations and voicing assimilations. We chose the voicing feature because compensation effects in adults are larger for French voicing assimilation than for English place assimilation (Darcy et al., 2009), in accordance with the high degree of French voicing assimilation that has been reported in a production study (Snoeren, Hallé, & Ségui, 2006), as well as with the finding that voicing assimilation is relatively strong and categorical (Hallé & Adda-Decker, 2007). In addition, as French voicing assimilation applies to a greater range of consonants than English place assimilation, studying the former allows us to use a greater variety of experimental items, drawn from the average 2-year-old's lexicon.

This study tests toddlers' word recognition using a modified version of the intermodal preferential looking task (IPL: Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987). We monitor toddlers' eye gaze for sentence-medial target words (e.g., *Can you find the **sheep** now?*) and measure their looking time toward a picture corresponding to the label (i.e., a sheep) and to an unfamiliar object (e.g., an astrolabe) shown side by side. Previous research has established that children look longer to the familiar picture when presented with a correct pronunciation of its label relative to a mispronunciation, when presented with such a display (White & Morgan, 2008).

We chose the IPL paradigm rather than Skoruppa et al.'s (2013) pointing task for two reasons. First, the pointing task is quite demanding, especially for children in the younger age group tested in this study. Second, IPL enables us to assess children's spontaneous processing of assimilations. This contrasts with Skoruppa et al. (2013), who devised an extensive training phase in which children were specifically taught to pay attention to sentence-final mispronunciations; consequently, they were only able to assess compensation for assimilation in a select group of participants who succeeded in this training.

One-feature-mispronunciations are difficult for toddlers to detect relative to larger mispronunciations (White & Morgan, 2008). Indeed, even adults find it hard to identify word-final consonants in sentence-medial positions (Redford & Diehl, 1999). Furthermore, pilot data assessing toddlers' spontaneous detection of sentence-medial word-final voicing mispronunciations yielded null results. In our paradigm, toddlers are therefore sensitized in each trial to the critical contrast; that is, they are first exposed to the familiar word (e.g., *shee**p***) and its referent and to a minimally different nonword (e.g., *shee**b***) paired with an unfamiliar object, before these two words are presented sentence-medially. Similar pretest labeling has also been used in a preferential looking study by Fernald, Pinto, Swingley, Weinberg, and McRoberts (1998) and in Skoruppa et al.'s (2013) pointing study. This labeling phase was designed to remind the toddlers of the familiar objects' labels, as well as to facilitate toddlers' pairing of the new label to the unfamiliar object, thus reinforcing the mutual exclusivity constraint (Markman, 1989). We then test the recognition of these items sentence-medially (e.g., *Can you find the shee**p** **n**ow*?).

In two experiments, we assess French (Exp. 1) and English (Exp. 2) toddlers' processing of standard pronunciations, voicing mispronunciations, and voicing assimilations. If they are sensitive to phonetic detail in sentence-medial words, they should look longer at the familiar object in the standard than in the mispronunciation condition. If toddlers compensate for assimilations, they should interpret the assimilated form as a variant of the familiar word and look longer to the familiar object in the assimilation condition than in the mispronunciation condition. If, on the contrary, toddlers are not sensitive to assimilations, they should treat them as mispronunciations and show reduced looks to the familiar object in both the assimilation and the mispronunciation conditions (compared with the standard condition). Finally, if compensation for assimilation is influenced by language experience at 2 years, only French toddlers should show an assimilation effect, but English toddlers should not, as voicing assimilation across word junctures occurs in French but not in English.

EXPERIMENT 1

Method

Participants

Thirty-three French 24-month-olds (16 girls, 17 boys, age range: 23.11–24.26 months) were tested in Paris, France. All toddlers were healthy, had no known developmental difficulties, and were raised in monolingual French families. Four additional toddlers participated in the experiment, but their data were not included in the analysis because their eye movements were too difficult to code (n = 3) or because they refused to participate in the task, saying *non* ("no") and hiding from the camera in each trial ($n = 1$). Written informed consent was obtained from the parents prior to testing.

Stimuli

Fifteen imageable monosyllabic French nouns ending with a single obstruent consonant were selected (e.g., *boîte* [bwat] "box," *chaise* [ʃɛz] "chair," for a complete list see Appendix 1). They were all acquired early in childhood according to French age-of-acquisition norms (Chalard, Bonin, Meot, Boyer, & Fayol, 2003) and pilot data from a French parental questionnaire (Kern & Gayraud, 2010). The nouns were presented in sentence-medial position in three conditions (for examples, see Table 1).

Standard condition. A correct, standard realization of the noun was recorded in a neutral context that would not give rise to any change in pronunciation like resyllabification or assimilation in French (i.e., followed by a sonorant consonant like *l* or *m*).

Mispronunciation condition. A mispronunciation of the noun, where the voicing feature of the final consonant was changed from voiceless to voiced and vice versa, was recorded in the same context as for the standard condition.

Assimilation condition. The same voicing change as for the mispronunciation was applied in a context that can induce French voicing assimilation (i.e., the noun was followed by a word starting with an obstruent consonant with the opposite voicing value of its final consonant). Importantly, in this condition, it is possible to interpret the changed form as an assimilated version of the target label.

TABLE 1
Examples of Stimuli used in Experiment 1

Condition	*Example*	*IPA Transcription*	*English Translation*
Standard	*Regarde le bus **m**aintenant*	[ʁəgaʁdləby**sm**ɛ̃tənɑ̃]	"Look at the bus now"
Mispronunciation	*Regarde le buz **m**aintenant*	[ʁəgaʁdləby**zm**ɛ̃tənɑ̃]	"Look at the [byz] now"
Assimilation	*Regarde le buz **d**evant toi*	[ʁəgaʁdləby**zd**əvɑ̃twa]	"Look at the bus in front of you"

Care was taken to ensure that the final voicing changes did not yield real French nouns known to French 24-month-olds; that linguistic contexts were semantically neutral and did not give any clues regarding the interpretation of the noun; and that nouns were never followed by words that would lead to a sequence of two identical consonants. A complete list of all the sentences used can be found in Appendix 1. A balanced bilingual French–English female speaker recorded the sentences in child-directed speech. She was instructed not to produce any pauses between words and to produce complete voicing changes, thus yielding strong assimilations. The speaker also recorded determiner-noun phrases with the correct label and with a voicing mispronunciation (e.g., *un bus* "a bus" and *un buz* "a [byz]").

Finally, color images depicting the nouns were paired with 15 pictures of objects whose labels were deemed unfamiliar to young children. Several of these pictures were taken from a colored version of the Snodgrass line drawings (Rossion & Pourtois, 2004). All pictures had a uniform light-gray background.

Procedure

During the experiment, toddlers sat on their caregiver's lap approximately 80 cm away from a wide-screen computer monitor (47 × 30 cm). Caregivers wore opaque glasses during the experiment, so that they could not see the pictures and influence the infant. Hidden behind a cardboard frame, a camera mounted above the screen recorded toddlers' eye movements throughout the experiment, and two loudspeakers to either side of the screen delivered the auditory stimuli at a fixed, comfortable level. An experimenter seated behind the cardboard frame initiated trials when the infant was calm and attentive.

Each child was presented with 15 trials, five in each condition (standard, mispronunciation, and assimilation). Figure 1 illustrates how the

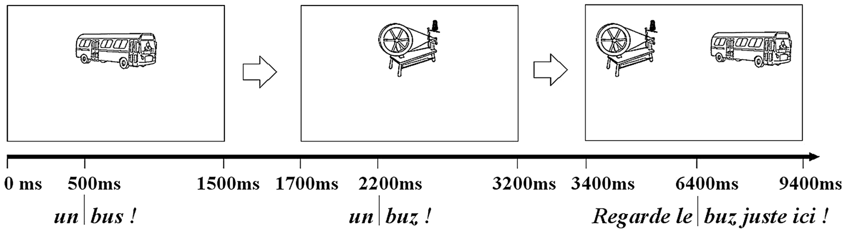

Figure 1 Schematic illustration of a sample trial.

trials were structured. Each trial started with the presentation of the familiar object in the middle of a black screen. The label for this object was then presented such that the noun started 500 msec after the picture onset (e.g., *un bus* "a bus"). The picture stayed on screen for a further 1000 msec after the noun onset. Following a 200-msec pause where the screen remained blank, toddlers were presented with an unfamiliar object on screen. This object was then labeled with an unfamiliar word minimally distinct from the label for the previously presented familiar object (e.g., *un buz* "a [byz]"). Following a further 200-msec pause, that is, 3400 msec into the trial, the two pictures appeared side by side in silence. Toddlers were then presented with a sentence (e.g., *Regarde le buz devant toi !* "Look at the bus in front of you!"), such that the critical noun started 3000 msec after the onset of the pictures. The pictures remained on screen until the end of the trial 3000 msec after the noun onset.

Each toddler saw each object pairing only once. Targets appeared equally often in each of the three conditions across children. The familiar object appeared eight times on the left and seven times on the right side of the screen. The experiment lasted about 5 min.

RESULTS AND DISCUSSION

A trained coder, blind to the condition being tested, assessed whether the infant looked to the left or to the right throughout the test phase of each trial. A second well-trained coder evaluated the data from 10% of the participants (coder agreement: $r = .93$). Four trials containing the target *boîte* ([bwat] "box") had to be excluded because the wrong audio file was played in this trial due to experimenter error.

Figure 2 shows the proportion of time toddlers spent looking at the familiar object, averaged by subject and by condition during the prenaming and postnaming phases. The 2633-msec prenaming window included the baseline phase during which pictures were displayed side by side, from 367 msec (the minimum time needed for a saccade in a young child, according to Swingley & Aslin, 2000) after picture onset until the start of the noun. The 2633-msec postnaming window started 367 msec after the target word onset and lasted until the end of the trial. All trials where toddlers did not look at both objects during the prenaming window were removed from analysis (17.4% of trials). The data from one child whose looking times deviated by more than ±2.5 standard scores from the mean in one condition were removed. Looking-time proportions were analyzed in a repeated-measures ANOVA with the within-subject factors Phase (prenaming vs. postnaming) and

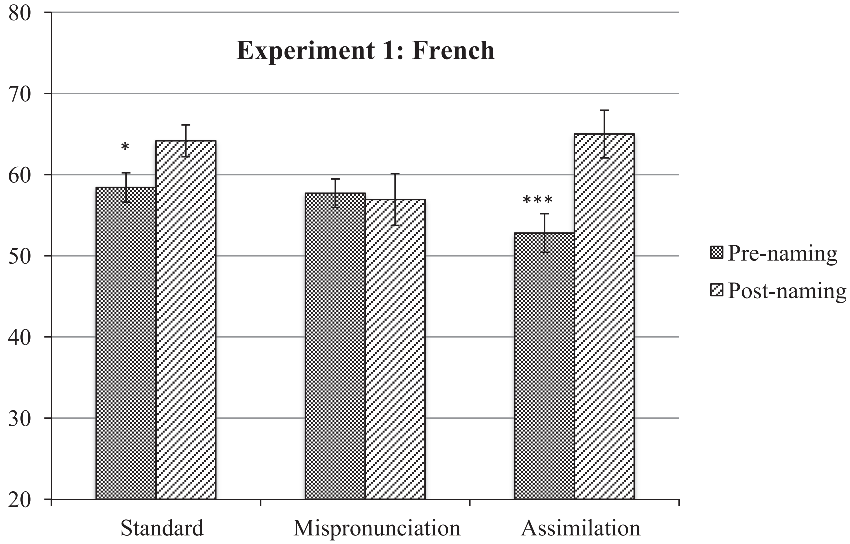

Figure 2 Mean proportions of looking to the familiar object by condition in the pre- and postnaming phase for French participants in Experiment 1. Error bars represent ±1 standard error. Asterisks indicate significance level in *t*-tests (**p* < .05, ***p* < .01, ****p* < .001).

Condition (standard, mispronunciation, and assimilation). There was a significant main effect of Phase ($F(1, 31) = 6.86$, $p = .014$, $\eta_p^2 = .18$), and a significant interaction between Phase and Condition ($F(2, 62) = 5.64$, $p = .005$, $\eta_p^2 = .16$).

Planned comparisons using pairwise *t*-tests were carried out to investigate difference between conditions in the postnaming phase. Both uncorrected and Holm–Bonferroni-corrected *p*-values will be reported. There was a significant difference in the proportion of time toddlers spent looking at the familiar object in the postnaming phase between the standard and the mispronunciation conditions ($t(31) = 2.73$, $p = .010$, corrected $p = .020$, $d = .52$) and between the assimilation and the mispronunciation conditions ($t(31) = 2.76$, $p = .009$, corrected $p = .027$, $d = .49$), but not between the standard and the assimilation conditions ($t(31) < 1$). Furthermore, the naming effect was analyzed by comparing pre- and postnaming phase by condition. Toddlers looked significantly more toward the familiar object in the postnaming phase compared with the prenaming phase following voicing assimilations ($t(31) = 4.02$, $p < .001$, corrected $p = .001$, $d = .72$). Target looking also increased significantly (with correction, marginally) following standard pronunciations ($t(31) = 2.21$,

p = .035, corrected p = .070, d = .39), but not following voicing mispronunciations (t(31) < 1).

To rule out the possibility that these effects were due to subtle differences in the realization of the critical consonants, we asked adult native speakers to evaluate the stimuli in a forced-choice perception experiment. Twelve monolingual French adults heard the final vowel–consonant portions of the targets (e.g., [ys] from *Regarde le bus maintenant*) in all conditions and were asked to label the final consonant, choosing between the unassimilated (here, *s*) and the assimilated consonant (here, *z*). An ANOVA revealed that identification rates were significantly different across conditions (F(2, 11) = 345.26, p < .001, η_p^2 = .97). Planned comparisons using pairwise t-tests showed that, as expected, participants chose the unassimilated consonant more often in the standard (89.4%) than in the assimilation (6.7%, t(11) = 22.30, p < .001, corrected p < .001, d = 6.65) and the mispronunciation (13.9%, t(11) = 18.29, p < .001, corrected p < .001, d = 5.31) conditions. There was also a significant difference between the assimilation and the mispronunciation conditions (t(11) = 3.03, p = .012, corrected p = .012, d = .91). Crucially, this difference was in the opposite direction from the assimilation effect found in our infant participants (with the segments in the mispronunciation condition being perceptually closer to the standard than the segments in the assimilation condition); acoustic differences between the assimilation and mispronunciation conditions cannot, therefore, explain our infant data.

Thus, our results show that, by 2 years of age, French toddlers associate both a standard pronunciation and a voicing assimilation of a familiar label with the familiar object, but not a voicing mispronunciation. In other words, French 24-month-olds are sensitive to voicing mispronunciations in sentence-medial contexts and compensate for voicing assimilations common to their native language during word recognition. The next experiment investigates which aspects of this performance are language specific, by testing English-learning 24-month-olds on similar changes to English words across assimilation and mispronunciation contexts. Like French, English has a final voicing contrast, so we would expect English 24-month-olds to detect voicing mispronunciations just as French toddlers do. In contrast to French, however, English does not allow voicing assimilation across word boundaries. Thus, if compensation for assimilations is language specific by the age of 2 years, we would expect English-learning toddlers to treat voicing assimilations that do not occur in their native language (e.g., *shee**b** **th**ere* for *shee**p** **th**ere*) as mispronunciations. If, on the contrary, early compensation for assimilation is language independent, we would expect English toddlers to show the same compensation effect for voicing assimilations as the French ones in Experiment 1.

EXPERIMENT 2

Method

Participants

Thirty-one English 24-month-olds (13 girls, 18 boys, range 23.20–25.0 months) were tested in Oxford, United Kingdom. All of them were healthy, had no known hearing or visual problems, and were raised in monolingual British English families. Two additional toddlers participated in the experiment, but their data were not included in the analysis because their eye movements were too difficult to code ($n = 1$) or because they were fidgety throughout the test phase ($n = 1$). Written informed consent was obtained from the parents prior to testing.

Stimuli

Fifteen imageable monosyllabic nouns ending with a single obstruent consonant (e.g., *sheep*, *leg*) were selected. They were reported to be known to toddlers according to parental reports from the British Communicative Development Inventory (Hamilton, Plunkett, & Schafer, 2000). A complete list of these words can be found in Appendix 2. The nouns were used in sentence contexts in the same three conditions as in Experiment 1 (for examples, see Table 2).

Standard condition. A correct, standard realization of the noun was recorded in a neutral context (i.e., followed by the sonorant consonant *n*).

Mispronunciation condition. A mispronunciation of the noun, where the voicing feature of the final consonant was changed from voiceless to voiced and vice versa, was recorded in the same context.

TABLE 2
Examples of Stimuli Used in Experiment 2

Condition	*Example*
Standard	*Can you find the shee**p** **n**ow?*
Mispronunciation	*Can you find the shee**b** **n**ow?*
Pseudo-assimilation	*Can you find the shee**b** **th**ere?*

Pseudo-assimilation condition. The same voicing change as for the mispronunciation was applied in a context that would induce voicing assimilation in languages like French (i.e., the noun was followed by a word starting with an obstruent with the opposite voicing value of its final consonant). Note that in this case, it would be possible to interpret the changed form (here, *sheeb*) as an assimilated version of the word *sheep* if voicing assimilation occurred in English.

As in Experiment 1, care was taken to ensure that the final voicing changes did not yield real English words familiar to young children; that linguistic contexts were semantically neutral and did not give any clues regarding the interpretation of the noun; and that nouns were never followed by words that would lead to a sequence of two identical consonants. A complete list of the sentences used can be found in Appendix 2. The sentences were recorded in child-directed speech by the same French–English bilingual speaker as in Experiment 1. As before, she was instructed not to produce any pauses between words and to produce complete voicing changes, thus yielding strong pseudo-assimilations. The speaker also recorded the correct pronunciation and the voicing mispronunciation in isolation (e.g., *sheep, sheeb*), to be used for object presentation.

As in Experiment 1, color pictures depicting the nouns were paired to 15 pictures of objects whose labels were deemed unfamiliar to young children. All pictures had a uniform light-gray background.

Procedure

During the experiment, toddlers sat on their caregiver's lap approximately 80 cm away from a projection screen (130 cm $\times$ 35 cm). Caregivers were instructed to close their eyes during the experiment. Toddlers' looking behavior was recorded using two cameras located exactly above where the two images would appear on the screen. Loudspeakers located above the screen presented the auditory stimuli. An experimenter sitting in a separate room initiated the trials based on when the infant was paying attention to the screen. The number and the structure of trials were the same as in Experiment 1.

RESULTS

Videos were coded and data were analyzed as in Experiment 1. Figure 3 plots the proportion of time toddlers spent looking at the familiar object, averaged across subjects split by condition and phase. Trials where toddlers did not look at both objects during prenaming were discarded

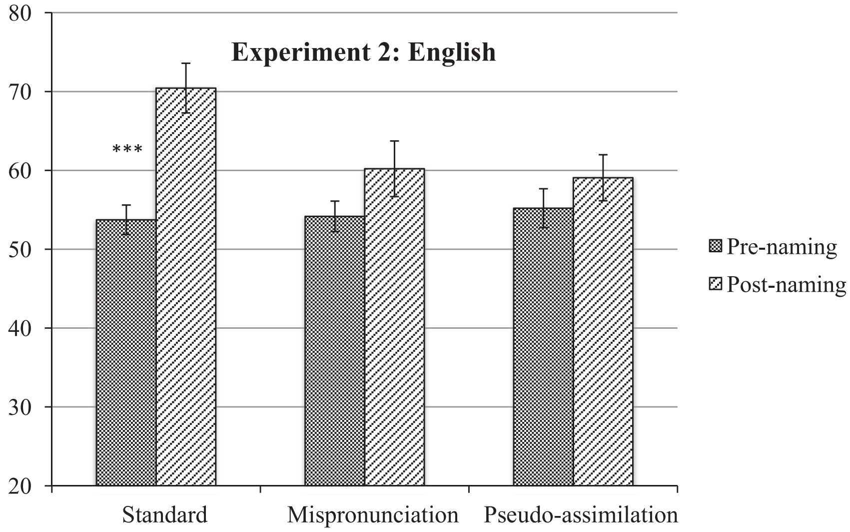

Figure 3 Mean proportions of looking to the familiar object by conditions in the pre- and postnaming phases for English participants in Experiment 2. Error bars represent ±1 standard error. Asterisks indicate significance level in *t*-tests (*$p < .05$, **$p < .01$, ***$p < .001$).

(12.9%), and following the same criterion as in Exp. 1 (2.5 *SD* above/below the mean in one condition), one outlier was removed. Looking scores were compared in a repeated-measures ANOVA with the within-subject factors Phase (prenaming vs. postnaming) and Condition (standard, mispronunciation, and pseudo-assimilation). There was a significant main effect of Phase ($F(1, 30) = 16.72$, $p < .001$, $\eta_p^2 = .36$) and a significant interaction between Phase and Condition ($F(2, 60) = 3.41$, $p = .040$, $\eta_p^2 = .10$).

Planned pairwise comparisons revealed a significant difference in the proportion of time toddlers spent looking at the familiar object in the postnaming phase between the standard and the pseudo-assimilation conditions ($t(30) = 2.99$, $p = .006$, corrected $p = .018$, $d = .54$) and between the standard and the mispronunciation conditions ($t(30) = 2.41$, $p = .022$, corrected $p = .044$, $d = .44$), but not between the pseudo-assimilation and the mispronunciation conditions ($t(30) < 1$). Furthermore, toddlers looked more toward the familiar object in the postnaming phase compared with the prenaming phase following standard pronunciations ($t(30) = 4.41$, $p < .001$, corrected $p < .001$, $d = .81$), but not following voicing mispronunciations ($t(30) = 1.71$, $p = .098$, corrected $p > .1$) or voicing pseudo-assimilations ($t(30) = 1.33$, $p > .1$).

As in Experiment 1, the stimuli were evaluated by adult native speakers in a forced-choice perception experiment. Twelve monolingual British English speakers heard the final vowel–consonant portions of the targets (e.g., [ip] from *Can you find the* ***sheep*** *now?*) in all conditions and were asked to label the final consonant, choosing between the unassimilated (here, *p*) and the pseudo-assimilated consonant (here, *b*). An ANOVA revealed that identification rates were significantly different across conditions ($F(2,\ 11) = 634.48$, $p<.001$, $\eta_p^2 = .98$). Planned comparisons using pairwise *t*-tests showed that, as expected, participants chose the unassimilated consonant more often in the standard (97.4%) than in the pseudo-assimilation (14.9%, $t(11) = 25.80$, $p < .001$, $d = 7.69$) and the mispronunciation (16.7%, $t(11) = 31.8$, $p < .001$, $d = 9.23$) conditions. There were no significant differences between the pseudo-assimilation and the mispronunciation conditions ($t(11) < 1$).

Finally, the infant data in both experiments were compared in a global ANOVA with the between-subject factor Language (English vs. French) and the within-subject factors Phase and Condition. This analysis yielded a significant effect of Phase ($F(1,\ 64) = 24.37$, $p < .001$, $\eta_p^2 = .28$), Condition ($F(2,\ 128) = 3.67$, $p = .045$, $\eta_p^2 = .047$), and a significant triple interaction between Phase, Condition, and Language ($F(2,\ 128) = 5.17$, $p = .007$, $\eta_p^2 = .075$), confirming that French and English toddlers reacted differently to the labels in the different conditions.

Like the French toddlers in Experiment 1, English toddlers looked more toward the familiar object upon hearing the standard pronunciation of the label for this object than upon hearing mispronunciations. Unlike the French toddlers, however, they treated voicing pseudo-assimilations as different from the standard pronunciations and similar to mispronunciations. Thus, English toddlers seem to associate only the standard pronunciations with the familiar objects and not voicing mispronunciations or pseudo-assimilations. These results show that like French toddlers, English toddlers take fine phonetic detail into account during word recognition in the middle of sentences. However, they do not show any sign of compensation for assimilation of the voicing feature. Taken together, the two experiments thus show that sentence-medial word recognition is influenced by language-specific processes, such as compensation for voicing assimilation, at the age of 2 years.

GENERAL DISCUSSION

The current study had three main goals: (a) determine the amount of phonetic detail toddlers retrieve from words presented in sentence context, particularly in sentence-medial position; (b) examine toddlers' sensitivity to assimilations common to their native language at a younger age and in a more sensitive paradigm than previous studies; (c) investigate whether toddlers' sensitivity to assimilations is language specific. We addressed these questions using an adaptation of the IPL task to test 24-month-olds' spontaneous processing of sentence-medial word-final mispronunciations, assimilations, and pseudo-assimilations (i.e., assimilations that do not occur in the native language input).

Experiments 1 and 2 show that French and English toddlers are sensitive to voicing mispronunciations of words in sentence-medial position. Despite toddlers' early difficulties with detecting (Seidl & Johnson, 2006) and understanding (Plunkett, 2005) words in sentence-medial position, by 2 years of age, French and English toddlers not only recognize words in these less salient positions, but also detect small changes to their phonological makeup. Furthermore, they do so despite the fact that these changes occur word-finally, a perceptually less salient position (Redford & Diehl, 1999). Thus, our results add to the growing body of evidence that toddlers' early sensitivity to phonetic detail extends to the word-final position (Nazzi & Bertoncini, 2009; Swingley, 2009). However, the present results should be modulated by the fact that the word-final voicing distinctions were highlighted during a prelabeling phase. Further research should investigate French and English toddlers' completely spontaneous detection of less subtle word-initial and word-final mispronunciations in sentence-medial and sentence-final positions, to provide a more complete picture of how toddlers' processing depends on word and sentence position in the two languages.

Furthermore, Experiment 1 showed that while French toddlers are sensitive to voicing mispronunciations of word-final consonants, they are also able to accommodate voicing changes where permitted by the phonology of their native language. In particular, when presented with word-final voicing changes in contexts that typically induce voicing assimilations in French, that is, preceding a word-initial obstruent with the opposite voicing value, toddlers compensate for such context-induced assimilations and show robust recognition of the target word, just as French adults do (Darcy et al., 2009; Snoeren et al., 2008). Our study demonstrates, therefore, that by 2 years of age, French toddlers compensate for native language assimilation in a preferential looking task. Experiment 2 suggests that compensation for assimilation is influenced by language experience as early as 2 years of age: English toddlers, exposed to a language that does not allow voicing assimilation, do not show a similar compensation effect for voicing assimilation. In what follows, we examine the implications of these findings for theories of toddlers' phonological representations of words.

A great deal of research has examined the phonological specificity of toddlers' representations of words (Stager & Werker, 1997; Mani & Plunkett, 2007, 2008, 2011; Swingley & Aslin, 2000, 2002 among others). The overall conclusion reached by this work is that toddlers possess detailed phonological representations of familiar words. Most of this research has examined changes to words presented in isolation or in salient positions in a sentence, for example, sentence-final position. The current research highlights an important component of the developing word recognition system by examining toddlers' sensitivity to mispronunciations of words in sentence-medial position in fluent speech. Despite a challenging sentence-medial context, 2-year-olds displayed robust detection of word-final mispronunciations, indicating that French and English toddlers can readily access detailed phonological representations across a range of linguistic contexts and memory loads. Our results underline the emerging flexibility of word recognition in different sentence positions during infancy, a skill that is important for the understanding of crucial key words in fluent speech.

The current study found that toddlers' representations of words are not only detailed with respect to word-internal content, but also with regard to the phonological context in which words occur and the changes that such contexts typically induce. Specifically, we focused on French toddlers' compensation for voicing assimilation, a phonological alternation that is common in their native language. French toddlers showed robust recognition of words with voicing changes only when they were presented in contexts that license voicing assimilation, that is, when the voicing-changed realization was followed by a word whose initial consonant was an obstruent bearing the opposite voicing value of the crucial word's final consonant. Indeed, toddlers treated the voicing-changed realization as equivalent to the standard pronunciation of the word. Crucially, toddlers did not equate the standard pronunciation with the voicing-changed realization when it was presented in a context that does not license voicing assimilation in French, that is, in the mispronunciation condition. The contrast between toddlers' responses to voicing changes in assimilation and nonassimilation contexts suggests that toddlers' robust recognition of the word in an assimilation context is due to their compensating for voicing assimilation and not to their lack of sensitivity to word-final changes. It would be interesting to investigate whether the reverse pattern could be found for English place assimilation, with English but not French toddlers compensating for English place assimilation, although this would be methodologically challenging due to the small number of words with final alveolar stops known by children at this age.

French toddlers' early compensation for assimilation at 24 months of age raises further questions with regard to the amount of experience required to sensitize toddlers to phonological alternations that occur in their native language. Would younger infants, say at 12 or 18 months of age, show similar compensation for native language assimilations? Is there an age at which infants fail to compensate for native language assimilations? And finally, is there any age at which infants compensate for assimilations that do not occur in their native language? For instance, very young infants may compensate for assimilations that do not occur in their native language, due to the greater acoustic fit between the assimilated consonant and the assimilation-licensing consonant. Indeed, some phonological theories view assimilation as the "unmarked" default and postulate that children have to *unlearn* these alternations if they do not exist in their native language (e.g., Donegan & Stampe, 1979; Smolensky, 1996), rather than having to learn assimilations present in their native language, as proposed by other theories (Peperkamp & Dupoux,2002). However, the current study did not find compensation for non-native assimilation in English toddlers at 24 months. Indeed, to the best of our knowledge, no study has yet documented a stage at which children compensate for non-native assimilations to the same extent as native assimilations.

Our findings raise further questions about the kinds of phonological representations that toddlers associate with familiar words. Clearly, these representations are detailed enough for toddlers to detect small changes to the words. However, do they also contain context-sensitive information regarding legitimate surface forms? That is, do French toddlers store the standard realization as well as a voicing-changed realization of the same word in an exemplar-based manner (Pierrehumbert, 2002), the latter being preferentially activated in certain contexts? Alternatively, do they "undo" assimilations in a rule-like manner as part of a normalization process during lexical access, as postulated, for instance, by Lahiri and Marslen-Wilson (1991)? Or, finally, do they store feature-based representations of words, with the stored features being relatively fluid and transferable across neighboring words, as claimed by phonological theories such as Feature Geometry (Clements, 1985) or Articulatory Phonology (Browman & Goldstein, 1992)?

In conclusion, our study suggests that there are language-specific effects in the processing of assimilations at the precocious age of 2 years, around a year earlier than previously found (Skoruppa et al., 2013), and in a more implicit paradigm without prior training. Our study also provides the first-ever demonstration of children's sensitivity to mispronunciations in sentence-medial contexts. Ongoing research on this topic examines how younger infants deal with assimilations and whether they show any language-independent compensation effects at an early age.

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APPENDIX 1

EXPERIMENT 1

All test sentences start with the carrier phrase *Regarde le/la/l'*... "Look at the...." Table A1 shows the following noun (which is presented with or without voicing change) and the corresponding context. For instance, the assimilation condition sentence for *boîte* was *Regarde la boide juste ici !* ("Look at the box just here!").

TABLE A1
Nouns and Contexts used in Experiment 1

Noun	*Context for Standard and Mispronunciation Conditions*	*Context for Assimilation Condition*
boîte [bwat] "box"	*là-devant* [ladəvɑ̃] "there in front"	*juste ici* [ʒystisi] "just here"
botte [bɔt] "boot"	*là-devant* [ladəvɑ̃] "there in front"	*juste ici* [ʒystisi] "just here"
bouche [buʃ] "mouth"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
brosse [bʁɔs] "brush"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
bus [bys] "bus"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
chaise [ʃɛz] "chair"	*là-devant* [ladəvɑ̃] "there in front"	*par ici* [paʁisi] "over here"
couche [kuʃ] "diaper"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
fraise [fʁɛz] "strawberry"	*là-devant* [ladəvɑ̃] "there in front"	*par ici* [paʁisi] "over here"
œuf [œf] "egg"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
pouce [pus] "thumb"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
robe [ʁɔb] "dress"	*là-devant* [ladəvɑ̃] "there in front"	*qui est là* [kiela] "that is there"
sac [sak] "bag"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
singe [sɛ̃ʒ] "monkey"	*là-devant* [ladəvɑ̃] "there in front"	*par ici* [paʁisi] "over here"
tasse [tas] "cup"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"
vache [vaʃ] "cow"	*maintenant* [mɛ̃tənɑ̃] "now"	*devant toi* [dəvɑ̃twa] "in front of you"

APPENDIX 2

EXPERIMENT 2

All test sentences start with the carrier phrase *Can you find the….* Table 2A shows the following noun (which is presented with or without voicing change) and the corresponding context. For instance, the assimilation condition sentence for *sheep* was *Can you find the sheep there?*.

TABLE A2
Nouns and Contexts used in Experiment 2

Noun	*Context for Standard and Mispronunciation Condition*	*Context for Pseudo-assimilation Condition*
bike [baɪk]	*now* [naʊ]	*there* [ðeə]
book [bʊk]	*now* [naʊ]	*there* [ðeə]
bus [bʌs]	*now* [naʊ]	*there* [ðeə]
cheese [tʃi:z]	*now* [naʊ]	*please* [pli:z]
clock [klɒk]	*now* [naʊ]	*there* [ðeə]
cup [kʌp]	*now* [naʊ]	*there* [ðeə]
dog [dɒg]	*now* [naʊ]	*please* [pli:z]
duck [dʌk]	*now* [naʊ]	*there* [ðeə]
horse [hɔ:s]	*now* [naʊ]	*there* [ðeə]
juice [dʒu:s]	*now* [naʊ]	*there* [ðeə]
leg [lɛg]	*now* [naʊ]	*please* [pli:z]
nose [nəʊz]	*now* [naʊ]	*please* [pli:z]
sheep [ʃi:p]	*now* [naʊ]	*there* [ðeə]
sock [sɒk]	*now* [naʊ]	*there* [ðeə]
truck [tɹʌk]	*now* [naʊ]	*there* [ðeə]