2aSC29. Acoustical cues versus top-down bias in infants’ parsing

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French liaison involves the surfacing of an underlying consonant as the onset of the following vowel-initial word (e.g., les amis - /le/ /zami/), creating misalignment. However, acoustic cues that support vowel-initial parsing may exist. In a preferential looking procedure we examined French-learning 30-month-olds’ parsing in liaison-related cases. Familiarization sentences in Experiment 1 contained a determiner preceding a vowel-initial non-word (e.g., ces onches). Two test conditions followed. The vowel-initial condition presented the vowel-initial non-word versus another non-target (onches - èque). The consonant-initial condition tested the consonant-initial parse (zonches - zèque). Infants in the vowel-initial, but not the consonant-initial condition, showed discrimination (p=.008), i.e., they correctly parsed the vowel-initial target, possibly using acoustic cues. Knowledge of underlying liaison consonants can also explain these results. In Experiment 2 we removed acoustic cues to vowel-initial parsing by using a consonant-initial non-word following a determiner in familiarization sentences (e.g., un zonche). Test conditions were the same as those in Experiment 1. Infants yielded the same results as Experiment 1, showing discrimination only in the vowel-initial condition (p=.047). Taken together, 30-month-olds perceived /z/ as an independent element unrelated to the preceding word; they used this partial liaison knowledge, rather than possible acoustical cues, for parsing.

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INTRODUCTION

Vowel-initial words can be harder to segment than consonant-initial words, because they are often subject to resyllabification that creates a misalignment of the word with the syllable. For instance, the word ice surfaces as dice in cold ice. Segmentation of vowel-initial words is particularly challenging for child language learners, who have less sophisticated lexical and grammatical knowledge. Previous infant studies showed that compared with consonant-initial words, vowel-initial word segmentation is delayed by several months (e.g., Mattys and Jusczyk, 2001; Nazzi et al., 2005; Seidl and Johnson, 2008). In French there is a common phenomenon called liaison, which triggers the misalignment of vowel-initial words with the syllable boundary. A liaison is manifested in speech by the surfacing of a consonant between two words. For example, a /z/ between les and amis ([le.zami]). The liaison consonant behaves as the onset consonant of the second word and only surfaces when the second word is vowel-initial. Unlike other kinds of resyllabification, the liaison consonant never appears as the coda of the first word (e.g., les balles [le.bal]), although it is related to the first word. These complex characteristics of liaison can lead listeners, particularly young language learners, to misinterpret the consonant as the onset of the second word.

Different sources of information such as acoustic cues and liaison knowledge can potentially assist vowel-initial segmentation in liaison contexts. Acoustic cues that can be used to distinguish vowel-initial words in liaison contexts from ambiguous consonant-initial words have been found in the literature (e.g., Gaskell et al., 2002; Spinelli et al., 2003; Tremblay, 2011; Yersin-Besson and Grosjean, 1996). For example, dernier rognon and dernier oignon are phonemically homophonous, and they can be differentiated by the subtle acoustical differences of the /r/ consonants (Spinelli et al., 2003). However, mixed results have been obtained on whether these acoustic cues can be perceived and used in word recognition (e.g., Shoemaker and Birdsong, 2008; Spinelli et al., 2003). On the other hand, liaison knowledge is a strong cue to vowel-initial segmentation in liaison contexts. This knowledge refers to the status given to the liaison consonant. In linguistics, the liaison consonant has been traditionally analyzed as the underlying coda of the first word (see the discussion of different accounts in Côté, 2011). The view that the liaison consonant can be treated as an independent element and not a part of the first word has also been proposed by some linguists (e.g., Tranel, 1981), although the first word is still required to trigger the surface of the independent element. Consistent with this view, infants may represent the /z/ that surfaces between les and amis as an independent consonant. Recent studies by Legendre and colleagues have shown that French-learning 30-month-olds use pronoun liaisons to understand subject-verb plural agreement (Legendre et al., 2010). They showed that infants can discriminate the meanings between ils /z/embrassent (“they kiss”) and il /l/embrasse (“he kisses”). In the first case, the presence of the liaison /z/ indicates a plural agreement context. These findings do not tease apart the two linguistic views on the status of the /z/ liaison. It is not clear if infants in their study interpreted /z/ as a part of the pronoun ils, or if they simply understood /z/ as an independent plural morpheme unrelated to the pronoun. Nevertheless, both explanations account for the fact that knowledge about liaison consonants may assist vowel-initial segmentation in liaison cases.

In this study we investigated how infants use these potential sources of information for word segmentation. In Experiment 1 our stimuli were created such that acoustic cues and liaison knowledge jointly indicated the correct vowel-initial parse in liaison cases.

EXPERIMENT 1

Methods

Participants and Stimuli

Thirty-two monolingual Quebec-French-learning 30-month-olds completed this experiment. We created two vowel-initial target words, onche and èque. They were non-words that were French-like phonologically. We used a French function word ces (“these”) before each target, creating a liaison context (e.g., ces [z]onches, “these onches”; ces [z]èques, “these èques”). Four sentences were created, two containing the phrase ces [z]onches, and two others containing ces [z]èques. The phrases appeared in different sentential positions. Twelve other filler sentences not containing the two noun phrases were created. Stimuli also included isolated word forms of the vowel-initial pseudo-nouns (onche, èque) and their ambiguous consonant-initial counterparts (zonche, zèque).

The sentences and the isolated word forms were produced multiple times by a female native speaker of Quebec French in an infant-directed speech style. The stimuli were recorded in an IAC acoustic chamber. For the
familiarization stimuli, eight sentences were used for each of the two conditions. Two tokens for each sentence were selected. For the test stimuli, 12 isolated productions for each of the pseudo-nouns (onche, èque, zonche, zèque) were selected, for a total of 48.

The visual image was an animation of a bird that was synchronously moving its mouth with the auditory stimuli during the familiarization and the test trials. To acquaint the infant with the procedure, a pre-trial was first presented. A post-test was presented following the last test trial to mark the end of the experiment. During these two trials, sounds of water bubbles were presented with the bird being still. An attention-getter, which was used between trials, was a video presenting a moving star and sounds of a cricket.

Procedure

Each infant was individually tested in a visual preferential procedure in an acoustic chamber. In front of a central monitor, there was a sofa in which the parent sat. The infant sat on his or her parent’s lap or stand next by the parent. On each side of the monitor was a loudspeaker that was used to present the auditory stimuli. The two loudspeakers presented stimuli simultaneously. The monitor presented the visual stimuli. Masking music was delivered through headphones to the parent, who was also told to not intervene in any way during the experiment. The task was run by a software program designed specifically for this procedure. Once the familiarization phase was completed, the experiment advanced automatically to the test phase.

In an adjacent room, a researcher blind to the stimuli observed the infant’s eye movement through a closed circuit TV. When the infant looked toward the monitor, a trial was initiated by a blind researcher. The researcher pressed down a computer key whenever the infant looked at the monitor and abstained from doing so whenever the infant looked away from the monitor. Trials had a fixed length and terminated automatically once the entire audio-visual materials for a trial were presented. The experimental sessions were videotaped and coded by another researcher who was blind to the stimuli. The offline video coding was done frame by frame (30 frames per second).

Design and Predictions

Infants were randomly divided into two groups, one for Experiment 1a, and the other Experiment 1b. Both groups included a familiarization phase and a test phase. Experiments 1a and 1b had the same familiarization conditions (Condition 1 and 2) and differed only in the test phase. For each group, infants were randomly assigned to one of the two familiarization conditions. Condition 1 consisted of sentences containing the pseudo-noun onche, and Condition 2 consisted of sentences containing the pseudo-noun èque (Table 1).

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Experiment 1a test trials: onche versus èque

Experiment 1b test trials: zonche versus zèque

The test phase for one group, Experiment 1a, presented isolated tokens of onche in one trial type and tokens of èque in another trial type. These two test trial types were presented alternatingly for a total of 10 trials (5 for each type). The presentation of the onche trial or the èque trial as the first test trial was counter-balanced across infants. One test trial was the familiarized target word for infants, and the other was the non-familiarized word. That is, if the infant heard the pseudo-noun onche in sentences during the familiarization phase, isolated onche would be the familiarized word and èque would be the non-familiarized word during the test phase. If the infant was familiarized with the pseudo-noun èque in sentences, onche would be the non-familiarized word and èque would be the familiarized word during the test phase. The test phase of the other group, Experiment 1b, included isolated tokens
of zonche in one trial type and zèque in another trial type. As in Experiment 1a, the two trial types were presented alternatingly (5 for each type), with the type of the first trial counterbalanced across infants. In Experiment 1b, one of the test word matched the surfaced form that an infant heard in the familiarization sentences (as in ces [z]onches or ces [z]èques). Thus, if the infant heard the pseudo-noun onche preceded by the liaison /z/ (i.e., ces [z]onches) during the familiarization phase, zonche was labeled as the familiarized form and èque as the non-familiarized form.

A total of 8 familiarization trials were presented to every infant. Each familiarization trial consisted of two different sentences and was 6.4 sec long. The sentences containing the target word were mixed among filler sentences in different trials. The average inter-sentence interval was 975 msec. Depending on the familiarization group, infants heard sentences containing one of the two pseudo-nouns (onche or èque). A total of 10 test trials were then presented, each 18.5 sec. The isolated tokens with a test trial had an average inter-stimulus interval of 1001 msec.

In the familiarization phase, both acoustic cues, if any exists, and liaison knowledge supported the correct vowel-initial interpretation for the target word. However, the surfaced form of the target was consonant-initial. We predicted that if infants use acoustic cues or if they have some liaison knowledge about the /z/, they should be able to discriminate between the familiarized word and the non-familiarized word in Experiment 1a test phase only. However, if 30-month-olds lack these abilities, they may attend to the surfaced forms of the targets and make a consonant-initial interpretation. In that case, only Experiment 1b should show discrimination.

Results

As it is commonly done in this procedure, the first two trials (one familiarized and one non-familiarized) were excluded from analyses due to their unstable nature. For the remaining eight trials, average looking times per trial to familiarized and to non-familiarized trials were calculated for each child. The looking times were analyzed in a paired t-test. As shown by the left two columns of Figure 1, infants in Experiment 1a showed a looking time difference while listening to the familiarized vowel-initial pseudo-noun (mean=9.70 s, SE=.59 s) versus to the non-familiarized vowel-initial pseudo-noun (mean=10.99 s, SE=.50 s), \( t(15)=-3.055, p=.008 \). Infants in Experiment 1b (the right two columns of Figure 1) showed no looking time difference while listening to the familiarized consonant-initial form (mean=9.99 s, SE=.46 s) versus to the non-familiarized consonant-initial form (mean=9.84 s, SE=.58 s), \( t(15)=.304, p=.765 \). All statistics were two-tailed. The results showed that infants successfully parsed the vowel-initial target, and that they did not have a consonant-initial misinterpretation. That is, infants can segment vowel-initial words in liaison cases, possibly using acoustic cues and/or liaison knowledge.

![Figure 1](image_url)

**FIGURE 1.** Infants’ mean looking (listening) times to the two types of test trials, familiarized versus non-familiarized. In the test phase of Experiment 1a, vowel-initial pseudo-nouns were presented, whereas consonant-initial pseudo-nouns were presented in Experiment 1b.
EXPERIMENT 2

Experiment 2 was designed to evaluate the relative weight of acoustic cues and grammatical knowledge related to the plural morpheme /z/ for word segmentation. This was done by familiarizing infants with a /z/-initial pseudo-noun in a non-liaison context. In this case, all acoustic properties should support consonant-initial segmentation. However, if infants represent /z/ as an independent plural morpheme without understanding its relation with the preceding word, this partial knowledge should lead to a vowel-initial bias for the following word. Experiment 2 thus examined which information, acoustic or independent /z/ morpheme, was more important for infants' word segmentation.

Methods

Participants and Stimuli

Another thirty-six monolingual Quebec-French-learning 30-month-olds were tested in this study. The target words in the familiarization sentences were consonant-initial non-words, zonche and zèque. They were each preceded by the French article un. The article un creates a /n/ liaison when preceding a vowel-initial word (e.g., un [n]ami ‘a friend’). However, its presence before the consonant-initial zonche and zèque do not trigger liaison. Thus, for mature speakers of French, the second word in un zonche and un zèque would be unambiguously consonant-initial. Four sentences were created, two containing the phrase un zonche, and two others containing un zèque. The phrases appeared in different sentential positions. Filler sentences similar to those of Experiment 1 were also used (Table 2).

Stimuli recording followed the same steps and used the same apparatus as in Experiment 1. Test stimuli were the same isolated words as in Experiment 1.

TABLE 2. Stimuli and design for the Experiment 2.

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Experiment 2a test trials:  
onche versus èque

Experiment 2b test trials:  
zonche versus zèque

Procedure, Design and Predictions

As for the procedure and design, only the familiarization phase differed from the one used in Experiment 1. In Experiment 2, the pseudo-nouns presented in the familiarization phase were truly consonant-initial. Thus, acoustic cues fully supported the correct consonant-initial word boundary. If acoustic cues guided infants’ interpretation, discrimination between the familiarized word and the non-familiarized word should be observed in Experiment 2b (zonche, zèque), but not in Experiment 2a (onche, èque). Moreover, if infants at this age have full knowledge about the liaison consonant /z/ including its relation to specific preceding words that can trigger it, they should notice that the determiner un has no relation with /z/, and they thus should show a consonant-initial interpretation (i.e., discrimination in Experiment 2b). However, if infants’ liaison knowledge is partial (i.e., understanding /z/ only as an independent plural morpheme without knowing its relation to the preceding word), they should have a vowel-initial interpretation. In this case, discrimination of test trials should only be observed in Experiment 2a.
Results

As in Experiment 1, the first two trials were excluded from analyses. For the remaining trials, average looking times for familiarized and non-familiarized test trials were calculated for each infant. Mean looking times for the two trial types were compared in paired t-tests. As shown by the left two columns of Figure 2, infants in Experiment 2a showed a looking time difference while listening to the familiarized vowel-initial form (mean=10.93 s, SE=.56 s) versus to the non-familiarized vowel-initial form (mean=10.13 s, SE=.57 s), \( t(19)=2.122, p=.047 \). Infants in Experiment 2b (the right two columns of Figure 2) showed no looking time difference while listening to the familiarized consonant-initial pseudo-noun (mean=9.97 s, SE=.55 s) versus to the non-familiarized consonant-initial pseudo-noun (mean=10.40 s, SE=.59 s), \( t(15)=-.898, p=.384 \). All statistics were two-tailed.

These results suggest that infants had a vowel-initial interpretation, but not a consonant-initial interpretation. Thus, infants seemed to be guided by their knowledge of the independent /z/ element rather than by acoustic cues.

**FIGURE 2.** Infants’ mean looking (listening) times to the two types of test trials, familiarized versus non-familiarized. In the test phase of Experiment 2a, vowel-initial pseudo-nouns were presented, whereas consonant-initial pseudo-nouns were presented in Experiment 2b.

**GENERAL DISCUSSION**

Our results show that at 30 months of age infants’ word segmentation is influenced by their grammatical knowledge. In Experiment 1, infants were able to parse vowel-initial pseudo-words from liaison environment despite misalignment due to resyllabification. Liaison knowledge and/or acoustic cues contributed to the successful segmentation. Experiment 2 further explored the role of acoustic cues and liaison knowledge in infants’ word segmentation. Results showed that infants were not guided by acoustic cues, since they failed to segment the consonant-initial pseudo-nouns in this experiment. Instead, infants misinterpreted the consonant-initial pseudo-nouns as vowel-initial. This pattern of response also suggests that 30-month-old do not yet have the full knowledge of liaison, since infants failed to perceive the lack of liaison relation between the determiner *un* and the following /z/. On the other hand, infants did demonstrate some knowledge of the liaison consonant. They appeared to understand /z/ alone as an independent element, and this knowledge was the dominant factor that influenced their segmentation. Our findings are consistent with those of Legendre et al. (2010), and we further showed that infants treat /z/ as a floating independent element, likely as a general plural marker. In particular, our stimuli separated full versus partial liaison knowledge, which offered an acquisition testing case of the two linguistic views concerning the /z/ liaison, suggesting that the view that treats /z/ as an independent plural morpheme is a more plausible linguistic account of liaison in the adult grammar. Infants’ vowel-initial misinterpretation of the /z/-initial pseudo-nouns showed that they were guided by their partial knowledge that /z/ was an independent unit. They did not seem to understand that the liaison /z/ is related to certain preceding words (such as *ces*, *les*, etc.) but not to other words such as *un*, which is related to the liaison consonant /n/. We suggest that the full knowledge of liaison involving the relation of the liaison consonant with the preceding word should be established shortly after the acquisition of the /z/
Furthermore, this knowledge may enable infants to acquire more sophisticated grammatical structures such as the number agreement in determiner-noun and subject-verb relations.

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REFERENCES