

## Development of Liaison Representation and its Top-Down Influence on Word Processing in Infants

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### ABSTRACT

We examined how toddlers process lexical ambiguity where different underlying forms are neutralized at the surface level. In a preferential-looking procedure, French-learning 30-month-olds were familiarized with either liaison-ambiguous phrases (i.e., sentences containing a determiner and a non-word, e.g., *ces /z/onches*, “these onches”, “these zonches”) (Experiment 1), or non-ambiguous (non-liaison) phrases (sentences containing *un zonche*, “a zonche”) (Experiment 2). Infants in both experiments showed a vowel-initial interpretation for the non-word, i.e., perceiving /z/ as an independent unit. In Experiment 3, 36-month-olds accepted both vowel- and consonant-initial forms (e.g., *zonche*, *onche*) after hearing the non-ambiguous cases (*un zonche*), suggesting an emerging but unstable understanding of the relationship between specific determiners and liaison consonants. Overall, infants represented the liaison consonant /z/ as an independent unit, consistent with the adult grammar. Furthermore, liaison knowledge biased infants’ interpretation of liaison-ambiguous cases (same as in adults) and even non-liaison cases.

### Introduction

During early acquisition infants face the task of extracting words from continuous speech. This task is non-trivial because boundaries between words are unclear and often ambiguous. This is especially the case for vowel-initial words. The final consonant of the preceding word is frequently resyllabified as the syllabic onset of the vowel-initial word. Resyllabification leads to surface forms in which the word and the syllabic edge are misaligned. For instance, *weird ice* and *weird dice* may be ambiguous, as they share a similar phonemic pattern. Fortunately, acoustic cues signalling which form is intended by the speaker can be present. Infants are sensitive to such cues. In Mattys and Jusczyk (2001), 8.5-month-old English-learning infants did not mis-segment *dice* from the resyllabified *weird ice*. However, it was not until the age of 16 months that they were able to extract vowel-initial forms (e.g., *ice*) from such resyllabification cases.

The case of French liaison is ideal for investigating surface form ambiguity. Liaison is a morpho-phonological process that yields complete resyllabification. An underlying floating consonant is triggered by certain preceding words (i.e., Word 1, e.g., determiners) to surface as the syllabic onset of the following vowel-initial word (i.e., Word 2). For example, the liaison consonant /n/ surfaces when a liaison-triggering Word 1 *un* [œ̃] is combined with *air* [ɛʁ] (“a melody”), i.e., [œ̃.nɛʁ], identical to the surface phonetic form of *un nerf* (“a nerve”), [œ̃.nɛʁ]. Subtle acoustic cues to such liaison vs. non-liaison phrases have been found in some studies (e.g., Gaskell, Spinelli, & Meunier, 2002; Spinelli, McQueen, & Cutler, 2003; Tremblay, 2011), but not in others (Nguyen, Wauquier-Gravelines, Lancia, & Tuller, 2007; Yersin-Besson & Grosjean, 1996). Although sensitivity to certain subtle acoustic cues has been found in online tasks (e.g., Spinelli et al., 2003; Tremblay & Spinelli, 2014a; 2014b), adults are

generally unable to recognize the intended Word 2 (e.g., *air* vs. *nerf*) upon hearing such ambiguous phrases in offline tasks (e.g., Shoemaker & Birdsong, 2008; Yersin-Besson & Grosjean, 1996).

Finding the correct word forms from liaison cases may thus be difficult. There is evidence that young children use a syllable alignment bias when interpreting word boundaries in liaison, as shown in their production errors. For instance, they mis-segment the vowel-initial word *ongle* as consonant-initial (*zongle*) (e.g., Chevrot, Chabanal, & Dugua, 2007; Chevrot, Dugua, & Fayol, 2009) from liaison cases such as *les ongles* “the nails” and *des ongles* “some nails”, in which the /z/ liaison consonant surfaces (i.e., *les /z/ongles*, *des /z/ongles*). Consonant-initial mis-segmentation has also been shown in perceptual studies with 20- and 24-month-old infants (Babineau & Shi, 2014). These findings are consistent with the onset bias in phonological theory (Kager, 1999), and with lexical access theories in psycholinguistics (Syllable Onset Segmentation Heuristic: Content, Dumay, & Frauenfelder, 2000; Possible Word Constraint: Norris, McQueen, Cutler, & Butterfield, 1997).

Young children’s consonant-initial bias also suggests that they have not acquired the rules of liaison in French, in particular, the underlying floating liaison consonants and their relation to particular preceding words (i.e., Word 1). For example, Word 1 such as the words *ces* [se] (“these/his/hers”) and *les* [le] (“the”) can trigger the surface realization of the /z/ liaison consonant as the syllabic onset of the following vowel-initial word (e.g., *ces amis* [se.zami], “these friends”). Adults have this knowledge about the underlying consonant of Word 1 (i.e., the liaison-triggering word), which influences their lexical processing of unambiguous Word 2 (i.e., the following word). In Spinelli, Cutler, and McQueen (2002), word recognition was impeded when a /t/ appeared as the onset of a vowel-initial word in *demi /t/agneau* (“half lamb”), but not when the consonant surfaced in *petit /t/agneau* (“little lamb”), showing that listeners perceived /t/ as a liaison consonant linked to the word *petit*, but as an intrusive illegal consonant unrelated to *demi*. Top-down effects of liaison knowledge (i.e., knowledge of the underlying coda consonant of Word 1) have also been shown with non-homophonous words that were ambiguous at their onset in an eye-tracking study (Tremblay & Spinelli, 2013). Adults heard phrases in which the first syllable of Word 2 was ambiguous, e.g., liaison (i.e., vowel-initial) *fameux /z/élus* vs. consonant-initial *fameux zélés*. Listeners were biased towards making the vowel-initial interpretation while hearing the first syllable of Word 2 regardless of the word being intended as vowel- or /z/-initial. The authors linked this vowel-initial bias to the high frequency of the /z/ liaison, and to the low frequency of /z/-initial words in French.

How do children come to understand the rules of liaison, given their limited lexicon and the surface ambiguity of words in liaison contexts? A recent study (Babineau & Shi, 2014) tested the hypothesis that infants may track distributional cues to correctly segment words in liaison phrases. In their experiments toddlers were presented with sentences containing a novel vowel-initial word preceded by different liaison consonants as the syllabic onset (e.g., *ces /z/onches*, *petit /t/onche*, *mon /n/onche*, *premier /r/onche*), providing distributional cues to vowel-initial word segmentation. They found that 20-month-olds were strongly influenced by the onset bias despite the disambiguating distributional cues, and interpreted Word 2 as consonant-initial rather than vowel-initial. The onset bias continued to have an effect at 24 months. However, 24-month-olds began to show the use of variable liaison distributional cues to interpret vowel-initial forms. Thus, the exposure to variable liaison contexts is a reliable way for infants to discover vowel-initial forms in liaison, but only by the age of 24 months.

It is interesting to note that in Babineau and Shi (2014) the 24-month-olds’ interpretation of /z/ liaison cases was fully ambiguous: infants accepted both vowel-initial and consonant-initial interpretations, showing no stronger bias for either. This was unlike adults, who only showed a liaison-driven vowel-initial bias when the pivotal consonant was /z/ (Tremblay & Spinelli, 2013). We suggest that with increasing experience, older infants can acquire the relationship between liaison consonants and Word 1, for example, *les* (“the”) triggering the /z/ liaison.

In Experiment 1, we tested 30-month-olds’ interpretation of /z/ liaison ambiguity. Given that /z/ is the most frequent liaison consonant (e.g., Côté, 2013; Durand & Lyche, 2008), it is likely to be understood first by toddlers. Furthermore, the presence of the liaison /z/ indicates a plural agreement context. In Legendre, Barrière, Goyet, and Nazzi (2010) French-learning 30-month-olds used pronoun liaisons to understand subject-verb plural agreement. Infants discriminated between the meanings of *ils /z/embrassent* (“they

kiss”) and *il* //embrasse (“he kisses”). In a follow-up study (Barrière, Goyet, Kresh, Nazzi & Legendre, 2011), 30-month-olds discriminated between sentences involving pseudo-verbs (i.e., *ils* /z/arrowvent vs. *il* //arrowve). These findings suggest that toddlers understand the plurality of /z/ and can generalize it to novel verbs. Most realized liaison comes from function word contexts, including Pronoun+Verb sequences (e.g., *ils* /z/aiment ‘they love’) at 35%, and Determiner+Noun sequence (e.g., *des* /z/amis ‘the friends’) at 26% of all liaison cases (Côté, 2013). However, it is unknown if toddlers have generalized the plural status of /z/ to noun contexts. Unlike the third person pronoun *ils* (“they”) and *il* (“he”), which share the same form in isolation (i.e., both [il]), determiners linked to plural (e.g., *ces* [se] “these”, *les* [le] “the”, *mes* [me] “my<sub>pl</sub>”) are phonologically different from determiners linked to singular (e.g., *ce* [cə] “this”, *le* [lə] “the”, *mon* [mɔ̃] “my<sub>sg</sub>”). Given that infants already segment and store frequent determiners (e.g., Hallé, Durand, & De Boysson-Bardies, 2008; Höhle & Weissenborn, 2003; Shi, Cutler, Werker, & Cruickshank, 2006; Shi & Lepage, 2008; Shi, Marquis, & Gauthier, 2006; Shi, Werker, & Cutler, 2006) and even inflectional suffixes (Marquis & Shi, 2012; Mintz, 2013) before one year of age, we may expect that by 30 months of age they can perceive the link between specific determiners (e.g., *ces*) and the /z/ liaison consonant, and that this knowledge may in turn bias their liaison interpretation, i.e., a vowel-initial bias, as shown in adults.

In Experiment 1a, the presence of a vowel-initial bias was tested with 30-month-olds. We used a preferential looking task that included a familiarization phase and a test phase. During the familiarization phase infants heard sentences containing a vowel-initial pseudo-word in liaison context; during the testing phase, infants heard the same vowel-initial pseudo-word vs. a new vowel-initial pseudo-word in isolation. If infants were successful in segmenting the familiarized vowel-initial target word from the liaison context, they should discriminate between the familiarized and new pseudo-words in isolation.

## Experiment 1A

### Method

#### Participants

Sixteen monolingual Quebec-French-learning infants aged 30 months completed this experiment (mean age = 943 days; range = 916–961 days; 7 girls). The data of another 12 infants were excluded from analyses because of parental interference (3), experimental error (1), and fussiness or failure to complete the study (8). Each child received a toy as a gift for participating in the experiment.

#### Stimuli

Two pseudo-nouns (*onche* and *èque*) were used in the experiment. Each of these targets was embedded in two sentences in which they were preceded by a frequent liaison-causing function word (i.e., *ces* [se] “these”, homophonous with *ses* “his, her”). The liaison consonant /z/ surfaced before the target pseudo-noun in the sentences (e.g., *ces* /z/onches). In addition to the four target sentences (i.e., two *onches* sentences and two *èques* sentences), 12 other filler sentences containing no liaison were created, yielding a total of 16 sentences. The non-target content words in the sentences were mostly infrequent.

Stimuli were recorded in an IAC acoustic chamber by a female native speaker of Quebec French (sample rate: 44.1 kHz; bit rate: 16 bit). Multiple tokens of the two pseudo-nouns in isolation and stimuli sentences were produced in an infant-directed speech style. The final stimuli set included two tokens for each of the 16 sentences, 12 isolated tokens of *onches*, and 12 isolated tokens of *èques*. The familiarization sentences might have contained subtle acoustic cues to the word boundary of the vowel-initial pseudo-nouns, since the pseudo-nouns were truly intended as vowel-initial. Nonetheless, the speaker produced the liaison consonant /z/ as the syllabic onset of the pseudo-noun.

An animation of a talking bird with its mouth synchronized with the auditory stimuli was created. During the pre-trial and the post-trial, the bird was still, accompanied by the sound of water bubbles. A video of a moving star together with the sound of a cricket served as the attention getter.

## Procedure

Each infant was tested individually in a sound-attenuated room in a visual preferential procedure. Auditory stimuli were presented through two loudspeakers on each side of a 42-in LG monitor, which presented the visual stimuli at the center. The infant sat on his or her parent's lap about 1.5 m in front of the monitor. The parent wore headphones playing masking music which prevented him/her from biasing the child.

In an adjacent room, a researcher blind to the audio-visual materials launched the experiment and observed the infants' eye movement through a closed-circuit TV. A program designed specifically for this procedure was used to run the experiment. Each trial was initiated by the infant. That is, when the infant looked toward the monitor, the researcher pressed down a computer key to start a trial. The length of the trials was fixed for both the Familiarization and the Test phase. The attention getter (i.e., the video of a moving star accompanied by cricket sound) appeared automatically between trials to attract the infant back to the screen. The pre-trial served to acquaint the child with the equipment. The post-trial marked the end of the experiment.

The experimental sessions were videotaped and offline-coded frame by frame (30 frames per second) by another researcher blind to the stimuli and naive to the purpose of the experiment.

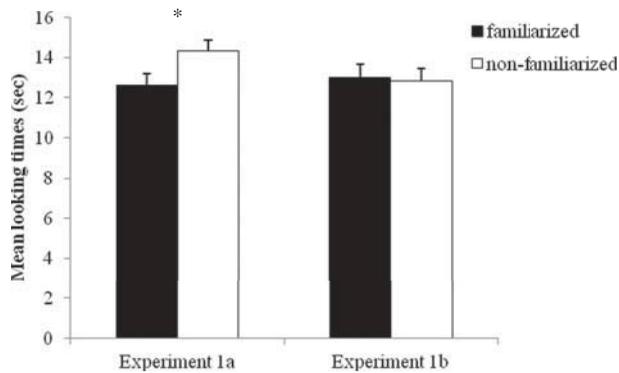
## Design

Each infant was first presented with a familiarisation phase, and then a test phase. The familiarization phase presented sentences containing the pseudo-noun *onche* for one group of infants, and sentences containing the pseudo-noun *èque* for the other group. Filler sentences were also presented. The test phase presented alternating trials of isolated tokens of *onche* and *èque* to both groups of infants. The stimuli are shown in Table 1. The first test trial was either the *onche* trial or the *èque* trial, counterbalanced across infants. Test trials were of two types: a new pseudo-noun (i.e., Non-familiarized), and a known pseudo-noun (i.e., Familiarized). Specifically, if an infant heard sentences containing the pseudo-noun *onche* during the familiarization phase, then the *onche* test trials were Familiarized, and the *èque* test trials were Non-familiarized. The reverse was the case for infants who were familiarized with *èque* sentences, with the *èque* test trials being Familiarized and *onche* test trials being Non-familiarized.

**Table 1.** Stimuli and design for Experiment 1a.

Familiarization	
Group 1	Group 2
<i>J'ai trouvé mon pagre sur le pavillon.</i> "I found my 'pagre' on the pavilion."	<i>Il y avait mon pagre sur l'étagère.</i> "There was my 'pagre' on the shelf."
<i>Il y avait couramment un pagre.</i> "There was commonly a 'pagre'."	<i>On ne réussit guère un pagre.</i> "We hardly accomplish a 'pagre'."
<i>C'était un petit lobe qui était ravi.</i> "It was a little lobe that was delighted."	<i>Voici un petit lobe que je trouve fou.</i> "Here is a little lobe that I consider crazy."
<i>Je suis camouflé au grand lobe.</i> "I am camouflaged at the tall lobe."	<i>Je t'ai fréquenté au grand lobe.</i> "I have frequented you at the tall lobe."
<i>Ça n'englobe pas ces onches.</i> "That does not include these 'onches'."	<i>J'avais déniché ces èques.</i> "I have unearthed these 'èques'."
<i>Ces onches sont de sales voyous.</i> "These 'onches' are dirty rascals."	<i>Ces èques le chagrinent beaucoup.</i> "These 'èques' sadden him greatly."
<i>Ce premier muge veut s'enfuir.</i> "This first 'muge' wants to run away."	<i>Le premier muge va rugir.</i> "The first 'muge' will roar."
<i>Il a discuté du dernier muge.</i> "He has discussed this last 'muge'."	<i>Voilà la plainte du dernier muge.</i> "Here comes the moan of the last 'muge'."
Test trial types	
<i>onche</i> (Familiarized) vs. <i>èque</i> (Non-familiarized)	<i>onche</i> (Non-familiarized) vs. <i>èque</i> (Familiarized)

Note. Isolated tokens of the two target words were presented in alternating test trials. Under each group the first test trial was either *onche* or *èque*, counterbalanced across infants.



**Figure 1.** 30-month-olds' mean looking times (and standard errors of the difference scores) to the Familiarized and the Non-familiarized test trials. Test words were vowel-initial in Experiment 1a and consonant-initial in Experiment 1b. Infants discriminated the test trials only in Experiment 1a.

Familiarization trials each lasted 6.4 s, and test trials each lasted 19.3 s. In each of the eight familiarization trials, two sentences lasting on average 2.49 s were presented with an average inter-sentence interval of 975 ms. There were five test trials for each word (five *onche* trials and five *èque* trials). Each trial presented the 12 isolated tokens of either *onche* or *èque*, with an average inter-stimulus interval of 1000 ms. The average duration of the pseudo-word tokens was 574 ms. There was a brief silence interval at the beginning and at the end of each familiarization/test trial.

If infants understood liaison and used this knowledge (i.e., that *ces* can trigger a /z/ liaison) to segment the vowel-initial pseudo-noun target from the familiarization sentences, they should discriminate between Familiarized and Non-familiarized test trials. However, if they perceived /z/ as the onset of Word 2, i.e., an onset bias, they should not show any discrimination of the test trials.

## Results

For each child, the total looking times for the Familiarized test trials and for the Non-familiarized test trials were compiled respectively. The first trial of each type was excluded from analysis, as it is usually unstable in this procedure (e.g., Cooper & Aslin, 1994). The average looking time per trial was then calculated for each trial type. All subsequent experiments followed this method of analysis. As shown in Figure 1, looking times to the Familiarized vowel-initial pseudo-noun ( $M = 12.63$  s;  $SE = 0.77$ ) and to the Non-familiarized vowel-initial pseudo-noun ( $M = 14.31$  s;  $SE = 0.65$ ) differed significantly (1.68 s;  $SEM = .55$ ),  $t(15) = -3.055$ ,  $p = .008$  (all t-tests reported in this article are two-tailed), 95% confidence interval (CI [-2.84, -.51]),  $d = -0.76$ , suggesting that 30-month-olds extracted the vowel-initial pseudo-noun.

To test if infants had a mixed interpretation (i.e., perceiving Word 2 also as consonant-initial), Experiment 1b used isolated consonant-initial pseudo-nouns (*zonche* and *zèque*) in the test phase after familiarizing infants with the same sentences of Experiment 1a.

## Experiment 1B

### Participants

A new group of 16 monolingual Quebec-French-learning infants aged 30 months participated in this experiment (mean age = 943 days; range = 923–959 days; 5 girls). An additional 9 children were tested, whose data were excluded from analyses because of parental interference (4) and fussiness (5).

**Table 2.** Stimuli and design for Experiment 1b.

Familiarization	
Group 1	Group 2
Same as the stimuli in Experiment 1a	Same as the stimuli in Experiment 1a
Test trial types	
<i>zonche</i> (Familiarized) vs. <i>zèque</i> (Non-familiarized)	<i>zonche</i> (Non-familiarized) vs. <i>zèque</i> (Familiarized)

*Note.* Isolated tokens of the two target words were presented in alternating test trials. Under each group the first test trial was either *zonche* or *zèque*, counterbalanced across infants.

## Stimuli

The stimuli for the familiarization phase were identical to those in Experiment 1. Two new pseudo-nouns were used for the test phase: *zonche* and *zèque*. The citation forms of the two pseudo-words were recorded by the same speaker as in Experiment 1a. The final test stimuli were 12 *zonche* tokens and 12 *zèque* tokens. The average inter-stimulus interval was 974 ms and the average duration of the pseudo-word tokens was 624 ms.

## Procedure and design

The only difference from Experiment 1a was the use of two consonant-initial pseudo-nouns (*zonche* and *zèque*) in the test trials (see Table 2). One type of test trials was Familiarized, and the other Non-familiarized. For infants familiarized with sentences containing *onches*, the Familiarized test stimuli matched the /z/ liaison surface form (e.g., *ces /z/onches*), although Word 2 was not intended as consonant-initial by the speaker. If infants were influenced by the onset bias and segmented Word 2 as /z/-initial, they should then discriminate the Familiarized and Non-familiarized test trials.

## Results

As in Experiment 1a, looking times to the Familiarized and the Non-familiarized test trials were calculated for each child, without the first trial of each type. As shown in Figure 1, 30-month-olds did not discriminate between Familiarized ( $M = 13.01$  s;  $SE = .60$ ) and Non-familiarized trials ( $M = 12.81$  sec;  $SE = .75$ ), since the difference (0.2 s;  $SEM = .64$ ) between the two types of trials was not statistically significant,  $t(15) = .304$ ,  $p = .765$ , 95% confidence interval (CI [-1.18, 1.57]),  $d = 0.08$ . This result shows that infants did not interpret Word 2 as consonant-initial.

We conducted a repeated-measure ANOVA, with Test Item (Familiarized vs. Non-familiarized) as the within-subject factor, and Interpretation (vowel-initial vs. consonant-initial, i.e., Experiment 1a vs. 1b) as the between-subject factor. The analysis revealed a significant interaction between Test Item and Interpretation ( $F(1,30) = 4.892$ ,  $p = .035$ ),  $\eta^2 = 0.13$ , indicating that infants in the two experiments responded differently. The ANOVA showed no significant main effect of Test Item ( $F(1,30) = 3.058$ ,  $p = .091$ ,  $\eta^2 = 0.08$ ), nor a main effect of Interpretation ( $F(1,30) = .399$ ,  $p = .532$ ,  $\eta^2 = 0.01$ ).

## Discussion

Results of Experiments 1a and 1b suggest that at 30 months of age infants were not guided by the onset bias. Rather, they parsed the vowel-initial word from a liaison context in which the consonant /z/ surfaced as its syllabic onset. This success in finding the word boundary, even though it was misaligned with the syllabic edge, was likely guided by their top-down knowledge about the /z/ liaison consonant as unrelated to Word 2. These results are striking in comparison with the responses of younger infants in Babineau and Shi (2014), in which 20-month-olds showed a strong consonant-initial interpretation and ignored the disambiguating contexts of variable liaisons that

supported the vowel-initial word boundary. Here the familiarization stimuli contained no such disambiguating cues, and 30-month-olds showed an adult-like vowel-initial bias.

The exact nature of the infants' knowledge is still unclear based on Experiment 1. Liaison knowledge is in fact complex. Specific liaison consonants are linked to a specific Word 1 (e.g., /z/ linked to *ces*), and the surface realization of the consonants as the syllabic onset of Word 2 is triggered by these specific words (e.g., *ces onches* → *ces /z/onches*). However, the consonants, which can be considered the underlying coda of Word 1, never surface as the coda of Word 1 in the language, including non-liaison cases (e.g., /z/ does not surface in *ces livres* [se.livʁ] “these books”). Thus, did our 30-month-olds understand the link of /z/ to *ces*? Or, did they represent /z/ as a separate unit totally independent from and unrelated to Word 1? Various accounts of liaison exist in linguistic theory (see Côté, 2011). Liaison consonants have traditionally been analyzed as the underlying coda of Word 1. Other linguists claim that the liaison consonant is an independent underlying element and is triggered to surface by Word 1 (e.g., Tranel, 1981). The recent results from Legendre and colleagues (Barrière et al., 2011; Legendre et al., 2010) on children's understanding of plurality in subject-verb agreement contexts (e.g., *ils /z/ embrassent* “they kiss”) do not tease apart the two linguistic views on the status of the /z/ liaison: Infants could have interpreted /z/ as a part of the pronoun *ils*, or simply understood /z/ as an independent element, possibly a plural morpheme.

To investigate the status of the liaison consonant /z/, a /z/-initial pseudo-noun (i.e., non-liaison) was used in Experiment 2. The /z/-initial pseudo-noun (i.e., *zonche* or *zèque*) was preceded by *un* “a” in the familiarization phase. Since the determiner *un* can only be linked with an underlying /n/ liaison consonant, the /z/ was non-ambiguously the onset of Word 2. After being familiarized to sentences containing a /z/-initial pseudo-word (e.g., *un zonche*), toddlers' interpretation of the word form was tested. The test phase was identical to Experiment 1. That is, two vowel-initial pseudo-nouns (*onche* and *èque*) were presented in Experiment 2a, and two consonant-initial pseudo-nouns (*zonche* and *zèque*) in Experiment 2b. One type of test trials was Familiarized, and the other Non-familiarized. If infants represent the /z/ as an independent element and unrelated to any specific Word 1, they should show a vowel-initial bias by discriminating between the test trials in Experiment 2a but not in Experiment 2b. However, if infants understand that /z/ is not triggered by *un*, a consonant-initial interpretation (*zonche*, *zèque*) should be obtained (i.e., discrimination in Experiment 2b only).

## Experiment 2A

### Participants

Sixteen monolingual Quebec-French-learning infants aged 30 months completed this experiment (mean age = 947 days; range = 932–962 days; 9 girls). The data of an additional 12 infants were excluded from analyses because of parental interference (2), ceiling looking (4), experimental error (1), and fussiness (5).

### Stimuli

The stimuli for the familiarization phase were similar to those in Experiment 1 (see Table 3). We created two new target sentences containing *un zonche*, and two other new sentences containing *un zèque*. In addition, four of the 12 filler sentences were newly created. These new sentences were recorded by the same speaker as in Experiment 1. Two tokens for each sentence were included in the final stimuli set. Test stimuli were those of Experiment 1a.

### Procedure and design

The familiarization phase presented sentences containing *un zonche* for one group of infants, and sentences containing *un zèque* for the other group, along with filler sentences. The test phase was the same as

**Table 3.** Stimuli and design for Experiments 2a & 3a.

Familiarization	
Group 1	Group 2
<i>J'ai trouvé un zonche sur le pavillon.</i> "I found a 'zonche' on the pavilion."	<i>Il y avait un zèque sur l'étagère.</i> "There was a 'zèque' on the shelf."
<i>Il y avait couramment un zonche.</i> "There was commonly a 'zonche'."	<i>On ne réussit guère un zèque.</i> "We hardly accomplish a 'zèque'."
<i>C'était un petit lobe qui était ravi.</i> "It was a little lobe that was delighted."	<i>Voici un petit lobe que je trouve fou.</i> "Here is a little lobe that I consider crazy."
<i>Je suis camouflé au grand lobe.</i> "I am camouflaged at the tall lobe."	<i>Je t'ai fréquenté au grand lobe.</i> "I have frequented you at the tall lobe."
<i>Ça n'englobe pas ces pagres.</i> "That does not include these 'pagres'."	<i>J'avais déniché ces pagres.</i> "I have unearthed these 'pagres'."
<i>Ces pagres sont de sales voyous.</i> "These 'pagres' are dirty rascal."	<i>Ces pagres le chagrinent beaucoup.</i> "These 'pagres' sadden him greatly."
<i>Ce premier muge veut s'enfuir.</i> "This first 'muge' wants to run away."	<i>Le premier muge va rugir.</i> "The first 'muge' will roar."
<i>Il a discuté du dernier muge.</i> "He has discussed this last 'muge'."	<i>Voilà la plainte du dernier muge.</i> "Here comes the moan of the last 'muge'."
Test trial types	
<i>onche</i> (Familiarized) vs. <i>èque</i> (Non-familiarized)	<i>onche</i> (Non-familiarized) vs. <i>èque</i> (Familiarized)

*Note.* Isolated tokens of the two target words were presented in alternating test trials. Under each group the first test trial was either *onche* or *èque*, counterbalanced across infants.

Experiment 1a. If a child heard sentences containing the pseudo-noun *zonche* during the familiarization phase, the *onche* test trials were labeled as Familiarized, and the *èque* test trials were Non-familiarized.

As in Experiment 1a and 1b, familiarization trials each lasted 6.4 s, and test trials each lasted 19.3 s. In each familiarization trial, two sentences lasting on average 2.53 s were presented with an average inter-sentence interval of 914 ms.

The target sentences containing the consonant-initial pseudo-noun *zonche* or *zèque* provided potentially useful acoustic cues (see Appendix) for consonant-initial parsing since they were truly intended to be consonant-initial. Moreover, if 30-month-olds had full knowledge about the liaison consonant /z/ including its relation to specific preceding words (Word 1, e.g., *ces*, *les*, etc.) that can trigger it, they should notice that the determiner *un* has no relation with /z/, and they should consequently show a consonant-initial interpretation and reject a vowel-initial interpretation. However, if infants' liaison knowledge was partial (i.e., understanding /z/ only as an independent unit without knowing its relation to Word 1), they should show a vowel-initial interpretation and discriminate between "Familiarized" and "Non-familiarized" test trials.

## Results

Infants discriminated the Familiarized vowel-initial pseudo-noun ( $M = 14.21$  s;  $SE = .70$ ) and the Non-familiarized vowel-initial pseudo-noun ( $M = 12.88$  s;  $SE = .71$ ), since the difference (1.34 sec.;  $SEM = .55$ ) between the two types of trials was statistically significant  $t(15) = 2.425$ ,  $p = .028$ , 95% confidence interval (CI [0.16, 2.51]),  $d = 0.61$  (see Figure 3). This result shows that the 30-month-old infants perceived /z/ as an independent element unrelated to the preceding word. Furthermore, this partial liaison knowledge, rather than any acoustical cues, biased infants to wrongly parse the vowel-initial form.

If the understanding of the link between specific Word 1 and specific liaison consonants (e.g., *un* with /n/, *ces* with /z/) is emerging, 30-month-olds may interpret both vowel-initial and consonant-initial forms as equally acceptable. The coexistence of two interpretations was found with 24-month-olds in Babineau and Shi (2014). Hence, in Experiment 2b we tested the possibility that 30-month-olds may segment a consonant-initial form (i.e., *zonche*, *zèque*) upon hearing the unambiguous phrases (*un zonche*, *un zèque*).

**Table 4.** Stimuli and design for Experiments 2b & 3b.

Familiarization	
Group 1	Group 2
Same as the stimuli in Experiment 2a	Same as the stimuli in Experiment 2a
Test trial types	
<i>zonche</i> (Familiarized) vs. <i>zèque</i> (Non-familiarized)	<i>zonche</i> (Non-familiarized) vs. <i>zèque</i> (Familiarized)

Note. Isolated tokens of the two target words were presented in alternating test trials. Under each group the first test trial was either *zonche* or *zèque*, counterbalanced across infants.

## Experiment 2B

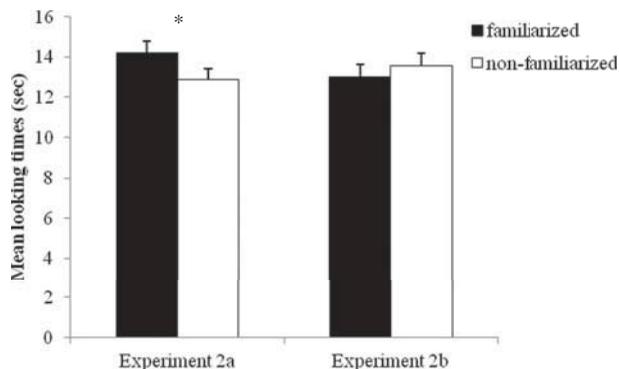
### Participants, stimuli, procedure, and design

A new group of 16 monolingual Quebec-French-learning infants aged 30 months participated in this experiment (mean age = 939 days; range = 922–958 days; 7 girls). An additional 9 children were tested, whose data were excluded from analyses because of parental interference (4) and fussiness (5).

The stimuli for the familiarization phase were identical to those in Experiment 2a, i.e., sentences containing *un zonche* or *un zèque* (see Table 4). The stimuli for the test phase were those of Experiment 1b, i.e., isolated *zonche* and *zèque*. One type of test trials was Familiarized, and the other Non-familiarized. For example, for infants familiarized with sentences containing *zonche*, the *zonche* test trials were the Familiarized type, and the *zèque* test trials the Non-familiarized type. The test word (e.g., *zonche*) matched the corresponding pseudo-noun in familiarization (e.g., *un zonche*), which was intended as consonant-initial by the speaker. The procedure and the design were the same as in the previous experiments.

## Results

As in Experiment 2a, looking times to the Familiarized and the Non-familiarized test trials were calculated for each child, without the first trial of each type. As shown in Figure 2, 30-month-olds did not show evidence for discrimination between Familiarized ( $M = 12.99$  s;  $SE = .71$ ) and Non-familiarized trials ( $M = 13.54$  s;  $SE = .77$ ), since the difference (0.56 s;  $SEM = .62$ ) between the two types of trials was not statistically significant,  $t(15) = -.898$ ,  $p = .384$ , 95% confidence interval (CI [-1.88, 0.76]),  $d = -0.22$ .



**Figure 2.** 30-month-olds' mean looking times (and standard errors of the difference scores) to the Familiarized and the Non-familiarized test trials. Test words were vowel-initial in Experiment 2a and consonant-initial in Experiment 2b. Infants discriminated the test trials only in Experiment 2a.

We conducted a repeated-measure ANOVA, with Test Item (Familiarized vs. Non-familiarized) as the within-subject factor, and Interpretation (vowel-initial vs. consonant-initial, i.e., Experiment 2a vs. 2b) as the between-subject factor. The analysis revealed a significant interaction between Test Item and Interpretation ( $F(1,30) = 5.210, p = .03, \eta^2 = 0.14$ ), indicating that infants in the two experiments responded differently. There was no significant main effect of Test Item ( $F(1,30) = .887, p = .354, \eta^2 = 0.02$ ), nor a main effect of Interpretation ( $F(1,30) = .09, p = .766, \eta^2 < 0.01$ ).

These results show that 30-month-olds interpreted the pseudo-nouns (i.e., Word 2) in *un zonche* and *un zèque* as being vowel-initial despite consonant-initial acoustic cues. Infants did not show the understanding that *un* as Word 1 can only trigger the underlying /n/ liaison consonant but not /z/. Rather, they were misled by their representation of /z/ as an independent unit.

## Discussion

The combined results of Experiments 1a, 1b, 2a, and 2b show that at 30 months infants perceive the liaison consonant /z/ as an independent unit and use this knowledge to bias their parsing. In Experiment 1, infants showed a vowel-initial interpretation for Word 2 upon hearing a liaison-ambiguous case (e.g., *ces /z/onches*). They showed the same vowel-initial bias in Experiment 2 upon hearing a non-ambiguous case (e.g., *un zonche*). They were not guided by acoustic cues, since they failed to parse the consonant-initial-intended pseudo-noun (e.g., *zonche*) in Experiment 2.

These results suggest that 30-month-olds have some knowledge about liaison, but their knowledge is not yet complete. They have not fully mastered the link between specific Word 1 and their triggering relation for particular liaison consonants. They failed to perceive the non-relatedness between the determiner *un* and the following /z/. In Experiment 3 we tested if the knowledge of liaison is fully developed at 36 months of age.

## Experiment 3A

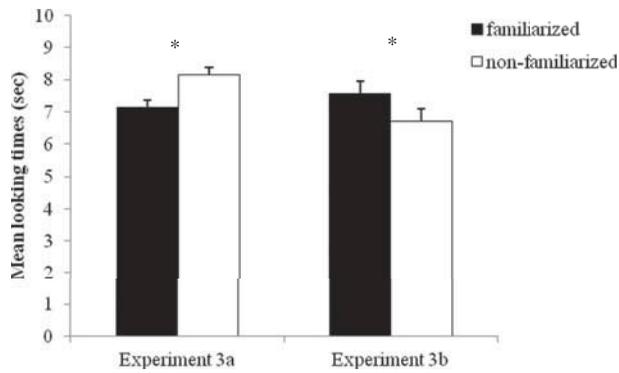
### *Participants, stimuli, procedure, and design*

A group of 16 monolingual Quebec-French-learning infants aged 36 months participated in this experiment (mean age = 1128 days; range = 1102–1149 days; 9 girls). An additional 6 children were tested, whose data were excluded from analyses because of technical problem (1), ceiling looking (1), and fussiness (4). The procedure and design were the same as those of Experiment 2a (see Table 3). The familiarization stimuli were also the same as Experiment 2a. The test stimuli were those of Experiment 1a. However, we shortened the test trials to a total length of 10.1 s in order to maintain older infants' attention throughout the experiment. The original trials contained 12 isolated tokens, but only the first 6 were used for Experiment 3. In Experiment 3a, there were five test trials for each type (five *onche* trials and five *èque* trials), each presenting the isolated tokens, with an average inter-stimulus interval of 1000 ms. The test words lasted on average 559 ms.

## Results

Infants discriminated the Familiarized trials ( $M = 7.13$  s;  $SE = .24$ ) and the Non-familiarized trials ( $M = 8.15$  s;  $SE = .27$ ), since the difference (1.01 s;  $SEM = .24$ ) between the two types of trials was statistically significant,  $t(15) = -4.21, p = .001$ , 95% confidence interval (CI [-1.53, -0.50]),  $d = -1.05$  (see Figure 3). This result shows that 36-month-olds perceived /z/ as an independent element unrelated to the preceding word, as did 30-month-olds. Furthermore, they mis-segmented the vowel-initial forms using this partial liaison knowledge.

In Experiment 3b the possibility of a co-existing consonant-initial interpretation from such a case was investigated.



**Figure 3.** 36-month-olds' mean looking times (and standard errors of the difference scores) to the Familiarized and the Non-familiarized test trials. Test words were vowel-initial in Experiment 3a and consonant-initial in Experiment 3b. Infants discriminated the test trials in both Experiments 3a and 3b.

## Experiment 3B

### Participants, stimuli, procedure, and design

A new group of 16 monolingual Quebec-French-learning toddlers aged 36 months participated in this experiment (mean age = 1128 days; range = 1106–1152 days; 4 girls). An additional 11 children were tested, whose data were excluded from analyses because of technical problems (2), ceiling looking (5) and fussiness (4).

The procedure and design were the same as those of Experiment 2b (see Table 4). The familiarization was the same as in Experiment 2a. The test stimuli were those of Experiment 1b. However, the test trials were shortened to a total length of 10.1 s, same as in the last experiment. There were five test trials for each type (five *zonche* trials and five *zèque* trials), each containing 6 isolated tokens of either *zonche* or *zèque*, with an average inter-stimulus interval of 985 ms. The words were on average 627 s.

## Results

As shown in Figure 3, 36-month-olds discriminated Familiarized ( $M = 7.55$  s;  $SE = .31$ ) and Non-familiarized trials ( $M = 6.70$  s;  $SE = .46$ ), since the difference (0.86 s;  $SEM = .40$ ) between the two types of trials was statistically significant,  $t(15) = 2.157$ ,  $p = .048$ , 95% confidence interval (CI [0.01, 1.70]),  $d = 0.54$ , suggesting that a consonant-initial interpretation co-existed with a vowel-initial interpretation for Word 2 of *un zonche/zèque* in 36-month-olds<sup>1</sup>.

We conducted a repeated-measure ANOVA, with Test Item (Familiarized vs. Non-familiarized) as the within-subject factor, and Interpretation (vowel-initial vs. consonant-initial, i.e., Experiment 3a vs. 3b) as the between-subject factor. The analysis revealed a significant interaction between Test Item and Interpretation ( $F(1,30) = 16.225$ ,  $p < .001$ ,  $\eta^2 = 0.35$ ), indicating that toddlers in the two experiments responded differently. There was no significant main effect of Test Item ( $F(1,30) = .116$ ,  $p = .736$ ,  $\eta^2 < .01$ ), nor Interpretation ( $F(1,30) = 1.585$ ,  $p = .218$ ,  $\eta^2 = 0.05$ ).

<sup>1</sup>The Test trials were not the same length in Experiment 3 as in Experiments 1 and 2. To examine if the same pattern of results would have been found in 30-month-olds had the trials lasted only 10.1 s, we analyzed the data focusing on the first 10.1 seconds of the trials. The results were similar to those obtained with 19.3 s of trial length. That is, there was a significant looking difference for Familiarized vs. Non-familiarized trials in Experiment 1a,  $t(15) = -2.741$ ,  $p = .01$ , but no difference in Experiment 1b,  $t(15) = 1.173$ ,  $p = .259$ . Similarly, no difference was found in Experiment 2b,  $t(15) = -.201$ ,  $p = .844$ . However, the looking difference between Familiarized and Non-familiarized trials in Experiment 2a was not found with shorter Test trials,  $t(15) = 1.402$ ,  $p = .181$ . This is because many infants looked throughout the whole 10.1 s part of the trial, suggesting that this initial shorter period was not sufficient for revealing younger infants' abilities.

## General discussion

In our study we used liaison-related cases to investigate infants' evolving biases in the processing of word forms. The experiments revealed several interesting findings. When hearing liaison ambiguous phrases containing a determiner and a non-word (Experiment 1, e.g., *ces /z/onches*, “these onches”), French-learning 30-month-olds were biased toward a vowel-initial interpretation for Word 2 (e.g., *onche*). This response contrasts with those of younger infants in previous work. Infants aged 20 months in Babineau and Shi (2014) showed a consonant-initial interpretation (e.g., *zonche*) driven by the onset bias, even though disambiguating distributional cues (i.e., variable liaisons) in the familiarization stimuli (e.g., *ces /z/onches*, *mon /n/onche*, *petit /t/onche*, *dernier /r/onche*) supported the vowel-initial interpretation. By 24 months of age the onset bias still persisted, while infants also began to use the distributional cues of variable liaisons to parse vowel-initial forms. Thus, they accepted multiple forms for Word 2 in perception, as children do in their early production (e.g., Chevrot et al., 2009). In the present study no context of variable liaisons was present, and the stimuli of Experiment 1 (e.g., *ces /z/onches*) were in principle ambiguous between vowel- and consonant-initial interpretations. Infants' vowel-initial bias thus suggests that by 30 months of age they have acquired some knowledge about liaison, and that they use this knowledge to process word forms in a top-down fashion. The results are consistent with the vowel-initial bias shown in adults' processing of /z/ liaison ambiguity (Tremblay & Spinelli, 2013).

Experiments 2 and 3 further examined the exact nature of infants' liaison knowledge. Specifically, we tested whether infants understood the link between specific Word 1 and the /z/ liaison consonant. Stimuli were unambiguous non-liaison phrases (e.g., *un zonche*, “a zonche”), in which /z/ was word-initial and had no relationship with the preceding determiner *un*. Infants, however, showed a vowel-initial bias, interpreting *onche* instead of *zonche*. They perceived /z/ as separate from Word 2 and did not know that *un* and /z/ have no liaison relationship. That is, they had no understanding about the link between Word 1 and liaison consonants (e.g., *ces* with /z/, *un* with /n/). By 36 months of age, infants perceived the unambiguous phrases (e.g., *un zonche*) as ambiguous, accepting both consonant- and vowel-initial forms (e.g., *zonche*, *onche*). This suggests that 36-month-olds began to pay attention to the relationship between Word 1 and liaison consonants, and made the correct interpretation sometimes, but the relationship was not yet fully acquired. Given the complexity of liaison knowledge, it is unsurprising that its acquisition may take a lengthy amount of time. Indeed, there is evidence that children at a later stage of learning eventually master liaison relations. For example, Dugua, Chevrot, and Fayol (2006) reported creative production errors such as *un nèbre* (for *un zèbre* “a zebra”) that peak around the age of 4–5 years. In this case, the word-onset consonant /z/ in *zèbre* was replaced by the liaison consonant /n/, which was linked to Word 1 (i.e., *un* triggering the surfacing of the underlying /n/ before a vowel-initial word). This was interesting because the form *nèbre* never occurs in the input; rather, *zèbre* should occur invariably in all contexts. The production error thus means that children understood the triggering relation between Word 1 and specific liaison consonants, and that they used this knowledge to guide their erroneous interpretation of *èbres* from *des zèbres*, yielding the erroneous production of *un nèbre*.

Our study revealed infants' developing morpho-phonological knowledge of liaison. In previous work (Babineau & Shi, 2014) 20-month-old infants showed no knowledge of liaison. The present experiments demonstrate that infants acquire partial liaison knowledge from 30 months of age. In particular, they represent the liaison consonant /z/ as an independent unit. This representation (i.e., the liaison consonant as being an independent unit) is in fact consistent with the adult grammar, as proposed in theoretical linguistics (e.g., Côté, 2005; 2008; Encrevé, 1988; Tranel, 1981; 1995; see also discussions in Côté, 2011). We note that linguists differ in their views on the exact detail of liaison representation in the adult grammar. Some interpret the liaison consonant as more closely linked to Word 1, whereas others view the liaison consonant as more closely linked to Word 2. For instance, those holding the classical view regard /z/ as the underlying coda of Word 1 (e.g., Schane, 1968), while others have argued that /z/ is a prefix of Word 2 (e.g., Morin & Kaye, 1982). There is evidence

for this latter view. In fact, the /z/ liaison consonant can be treated as independent in the adult grammar. For instance, it may surface in plural cases as the syllabic onset of any vowel-initial noun after any adjective (e.g., *petits /z/enfants*, [pəti. zɑ̃fɑ̃] “little children”), in which it is not clear whether the preceding word triggers it. Furthermore, for a specific vowel-initial Word 2, the /z/-surfaced onset may alternate with cases with other consonant-onsets, (e.g., *petits /z/enfants*, “little children”; *petit /t/enfant*, “little child”; *ils /z/arrivent*, “they arrive”; *il /l/arrive*, “he arrives”), suggesting also that /z/ may be independent. Adults also tend to produce liaison errors in contexts linked to plurality by incorrectly inserting a /z/ before the noun (e.g., incorrectly producing *vingt amis* as [vɛ̃zami] “twenty friends”; Côté, 2011). Likewise, the 30-month-olds in our study did not link the /z/ consonant to either Word 1 or Word 2, as they showed a vowel-initial bias when interpreting /z/ in both liaison forms (Experiment 1, e.g., *ces /z/onches*) and non-liaison consonant-initial forms (Experiments 2 and 3, e.g., *un zonche*). Our results suggest that infants’ representation of /z/ as an independent unit is continuously present in the grammar once it emerges.

Previous studies in the literature showed that word segmentation begins early in infancy, within the first year of life (e.g., Johnson & Jusczyk, 2001; Johnson & Tyler, 2010; Jusczyk & Aslin, 1995; Marquis & Shi, 2008; Mersad & Nazzi, 2012; Saffran, Aslin, & Newport, 1996; Shi et al., 2006). The stimuli in studies that demonstrated early segmentation typically involved the alignment of the syllable with the word edge, suggesting that the alignment may have played a facilitative role. Furthermore, some researchers view the syllable in French as a language-specific rhythmic unit driving infants’ initial word segmentation (e.g., Nazzi, Iakimova, Bertoni, Fredonnie, & Alcantara, 2006), a strategy that is cohesive with the idea of syllable alignment. Experimental research with adults has directly tested alignment, showing that syllable integrity is favored over sub-syllabic parsing in adults’ lexical processing (e.g., Syllable Onset Segmentation Heuristic: Content et al., 2000). Mis-alignment, however, does occur commonly in natural languages, as in resyllabification cases. How do children learn to perform sub-syllabic word segmentation in mis-alignment cases such as liaison? The present study and that of Babineau and Shi (2014) directly address the question of mis-alignment, and provide a clearer understanding of the developmental stages for the comprehension and processing of words in liaison contexts. At 20 months of age infants are still strongly guided by syllable alignment (i.e., the onset bias), thus mis-segment consonant-initial word forms from liaison cases. Despite this language-general preference for syllabic alignment, the high frequency of occurrences of liaison in French (i.e., once every 16 words in adult speech; Boë & Tubach, 1992) can enable infants to eventually parse the misalignment cases and learn the rules of specific liaison consonants (e.g., /z/, /n/, /t/). Indeed, infants around the age of 24 months overcome the onset bias and begin to correctly segment vowel-initial words in liaison cases using sub-syllabic distributional cues (i.e., variable liaison consonants). Our present study shows further that by 30 months of age, children have developed more in their understanding of liaison, showing a liaison (i.e., vowel-initial) bias in segmentation as adults do (e.g., Tremblay & Spinelli, 2013). They perceive the liaison consonant /z/ as an independent unit and can use this knowledge to interpret adjacent novel words in a top-down fashion, yielding mis-segmentation sometimes. Children’s responses throughout these ages were not influenced by any acoustic cues. Our study also demonstrates the emergence of advanced liaison knowledge (i.e., understanding of the relationship between Word 1 and the associated underlying liaison consonant) at 36 months of age. These results indicate that children progress from relying on a universal processing heuristic (i.e., the onset bias) to using a language-specific bias (i.e., a vowel-initial bias following /z/ liaison consonant) to entertaining both possibilities as they are figuring out the relationship between specific words for Word 1 and the associated liaison consonants. Further research can examine how children’s interpretation of liaison and non-liaison cases evolves in later development. It would be intriguing to investigate the acquisition of other liaison consonants (e.g., /n/, /t/, /r/), some of which differ from /z/ in distributional patterns. The study of liaison may offer particular insights on the general questions concerning language-universal vs. language-specific processing mechanisms in children.

It is interesting to note that French-learning infants initially mis-segment liaison cases as consonant-initial (e.g., segmenting *zonche* from *ces onches*), as shown by the 20-month-olds in Babineau and Shi (2014). In the present study much older children (30- and 36-month-olds) mis-segmented non-liaison cases as vowel-initial (e.g., segmenting *onche* from *un zonche*). However, these two types of mis-segmentation are driven by different factors, with the younger infants being guided by the onset bias and the older infants by upper-level knowledge of the /z/ unit. In neither scenario were acoustic cues used by infants. Resyllabification is phonetically more complete in liaison than in non-liaison cases in French, with disambiguating acoustic cues being weaker in the former than the latter cases (e.g., Yersin-Besson & Grosjean, 1996). Therefore, the 20-month-olds in Babineau and Shi (2014) mis-segmented vowel-initial words in liaison cases as being consonant-initial. On the other hand, English-learning infants in Mattys and Jusczyk (2001) did not mis-segment vowel-initial words (e.g., *ice*) in non-liaison resyllabification cases (e.g., *weird ice*) as being consonant-initial (e.g., *dice*), suggesting that the infants may have used the acoustic cues in such context. Thus, acoustic cues to liaison are less important than distributional cues for infants' segmentation of liaison cases. Children in the present study were much older than in the previous studies, but they were still not paying attention to the acoustic cues, likely because of the weaker cues in liaison. Our 30- and 36-month-olds instead used upper-level knowledge to guide their segmentation. These results are consistent with the idea of hierarchy of word segmentation cues proposed by Mattys and colleagues (e.g., Mattys & Melhorn, 2007; Mattys, Melhorn, & White, 2007; Mattys, White, & Melhorn, 2005; White, Melhorn, & Mattys, 2010). According to their view, segmentation cues have different weights for listeners, with lexical, syntactic, semantic, and contextual cues dominating lower-level cues such as phonotactic and acoustic cues.

In our study some experiments showed a novelty preference, and others a familiarity preference. In preferential looking procedures both novelty and familiarity preferences can be observed, and a group preference in either direction is evidence for successful segmentation. The direction of preference has been shown to be indicative of task difficulty and infants' abilities/knowledge (e.g., Cyr & Shi, 2013; Hunter & Ames, 1988; Seidl & Johnson, 2008; Thiessen & Saffran, 2003). A novelty preference is often interpreted as indicating a robust ability, whereas a familiarity preference may suggest that an ability is emerging. Our results are coherent with this idea. Given that children begin to segment vowel-initial words from variable liaison contexts at 24 months of age (Babineau & Shi, 2014), it is unsurprising that vowel-initial segmentation was easy for our 30-month-olds in liaison context, thus yielding a novelty preference (Experiment 1a). The familiarity preference in Experiment 2a suggests an emerging generalized knowledge of /z/ as an independent unit unrelated to either Word 1 or Word 2. This generalized knowledge becomes robust at 36 months of age, consistent with the novelty preference in Experiment 3a. In Experiment 3b 36-month-olds also showed the ability to pay attention to the triggering relation between Word 1 and the associated underlying liaison consonant, and this emerging ability yielded a familiarity preference.

In summary, our experiments demonstrate that 30- to 36-month-old infants use partial liaison knowledge to guide their interpretation of word forms, exhibiting adult-like top-down processing upon hearing liaison-ambiguous cases, i.e., a vowel-initial bias. Furthermore, we showed that although the full knowledge about liaison context is still impoverished at 30–36 months of age, infants already represent the liaison consonant /z/ as an independent unit, consistent with the adult grammar.

## Acknowledgment

We thank all the families who participated in the study.

## Funding

This research was supported by SSHRC, NSERC, and CFI grants to the second author.

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## Appendix

### Mean durations (in ms) and standard deviations of the consonant /z/ in the target phrases, as well as the intensity (in dB) of the consonant

	/z/ duration	/z/ intensity
Experiment 1 stimuli		
ces /z/onches	92.35 (10.1)	71.59 (1.87)
ces /z/èques	94.61 (16.69)	72.01 (1.81)
Experiments 2 and 3 stimuli		
un zonche	99.96 (8.28)	75.03 (1.43)
un zèque	119.34 (4.67)	73.58 (1.84)

Independent *t*-tests (liaison vs. non-liaison contexts): /z/ duration,  $t(14) = -2.6$ ,  $p = .021$ ; intensity:  $t(14) = -2.93$ ,  $p = .011$ .