

The Recognition of Verb Roots & Bound Morphemes when Vowel Alternations Are at Play

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Introduction

For language learners, establishing a vocabulary is complex because it involves learning several levels of representations, including the phonological forms, semantic information, syntactic information, morphological regularities, etc. Even for the early vocabulary items, these representations may take infants several years to be fully acquired. One of the basic problems for the young language learners is finding the forms in the continuous speech stream that correspond to linguistically relevant units such as words and morphemes. This is because most utterances found in parental speech to infants contain multiple words (e.g., Weijer, 1998), and unit boundaries are not marked by pauses in the speech signal (e.g., Cole & Jakimik, 1978). Recent studies show that infants begin to segment word-like forms from continuous speech at around six months of age, using cues such as transitional probabilities between syllables or phonemes, stress, syllabic boundaries, or phonotactic regularities (e.g., Curtin, Mintz, & Byrd, 2001; Jusczyk, Houston, & Newsome, 1999; Nazzi, Dilleys, Jusczyk, Shattuck-Hufnagel, & Jusczyk 2005; Saffran, Aslin, & Newport, 1996). Little is known about infants' processing of bound morphemes. Bound morphemes are of great linguistic importance since they happen to be either morphosyntactic feature markers or derivational affixes. However, these units only occur as part of a word and are often not syllabic (e.g., English *-s*). Moreover, the acoustic and phonological realizations of these grammatical morphemes are generally reduced (e.g., Shi, Morgan, & Allopenna, 1998), compromising the syllabic boundaries with the roots. In previous studies, infants aged between 16 and 19 months have been shown to be sensitive to grammatical relations of bound morphemes (e.g., English *-s*, *-ing*; German *-en*) with other linguistic elements (Soderstrom, White, Conwell, & Morgan, 2007; Santelmann & Jusczyk, 1998; Höhle, Schmitz, Santelmann, & Weissenborn, 2006), suggesting that they must have recognized the bound morphemes. And in a segmentation study, English-learning infants have demonstrated that they could segment the English morpheme *-ing* (Mintz, 2004). In that study, infants were familiarized with sentence passages comprising nonsense words ending with *-ing* or ending with a pseudo-morpheme *-dut*, and then tested with the words with the *-ing* and *-dut* removed. Results reveal that infants preferred listening to the nonsense words affixed with the morpheme *-ing* during familiarization. These results suggest that infants can recognize bound morphemes despite their reduced forms and weak boundaries. What is not yet known is whether infants can recognize roots and bound morphemes that are greatly altered by morphophonological processes.

Bare roots are commonly affixed with various inflectional morphemes marking features such as number, person, tense, or aspect. In certain languages, affixation may alter syllabic boundaries and sound forms roots and bound morphemes. French verb conjugation exhibits rich morphological variations like allophonic alternations and resyllabification. Tense and lax vowels are in complimentary distribution in Quebec French. No tense vowels appear in closed syllables (e.g., /di/ - /dIt/). Verb stems ending with a closed syllable containing tense vowels are subject to this alternation when conjugated with a vowel or vowel-initial suffix that reorganizes the root syllable structure. For instance, the stem [kUt] becomes [ku te] when affixed with the present infinitive and past participle /e/ morpheme. In this case, the syllabic boundary between the root and the suffix is altered by resyllabification process, which also leads to an allophonic alternation between [U] and [u]. A question that arises is whether infants are able to recognize verb stems despite such complex rule-governed alternations.

The awareness of suchlike alternation is part of the native language phonology. Evidence exists about infants becoming increasingly sensitive to the phonological patterns of their native language during the first year of life. Infants' perception begins to focus more on the native language phonemes (e.g., Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Werker & Tees, 1984), as they begin to show sensitivity to the distributional relations between different phonetic sounds such as phonotactic patterns (e.g., Jusczyk, Cutler, & Redanz, 1993; Jusczyk, Luce, & Charles-Luce, 1994; Mattys & Jusczyk, 2001). Infants can also use phonotactic patterns for successful word segmentation (e.g., Mattys & Jusczyk, 2001). The questions of whether and how infants may be processing phonological alternations have received little attention.

One study tested infants' learning of some phonological alternations (White, Peperkamp, Kirk, & Morgan, 2008). In this study, infants were familiarized with *na* or *rot* always followed by a stop or fricative initial disyllable (e.g., *na boli*, *rot boli*, *na zuma*, *rot suma*). Some conditions of familiarization were such that disyllables starting with

a voiced consonant occurred only after *na*, while those starting with a voiceless consonant occurred only after *rot*. Infants were tested on their learning of the alternations presented during familiarization, with novel disyllables that were preceded by *na* and *rot* (e.g., *na bazo*, *rot pazo*, *na zadu*, *rot sadu*). Results reveal that infants can learn such phonological alternations at 8.5 and 12.5 months of age. The White et al. (2008) study tested infants' ability to learn phonological alternations between different phonemes that occurred in complementary distribution. It is interesting to ask whether infants are also aware of allophonic alternations such as the [U]-[u] alternation found with French verbs. Peperkamp and colleagues (Peperkamp, Le Calvez, Nadal, & Dupoux, 2006) showed, using computational modeling, that statistical algorithms can learn some French allophonic rules like palatalization of /k/ and /g/ before front vowels and semivowels, and devoicing of nasal and liquid consonants before voiceless consonants.

In the present study we examine the issues of morphological segmentation and phonetic alternation conjointly. We test whether preverbal French-learning infants can parse bound morphemes and verb roots in cases where the suffixation also involves allophonic alternations. The type of alternations discussed above (e.g. [kUt]-[ku te]) is highly frequent in French verb morphological operations, surfacing between the present and other tenses. We asked whether infants could match a bare root verb with the affixed root, when the two occur with resyllabification and vowel alternation.

2. Experiment 1

Recently, it has been found that French-learning infants can segment bare verbs that did not go through conjugation as early as 11 months of age (Marquis & Shi, 2008). In this previous experiment, infants were familiarized with a bare verb presented in isolation and then tested with sentences containing the familiarized bare verb versus sentences containing another bare verb. Infants showed a preference for the sentences containing the familiarized bare verb, revealing that they indeed recognized the verb root. In the current experiment, we test 11-month-old infants to determine whether they can also segment verbs that are conjugated with a frequent bound morpheme.

2.1.1. Participants and Stimuli

Participants. Sixteen eleven-month-old infants completed the experiment. Infants were monolingual Quebec French learners. The infants had an average age of 345 days (range: 338 days to 355 days).

Stimuli. The auditory stimuli constructed for the familiarization phase of this experiment were CCVC nonce verb roots, [glYt] and [trId]. Because they do not exist in French, they should allow us to assess infants' ability to segment novel verbs. Two passages were also constructed. One passage contained [glyte] (i.e., [glYt] conjugated with the French morpheme /e/), and the other passage contained [tride] (i.e., [trId] conjugated with the French morpheme /e/). Note that both conjugated forms were subject to resyllabification as well as vowel allophonic tense-lax alternation. The conjugated forms appeared in various sentential positions (see Table 1).

A native Quebec French female speaker recorded the linguistic stimuli using an infant-directed register. Recordings took place in an IAC sound chamber, at 44.1 Khz sampling frequency using 16-bit samples. The final stimulus set consisted of seven versions for each passage and twenty-eight isolated tokens for each of the root words. Two visual files were also used, a picture of an abstract green leaf and an animation of a rotating spiral. The abstract picture was displayed during each trial accompanying the auditory stimuli. Between trials, the spiral animation was presented along with a cricket sound in order to attract infants' attention. Finally, water sounds were used as pre- and post-test auditory stimuli.

2.1.2. Design

In order to test infants' speech segmentation capacities, we used the two-phase (Familiarization & Test) design introduced by Jusczyk and Aslin (1995). Infants were randomly assigned to either [glYt] familiarization condition or [trId] familiarization condition. They were familiarized with multiple tokens of a target root produced in isolation. The Test phase began after infants reached the 23 s familiarization criterion. Infants heard both Test passages presented in alternation. The first test trial was either the passage containing the familiarized target or the one containing the non-familiarized root, counterbalanced between subjects. The inter-token interval during the Familiarization phase was 500 ms, and the inter-sentence interval during the Test phase was 250 ms. Maximal length was 8 s for each familiarization trial and 16 s for each passage trial.

Table 1. Experimental passages of Experiment 1.

[glyte] :	Maman a gluté le magot. (Mommy has glutted the pile.) Gluter les grappes est amusant. (To glut the grapes is amusing.) Il a gluté la parcelle. (He has glutted the parcel.) C'est le lot qu'on a gluté. (It's the lot that we've glutted.) Bébé va gluter les gondoles. (Baby will glut the gondolas.) Le songe j'ai gluté. (The dream I've glutted.) Glutez la coquille! (Glut the shell!)
[tride] :	Maman a tridé les poèmes. (Mommy has trided the poems.) Trider les verbes est amusant. (To trid the verbs is amusing.) Il a tridé la virgule. (He has trided the comma.) C'est le feu qu'on a tridé. (It's the fire that we've trided.) Bébé va trider le graphème. (Baby will trid the grapheme.) La phrase j'ai tridé. (The sentence I've trided.) Tridez le juron! (Trid the curseword!)

2.1.3. Procedure

The central fixation procedure was used. In a sound-attenuated chamber, infants sat on a caregiver's lap facing the display monitor and loudspeaker. The caregiver was listening to masking music through noise-cancellation headphones. Infants' visual responses to the display monitor were measured using the Habit software (Cohen, Atkinson, & Chaput, 2000). The researcher, blind to the stimuli, controlled the experiment from an adjacent room through a closed circuit monitor. A key was pressed down whenever the infant looked at the display monitor. Each trial was initiated by the infant's look to the monitor and continued until the infant stopped looking for at least 1 s or until the end of the trial. The Habit software recorded the number of looks to the display monitor and calculated the total looking time for each trial.

2.2. Results

Infants' total looking times to the test passages were calculated. Thirteen of the 16 infants had longer looking times for the passages containing the familiar root. Across all subjects, the mean looking times were 27.28 s ($SD = 9.81$ s) for the passages containing the familiarized root and 22.24 s ($SD = 8.27$ s) for the passages containing the non-familiarized root (see Fig. 1). A paired t -test revealed that this difference was significant ($t(15) = 3.113$, $p = .007$). Thus, 11-month-old French-learning infants appear to have recognized the familiarized roots when presented with passages containing the roots conjugated with the French morpheme /e/.

However, based on this single experiment, we cannot be certain that infants have actually encoded the /e/ morpheme. Infants could have mapped the familiarized root with its conjugated form based on the fact that some initial segments of the two forms overlap, without any regard to the presence of the morpheme.

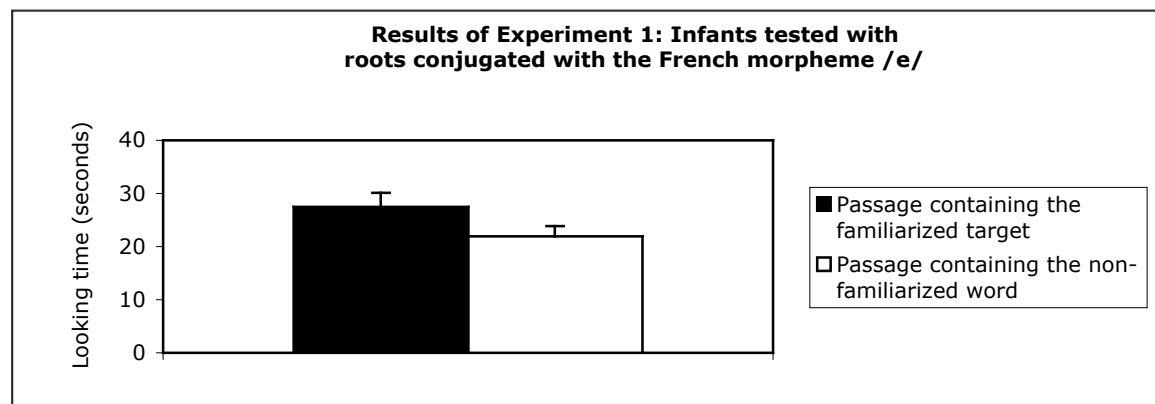


Fig.1. Results of Experiment 1

3. Experiment 2

Experiment 1 revealed that 11-month-old French-learning infants are capable of mapping conjugated verb forms to their roots. But these results could also be interpreted in terms of partial mapping, i.e., recognizing that the initial part of [glyte]-[glYt] overlap. Therefore, the results of Experiment 1 cannot definitively indicate whether infants have any knowledge of the French morpheme /e/. Experiment 2 was designed as a control study to further assess the question of morphological encoding. In this second experiment, infants were tested with passages containing the roots ending with a sound that is not used as a verb morpheme in French. We predict that if infants' success in the first experiment was a result of the French morpheme recognition, then infants in this second experiment should demonstrate no preference when the ending is not a morpheme.

3.1.1. Participants, Stimuli, Design, and Procedure

Participants. Sixteen eleven-month-old infants completed the experiment. Infants were monolingual Quebec French learners. The infants had an average age of 344 days (range: 338 days to 354 days). Two additional infants were tested but their data were excluded from the analyses due to excessive crying.

Stimuli. The auditory stimuli for the familiarization phase of this second experiment were the same CCVC nonce roots as those used in Experiment 1, [glYt] and [trId]. The test passages were nearly identical to the ones used in Experiment 1, except that the novel words were conjugated with a nonsense bound morpheme /u/ (see Table 2). The passages thus contained the non-suffixed disyllabic [glytu] or [tridu] occupying the verb positions. The same native female speaker who recorded the stimuli for the first experiment recorded the new test stimuli. The final stimulus set consisted of seven versions of each passage. The inter-stimulus interval was 250 ms for the sentences, resulting an average duration of 15.5 s for each passage.

The remaining stimuli were the same as in Experiment 1. The design and procedure were as those used in Experiment 1.

Table 2. Experimental passages of Experiment 2.

[glytu] :	*Maman a glutou le magot. (*Mommy has glutou the pile.) *Glutou les grappes est amusant. (*Glutou the grapes is amusing.) *Il a glutou la parcelle. (*He has glutou the parcel.) *C'est le lot qu'on a glutou. (*It's the lot that we've glutou.) *Bébé va glutou les gondoles. (*Baby will glutou the gondolas.) *Le songe j'ai glutou. (*The dream I've glutou.) *Glutou la coquille! (*Glutou the shell!)
[tridu] :	*Maman a tridou les poèmes. (*Mommy has tridou the poems.) *Tridou les verbes est amusant. (*Tridou the verbs is amusing.) *Il a tridou la virgule. (*He has tridou the comma.) *C'est le feu qu'on a tridou. (*It's the fire that we've tridou.) *Bébé va tridou le graphème. (*Baby will tridou the grapheme.) *La phrase j'ai tridou. (*The sentence I've tridou.) *Tridou le juron! (*Tridou the curseword!)

3.2. Results

As in the first experiment, infants' total looking times to the test passages were calculated. Six of the 16 infants preferred listening to the passages containing the familiarized root. Across all subjects, the mean looking times were 22.15 s ($SD = 10.63$ s) for the passages containing the familiarized root and 25.34 s ($SD = 14.23$ s) for the passages containing the non-familiarized root (see Fig. 2). A paired t -test revealed that, unlike Experiment 1, this difference was not significant ($t(15) = .945$, $p = .359$). These results demonstrate that infants did not listen longer to passages containing the non-suffixed disyllabic [glytu] or [tridu]. If infants were to be indifferent to word endings, a replication of the robust lexical preference obtained in Experiment 1 should have also been found in Experiment 2.

In order to confirm the contrast between Experiment 1 and Experiment 2, subjects' test scores were further

compared in a 2x2 mixed ANOVA with Passage Type (containing the familiarized target root vs. containing the non-familiarized root) as the within-subject factor and Morphological status (real morpheme vs. nonce morpheme) as the between-subject factor. This comparison yielded a significant interaction of Passage Type x Morphological status ($F(1,30) = 4.836, p = .036$), while no main effect of Passage Type was obtained. We take these results as evidence of infants' perception of the French morpheme /e/, since both experiments were identical except for the words occupying the verb positions within the Test passages. It is common in other studies to take significant interactions between experiments as evidence of infants' sensitivity to the distinction between almost identical words (e.g., Jusczyk & Aslin, 1995; Hallé & de Boysson-Bardies, 1996; Vihman, Nakai, DePaolis, & Hallé, 2004).

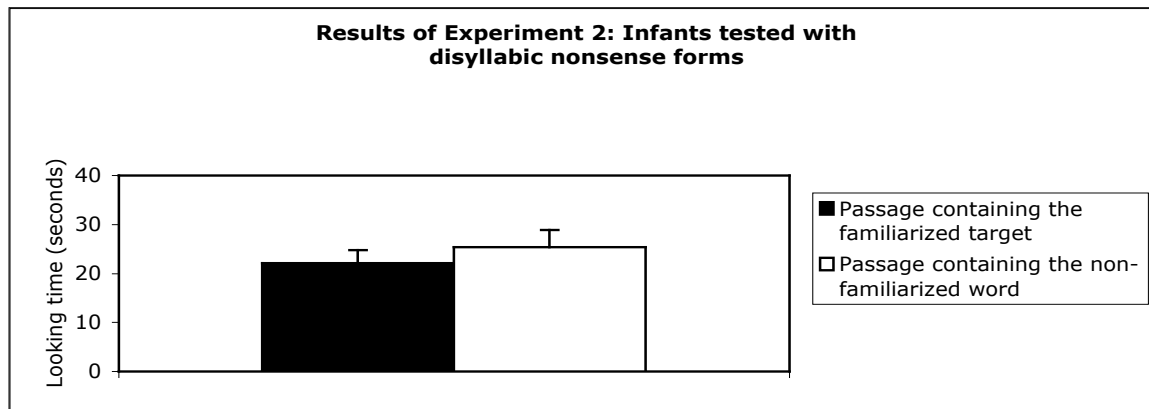


Fig.2. Results of Experiment 2

4. General Discussion

The present study reveals that 11-month-old infants can parse French bound morphemes from roots, suggesting that they are beginning to build basic knowledge about regular French verb morphology. Results confirm that the French suffix was important for root recognition in Experiment 1. Moreover, our study suggests that preverbal infants perceive allophonic alternations during morphological parsing. Sensitivity to such alternations is important since they occur commonly in French bound morphology. Children must learn to associate alternating allophones as the same phoneme because this knowledge is crucial for acquiring word meaning. Moreover, alternations do not exclusively surface with verbs in French, they also appear in morphological operations of other grammatical categories, for example, between certain masculine and feminine adjectives (e.g., allophonic alternation: *petit-petite*), or between some masculine and feminine nouns (e.g., phonemic alternation: *copain-copine*). Therefore, our results with verbs have broader significance for understanding infants' learning of phonological alternations related to French morphology in general.

The ability to parse verb roots and their suffixes is present at an age younger than shown in English-learning infants. As mentioned in the Introduction, Mintz (2004) showed that English-learning infants segmented verb roots and the English *-ing* morpheme by 15 months of age. One possible reason for this age difference may be that as a syllable-timed language, French has functional morphemes that are acoustically fuller than in English, thus perceptually more salient. Distributional properties may also account for the differences found between French- and English-learning infants. It has been suggested that quantitative differences among languages explain the varying status of phenomena specific to a language. Legate & Yang (2007) counted the frequency of appearance of tensed verb forms in child-directed English, Spanish, and French. They found quantitative differences between the three languages: English marks verb forms 54.4% of the time, Spanish 77.2% of the time, and French 69.9% of the time. This difference in overt morphology could explain why the French-learning infants in our study demonstrated morphological knowledge at 11 months of age, four months before the English-learning infants (Mintz, 2004). Moreover, /e/ is the most frequent verb morpheme in French. It applies to the most dominant verb group in French, the first group, which accounts for about 90% of all verbs (Bescherelle, 1980). It is therefore not surprising that infants can segment this morpheme at a very young age. In subsequent experiments, we plan to test infants' parsing of verb morphemes that occur less regularly in French. We expect that infants' ability to segment such forms should happen later than the one for the /e/ morpheme.

Frequency has been shown to play an important role especially for infants' word recognition (e.g., Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Höhle & Weissenborn, 2003; Shi, Cutler, Werker, & Cruickshank, 2006; Shi & Lepage, 2008; Shi, Marquis, & Gauthier, 2006; Shi, Werker, & Cutler, 2006). French-learning infants in our experiments were likely to have learned the vowel alternations from their previous exposure to their native language. The allophonic alternations that we presented here represent only one kind of phonological regularities that commonly exist in French. It has been previously demonstrated that infants are sensitive to the distribution of novel phonemic groupings (i.e., phonotactic patternings) in words even during a brief period of training (e.g., Chambers, Onishi, & Fisher, 2003). It is hence plausible that the frequent occurrence of such rule-governed allophonic alternations across affixed words is likely to drive infants' learning of the rule. In previous segmentation studies (e.g., Bortfeld, et al., 2005; Jusczyk & Aslin, 1995), when the target words were altered by one phoneme, infants treated the altered form as unrelated to the familiarization target. The present study differs from previous studies in that we used an allophonic change, which infants accepted as the same phoneme. Our results complement the abundant empirical evidence on infants' phonemic and phonotactic perception by showing their allophonic processing. Furthermore, we examined the question of allophonic alternations from the perspective of bound morpheme parsing. Our study thus contributes to the understanding of infants' phonological and morphological development.

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