

LENGTHENING AND PROSODY IN TUSCAN ITALIAN

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1. Introduction

Prosodic structure is frequently cued by changes in duration, including longer sounds in stressed syllables and lengthening at the edges of prosodic phrases. In several Italian dialects, these cross-linguistic tendencies interact with the lengthening phenomenon known as *Raddoppiamento fono-sintattico* (RF), which affects word-initial consonants under certain phonological and lexical conditions. This study focuses on those cases where RF lengthening is triggered by a preceding word-final stressed vowel. The examples in (1) illustrate the phenomenon.

- (1) città [s:]anta “holy city” *RF*
frutta [s]ekka “dried fruit” *no RF*

This type of Raddoppiamento is a productive process, as opposed to lexically-constrained types of RF, which have a limited set of lexical triggers and, thus, are not productive. This morpho-lexically restricted Raddoppiamento is discussed elsewhere in the literature (for example, recently in Absalom et al. 2002) and will not be further considered here. RF is not found in all Italian dialects. This process is not present in the varieties spoken in northern Italy. Traditionally, it is said to occur in the dialects spoken south of the imaginary line that goes from La Spezia to Rimini as well as in Sicily, Sardinia and Corsica (Absalom et al. 2002). However, even those dialects that supposedly present RF display much variation, making it hard to reach any generalizations about RF that would apply cross-dialectally (among others see Loporcaro 1997). For this reason, the present study focuses on Tuscan Italian and aims at analyzing RF as manifested in this dialect.

RF was first reported by the xvii century scholar, Claudio Tolomei (Fiorelli 1958) and has since then received much attention in the Italian dialectological and phonological literature. Traditionally, these studies were based on impressionistic data but recently, production and perception studies have been conducted in order to understand the phonetic underpinnings of the process and what factors, if any, condition its application. One of the main conclusions that stem from these instrumental studies is that RF is variable, i.e., far less categorical than previously thought. This finding raises the question of what conditions this variability, something that will be explored here. Furthermore, these studies have shown that the actual duration of the sounds involved in RF, i.e., the final stressed vowel and the lengthened consonant, is different and more gradient than traditionally considered, putting into

question theoretical explanations of RF. Let us review some of the literature that informs our study and helps to develop our hypotheses.

1.1. Previous theoretical and empirical studies on RF

Previous studies on RF can be divided into two groups: theoretical studies based on impressionistic data and instrumental studies based on acoustic data. The former group presents claims regarding the nature of RF that will be tested in this paper. The latter provides us with some of the phonetic details of the process, which will be further explored in the current study. For our purposes, first I discuss different phonological explanations present in the literature, together with empirical findings supporting or refuting those explanations, and then I focus on what has been said about the possible blockers or restrictions on RF, both from a theoretical and empirical perspective. I am ultimately interested in understanding what conditions the degree of lengthening and its possible blocking.

1.1.2. Phonological explanations

Different phonological explanations have been proposed to explain why RF takes place. Vogel (1978) presents RF as a resyllabification rule, by which the well-formedness conditions of Italian are met. Within the framework of autosegmental phonology, she proposes that the first consonant of word2 associates with the final stressed vowel of the preceding word in order to form a closed syllable. The consonant also remains as the onset of the initial syllable in word2, giving rise in this way to lengthening. In line with Vogel (1978), Chierchia (1982, 1986) explains RF as an effect of more general syllabification rules operative in the language. This view holds that there is no specific RF rule and that the lengthening results from the Italian syllabification requirements. Crucial to Chierchia's argument is the claim that words beginning with /s/ (e.g. *sporca* 'dirty') followed by a consonant do not undergo RF. McCrary (2004) presents acoustic data lending support to Chierchia's observation. McCrary shows that RF affects words that begin with a consonant followed by a vowel or a liquid but not words that begin with sequences of /s/ and a consonant.

Another phonological approach to RF claims that this lengthening process is a technique to avoid a stress clash, i.e., two adjacent stresses. Nespor and Vogel (1979) argue that RF obtains in order to separate two primary stresses. The problem with their proposal is that they assume that RF only occurs when word1 has final stress and word2 has initial stress, but subsequent work has shown that RF may occur when word2 has non-initial stress (Loporcaro 1997, Agostiniani 1992). Marotta (1986) takes a similar approach and argues that RF takes place to increase the distance between two primary stresses. More precisely, she predicts that the duration of the resulting lengthened consonant is inversely proportional to the size of the interstress interval. Payne (2005) does not find any support for Marotta's hypothesis since the lexical stress of the second word does not influence the duration of RF long consonants, more precisely, she does not find that lengthened consonant duration decreases as the interstress interval increases.

The most prevalent phonological approach to RF is the bimoraic analysis. According to this view, Italian has a bimoraic rule, by which stressed syllables have to be heavy, i.e., they must contain two moras. This bimoraic requirement is satisfied for word final stressed syllables by lengthening a following consonant. Crucially, these analyses rely on a ban on word-final long vowels to explain why bimoraicity is achieved by lengthening the consonant rather than the stressed final vowel (see among others Bullock 2000, 2001, Chierchia 1982, 1986, D'Imperio and Rosenthal 1999, Morén 1999, Repetti 1991, Wiltshire and Maranzana 1998). Absalom et al. (2002) argue that bimoraic analyses face several problems and present evidence against the bimoraic rule that comes from different phenomena in the language. Of importance here, Absalom et al. (2002) argue that a further problem for bimoraic analyses is that final stressed vowels do seem to be able to lengthen. Other studies have also focused on the ban on final long vowels and refuted it by analyzing acoustic data that show that such vowels can be long when compared with their unstressed counterparts (McCrary 2004).

It should be noted that the ban on final long vowels for Italian is common to all phonological analysis of RF (see also Borrelli 2000, Lepschy and Lepschy 1977). They all assume that final stressed vowels are short, and that long vowels are found only in stressed open non-final syllables. This restriction is not immediately obvious because it contradicts the phonetic tendency found cross-linguistically to lengthen stressed final vowels (Farnetani and Kori 1986). In order to understand the motivation behind such a claim, it might be relevant to consider some phonetic work on Italian vowel duration in different stressed positions within the word. For instance, D'Imperio and Rosenthal (1999) carry out an experiment to compare the differences in duration between stressed vowels depending on their position in the word, i.e., initial, medial or final. From their results, D'Imperio & Rosenthal conclude that final stressed vowels in open syllables are shorter than stressed vowels in open syllables in any other position. The authors argue that "a stressed vowel in a final open syllable does not lengthen" (1999: 2), based on the comparison between stressed vowels in different positions within the word. However, for cases of RF, we need to consider if the final stressed vowel does not lengthen with respect to its unstressed final counterpart. Consequently, it might be possible that the origin of the phonological ban on long stressed final vowels comes from a misinterpretation of the facts. In fact, Farnetani and Kori's (1986) experimental results show that there is a significant duration difference between stressed and unstressed vowels in all positions, although they do not consider cases of RF.

1.1.3. Restrictions on RF

As mentioned earlier, recent studies have instrumentally shown that RF is variable and less categorical than previously considered. In relation to this, some early work on RF focused on what restricts or blocks the application of the process. Initial claims argued that RF is prosodically and/or syntactically restricted, more precisely, that the process is subject to syntactic or phonological constraints. In fact, this differentiation has been the object of debate among scholars. Some regard the process as purely phonologically limited by prosodic constraints, while others have claimed that

syntactic structure plays a role as a constraint. Among the latter, work by Napoli & Nespor (1979) has been especially influential because they propose a condition called the Left Branch Condition that is operative not only in Italian but in other languages with external sandhi rules and left-branching structures.¹ They examine instances in which RF is blocked and conclude that the syntactic tree of the particular utterance is crucial in determining the application or non-application of the lengthening rule.

Among the studies dealing with the prosodic conditions on RF, Nespor and Vogel (1986) claim that the process is restricted to the phonological phrase. This claim is couched within their Prosodic Phonology theory according to which speech is structured into hierarchical prosodic constituents in a non-recursive way. The different constituents of the prosodic hierarchy are the application domains of certain phonological rules. Thus, in the case of RF, its application domain would be the phonological phrase. Later work by the same authors argues that in fact, RF is not limited to the phonological phrase but rather to the phonological utterance (Vogel 1997) based on data from Agostiniani (1992), who cites cases where RF applies across intonational phrase boundaries. Other studies have also noted that RF can apply across intonational boundaries (Absalom 1995, Roca 1994).

The presence of a pause between word1 and word2 has been reported to block RF (Absalom et al. 2002, Agostiniani 1992, Canepari 1991, Loporcaro 1997, Stevens et al. 2002). Stevens and Hajek (2006) argue that pauses, together with pitch breaks, vowel lengthening and glottal stop insertion, signal the presence of a phonetic phrase boundary and act as blockers of RF, which is restricted by this type of boundary. The authors perform an auditory analysis of contexts where RF could potentially apply (i.e., contexts where there is a word that ends with a stressed vowel followed by a consonant-initial word) and identified those cases where one of these blockers occurred. They found that pauses occurred more frequently than any of the other three blockers. They do not report any measurements of the word initial consonant in order to assess whether RF takes place or not. Rather, since they do not expect to find any cases where RF applies in the presence of a blocker, they argue that “the length or duration of word-initial consonants is irrelevant because [RF] can only apply where no break is perceived between word1 and word 2”. However, this claim is based on their expectations and not on an analysis of their data.

Long vowels have also been reported as blockers of RF. Absalom et al. (2002) say that final vowel lengthening is possible and that when it occurs, it has the potential to prevent RF from taking place. The explanation for this is that vowel lengthening indicates the presence of a pause or a prosodic boundary and thus, this type of lengthening is associated with a lack of RF (Loporcaro 1997, D’Imperio & Gili Fivela 2003). Note that this claim does not necessarily apply to lengthened vowels that may occur as the result of stress rather than as the result of the presence of a prosodic boundary, i.e., there is an interaction between long vowels and prosodic structure in terms of blocking RF. Finally, RF is also reportedly blocked by the insertion of different glottal phenomena (Absalom, Stevens and Hajek 2002, Stevens &

¹ See Napoli and Nespor (1979, section 8) for details about other languages that seem to have phonological processes conditioned by this Left Branching Condition.

Hajek 2006). Stevens & Hajek (2005) analyze these glottal phenomena and conclude that they are better described as pre-aspiration of the lengthened voiceless stop. Stevens & Hajek found that this pre-aspiration occurs for consonants lengthened by RF and also for word-medial geminate consonants. Based on their acoustic results, the authors argue that pre-aspiration is used to enhance the length of the voiceless consonant.

1.2. Goals of the study

The current study explores the role of different factors in blocking RF, in order to better understand the nature of this lengthening process and its acoustic characteristics in relation to the duration of the segments involved. More precisely, I analyze the role of prosodic structure and the quality of the segments involved in favoring or disfavoring the occurrence of RF. In terms of prosodic structure, the presence of an intonational boundary does not reportedly block RF. However, recent studies on the effect of prosodic boundaries have shown that these are elastic phenomena and that the effects are gradient rather than categorical (Byrd & Saltzman 1998, 2003, Byrd 2006). Extending these results, we would expect that the presence of an intonational phrase boundary would have some gradient effect on RF, i.e., such a boundary might not categorically block RF but it might attenuate the lengthening. Note that there is no instrumental data showing what exactly happens with intonational phrase boundaries. Similarly, I explore the role of pauses on RF and their potentially gradient effects on the lengthening process: I test whether pauses actually block RF or just decrease the extent of the lengthening.

In terms of the role of the segments involved, I include an environment that is usually not discussed in the RF literature, namely contexts in which the initial segment of word2 is a vowel. All analyses and explanations of this lengthening process have focused on the cases where a sequence of a vowel and a consonant is found. But, in order to have a comprehensive characterization and understanding of RF, we need to know what actually happens when the second segment is a vowel. The prediction is that an initial vowel is not lengthened, based on impressionistic descriptions of the process. Here, I present acoustic data to prove this observation. Relatedly, the present study analyzes the duration of final stressed vowels in order to corroborate recent claims that these vowels do in fact lengthen, despite the traditional ban on final stressed long vowels adopted by bimoraic approaches to RF.

With these goals in mind, I elaborate the hypotheses in (2) related to the presence and degree of lengthening of the segments involved in the process, i.e., the last segment of word1 and the first segment of word2, with respect to several variables, namely stress, boundary and identity of the segments under study. The first two hypotheses (i, ii) test the traditional environment for Raddoppiamento, i.e., the environment where word2 begins with a consonant, in relation to the presence or absence of an intonational phrase boundary. The next two hypotheses (iii, iv) test the occurrence of RF in a new environment that has not been analyzed before, namely, when word2 begins with a vowel. The boundary effect is also considered for this context. The last hypothesis (v) tests the lengthening of final stressed vowels in RF contexts. Thus, the current experiment is designed to obtain from native Italian speakers

acoustic data containing the relevant environments under controlled conditions. The results will confirm or refute the influence of the factors mentioned above in the duration of the segments and the interaction between some of them, such as stress and boundary. Section 2 describes the experimental methodology developed to test the five hypotheses. Section 3 reports the results regarding the duration of the different segments involved and the influence of the different factors. Section 4 offers some discussion of these results and relates them to previous findings. Section 5 concludes with the implications of the findings and venues for future research.

- (2) Hypotheses:
- i. Initial consonant in word2 lengthens after a stressed vowel.
 - ii. Initial consonant in word2 lengthens after an intonational phrase boundary but to a lesser extent.
 - iii. Initial vowel in word2 does not lengthen after a final stressed vowel.
 - iv. Initial vowel in word2 does not lengthen after boundary due a final stressed vowel
 - v. Final vowel is word1 lengthens when stressed relative to its unstressed counterpart.

2. Experimental Methodology

2.1. Stimuli

In order to test the three factors mentioned above, each stimulus contains a particular environment according to stress, phrasal boundary and the quality of the segments involved. Let us discuss each of these factors in turn. The first word in the sequence word1 word2 is variably stressed in the last syllable, i.e., it contains either final or non-final stress. Since lengthening is conditioned by the position of the stress within the first word and not within the second word, the latter word is invariably stressed in the first syllable. Consequently, we have pairs of sentences like those in (3) and (4), where the environment is exactly the same except for the stress in word1. Although the target segments appeared italicized in the following examples, the speakers did not see them in italics. Notice also that all the phrases were formed by a noun and an adjective, where word1 was always a noun and word2 an adjective. This prevents any difference depending on semantics or syntax.

- (3) La nostra è una *facoltà* *ibrida*. “Ours is a hybrid faculty”
 (4) È una *pianta* *ibrida*. “It’s a hybrid plant”

In order to test the boundary effect, the target words, i.e., word1 and word2, were placed within the same phrase or separated by an intonational phrase boundary, so that both words belong to different phrases. Consequently, sentences such as (5) and (6) were included, where the only difference is whether the relevant environment is phrase internal (5) or at the phrase juncture (6).

- (5) Roma è una *città* *santa*. “Rome is a saint city”
 (6) Se conosci la *città*, *santa* non è. “If you know the city, it’s not holy”

Since the lengthening process is triggered by a stressed word final vowel, word1 always ended in a vowel, either /i/ or /a/. On the other hand, the second word could begin with a consonant (/s/²) or with a vowel (/i/ or /a/). This presents a widening of the contexts considered by previous work that only took into account the effect on an initial consonant. Examples (7) and (8) illustrate two sentences that differ only in the quality of the first segment in word2. Table I summarizes the structure of the stimuli according to the three factors tested for, i.e., location of stress within word1, the presence or absence of an intonational phrase boundary between word1 and word2 and the quality of the segments involved, and it includes the target words. The sixteen complete sentences included in the experiment can be found in the Appendix 1.

- (7) Fu un giovedì *acido*. “It was a harsh Thursday”
 (8) Fu un giovedì *sobrio*. “It was a sober Thursday”

Table I

Summary of stimuli according to stress, phrase boundary and segment quality
 (# indicates a word boundary; ## indicates an intonational phrase boundary)

	Final stress in word1		Non-final stress in word1	
	V1 V2	V1 C	V1 V2	V1 C
Phrase internally	facoltá # ibrida giovedì # acido	cittá # santa giovedì # sobrio	pianta # ibrida studenti # abili	frutta # secca studenti # sobri
Phrase juncture	facoltá ## ibrida giovedì ## acido	cittá ## santa giovedì ## sobrio	pianta ## ibrida studenti ## abili	frutta ## secca studenti ## sobri

2.2. Participants and data collection

Acoustic data from four native speakers of Italian was collected. All of them came from the same geographical area in Italy, namely Tuscany. They were all young college-educated adults. Three of the speakers were from Florence and one from Pisa. Special attention was paid to the origin of speakers, since dialectal differences with respect to the phenomenon of RF have been reported (Borrelli 2000, Loporcaro 1997 and references in section 1).

The sixteen sentences containing the different environments were divided in two blocks according to the presence or absence of an intonational phrase boundary between word1 and word2 and arranged so that the two blocks alternate. Each of these blocks (eight sentences) was pseudorandomized for each speaker avoiding the subse-

² /s/ was chosen as the relevant consonant rather than a stop in order to avoid spirantization, i.e., the Gorgia Toscana, which targets voiced and voiceless stops in intervocalic position in Tuscan Italian (Marotta 2001, Soriano 2001 and Villafañá Dalcher 2006). Furthermore, stops have been reported to show glottal phenomena in their production in RF environments (Stevens & Hajek 2005). These effects were minimized by using a target word-initial /s/.

quent occurrence of the same environment and rerandomized for each repetition. A total of ten repetitions for each environment were produced by each speaker. A Marantz PMD 201 portable cassette recorder and a Sennheiser e845 microphone were used for the recordings. Subjects were given written instructions in Italian. They were asked to read the sentences in an informal style, as if they were talking to a friend.

2.3 Data analysis

The data was digitized at a 22,000 Hz sampling rate using the Macquiere program of data analysis. The same program was employed to obtain the synchronized waveforms and spectrograms used to measure the duration of the relevant segments, i.e., the vowel and consonant duration in the VC sequences, and the two vowels in the VV sequences.

In the sequences formed by a vowel and a fricative consonant (VC), the vowel was measured from the beginning of the first glottal pulse, right after the opening of

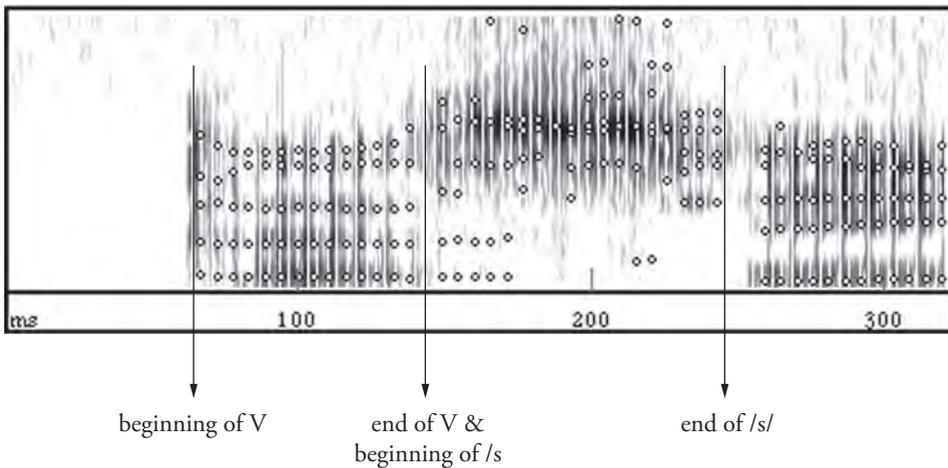


Fig. 1

Spectrogram for a V/s/ sequence

the closure for the preceding stop, to the last vocal pulse corresponding to the vowel as identified in the acoustic representations. The fricative consonant /s/ was measured in the spectrogram from the beginning of the period of frication with high energy above the vowel formant range to the end of this period. Figure 1 illustrates the measurements for a VC sequence.

In the VV sequences formed by two vowels, the first vowel was measured following the same criteria as for the vowel in a VC sequence, i.e., from the beginning of the first glottal pulse to the end of the last pulse. The second vowel was measured in the same manner. It should be noted that this system was useful only in those cases where there was a pause between both vowels. Figure 2 illustrates an instance of a /i a/ sequence with the presence of a period of silence, i.e. no voicing, between the two vowels.

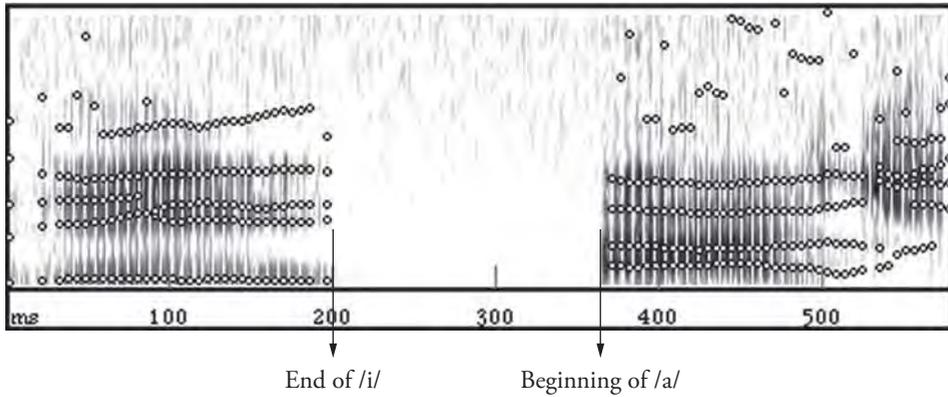


Fig. 2

Spectrogram for the sequence /i a/ with silence inbetween the two vowels

In the instances where no pause was present, different criteria had to be used to define the end of the first vowel and the beginning of the second. For this purpose, both the waveform and spectrogram for the relevant sequences were taken into account. Diagnostic for the end of one vowel and the beginning of the following was a change in the waveform shape corresponding to the transition from one vowel to the next, more precisely a change from low to high amplitude for /a i/ sequences or from high to low amplitude for /i a/ sequences. Synchronously, in the spectrogram the relevant diagnostic was the amount of change in the F1 formant transition. LPC formant tracking of the sequence allowed us to establish the end of the first vowel to be where the biggest fall, for /i a/, or rise, for /a i/, in the value of F1 took place. That same point was considered the beginning of the second vowel. In the rare cases where the waveform shape change and the F1 drop/fall did not coincide, the spectrogram diagnostic was used. The spectrograms in figures 3 and 4 illustrate how the measurement of these sequences was carried out.

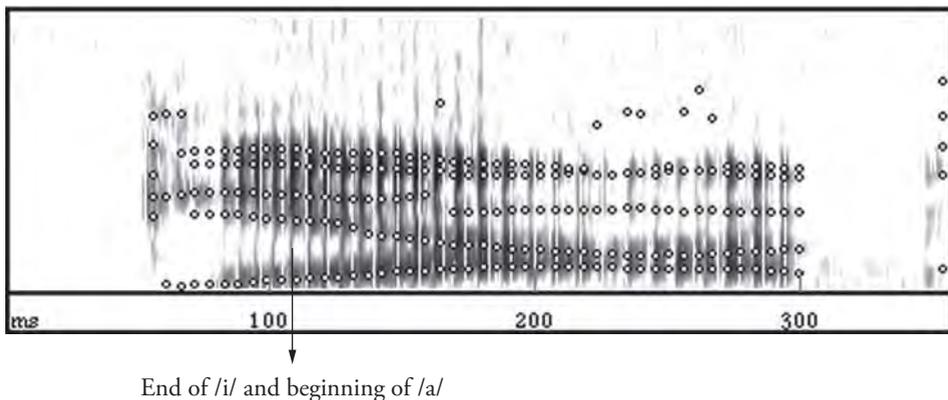


Fig. 3

Spectrogram for the sequence /i a/ without an intervening pause

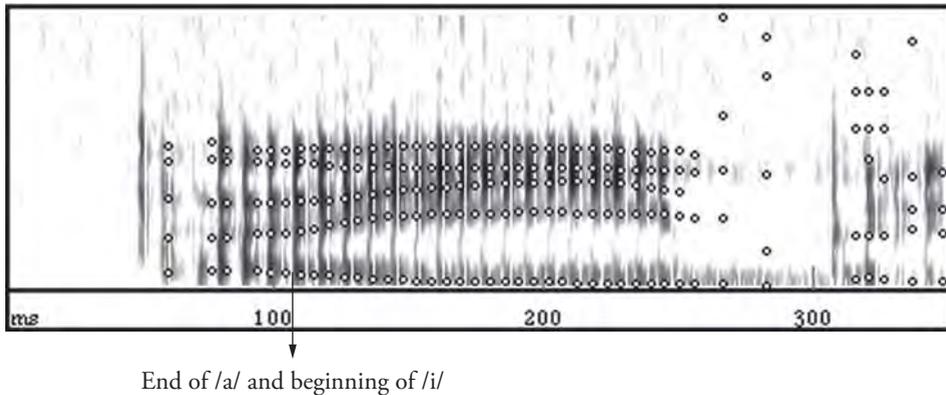


Fig. 4

Spectrogram for the sequence /a i/ without an intervening pause

In order to evaluate whether the hypothesized factors, i.e., stress, boundary, and segment identity (/a/, /i/, /s/), have an effect on the duration of a segment, three-factor full interaction ANOVAs were carried out for the duration of the three relevant segments (V_{w1} , C_{w2} , V_{w2}) for each subject. Further, it is necessary to test the difference between the initial consonant duration after a stressed vowel and a boundary vs. after an unstressed vowel and a boundary to determine whether RF lengthening occurs or fails to occur after a phrasal boundary. For this purpose, we carried out a planned means comparison test.

3. Results

The results are organized according to the segments whose duration is considered, i.e., initial consonant in word2 (section 3.1), initial vowel in word2 (section 3.2) and final vowel in word1 (section 3.3). Section 3.4 reports the results with respect to the presence of a pause, followed by a summary of the main results.

3.1. Duration of initial consonant in word2

The results of the ANOVA for speaker A indicate that stress has a statistically significant effect on the duration of the consonant ($F(1, 72) = 47.89$, $p < .0001$). The initial consonant is longer when it is preceded by a stressed vowel (142 ms) than when this vowel is unstressed (128 ms). The presence or absence of a boundary is also a significant factor for consonant duration ($F(1, 72) = 72.6$, $p < .0001$). The consonant is longer after a boundary (143 ms) than when there is no boundary (126 ms). The statistical results show that there is no significant effect of the preceding vowel identity on fricative consonant duration. Finally, there is a significant interaction between boundary and stress ($F(1, 72) = 37.81$, $p < .0001$) such that the stress effect is greater when no boundary is present. Figure 5 illustrates this point. The results of the planned means comparison indicate that there is no significant

difference in the postboundary consonant duration after a stressed or an unstressed vowel, i.e., there is not difference between the two leftmost bars in Figure 5.

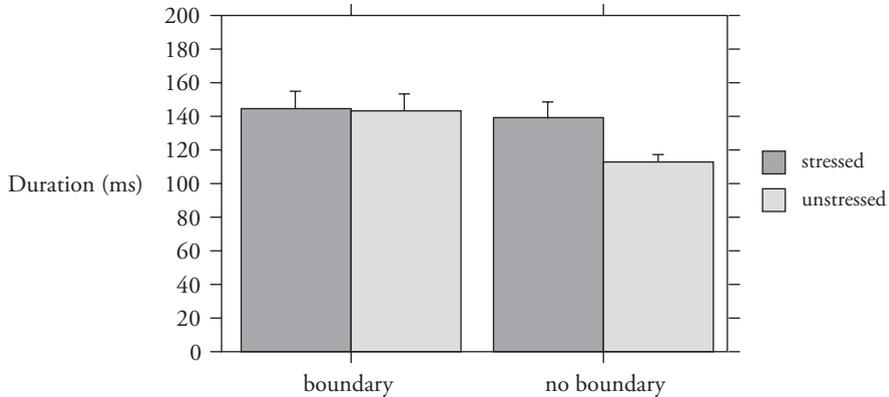


Fig. 5

Interaction between stress and boundary for C duration (speaker A)

The ANOVA test for speaker B reveals that stress is a significant factor for consonant duration ($F(1, 72) = 152.18, p < .0001$). The initial consonant is longer after a stressed vowel (153 ms) than after an unstressed vowel (115 ms). The presence or absence of a boundary also has a significant effect on consonant duration ($F(1, 72) = 29.57, p < .0001$). The consonant is longer when there is no boundary (142 ms vs. 125 ms). For speaker B, the identity of the preceding vowel is a significant factor for consonant duration ($F(1, 72) = 21.77, p < .0001$). We find a longer consonant after /i/ than after /a/. There is a significant interaction between boundary and stress ($F(1, 72) = 86.76, p < .0001$) such that the stress effect is greater in the absence of a boundary. Figure 6 shows this interaction. The planned means compar-

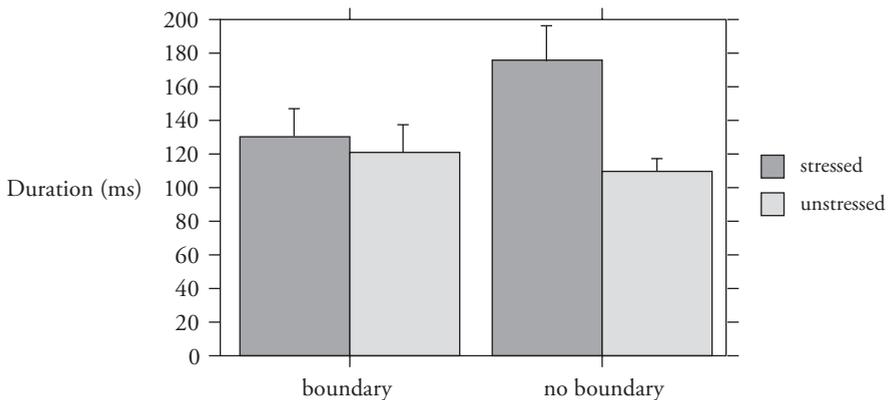


Fig. 6

Interaction between boundary and stress for C duration (speaker B)

ison results for this speaker indicate that there is a significant difference in the post-boundary consonant duration depending on whether the preceding vowel is stressed or unstressed ($F(1, 72) = 4.56, p = .036$), i.e., the two leftmost bars in Figure 6 are significantly different. The postboundary consonant is longer after a stressed vowel (130 ms vs. 120 ms).

The ANOVA results for speaker C show that stress is a significant factor for consonant duration ($F(1, 72) = 206.23, p < .0001$), with the initial consonant being longer after a stressed vowel (141 ms) than after an unstressed vowel (108 ms). Boundary is also a significant factor ($F(1, 72) = 30.01, p < .0001$). The duration of the consonant is greater when there is no boundary (131 ms vs. 118 ms). The identity of the preceding vowel has a significant effect on the consonant duration ($F(1, 72) = 36.81, p < .0001$). The consonant is longer after /i/ than after /a/. There is a significant interaction between stress and boundary ($F(1, 72) = 104.9, p < .0001$) such that the stress effect is greater in the absence of a boundary, as Figure 7 illustrates. For speaker C, the planned comparison test indicates that the status of the preceding vowel as unstressed or stressed makes a significant difference in postboundary consonant duration ($F(1, 72) = 8.48, p = .0048$), i.e., the two leftmost bars in Figure 7 are different. The postboundary consonant is longer after a stressed vowel (123 ms vs. 113 ms).

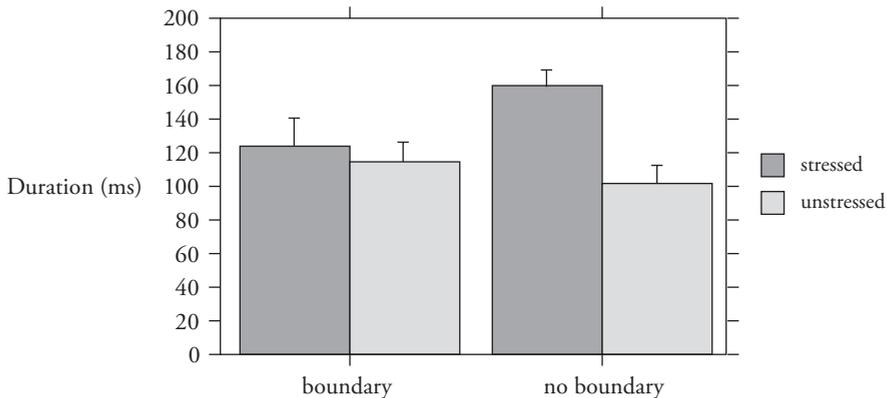


Fig. 7

Interaction between stress and boundary for C duration (speaker C)

The ANOVA results for speaker D indicate that stress is a significant factor for consonant duration ($F(1, 72) = 139.89, p < .0001$). The initial consonant is longer after a stressed vowel (148 ms) than after an unstressed vowel (114 ms). According to the results, the presence or absence of a boundary has a significant effect on consonant duration ($F(1, 72) = 85.66, p < .0001$), the consonant being longer when there is not any boundary (145 ms vs. 118 ms). The identity of the preceding vowel is not a significant factor for this speaker. There is a significant interaction between stress and boundary ($F(1, 72) = 89.21, p < .0001$) such that the stress effect is greater when no boundary is present (see Figure 8). The planned comparison shows that

there is no significant difference in postboundary consonant duration depending on the stressed or unstressed status of the preceding vowel ($F(1, 72) = 2.84, p = .0964$), although the p -value could indicate a trend.

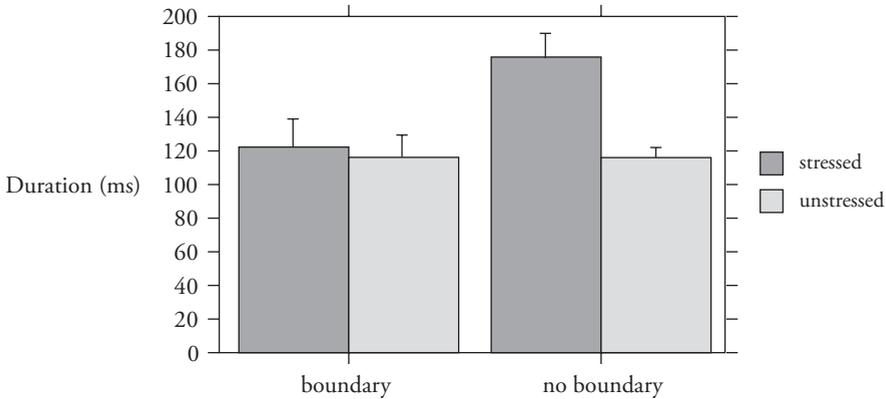


Fig. 8

Interaction between stress and boundary for C duration (speaker D)

3.2. Duration of initial vowel in word2

Next, I consider the results for the environment where the initial segment in word2 was a vowel. The ANOVA results for speaker A show that stress is not a significant factor for vowel duration. On the other hand, the presence or absence of a boundary proves to be a significant factor ($F(1, 72) = 10.14, p = .0021$). The vowel is longer when there is no boundary (140 ms vs. 129 ms). Not surprisingly, the identity of the vowel has a significant effect on the vowel duration ($F(1, 72) = 245.49, p < .0001$). The vowel is longer when it is /a/. Finally, there is not a significant interaction between stress and boundary for speaker A.

For speaker B, stress is a significant factor for vowel duration ($F(1, 72) = 4.93, p < .0295$). The vowel is longer when the preceding vowel is unstressed (142 ms vs. 130 ms). The results show that the presence or absence of a boundary has a significant effect ($F(1, 72) = 100.02, p < .0001$). The vowel is longer when there is not any boundary (164 ms vs. 109 ms). The identity of the vowel is a significant factor ($F(1, 72) = 16.613, p = .0001$). When it is /a/, the initial vowel in word2 is longer. There is not a significant interaction between boundary and stress for speaker B.

The ANOVA results for speaker C reveal that stress is not a significant factor for vowel duration. The presence or absence of a boundary has a significant effect ($F(1, 72) = 21.00, p < .0001$). The vowel is longer when there is no boundary (149 ms vs. 127 ms). The identity of the vowel is a significant factor ($F(1, 72) = 56.33, p < .0001$). The vowel is longer when it is /a/. There is no significant interaction between stress and boundary for speaker C.

The effect of stress on vowel duration proves to be non-significant for speaker D. The results show that the presence or absence of a boundary is significant

($F(1,72) = 28.08, p < .0001$). The absence of a boundary correlates with a longer vowel (159 ms vs. 126 ms). Also for this speaker, the identity of the vowel turns out to be a significant factor ($F(1, 72) = 55.08, p < .0001$). The vowel is longer when it is /a/. There is no significant interaction between stress and boundary for speaker D.

3.3. Duration of final vowel in word1

In this section, I consider the effect of stress, boundary and segment identity on the final vowel of word1. The statistical results for speaker A reveal that stress is a significant factor for vowel duration ($F(1, 148) = 384.24, p < .0001$). The final vowel is longer when it is stressed (108 ms vs. 66 ms). Also, the presence or absence of a boundary proves to be significant ($F(1, 148) = 447.63, p < .0001$). The vowel is longer before a boundary, i.e., phrase finally (109 ms vs. 65 ms). The identity of the following segment, i.e., /a/, /i/ or /s/, proves to have a significant effect on the vowel duration ($F(2, 148) = 3.73, p = .026$). The final vowel is longest when preceding /i/. The results show that there is a significant interaction between boundary and stress ($F(1, 148) = 59.12, p < .0001$) such that the lengthening of V1 when phrase final is heightened when the vowel is stressed as compared to unstressed, as the two leftmost bars in Figure 9 show.

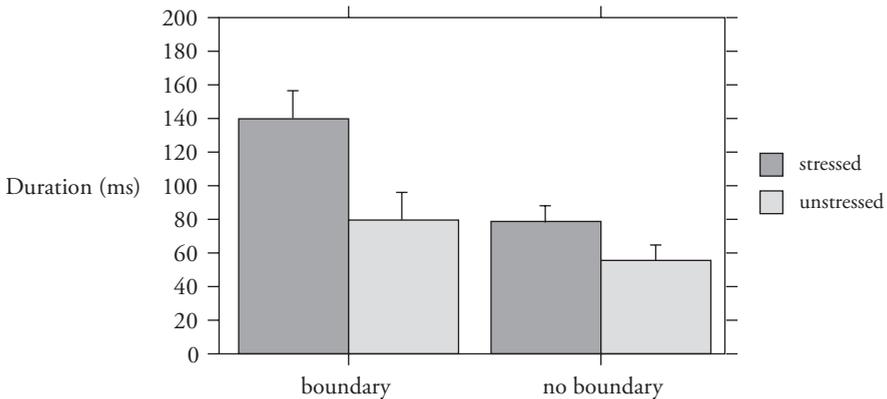


Fig. 9

Interaction between stress and boundary for V1 duration (speaker A)

According to the ANOVA results, stress is a significant factor for vowel duration ($F(1, 148) = 186.38, p < .0001$) for speaker B. The final vowel is longer when it is stressed (129 ms vs. 75 ms). The presence or absence of a boundary also has a significant effect on the final vowel ($F(1, 148) = 87.56, p < .0001$). This vowel is longer when it precedes a boundary (122 ms vs. 83 ms). For this speaker, the identity of the following segment does not have a significant effect on the vowel duration. As the ANOVA test results show, there is a significant interaction between stress and boundary ($F(1, 148) = 9.62, p.002$) such that the lengthening of V1 in phrase final

position is greater when the vowel is stressed as compared to unstressed, as can be seen in Figure 10.

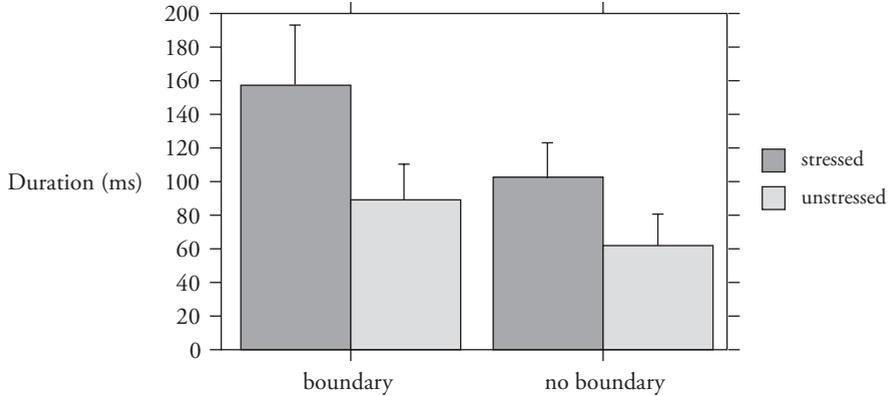


Fig. 10

Interaction between stress and boundary for V1 duration (speaker B)

Stress proves to be a significant factor ($F(1, 148) = 295.36, p < .0001$) for speaker C. The final vowel is longer when it is stressed (124 ms vs. 66 ms). From the ANOVA results, we see that the presence or absence of a boundary has a significant effect on the vowel duration ($F(1, 148) = 209.91, p < .0001$). The final vowel is longer when it precedes a boundary (121 ms vs. 70 ms). The identity of the following segment proves to be significant for the vowel duration ($F(2, 148) = 27.29, p < .0001$). The final vowel is longest with /i/ and next longest with /s/. The results show that there is a significant interaction between stress and boundary ($F(1, 148) = 19.8, p < .0001$) such that the lengthening of V1 in phrase final position is greater when the vowel is stressed, compared to its unstressed counterpart, as Figure 11 illustrates.

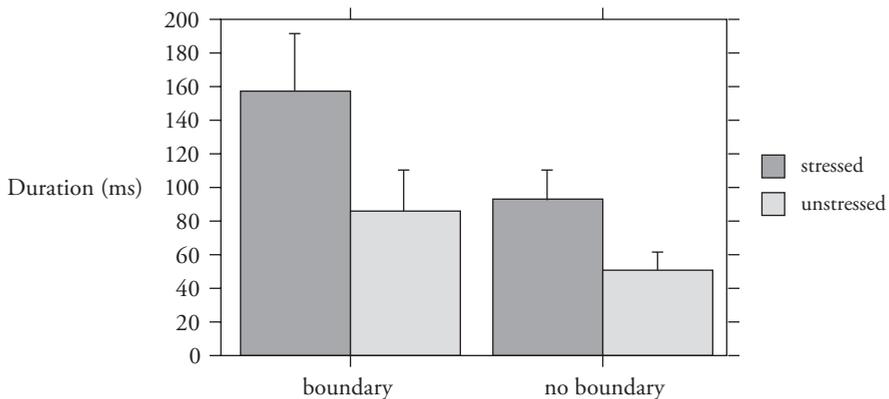


Fig. 11

Interaction between stress and boundary for V1 duration (speaker C)

For speaker D, the results show that stress is a significant factor ($F(1, 148) = 222.5, p < .0001$). The final vowel is longer when it is stressed (132 ms vs. 73 ms). The presence or absence of a boundary is also significant ($F(1, 148) = 431.81, p < .0001$). The final vowel is longer before a boundary (142 ms vs. 63 ms). On the other hand, the identity of the following segment proves to be a non-significant factor for vowel duration. Finally, the ANOVA results show that there is a significant interaction between stress and boundary ($F(1, 148) = 15.74, p = .0001$) such that the lengthening of V1 in phrase final position is greater when the vowel is stressed as compared to unstressed, as we can see in Figure 12.

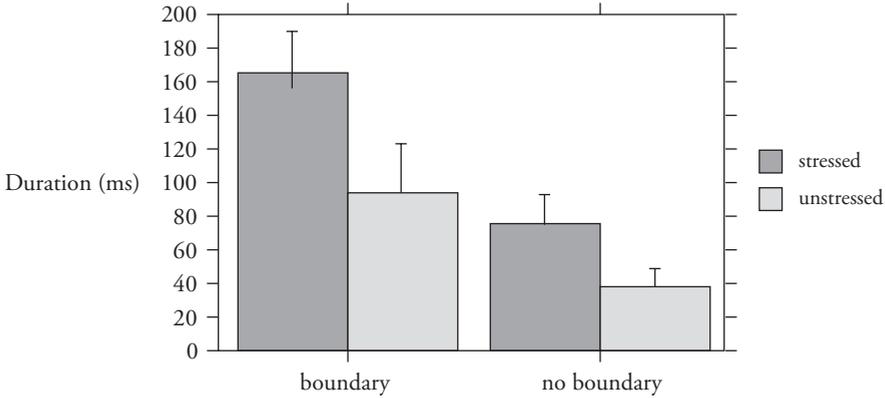


Fig. 12

Interaction between stress and boundary for V1 (speaker D)

3.4. Pause effects

The environments where a phrase boundary is present are the potential contexts for the appearance of a pause. Figure 13 shows the distribution of periods of silence according to their length (ms) for each speaker.

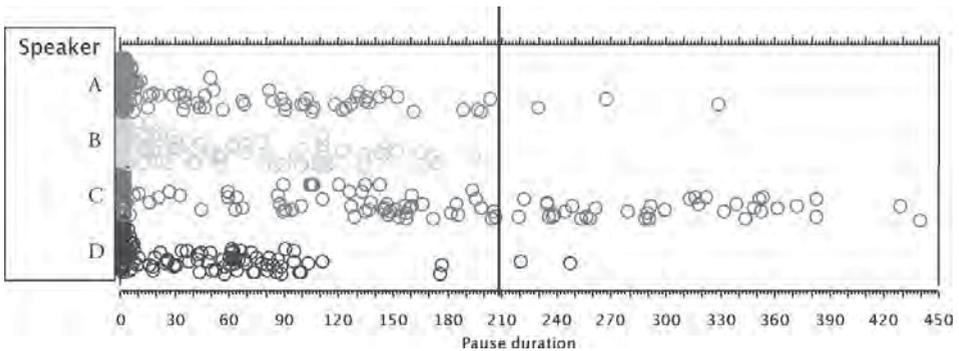


Fig. 13

Distribution of pause duration by speaker

It is evident from this distribution that there are different degrees of length for the periods of silence. It should be noted that not every period of silence constitutes a pause. Duez (1981) establishes that any period of 200ms and over showing no periodic or aperiodic noise constitutes a pause. However, in our data, shown in Figure 13, there is a discontinuity in the distribution at 210ms. For this reason, I establish the pause level at 210ms instead of 200ms. After establishing this criterion, we see that only speaker B has a substantial number of tokens with pauses. Consequently, the stress and pause effects were tested only for this speaker.

A two-factor ANOVA was carried out with the duration of the initial fricative of word2 as the dependent variable, and stress and pause as the independent variables. The results show that the presence or absence of a pause has no significant effect on the segment duration ($F(1, 76) = 3.57, p = .0627$) (123 ms with pause vs. 135 ms without pause).

3.5. Summary of results

With regards to the duration of the initial consonant in word2, stress has an effect for all the speakers, namely the consonant is longer when it follows a stressed vowel. Similarly, the presence or absence of a boundary is significant for all speakers. The consonant that does not follow a boundary is longer than a postboundary consonant. This is true for all speakers except for speaker A, for whom a postboundary consonant is longer. The identity of the vowel preceding the consonant is a significant factor only for speakers B and C. For these speakers, the consonant following /i/ is longer than that following /a/. The interaction between stress and boundary proves to be significant for all speakers such that the stress effect is greater when no boundary is present. However, the difference in duration of a postboundary consonant depending on whether the preceding vowel is stressed or unstressed is significant only for speakers B and C. Table II is a summary of the relevant effects on the initial consonant duration.

Table II

Summary of effects on the duration of the initial consonant in word2

	Stress effect	Boundary effect	V1 identity effect	Stress & Boundary interaction	boundary&stress vs. boundary&no-stress difference
speaker A	✓ s > u	✓ b > nb	no	✓ snb > sb	no
speaker B	✓ s > u	✓ nb > b	✓ i > a	✓ snb > sb	✓
speaker C	✓ s > u	✓ nb > b	✓ i > a	✓ snb > sb	✓
speaker D	✓ s > u	✓ nb > b	no	✓ snb > sb	no

As far as the duration of the initial vowel in word2, stress does not have a significant effect on the vowel duration for speakers A, C or D. However, stress proves to be significant for speaker B, for whom the initial vowel is longer when it follows an unstressed vowel. On the other hand, boundary is a significant factor for all the speakers. The initial vowel is longer when there is no boundary. The identity of the vowel proves to be a significant factor for all speakers. When the initial vowel is /a/, its duration is longer. Finally, stress and boundary do not have a significant interaction for any speaker. Table III summarizes the main effects on the initial vowel duration.

Table III

Summary of effects on the duration of the initial vowel in word2

	Stress effect	Boundary effect	V2 identity effect	Stress & Boundary interaction
speaker A	no	✓ nb > b	✓ a > i	no
speaker B	✓ u > s	✓ nb > b	✓ a > i	no
speaker C	no	✓ nb > b	✓ a > i	no
speaker D	no	✓ nb > b	✓ a > i	no

Finally, the duration of the final vowel in word1 is significantly affected by the stress. This vowel is longer when it is stressed. This is the case for all the speakers. The presence or absence of a boundary is also a significant factor. The final vowel is

Table IV

Summary of effects on the duration of the final vowel in word1

	Stress effect	Boundary effect	Following segment effect	Stress & Boundary interaction
speaker A	✓ s > u	✓ b > nb	✓ i > a > f	✓ sb > snb
speaker B	✓ s > u	✓ b > nb	no	✓ sb > snb
speaker C	✓ s > u	✓ b > nb	✓ i > f > a	✓ sb > snb
speaker D	✓ s > u	✓ b > nb	no	✓ sb > snb

longer when it occupies a preboundary position. This is true for all speakers. With regard to the identity of the following segment, it is not a significant factor for speakers B or D. However, speaker A and C present a significant influence of the identity of this segment. The interaction between stress and boundary is significant for all the speakers such that the lengthening of V1 in phrase final position is greater when the vowel is stressed as compared to unstressed. Table IV shows the results for the duration of the final vowel in word1.

4. Discussion

This section evaluates the results presented above in relation to our hypotheses (see (2) in section 1.2). The first hypothesis tests whether RF lengthening takes place in the traditional environment, i.e., where word1 ends with a stressed vowel and word 2 begins with a consonant. The results support this hypothesis and evidence RF – an initial consonant is longer when it follows a stressed vowel than an unstressed one. However, it is important to consider the amount of lengthening of the consonant in order to evaluate previous claims which suggest that RF is the same as gemination (Borrelli 2000, Chierchia 1982, 1986, Stevens & Hajek 2005). Table V shows the duration for the consonant in question, in the presence or absence of a preceding stress. Only the environments with no boundary are taken into account, since the traditional formulation of RF refers to the absence of boundaries between word1 and word2.

Table V

Duration (ms) of the initial consonant after a stressed and unstressed vowel and percentage of lengthening for each speaker

	Duration after a stressed vowel	Duration after an unstressed vowel	Percentage of lengthening
Speaker A	139	113	23%
Speaker B	175	109	60%
Speaker C	159	103	54%
Speaker D	175	115	52%

In order to compare the results from RF environments with the duration of parallel single and geminate consonants, relevant data from two of the experiment's speakers was collected in a follow-up study, where the duration of word internal single and geminate [s] was measured. Remember that Italian has a contrast between singleton and geminate consonants only word-medially. The stimuli in this follow-up consisted of sentences with similar structure to those in our first experiment. The difference being that in this case the target segment was in word internal position. The word carrying the relevant consonant was a noun of the shape CVCV (e.g. *basi* 'bases') or CVCCV (e.g. *passi* 'steps'), with initial stress. This noun was followed by an adjective to mirror the structure of the RF experiment sentences. See Appendix 2 for a complete list of the relevant utterances. The speakers were recorded in exactly the same

conditions as in the first experiment. Table VI shows the duration of geminate and single consonants from this follow-up sentence set. By comparing Table V and VI, we can see that the percentage of lengthening in the RF environment is not as great as the lengthening for geminates. This suggests that the RF process as exemplified in the present study does not involve the formation of geminates, but only the lengthening of the segment to a lesser degree than that found for geminate consonants.

Table VI
Geminate and singleton duration (ms) from follow-up experiment

	Geminate	Singleton	Percentage
Speaker A	123	41	200%
Speaker D	143	38	276%

The results for percentage of RF lengthening in Table V can also be compared with those found in an independent study by Farnetani and Kori (1986) for singleton and geminate [s], shown in Table VII. As reported above, consonants subject to RF (see Table V) lengthen to a lesser degree than the geminate consonants in Farnetani and Kori's data. Relatedly, Payne (2005) analyzes RF long consonants and geminate consonants and finds that these two types of long consonants are different not only in terms of their duration (lexical geminates being longer) but also in terms of their non-durational cues, i.e., their formants values. These results lead the author to conclude that RF consonants and lexical geminates are different and that consonants lengthened by RF do not result in geminates, confirming what the current study reports.

Table VII
Duration (ms) of fricative single and geminate consonant from Farnetani and Kori (1986)

	Geminate C	Single C	Percentage of Lengthening
Speaker 1	221	127	74%
Speaker 2	255	87	193%
Speaker 3	271	117	131%

Our second hypothesis predicted that the initial consonant in word2 would lengthen after a boundary but to a lesser extent. The results show that the presence or absence of a boundary is a significant factor on the realization of RF, in that the initial consonant is longer when no boundary is present. Focusing on those contexts where there is an intonational phrase boundary, the difference in duration for the initial consonant depending on whether the preceding vowel was stressed or unstressed was significant for two of the speakers. This means that the presence of a boundary did not block the lengthening from taking place for these two subjects. On the other hand,

this difference was not significant for the two other speakers, although they show the same qualitative pattern. Thus, our results lend support to claims that the presence of a boundary is a not a categorical blocker for RF. However, I find that an intonational boundary does have some effect on RF but that this effect is gradient, i.e., there is some lengthening but less than when no boundary is present. At this point, it is worth looking at the mean duration for the postboundary consonant after a stressed and an unstressed vowel for those speakers where the difference is significant. See Table VIII.

Table VIII
Duration (ms) of postboundary consonants

	After stressed vowel	After unstressed vowel	Percentage of lengthening
Speaker B	130	121	8%
Speaker C	123	114	8%

Notice that the percentage of lengthening is not as great as in the environment where there is no boundary (see Table V). It seems that the RF lengthening is a gradient phenomenon since it is greater or smaller depending on the context. Although the boundary does not block lengthening for these speakers, the lengthening obtained is smaller compared to the cases where no boundary is present. These results lend support to the view of boundaries as elastic phenomena with gradient effects on neighboring sounds (Byrd & Saltzman 2003).

Next, let us consider the results regarding the presence of a pause in the RF environments and the initial /s/ duration. For the speaker that presented a significant number of tokens with pauses (speaker B), there was no effect of the pause on the lengthening. This is contrary to what had been previously reported, namely that when a pause occurs between word1 and word2 RF does not apply (Absalom et al. 2002, Agostiniani 1992, Canepari 1991, Loporcaro 1997, Stevens and Hajek 2006). The current results show that the occurrence of a pause is not a blocker of the phenomenon, although it does have an effect on the amount of lengthening. Table IX includes the initial consonant duration in contexts with and without a pause, and it shows that the lengthening is greater when there is no pause. This indicates that the presence of a pause has a gradient effect on RF in that the amount of lengthening is smaller. Thus, we can conclude that RF lengthening is gradient and it depends on

Table IX
Duration (ms) of initial consonant with and without pause
and after stressed/unstressed vowel

	pause		no pause	
	after stressed V	after unstressed V	after stressed V	after unstressed V
Speaker B	130	113	157	115

factors such as phrase boundary and pause, but, crucially, the presence of these prosodic elements does not rule out the process. I argue that this is directly related to the elastic nature of prosodic phenomena, which is manifested in gradiently varying degree of disjuncture at phrase boundaries (Byrd & Saltzman 1998, 2003, Byrd 2006).

The third hypothesis was that an initial vowel in word2 does not lengthen in the RF environment. The results clearly support this hypothesis. For three of the speakers, stress does not have a significant influence on the duration of this vowel, i.e., there is no difference in its duration after a stressed or an unstressed vowel. For one of the speakers, there was a significant difference depending on the presence of a preceding stressed element. However, in this case, the initial vowel was shorter after a stressed element. This shows that consonants are the only segments subject to RF lengthening.

The fourth hypothesis makes reference to the fact that the initial vowel in word2 will not lengthen after a boundary. As we just saw, this vowel does not lengthen in the RF environments, i.e., without a boundary and after a stressed vowel. So, this hypothesis is already refuted by the results discussed with respect to hypothesis three. However, it is useful to consider the boundary effects independently of the preceding stressed or unstressed element. The results show that the boundary is a significant factor for initial vowel duration, namely this vowel is longer in the absence of a boundary. This indicates that initial vowels undergo postboundary or phrase initial shortening.

The last hypothesis states that a final vowel lengthens when stressed. The results lend support to this hypothesis. The final vowel is significantly longer when it is stressed than when it is unstressed. Table X illustrates the percentage of lengthening of the final vowel depending on whether it is stressed or unstressed, in the absence of a following boundary.

Table X
Duration (ms) of final vowel without a following boundary

	Stressed	Unstressed	Percentage of lengthening
Speaker A	78	53	44%
Speaker B	102	63	62%
Speaker C	91	49	85%
Speaker D	83	42	96%

If we compare the percentage of lengthening for final vowels (Table X) and initial consonants (Table V) in the RF environment, we see that the percentage of vowel lengthening is greater than that of consonant lengthening for all the speakers. These findings clearly refute the claim of bimoraic analyses that final stressed vowel cannot be long in Italian (see Borrelli 2000 for a review of these analyses). Furthermore, these results show that vowel lengthening and consonant lengthening can occur at the same time, i.e., they do not exclude each other. Finally, it should be

noted that the final vowel is longer in preboundary position, indicating that there is preboundary lengthening (see for example Wightman, Shattuck-Hufnagel & Ostendorf 1992 for American English). This stands in contrast with the results obtained for the initial vowel, which was shorter in postboundary position.

5. Conclusion

This study provides a quantitative, empirical analysis of RF and of the effect of different factors on the lengthening, focusing on the role of prosodic boundaries, pauses and the quality of the segments. Regarding the characteristics of RF in terms of the segment involved, I found that this process only targets initial consonants; initial vowels are not affected by RF. On the other hand, the final stressed vowel lengthens considerably when it carries a stress. That is, RF environments present not only initial consonant but also final vowel lengthening, contradicting previous accounts of the process.

The results presented above shed light on the nature of RF and more precisely, characterizes its interaction with prosodic structure. I argue that this interaction is gradient and elements that had been previously reported as blockers of RF do not categorically define the result of RF. More precisely, this study shows that the presence of a boundary or a pause has gradient effects on RF: RF can lengthen a postboundary or a postpause consonant, but the degree of lengthening will be smaller than when no boundary or pause is present. This behavior agrees with approaches to prosodic structure that view boundaries as elastic phenomena that affect segmental structure in a gradient manner (Byrd & Saltzman 2003). The current study has some limitations and some of the factors interacting with RF need to be analyzed in more detail. For instance, the effect of pause may need further study since our data does not provide many tokens for this context. The challenge when analyzing pause effect is how to incorporate different ways to manipulate pause production into the experimental methodology.

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Appendix 1

Stimuli used in the main experiment analyzing RF (target sounds are in bold).

1. La nostra è una facoltà **ibrida**.
«Ours is a hybrid faculty»
2. Fu un giovedì **acido**.
«It was a sour Thursday»
3. Roma è una città **santa**.
«Rome is a holy city»
4. Fu un giovedì **sobrio**.
«It was a sober Thursday»
5. È una pianta **ibrida**.
«It is a hybrid plant»

6. Sono studenti **abili**.
«They are handy students»
7. Ha comprato frutta **secca**.
«He's bought dry fruit»
8. Sono studenti **sobri**.
«They are sober students»
9. Se conosci la facoltà, **ibrida** non è.
«If you know the faculty, it is not hybrid»
10. Quando lo mangiammo giovedì, **acido** non era.
«When we ate it on Thursday, it was not sour»
11. Se conosci la città, **santa** non è.
«If you know the city, it is not holy»
12. Quando lo vedemmo giovedì, **sobrio** non sembrava.
«When we saw him on Thursday, he did not look sober»
13. Quando studiamo quella pianta, **ibrida** non era.
«When we studied that plant, it was not hybrid»
14. Quando abbiamo conosciuto gli studenti, **abili** non erano davvero.
«When we met the students, they were not handy at all»
15. Quando mangiammo la frutta, **secca** non era.
«When we ate the fruit, it was not dry»
16. Quando abbiamo conosciuto gli studenti, **sobri** non sembravano.
«When we met the students, they did not look sober»

Appendix 2

Stimuli used in follow-up experiment analyzing single/geminate consonants duration (target single and geminate consonants are in bold).

1. Le nostre sono **basi** deboli.
«Ours are weak bases»
2. Cammina a **passi** lunghi.
«He walks with long steps»
3. Abbiamo ricevuto la carta **Visa** nuova.
«We have received the new Visa card»
4. Siamo finiti in una **rissa** furiosa.
«We ended in a furious fight»