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The magnet effect on interdialectal speech perception: evidence from the palatalization of /t/ in Brazilian Portuguese

João Pessoa - Paraíba

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Orientador: Prof. Dr. Leonardo Wanderley Lopes

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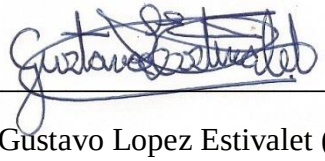

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Resumo

O principal objetivo desta dissertação é de investigar o efeito ímã na discriminação de ouvintes quanto à duração do ruído de fricção de /t/, relativo à palatalização de /t/ antes de /i/ no Português Brasileiro. A palatalização é geralmente caracterizada por quando uma plosiva alveolar é produzida como uma africada (BISOL, 1986; HORA, 1997; BATTISTI; ROSA, 2012; AMORIM et al., 2019). O efeito ímã se refere à influência da exposição linguística na discriminação de ouvintes. Ele é caracterizado por uma redução na sensibilidade a mudanças acústicas nas regiões próximas exemplares ideais (protótipos), e por um aumento próximo a exemplares não ideais (não-protótipos) (KUHL et al., 1992; KUHL et al., 2007). Para esta dissertação, cinco experimentos foram desenvolvidos com dois grupos: nativos e não nativos. Os nativos foram os indivíduos de João Pessoa, Paraíba, Brasil, onde a palatalização é a variante mais frequente. Os não nativos foram os indivíduos que moram em João Pessoa, mas viveram maior parte de sua vida em um local onde a africada é a variante mais frequente. O primeiro experimento investigou a distribuição da duração do ruído de /t/ e forneceu importantes contribuições para a elaboração dos estímulos dos outros experimentos. O segundo experimento foi um teste de discriminação, que analisou o efeito da exposição linguística na discriminação de ouvintes, comparando tokens em que os ruídos de /t/ diferiram em 5, 10, 15 e 20 ms. O terceiro experimento foi um estudo piloto ABX. Ele analisou a influência da exposição linguística nas respostas dos ouvintes, mas falhou porque os estímulos diferiram em apenas 5 ms. O quarto experimento foi um teste de julgamento de *goodness*. Ele mostrou que o julgamento variou de acordo com os estímulos. O quinto experimento foi um teste ABX, semelhante ao piloto, mas usando os estímulos do teste de julgamento. Ele confirmou a principal hipótese deste estudo quando demonstrou que as respostas dos ouvintes dependem da exposição à língua. Concluindo, a presente dissertação está de acordo com os estudos anteriores sobre o modelo Ímã da Língua Materna, que defende que a sensibilidade dos ouvintes a mudanças acústicas é motivada pela experiência linguística. Os estímulos que eram exemplares ideais produziram uma diminuição na sensibilidade às mudanças acústicas, ao passo que aqueles que eram exemplares ideais produziram um aumento, o que indica o efeito ímã.

Palavras-chave: Palatalização de /t/. Português Brasileiro. Modelo Ímã da Língua Materna.

Abstract

The main objective of this dissertation is to investigate the magnet effect on listeners' discrimination of the duration of /t/ frication burst, from the palatalization of /t/ before /i/ in Brazilian Portuguese. The palatalization is generally characterized by when an alveolar plosive is produced as an affricate (BISOL, 1986; HORA, 1997; BATTISTI; ROSA, 2012; AMORIM et al., 2019). The magnet effect refers to the influence of language exposure on listeners' discrimination. It is characterized by a reduction in sensitivity to acoustic changes in the region near good exemplars (prototypes), and an increase near poor exemplars (non-prototypes) (KUHL et al., 1992; KUHL et al., 2007). For this dissertation, five experiments were conducted with two groups: natives and non-natives. Natives were the individuals from João Pessoa, Paraíba, Brazil, where the palatalization is the most frequent variant. The non-natives were the individuals who live in João Pessoa, but lived most of their life in a place where the affricate is the most frequent variant. The first experiment investigated the distribution of the duration of /t/ frication burst and provided helpful insights for the elaboration of stimuli from the other experiments. The second experiment was a discrimination test, which analyzed the effect of language exposure on listeners' discrimination when comparing tokens that the burst differed in 5, 10, 15 and 20 ms. The third experiment was a pilot, an ABX task. It examined the influence of language exposure on listeners' responses, but it failed because the stimuli differed only in 5 ms. The forth experiment is a goodness judgment task. It showed that the goodness varied with the stimuli. It contributed to validate the stimuli to be used in the following experiment. The fifth experiment was a ABX test, which was similar to the pilot, but using the stimuli from the goodness test. It confirmed the main hypothesis of the current study when demonstrated that listeners' responses depend on language exposure. Concluding, the current dissertation is in line with prior studies on the Native Language Magnet model, which show that listeners' sensitivity to acoustic changes is motivated by language experience. The stimuli that were good exemplars yielded a decrease in sensitivity to acoustic changes, whereas those that were poor exemplars yielded an increase, what indicates the magnet effect.

Keywords: Palatalization of /t/. Brazilian Portuguese. Native Language Magnet model.

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List of abbreviations and acronyms

BP	Brazilian Portuguese
JP	João Pessoa
NLM	Native Language Magnet
PB	Paraíba
UFPB	Universidade Federal da Paraíba (Federal University of Paraíba)

Contents

1 Introduction

The palatalization of the alveolar plosive /t/ before /i/ in Brazilian Portuguese (BP) has been extensively investigated (BISOL, 1986; HORA, 1990a; PAGOTTO, 2001; BATTISTI et al., 2007; BATTISTI; FILHO, 2012; HORA; HENRIQUE; AMORIM, 2018; AMORIM et al., 2019). It is generally described as when, triggered by /i/, an alveolar plosive is produced as an affricate. For instance, when [t]ia "aunt" is produced as [tʃ]ia. The literature on palatalization of /t/ in BP reveals that the affricate is the most regular variant in BP. According to Cardoso et al. (2014), this is not the case only in four of the Brazilian state capitals.

Although there is a large number of studies that investigate this process in BP, there is a lack of studies that analyze it in the domain of Acoustic Phonetics (KENT; READ, 1992; STEVENS, 2000; BARBOSA; MADUREIRA, 2015). The major contribution from this perspective is that it makes possible to explore the continuum of variation. Instead of considering this process in terms of occurrence or not, as it is usually described, from an acoustic perspective it is possible to observe the palatalization in its theoretically infinite stages. For example, Pozzani and Albano (2016) investigated this process by means of the four spectral moments of the /t/ frication burst. Based on its frequency, they measured its mean, standard deviation, skewness and kurtosis, which were used to observe different stages of the palatalization in the speech production of their participants. Moreover, Silva et al. (2012) and Freitag and Souza (2017) evidenced a continuum concerning the duration of the aspiration of /t/, which was not further investigated in terms of acoustics by the literature of BP. Therefore, an acoustic investigation of palatalization can provide more details in relation to the different distributions that this variable can assume.

An interesting model to investigate the palatalization by means of Acoustic Phonetics and considering its continua is the Native Language Magnet (NLM) (KUHL et al., 1992; KUHL et al., 2007). This model differs from other models because it explains speech perception from an acoustic perspective (KKESE; KARPAVA, 2019). Prior research based on this model provides experimental evidence of a phenomenon called the *perceptual magnet effect* (KUHL, 2000; IVERSON; KUHL, 1996; KUHL et al., 2007; KUHL; PADDEN, 1983; KUHL; PADDEN, 1982; KUHL, 1991; KUHL, 1993). It is characterized by a reduction in sensitivity to acoustic changes in the region near good exemplars (prototypes), and an increase near poor exemplars (non-prototypes). For example, when examining the perception of six-month-old infants from America and Sweden, Kuhl et al. (1992) found that, although acoustic distances were equal between the stimuli (sets of vowels of American English /i/ and Swedish /y/), prototypes were equated more often than non-prototypes. Therefore, the model predicts that the magnet effect shrinks perceptual

distances near prototypes, which are ideal representatives of a phonetic category, and stretches them near non-prototypes. It proposes that exposure to a specific language affects the mechanisms underlying speech perception.

Considering that the NLM theory predicts that prior exposure to a particular language affects speech perception, this dissertation aims at investigating the role of language exposure in relation to the duration of the /t/ frication burst from the palatalization of /t/ before /i/ in Brazilian Portuguese. For this purpose, five experiments were conducted with two groups: natives and non-natives. The native were called the individuals who have always lived in the city of João Pessoa, Paraíba, in Brazil, where the alveolar plosive variant is the most frequent (HORA, 1997; HENRIQUE; HORA, 2012; HORA; HENRIQUE; AMORIM, 2018; AMORIM et al., 2019; AMORIM et al., 2019). The non-natives were called those who live in João Pessoa, but lived most of their life in a city where the affricate is the most regular variant, as in most cites of Brazil.

Based on the NLM model (KUHL et al., 2007; KUHL et al., 1992), the main hypothesis of this dissertation is that there is a significant association between language exposure, assumed here as being native or non-native, and listeners' responses from the speech perception experiments. Therefore, it is expected to find significant differences in responses from natives and non-natives, which are motivated by the magnet effect. The specific hypothesis is that speech perception also depends on the gender of listeners. Thus, it is expected to find a significant association between gender and listeners' responses. This assumption is based on previous studies on palatalization (BATTISTI; FILHO, 2015; HENRIQUE; HORA, 2012; HORA, 1997), which found gender-related differences in the use of this variable.

Each of the five experiments is presented in this master's dissertation as an independent chapter. For didactic purposes, some pieces of information were repeated. Before the chapters from the experiments, chapter 2 presents some studies on palatalization and characterizes it acoustically, and chapter 3 discusses the NLM model and some studies in its domain. The chapter 4 reports the first experiment of this dissertation, which is a speech production study. The duration of /t/ frication burst from natives and non-natives were acoustically investigated. This study was pivotal to the development of the stimuli to be used in the other experiments, since it explored the distribution of the duration of /t/ frication burst. The study from chapter 5 is a discrimination experiment. It investigated the effect of language exposure on listeners' responses from a perceptual task. The most contribution of this study was to demonstrate that differences in responses can not be observed when the /t/ frication burst of stimuli differs in 5 or 20 ms. Significant differences were found only when the burst differed in 10 and 15 ms. The experiment from chapter 6 is an ABX test. As a pilot study, it failed in demonstrating that listeners' responses depend on language exposure, but it served as a basis for further research. The study from

chapter 7 is a goodness judgment task. It revealed that the duration of the /t/ frication burst vary in perceived goodness. The major contribution of this study to the current dissertation was to validate the stimuli that were used in the following experiment, since a linear and significant correlation was found between the ratings and the duration of the burst from the stimuli. The study from chapter 8 is a ABX test, which is similar to the pilot from chapter 6, but used the stimuli from chapter 7. It confirmed the main hypothesis of this dissertation when found that language exposure affected listeners' discrimination.

2 Palatalization of alveolar plosives

Palatalization is a phonological process triggered by the interaction of consonants with front vowels, high vowels, and the palatal glide *j* (BATEMAN, 2007). According to Kochetov (2011, p. 1), "consonants acquire secondary palatal articulation or shift their primary place to, or close to, the palatal region". Documented in several languages (BHAT, 1978), this process "has a clear phonetic motivation" (KOCHETOV, 2011, p. 1). The following examples were given by Bateman (2007, p. 11) and refer to palatalization. Notice that, triggered by a front vowel or a glide, the consonants are palatalized.

a) /pi**t**iko/ [pi**ʧ**iko] 'small' (Apalai, Carib)

b) /ku**k**ira/ [kʊ**ʧ**ɪɹæ] 'exceed' (Nkore-Kiga, Bantu)

c) [don**t** **j**u] ~ [don**ʧ**ju] 'don't you' (English, Germanic)

In addition to these languages, it has been widely attested that in BP some consonants undergo palatalization, depending on the dialect. For example, the following consonants can be palatalized in BP: /l/ before [i] (OLIVEIRA et al., 2009), /S/ in medial (HORA, 2003) and final coda (CALLOU; LEITE; MORAES, 2002), /t, d/ as a progressive (HORA; HENRIQUE, 2015) or regressive (BISOL, 1986; HORA, 1997; BATTISTI; ROSA, 2012; CARDOSO et al., 2014) assimilation, etc.

The palatalization of the alveolar plosives /t, d/ in BP[1], which is the object of this dissertation, is subject to three types of assimilation: progressive assimilation, regressive assimilation and bidirectional assimilation (HORA, 1990b; MAGALHÃES, 2014). Assimilation is defined as a process in which a targeted segment takes on the characteristics of the trigger (MCCARTHY; SMITH, 2003). Magalhães (2014) explains that when the trigger is on the left side of the target, it is called a *progressive assimilation* (jei[t]o ~ jei[ʧ]o 'way'), whereas when the trigger is on the right side of the target it is a regressive assimilation ([d]ia ~ [ʤ]ia 'day'). The bidirectional assimilation is the process in which there is a trigger on both sides of the target (noi[t]e ~ noi[ʧ]e 'night').

Bateman (2007) argues that there is a strong tendency for regressive palatalization in general, since the preferred position of the trigger is on the right side of the target, what is consistent with Bhat (1978). This seems to be the same in relation to BP. Magalhães (2014) states that regressive assimilation is the norm in BP, whereas progressive assimilation is the exception. Considering the palatalization of alveolar plosives in BP, it seems that the progressive assimilation is restricted to some dialects from the northeast of Brazil, at least

[1] Plosives are often referred to as stops, since all stops require a closure along the vocal tract (KENT; READ, 1992). However, in languages such as English, some stops are not plosives. Considering that in Brazilian Portuguese all stops are plosives, the current study will give preference to this term.

this is what the scarce literature suggests (HENRIQUE; HORA, 2012; HORA; HENRIQUE, 2015; OLIVEIRA, 2017). On the other hand, this process has been widely explored as a regressive assimilation, which is the focus of this dissertation. Probably, this palatalization as a regressive assimilation is one of the most investigated phonetic-phonological processes in Brazil.

There are dozens of studies on the palatalization of alveolar plosives as a regressive assimilation in BP (BISOL, 1986; HORA, 1990a; PAGOTTO, 2001; ABAURRE; PAGOTTO, 2002; BATTISTI et al., 2007; BATTISTI; FILHO, 2012; HENRIQUE; HORA, 2012; HORA; HENRIQUE, 2015). Investigated in several dialects, this process is usually described as when alveolar plosives can be produced as affricates. Thus, /t/ can be produced as [t] and [ʧ], and /d/ as [d] and [ʤ]. For instance, *pote* (pot) could be pronounced as po[t]e or po[tʃ]e, and *pode* ("you" can) as po[d]e or po[ʤ]e. Note that in BP this is a case of allophonic variation, since the affricates are not phonemes in this language. Another aspect is that, depending on the dialect, /t/ is more likely to be palatalized than /d/ (PAGOTTO, 2001; DUTRA, 2007; BATTISTI; FILHO, 2012; AMORIM et al.,), what shows an association of this palatalization and voicing.

According to the Linguistic Atlas of Brazil (Appendix A), the alveolar plosives are the most frequent variants only in some dialects from the northeast of Brazil, while the affricates are more regularly used in almost the whole country. The Atlas shows that João Pessoa (JP), which is analyzed in this dissertation, is one of the capitals with the lowest rate of palatalization in Brazil. This is in line with other studies in this capital. In Hora (1997), the natives palatalized at the rate of 7,4% in interviews, what indicates that the alveolar plosives are really the most frequent variants in this dialect[2].

Although many works were carried out on this palatalization in BP, there is a lack of studies that are interested in describing this process acoustically. In fact, some acoustic examination have been conducted to ascertain whether the palatalization occurred, as in Silva et al. (2012) and Freitag and Souza (2017), but no acoustic measure was reported. Nevertheless, both studies evidenced an acoustic continuum concerning the palatalization under study. They hypothesized a range of variants from an alveolar plosive to an affricate, what is in line with some previous studies and with what is investigated by the current dissertation.

For instance, Hora (1990b) and Silva et al. (2012) reported that in some dialects there are other variants of /t/ and /d/, beyond [t] and [ʧ], [d] and [ʤ], as generally assumed by most studies. They explain that this variable can be also produced as [ts] and [ds]. Silva et al. (2012) argue that there is a phonetic continuum in which the first step is [t], then [t^h] and finally [ʧ]. Although Silva et al. (2012) did not present acoustic data, they

[2] Other studies were conducted on the palatalization in João Pessoa (HENRIQUE; HORA, 2012; AMORIM, 2017; HORA; HENRIQUE; AMORIM, 2018; AMORIM et al., 2019; AMORIM et al., 2019)

reported that their acoustic analysis found a variable aspiration concerning the duration of the plosive's release, what is an interesting evidence to be further investigated.

Different from prior studies, Pozzani and Albano (2016) carried out an investigation on this process that assumed a phonetic continuum. They investigated the palatalization considering the four spectral moments (mean, standard deviation, skewness and kurtosis) of the frication bursts of /t/ and /d/. This study seems to be the first to explore the palatalization of alveolar plosives in BP focusing on these parameters. However, it did not study the role of the duration, as evidenced by Silva et al. (2012).

Pozzani and Albano (2016)'s study is an example that the acoustic analysis of speech can substantially contribute to linguistic description when it handles with the gradient aspect of palatalization in a more objective and detailed perspective. Using instruments to measure the aspects of speech sounds can reveal subtle differences that can not be perceived by the human ear (HAYWARD, 2000). Therefore, a research based on experimental phonetics may contribute to the vast body of knowledge on the palatalization in BP, since it may overcome some limitations imposed by impressionist methods.

One of the contributions may be related to studies on speech perception and language attitudes. The acoustic characterization of the stimuli in those experiments is crucial to the reproducibility of research and to avoid errors caused by non-controlled variables. The literature shows that previous research on speech perception and language attitudes considering the palatalization of alveolar plosives in BP did not account for these issues. For example, the studies on speech perception of Amorim (2017) and Hora, Henrique and Amorim (2018) and on language attitudes of Lopes and Lima (2015), Freitag and Santos (2016) and Ribeiro and Corrêa (2018) did not report the acoustic characterization of their stimuli, making it difficult to adequately reproduce their research. Since alveolar plosives' parameters (such as mean, standard deviation, skewness and kurtosis) can assume an infinite range of values in a given scale, how a research from this perspective would be reproduced if an acoustic description of the stimuli is not reported? How to account for the results from these experiments in case when the value of a given acoustic measure from a stimulus is not controlled? Therefore, studies that explore the continuum of the palatalization, as Pozzani and Albano (2016), may support these works when providing adequate methods and parameters to describe the process. The findings from works like these may contribute to improve further research.

However, an acoustic investigation is not a simple and easy task when the literature is scarce. One of the challenges is to employ an efficient method to study the process and to determine the acoustic parameters to describe it. Despite the small number of works, it was shown that prior research suggests at least two alternatives: the four spectral moments measured from the frication burst (POZZANI; ALBANO, 2016) and the duration of the frication burst (SILVA et al., 2012). As it seems that no previous research described this

palatalization in BP from the duration, this dissertation focuses on it.

As already mentioned, there is a lack of studies on this process in BP analyzing the role of the burst duration. It implies the emergence of several challenges to describe this process acoustically, especially in practical terms. Considering the limited amount of time to conduct the current work and that prior research reveals that in BP /t/ is more frequently palatalized than /d/, this dissertation focuses on /t/. Although it does not account for the counterpart of /t/, an acoustic study on this palatalization, which has been studied for decades in Brazil, can contribute to its theoretical understanding and to trigger future research from the current perspective.

To understand the duration to be measured from the frication burst of the alveolar plosive and affricate, it is necessary to characterize it within Phonetics. The alveolar plosives [t, d] and affricates [tʃ, dʒ] in onset position are generally characterized by three events in the vocal tract: (1) constriction, (2) release from a constriction, and (3) no constriction/transition (BARBOSA; MADUREIRA, 2015; STEVENS, 2000; KENT; READ, 1992). The first phase represents the closure at a particular point along the vocal tract, made by the tongue or the jaw. The second phase is when the closure is released, producing a small burst. The vocal folds during or after the closure interval can be manipulated in order to produce voicing[3]. The third and last phase is related to when there is no closure, and there is a transition to the next segment[4]. In the case of the affricates, they are generally described as a combination of a plosive followed by a fricative (LADEFOGED; JOHNSON, 2014). According to Barbosa and Madureira (2015), as in BP the fricative segment is post-alveolar, the constriction does not occur at the same point of the alveolar plosive, but in the alveolar-palatal point.

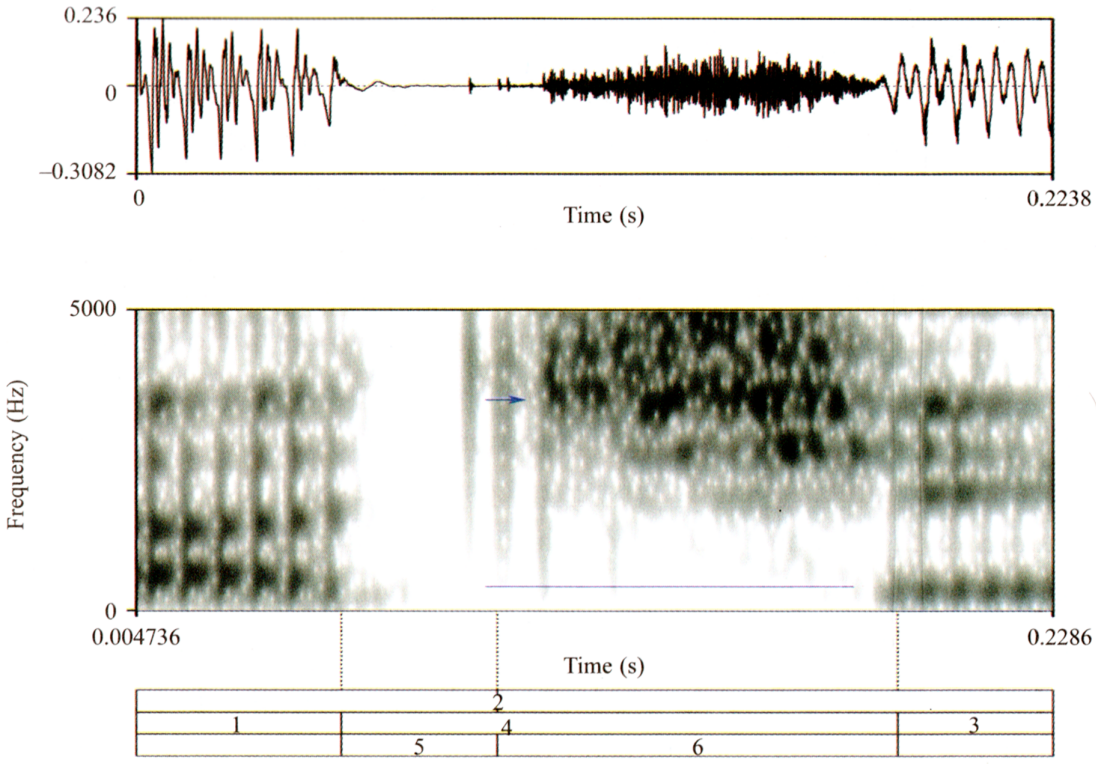
Figure 1 shows the delimitation of an intervocalic voiceless alveolar-palatal affricate. According to Barbosa and Madureira (2015, p. 317), (1) shows the end of the vowel before the affricate; (2) delimits the consonant [tʃ], with 136 ms; (3) is the beginning of the vowel following the affricate; (4) is the beginning of the frication noise from the burst generated by the release; (5) is the closure interval related to the constriction (38 ms); (6) is the frication noise (98 ms); the arrow indicates the region from the frication noise with more energy (around 3700 Hz), and the blue line points to the interval of continuous friction.

Based on the evidence of Silva et al. (2012), the phase to be studied in this dissertation is the 6, which refers to the frication noise from the burst generated by the release. Different from previous works, the palatalization may not be studied here as a dichotomous variable: palatalization and non-palatalization. Instead, the variable is the duration of the frication burst, assumed as a continuous variable, which can be expressed

[3] As this study does not aim at analyzing voiced alveolar plosives and affricates, only their voiceless counterparts will be described.

[4] However, this phase is considered to be part of the vowel (BARBOSA; MADUREIRA, 2015).

Figure 1 – Sound wave, spectrogram, and segmentation tiers of [atʃi], from the pronunciation of *recitativo* "recitative", produced by a BP speaker from São Paulo.



Source: Barbosa and Madureira (2015, p. 317)

in theoretically infinite values. Barbosa (2019) explains that duration is measured from two given points in a spectrogram. In this case, therefore, the duration refers to the two points delimited in Figure 1, as indicated by the phase 6.

The next chapter describes the Native Language Magnet Theory, which underlies the experiments conducted by the present study.

3 Native Language Magnet Theory

The Native Language Magnet Theory (KUHL et al., 1992) suggests that speech perception is warped by mental representations for phonetic categories produced by linguistic experience. Because of the magnet effect, good exemplars of phonetic categories evoke special responses when compared with poor exemplars. It means that perceptual space is shrunk near prototypes and stretched near non-prototypes. They seem to work as a magnet to other stimuli from their category. Kuhl et al. (1992, p. 255) define prototypes as "speech sounds that are identified by adult speakers of a given language as ideal representatives of a given phonetic category". As Kuhl et al. (2007, p. 982) explain, they are "language-specific representations".

The concepts of prototypes and non-prototypes were used by Kuhl et al. (1992) to demonstrate the magnet effect on the speech perception of 6-month-old infants from United States and Sweden. Under similar experimental conditions, they had to discriminate stimuli based on two vowels, /i/ from American English, and /y/ from Swedish. Considering the first and second formants, they elaborated 4 rings with 8 tokens each, for prototypes and non-prototypes. Both groups of infants had to discriminate a total of 32 variants of prototypes and non-prototypes, resulting in 64 stimuli. The study demonstrated that, for American infants, the English vowel was considered to be their prototype, while for Swedish infants it was their non-prototype. On the other hand, Swedish /y/ was considered to be the prototype for Swedish infants, but the non-prototype for American infants. The authors found that, although the distance between each stimulus was controlled, the magnet effect induced infants from both groups to equate the prototype to its variants more often than to the non-prototype and its variants. Therefore, the magnet effect produced by the infants from both countries reveals that, by 6 months, they began to show a specific speech perception pattern based on their native language. In consonance with the NLM theory, it is an evidence that, by 6 months, exposure to a specific language begins to alter infants' speech perception.

With the objective of testing the magnet effect in different contexts, several works have been carried out after the evidence of Kuhl et al. (1992). For example, in addition to experiments with infants, some researchers have attempted to explore the magnet effect on monkeys and on adult speakers of second language. Studies with macaques showed that their discrimination was the same for prototypes variants and for non-prototype variants, suggesting that the magnet effect did not occur in macaques (KUHL; PADDEN, 1982; KUHL; PADDEN, 1983). In terms of adults' perception of second language, Kuhl (1993) argue that the magnet effect does affect their discrimination. Differently from American listeners, enhanced discrimination does not occur at the phonetic boundary between /ra/

and /la/ for Japanese listeners. The authors argued that it occurs because this distinction is phonemic in English and only phonetic in Japanese. Therefore, prototypes of a native language are assimilated by the magnet effect, while segments of other language are treated as non-prototypes for the native language.

Kuhl et al. (2007) reviewed the NLM model and listed five basic principles underlying it, which are are: (i) *Distributional patterns and infant-directed speech are agents of change*. From this perspective, distributional differences in input and 'motherese' can explain infants' language-specific perception; (ii) *Language exposure produces neural commitment that affects future learning*. Conforming to it, native language exposure produces physical changes in neural tissue and circuity, which affects the learning of the phonetic scheme of a new language; (iii) *Social interaction influences early language learning at the phonetic level*. NLM shows that, in natural and complex language learning situations, infants need a social tutor to learn, since the tutor emphasizes relevant information; (iv) *The perception–production link is forged developmentally*. The theory stipulates that speech production is developed after speech perception; and (v) *Early speech perception predicts language growth*. At 6 months of age, the speech perception patterns of typically developing infants can explain their linguistic development over the next 18 months.

The NLM model differs from other models in terms of the perceptual framework. For Kkese and Karpava (2019, p. 73), "their main difference is whether perceptual mechanisms operate on acoustic or articulatory information". They explain that the Perceptual Assimilation Model (BEST, 1995) focuses on articulatory phonology and the Speech Learning Model (FLEGE, 2005) on phonetic similarity (but not on individual phonemes). On the other hand, the NLM model addresses the perceptual framework based on relevant acoustic cues, what seems to be more suitable for the purposes of the current dissertation.

For the palatalization of alveolar plosives in BP, the prototype would depend on the dialect of the individual. If in the dialect of a given individual /t/ is hardly ever produced as [t], then [t] would be the non-prototype, whereas [ʧ] would be the prototype, since the latter is expected to be the ideal representative of such phonetic category. On the other hand, if in the dialect /t/ is hardly ever produced as [ʧ], thus [ʧ] would be the non-prototype, whereas [t] would be the prototype. Therefore, assuming that the duration of the frication burst of two stimuli for each category (prototype or non-prototype) differ equally (for example, 10 ms of difference in both prototype and non-prototype conditions), what means that the difference between the stimuli is the same for both categories, individuals would have their perceptual space distorted depending on the phonetic category of the stimuli. In case they are prototypes, the NLM theory predicts that the perceptual space is shrunk, what induces listeners to have a poor discrimination, when comparing with non-prototypes. On the other hand, in case when the stimuli are non-prototypes, the perceptual space is stretched. Thus the difference becomes more salient, what implies that listeners will have

a better discrimination regarding acoustic differences.

Therefore, considering that the NLM theory draws upon acoustic differences, it seems to be an adequate model to explain the gradient of frication bursts of /t/, which is the present object of study. The following chapter investigates this issue and demonstrates that the referred duration seems to be a productive clue to explain the palatalization in terms of acoustics. This experiment may support and encourage future studies that aim at analyzing the magnet effect related to palatalization, since it provides an acoustic description of the palatalization considering this parameter.

4 An acoustic analysis on the duration of /t/ frication bursts

4.1 Introduction

As previously shown, probably the palatalization of alveolar plosives /t/ and /d/ before /i/ is one of the most investigated phonetic-phonological processes in Brazilian Portuguese. This variable was broadly described in a large number of dialects in Brazil, such as in Flores da Cunha (BATTISTI; FILHO, 2012), Alagoinhas (HORA, 1990a), Maceió (SANTOS, 1996) and João Pessoa (HORA, 1997; HENRIQUE; HORA, 2012; HORA; HENRIQUE; AMORIM, 2018; AMORIM et al., 2019; AMORIM et al., 2019). However, most of the works analyzed this process from impressionistic methods.

The impressionistic methods adopted by those studies are currently related to "[...] the idea of the phonetician relying entirely on his own impressions of sound, unaided by technology", as argues Hayward (2000, p. 2). According to her, although they are fundamental to experimental phonetics, they are "limited by the capabilities of the human senses" (HAYWARD, 2000, p. 6). The core problem of this approach is that it can not take into account some details in speech that can provide more information on variation, since it "focusses on the positions and movements of the speech organs involved in the production of individual speech sounds" (HAYWARD, 2000, p. 3). For example, Pozzani and Albano (2016) investigated the palatalization in BP from a different perspective of the above-mentioned studies. They studied the effect of language contact on the palatalization in BP. From the analyzes of the four spectral moments (mean, standard deviation, skewness and kurtosis) of /t/ and /d/'s frication bursts, the authors demonstrated that there were different stages of palatalization. Their participants tended to accommodate it as long as they were exposed to a new dialect. The major difference of this research is that they examined the palatalization not as a categorical and dichotomous variable (alveolar plosive or affricate), but as a quantitative variable that can be observed in different stages. Therefore, although experimental analysis of the palatalization in BP has received limited attention, it can extend the understanding of this variable, what contributes to the literature.

In that context, the current study aims at expanding the knowledge on the palatalization in BP, treating it as a quantitative variable and using an experimental method. Differently from Pozzani and Albano (2016), the duration of the /t/ frication burst is the current object of study, instead of the the four spectral moments. The reason is twofold. The first is that it is the first time that the palatalization is investigated in BP focusing

on the duration of the burst, and the second is simplicity. Instead of using four dependent variables, this research uses only one. However, this study is limited to analyze only the palatalization of /t/. Using its counterpart would double the time of the experiment, what may affect listeners' responses. Further research should analyze the /d/ to better understand the palatalization in its complexity.

For the current study, individuals from speech communities where /t/ is usually palatalized (called non-natives) and those from where it is usually not palatalized (called natives) were recorded in order to have their speech investigated. They were male and females from 18 to 30 years old, academic students, who were living in João Pessoa during the data collection. The natives are from João Pessoa, and had never lived in a speech community where people often palatalize, whereas the non-natives were living in João Pessoa, but were born and lived most part of their life in cities where the use of palatalization is almost categorical.

Given that prior research reveals that the palatalization is produced in different rates in Brazil (CARDOSO et al., 2014), the main hypothesis is that both groups differ in terms of the duration of /t/ frication bursts. In relation to this hypothesis, there is a large number of study that corroborates with that, even assuming that they treated the palatalization as a dichotomous variable. However, since there is a lack of studies that intend to acoustically measure that difference, this study is the first to explore the palatalization in terms of duration. In relation to the specific hypotheses, the first is that the frication burst duration of /t/ depends on the Gender of the speaker. This is based on the literature regarding palatalization in João Pessoa, which found that the Gender influences the use of palatalization (HORA, 1997; HENRIQUE; HORA, 2012). The second hypothesis is based on studies on language in contact, for example, Pozzani and Albano (2016), and on NLM theory (KUHL et al., 2007), which claims that the language exposure affects the language use. The hypothesis is that the frication burst duration of /t/ depends on the years lived in the community[1] of João Pessoa for the individuals who lived most of their life within a speech community where the palatalized variant is the most frequent one.

[1] Although it is exposition to dialects that affects language, instead of solely the `time`, the years that individuals lived within the speech community were used in this study to quantify language exposure given that this is one of the most convenient methods to address this problem. Evidently, more complex studies should be carried out if they are interested in exploring with more robustness the complexity of language exposure.

4.2 Methods

4.2.1 Location and participants

This study was conducted at Universidade Federal da Paraíba, in João Pessoa - Paraíba, Brazil, in 2019. Ten participants had their speech production analyzed. They were 4 male and 6 female native speakers of BP, academic students, from 20 to 30 years old, and with normal hearing. Five are "natives", individuals who were born and have always lived in JP, and five are "non-natives", who live in JP, but were born and used to live in any Brazilian speech community where people most often palatalize the alveolar plosives /t/ and /d/. Each group had two males and three females participants. Table 1 presents the participants' distribution.

Table 1 – Participants by Gender and Nativeness.

Nativeness	M	F	Total
Native	2	3	5
Non-native	2	3	5
Total	4	6	10

Note: M = Male. F = Female

Source: Elaborated by the author.

Given that there was a lack of works regarding the palatalization of /t/ in BP that explored the frication burst duration, the current study also aimed at investigating the effect of the years lived in João Pessoa on the palatalization. Table 2 shows the frequency of the non-native individuals that were recruited by Gender and according to years lived in the community.

4.2.2 Data collection

Data were collected in a sound-attenuated booth at UFPB with noise below 20 dB SPL. They were recorded using Praat (BOERSMA; WEENINK, 2019), in a sample frequency of 44.1 kHz and 16-bit quantization, with the Sennheiser E-835 recorder connected to the Behringer UMC 202 HD audio interface. The recordings comprised the production of words embedded in the carrier sentence "digo t*V*.pa baixinho" (I say 'tV.pa in low voice) (BARBOSA; MADUREIRA, 2015), where *V* is /a, ɛ, i, ɔ, u/, stressed vowels of Brazilian Portuguese. The words that they had to read, at a normal speech rate, were "tapa, tepa, tipa, topa, tupa". The vowels besides /i/ were the fillers. 5 sentences were presented at random, in 10 blocks (each one with the five sentences, showed at random),

Table 2 – Non-native participants by Gender and Years lived in João Pessoa.

Participant	Gender	Years
P1	M	1
P2	M	2
P3	F	2
P4	F	5
P5	F	11

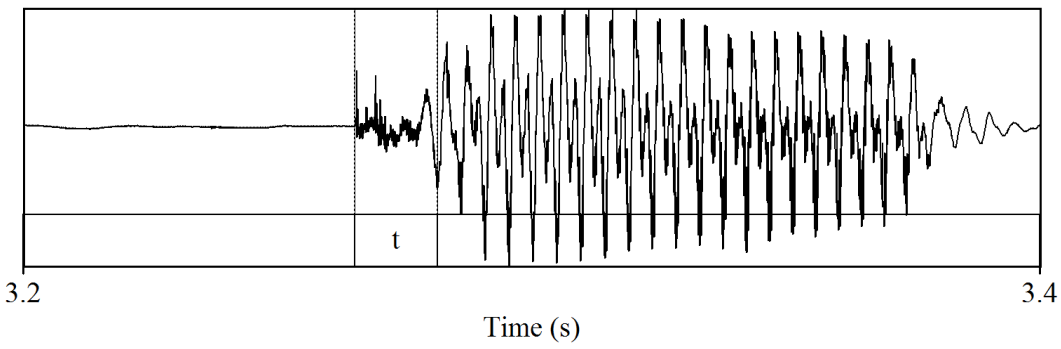
Note: P = Participant. M = Male. F = Female.

Source: Elaborated by the author.

on a laptop screen, through the booster's window. In order to induce participants to read, each sentence appeared in a different spot on the screen. The total duration of data collection for each participant was 15 minutes, on average. As each participant produced 50 tokens, a total of 500 observations was gathered (100 target words and 400 fillers).

Then, for all tokens, each burst was labeled manually in Praat (BOERSMA; WEENINK, 2019), as shown in Figure 2, and its duration value in milliseconds was extracted automatically, using the *duration_multiple* script (ARANTES, 2008).

Figure 2 – /t/ sound wave and segmentation.



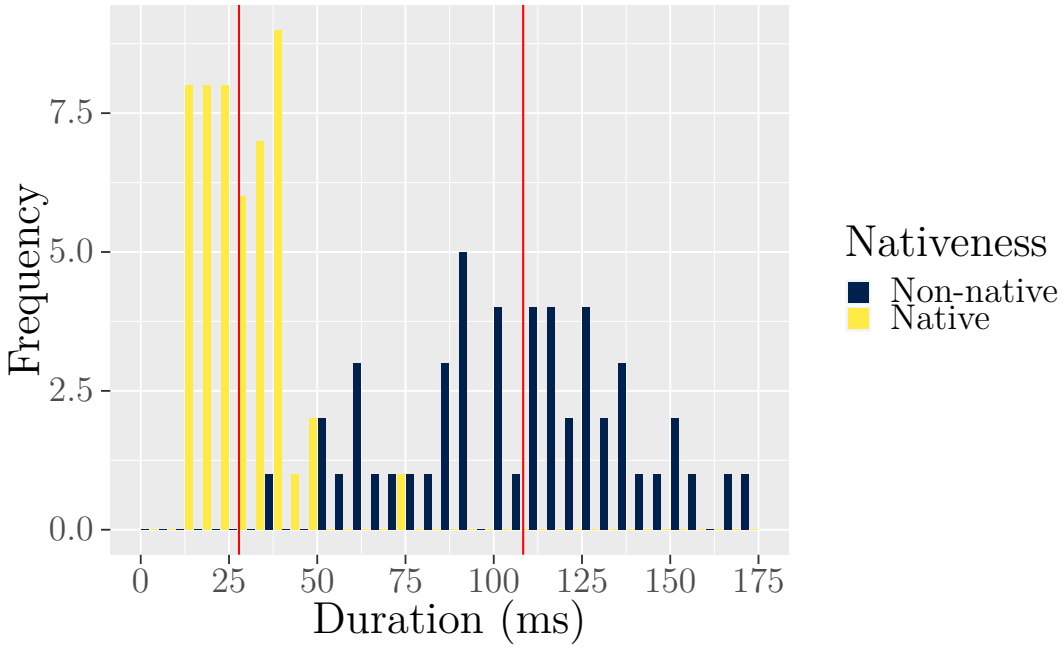
Source: Elaborated by the author.

After data collection, R (R CORE TEAM, 2019) was used to perform statistical tests, to estimate models, and to plot graphs. Generalized Linear Mixed models were fit using the *glmer* function, from the *lme4* package (BATES et al., 2015). The significance level adopted for all statistical tests was at 0.05.

4.3 Results

General results show that the duration of /t/ bursts differed significantly when comparing data from natives and non-natives. Figure 3 reports raw values of /t/ burst durations according to Nativeness. Although around 30 ms there is an overlapping of tokens for *native* and *non-native*, the values differ considerably. The red lines indicate the mean for each group: 27.82 for native and 108.34 for non-native. Another visual aspect of the histogram is that its shape suggests that both distributions are not normal, what would require non-parametric tests for inferential analysis. The histogram also indicates that the variability of the tokens produced by the speakers who are expected to use the palatalized form ($SD = 31.9$) is much greater than of the members from speech community of João Pessoa ($SD = 12$). Moreover, an outlier of 74 ms shows that a *native* read the nonce word using the palatalized form[2].

Figure 3 – Histogram of /t/ duration according to *Nativeness.*



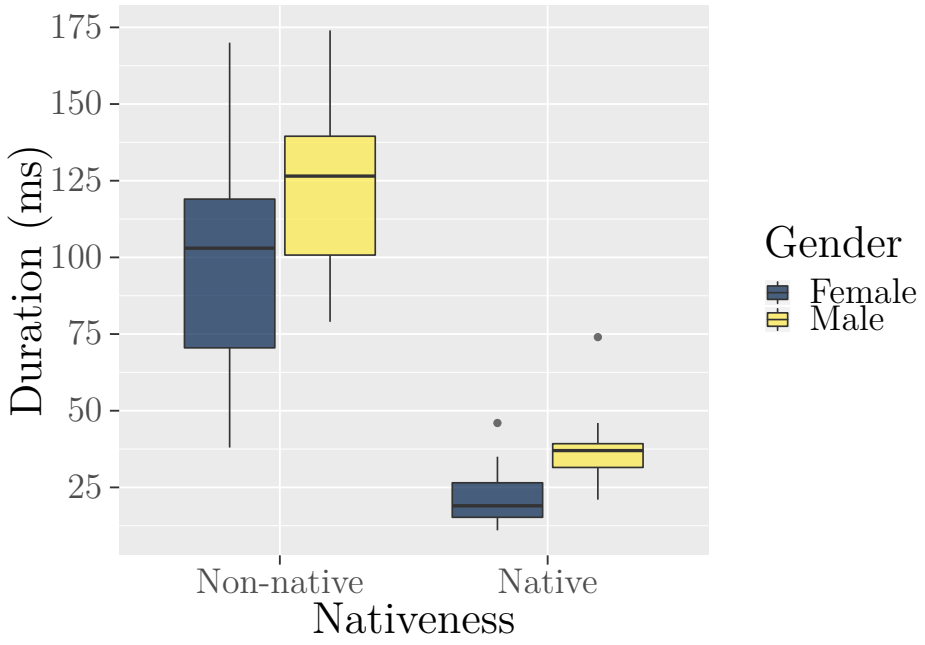
Source: Elaborated by the author.

The inferential analyses reveal that the duration of the /t/ frication bursts differed substantially according to the two groups. This was confirmed by a Mann-Whitney test, performed after normality tests. The Shapiro-Wilk normality tests were conducted for both groups, indicating that the distribution for native's data is not normal ($W = 0.90649$, $p < 0.05$), while the non-native one is normal ($W = 0.98665$, $p = 0.8397$). For the violation of normality, data from natives have to be analyzed using non-parametric tests, while from

[2] Given that it is an authentic production, this outlier was not deleted in the analysis.

non-natives using parametric tests. To infer if data come from different distributions, a Mann-Whitney test ($U = 2484.5$, $p < 0.05$) indicated that, as expected, the burst duration differed significantly for native ($Mdn = 27.5$) and non-native ($Mdn = 111.5$) participants.

Figure 4 – Boxplot of duration by Gender and Nativeness.

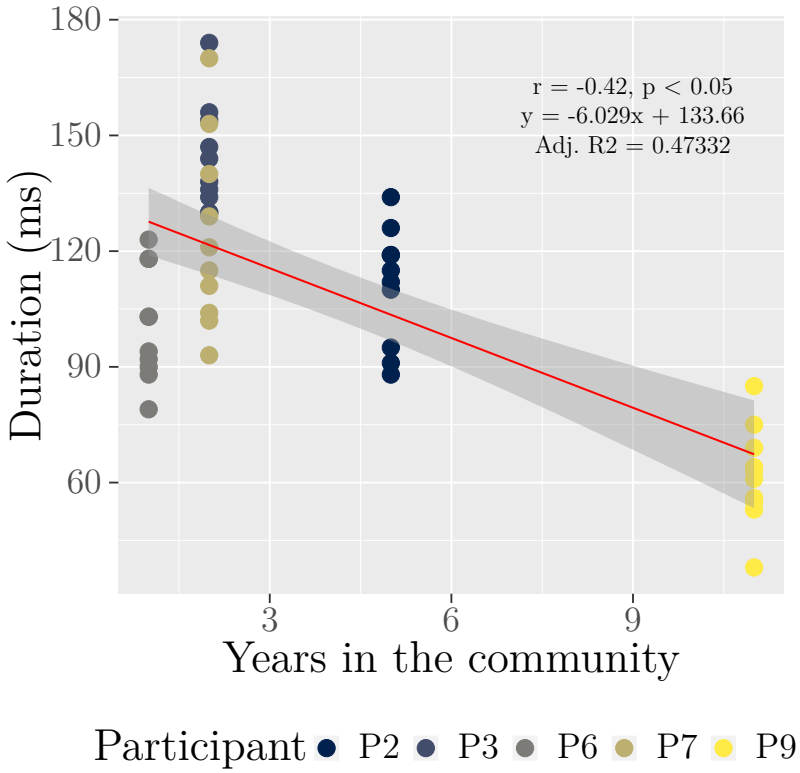


Source: Elaborated by the author.

Another variable that affected the burst is Gender. The results from the current experiment reveal that the duration differed depending on the Gender of the participant, what is consistent with the above-mentioned hypothesis. As illustrated in Figure 4, in both groups, the female participants had shorter duration than the male ones. When comparing mean differences related to duration, the Mann-Whitney test indicates that the burst differed significantly for native male ($Mdn = 37$) and female ($Mdn = 19$) participants ($U = 63.5$, $p < 0.05$), the same for the Two Sample t-test (t (48) = 2.7275, p < 0.05) for non-native male ($M = 122.55$) and female ($M = 98.86$) participants. Although mean differences were observed, no considerable difference between the groups was found in terms of the variability. A Levene's Test for Homogeneity of Variance ($F = 0.0225$, $p > 0.05$) shows that there is evidence that all variances are equal for native male and female participants, and a F test to compare two variances indicates that the assumption of homoscedasticity is not violated for non-native (F(29, 19) = 1.5039, p > 0.05) male and female participants. This result reveals that male and female participants from both groups varied similarly.

In terms of Years in the Community and Duration, a Spearman's rank correlation test indicates that there is a statistically significant negative correlation between the two

Figure 5 – Correlation and regression line for Duration by Years in the community.



Source: Elaborated by the author.

variables (r = -0.42, p < 0.05). According to the model of Figure 5, the burst duration tends to be shortened as long the years the individual lives in the community. This data should promote a higher variability in speech perception results, since participants from this group are stratified according to different levels, instead of having the same characteristics.

Table 3 – Linear regression model.

Predictor	Estimate	Std. Error	t value	p
Intercept	141.23	5.80	24.32	< 0.001
Year	-7.06	0.82	-8.60	< 0.001
GenderMale	-83.93	13.23	-6.34	< 0.001
Year*GenderMale	50.562	7.570	6.680	< 0.001

R^2 = 0.74. Year = years living in the community

Source: Elaborated by the author.

In order to predict the effect of year of living in the community, gender, and their interaction on /t/ burst duration, considering that the assumptions of normality, homoscedasticity and independence were not violated, a linear model was fit to the duration of participants. With the reference value "Female" for Gender, the model in Table 3 reports

a significant influence of all predictors on the response variable. Explaining 74% of the variability of duration around its mean, according to the model, among female speakers, every additional year of living in the community is associated with a -7.06 decrease in the duration of /t/, on average. Gathering data from probability sampling, with a satisfactory sample size and representativity, it would be possible to predict a more accurate estimation for those predictors.

4.4 Discussion

The statistical analyses of the current speech production experiment confirmed the main hypothesis of this research. The duration of the /t/ frication bursts in BP is affected by language exposure, assumed here by having the participants lived most part of their life where people palatalize more frequently (non-natives) or having always lived in João Pessoa, where the use of the palatalization is almost absent (natives). This implies that there is enough statistical evidence to state that the two groups assumed in this research are really two different groups, distinguished here in terms of the palatalization. This finding is in line with a comparison that is possible to make from several studies on the palatalization that were carried out in BP. Although they analyze a single dialect and assume the palatalization as a dichotomous variable (HORA, 1997; ABAURRE; PAGOTTO, 2002; BATTISTI et al., 2007; BATTISTI; ROSA, 2012; HENRIQUE; HORA, 2012; AMORIM et al., 2019), it is possible to compare them and note that the palatalization is distributed in different rates in Brazil. When the dialect spoken in the capital of the Brazilian states is compared, according to Cardoso et al. (2014), the palatalization is not the most representative variant only in four capitals, what includes João Pessoa.

The distribution of the data illustrated in Figure 3 contributes to the literature on palatalization when it reveals that within the categories *alveolar plosive* and *affricate* there are theoretically infinite variants, since they can assume infinite values in the axis of duration (for example: 21.1 ms, 21.11 ms, 21.111 ms, 21.1111 and so son). This conclusion is similar to the one that can be drawn from the study of Pozzani and Albano (2016), which found differences when investigating the palatalization in terms of quantitative and numerical variables (the four spectral moments). Different from the analyzes based on a dichotomous variable, the perspective adopted here can reveal different stages of a variable. For example, Figure 3 shows the mean of the burst duration for each group, which is 27.82 ms for natives and 108.34 ms for non-natives. The distribution of the non-natives includes durations from 50 ms to 70 ms. If those productions were treated as a dichotomous variable, probably they would be categorized as affricates. However, they are considerably distant from those around the mean, which would be still categorized as affricates. The speech of the one whose palatalization is distributed around the 50 to 70 ms is much more similar to the one whose palatalization distribution is around the mean. Therefore, the

current research demonstrates that the palatalization of /t/ can be observed by means of its acoustic details (as in Pozzani and Albano (2016)) and is motivated by group differences that can be found when the duration of the /t/ frication bursts is examined.

The description of acoustic cues related to the palatalization is relevant even to speech perception. For example, regarding the NLM theory, Kuhl (1991) revealed that the variants of /i/ indicated as prototypes matched the average acoustic production of that vowel. Given that no research to date has investigated the palatalization in BP focusing on the frication burst duration, this study contributes to future researchers who intend to explore this process considering that acoustic cue. Another consideration on speech perception is that the current findings may anticipate some trends in respect with experimental analysis. From Figure 3, it is possible to suggest that the difference between an expected alveolar plosive and an expected affricate before [i] might be ambiguous. Note that around 40 ms the values from both groups are distributed very close and less frequent. It implies that the phonetic boundary seems not to be so clear when comparing the speech of both groups, since some productions of a group are very close to the ones from the other group. It may be expected that listeners will have some difficulty in interpreting whether the speaker aimed at an plosive or affricate, especially when the burst from the stimulus is around 50 ms. Therefore, the stimulus with the burst around that duration may be much more misunderstood, comparing with the ones in which duration is around the mean.

This study also demonstrates that the duration of the bursts depend on the participant's Gender, what confirms the hypothesis previously stated. The female native and non-natives had shorter duration than the male ones. This difference was expected since the literature on palatalization suggests that there is Gender differences regarding its use (HORA, 1997; HENRIQUE; HORA, 2012; BATTISTI; FILHO, 2015). The relevance of this research is that it found differences not in the occurrence or not of the palatalization, as prior studies did, but in the duration of the frication bursts. Although the lower the duration the closer to an alveolar plosive the /t/ is, it is not possible to assume that the female participants produce a /t/ that is closer to an alveolar plosive, when compared with the male one, since listeners seem to normalize speech. Also, although this study found strong evidences that language exposure affects the duration of the bursts, it is still not clear if this difference is due to gender, that is, because of the social role the female participants are influenced to speak in a given way, or to biological differences, that is, something related to their vocal apparatus which is what affects the duration, or even due to both. Given that duration is characterized as a time interval between two related events, it is not possible from this study to further explain this difference, since it is a confound variable. Probably duration is related to frequency, and it is determined by the vocal folds.

The Spearman's rank correlation found a significant linear relationship between Years in the Community and Duration. The negative correlation shows that the more

the years in João Pessoa the non-natives lived, the shorter was the duration of their /t/ frication burst. The strength of the correlation would be stronger if more diverse data were collected, since a more representative result would be found. Moreover, this correlation results from a confounding variable, the language exposure, which is defined by Gries (2013) as a variable that is correlated with a dependent and an independent variable. In this case, it is not simply the years that an individual spend in a given place that will affect his or her language, but the linguistic experience that he or she had with speakers from that place. Thus, language exposure may be correlated with the Years in the Community, since, the longer individuals live in a given place, the more they will tend to be exposed to the language from that place, and also correlated with the duration of the bursts, since individuals will be inclined to accommodate their speech according to their language exposure[3]. This is consistent with the literature on dialects in contact (TRUDGILL, 1986), which highlights the role of language exposure. For example, Chacon (2012) reported the effect of the years that speakers from São Paulo spent in João Pessoa on the palatalization of /S/ in medial coda when it precedes an alveolar plosive. She found that those speakers tended to palatalize more often as long as the years they lived in João Pessoa. Therefore, this research adds further details to the literature on the role of language exposure on the duration of /t/ frication bursts.

4.5 Summary, limitations, and future research

This experiment found that the duration of the frication burst of /t/ before /i/ depends on speakers' language exposure (assumed here by the years lived in João Pessoa) and on their Gender. The distribution of that duration was described and analyzed from data of individuals who have always lived in João Pessoa (natives) and from those who lived most part of their life where people palatalize most frequently, but were living in João Pessoa during data collection (non-natives).

From the data obtained in this experiment, substantial differences between natives and non-natives were demonstrated, what corroborates with the main hypothesis. As expected, the natives produced /t/ with lower duration of frication burst than non-natives. Regarding the specific hypotheses, the current study found differences related to Gender. In both groups, the female speakers produced /t/ with a lower duration. With relation to the years lived in the community, this study demonstrates that the longer the speakers lived in João Pessoa, the more similar was their production of /t/ to the individuals from that community.

Although this study was limited by the sample size, it provides helpful insights with respect to speech perception experiments that focus on the palatalization under analysis.

[3] In order to account for this complexity, future studies should look for different methods to measure language exposure.

The description and comparison of /t/ before /i/ between both groups is pivotal for those experiments, given that they require this information to generate or manipulate stimuli and to test their hypotheses. Therefore, assuming that speakers use that acoustic clue in discriminating their speech, future studies should investigate the role of that acoustic clue on speech perception.

5 Same or different? The effect of listeners' dialect on the discrimination of the palatalization of /t/

5.1 Introduction

This research aims at analyzing the role of language exposure on the discrimination of the palatalization of the alveolar plosive /t/ in Brazilian Portuguese (BP), which is triggered by a following /i/ (AMORIM et al., 2019). This process occurs in words like *tia* 'aunt' and *dia* 'day', which can be produced as an alveolar plosive or an affricate. Prior studies reveal that in João Pessoa, unlike most cities in Brazil, the /t/ is hardly ever palatalized in spontaneous speech (HORA, 1997; HENRIQUE; HORA, 2012; AMORIM et al., 2019; AMORIM et al., 2019). According to Cardoso et al. (2014), besides JP, only in other 3 capitals of the Brazilian states the palatalization is not the most used variant, what reveals the singularity of the dialect spoken in that city. Taking these findings into consideration, a comparison is made with two groups: natives and non-natives. The first group is composed of individuals who have always lived in JP, the capital of Paraíba, in Brazil. The second group, the non-natives, is composed of individuals who have lived most of their life in a city where the palatalization is the most used variant.

For the discrimination task, the stimuli were pairs of tokens of the nonce word /tipa/, with the duration of the /t/ frication burst in a ten-step continua that were acoustically manipulated. The tokens varied only in terms of the burst, which differed in approximately 5 ms when compared with their closest neighbor stimulus[1]. The first token from the continua had 15 ms, while the last one had 60 ms of that burst. They were combined with each other, what resulted in 55 different stimuli.

The main hypothesis is that there is an association between the variable Nativeness and the responses from the discrimination experiment. This is based on the assumption that language exposure affects speech perception, as predicts the Native Language Magnet Theory (KUHL et al., 1992). According to that theory, exemplars of phonetic categories exert a warping effect over the variants that surround them in acoustic space, depending on if they are good exemplars (called prototypes) or poor exemplars (non-prototypes) (IVERSON; KUHL, 1996). The perceptual space related to those exemplars is expected to be shrunk near good exemplars and stretched near poor exemplars. Given that prototypes

[1] Given that there was no study to date to investigate the palatalization of alveolar plosives in Brazilian Portuguese (BP) from the duration of the frication bursts, this was decided arbitrarily.

are defined as "speech sounds that are identified by adult speakers of a given language as ideal representatives of a given phonetic category" Kuhl et al. (1992)[p. 255], the tokens from which the /t/ frication burst has the lowest durations are assumed to be prototypes for natives and non-prototypes for non-natives, while the ones with the burst that has the highest durations are assumed to be prototypes for non-natives and non-prototypes for natives. The natives are expected to indicate more frequently that there is no difference in a pair of stimuli when the two tokens are alveolar plosives, which would be their prototype, and that there is a difference when the tokens are affricates, which would not be their prototypes. Unlikely, the non-natives are expected to indicate that there is no difference when the two tokens are affricates, which would be their prototypes, and that there is a difference when the tokens are alveolar plosives, which would not be their prototypes.

The findings from this research contribute to the literature on palatalization in BP when it addresses this process in terms of speech perception, instead of speech production. Although the palatalization has been investigated by a large number of studies in Brazil, their focus is mostly on speech production, instead of also taking speech perception into consideration. Moreover, since the alveolar plosive variant of /t/ is not regular in most part of Brazil, it is relevant to study it from the effect of language exposure on listeners' speech perception, especially when considering the NLM theory.

5.2 Methods

5.2.1 Location and Participants

In order to elaborate the stimuli to the discrimination experiment, a female speaker was recorded in a sound-attenuated booth at Universidade Federal da Paraíba (UFPB), in JP, in 2019. She was an academic student, from 20 to 30 years old, native speaker of BP, and have always lived in João Pessoa. Since she was used for that task, she did not respond to the discrimination experiment.

The discrimination task was performed in a silent room at UFPB, in JP, in 2019. The individuals who responded to it were ten academic students (4 male and 6 female), native speakers of BP, from 20 to 30 years old and with normal hearing. Five were called "natives", individuals who were born and have always lived in JP, and five "non-natives", those who live in JP, but were born and lived most part of their life in any city in Brazil in which the palatalization is the most regular variant of /t/. In each group there were two male and three female participants.

5.2.2 Stimuli

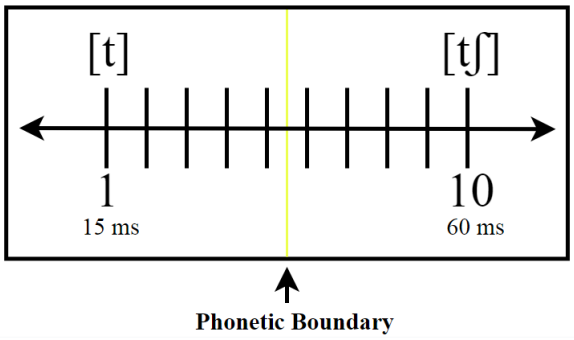
The female additional participant was recorded producing words embedded in the carrier sentence "digo t*V*.pa baixinho" (I say 'tV.pa in low voice) (BARBOSA; MADUREIRA, 2015), where *V* is /a, ɛ, i, ɔ, u/, stressed vowels of Brazilian Portuguese. The words "tapa, tepa, tipa, topa, tupa" were read at a normal speech rate. The words with vowels besides /i/ were the fillers. The data were gathered in the sound-attenuated booth with noise below 20 dB SPL. Praat (BOERSMA; WEENINK, 2019) was used to record in a sample frequency of 44.1 kHz and 16-bit quantization, with the Sennheiser E-835 recorder connected to the Behringer UMC 202 HD audio interface. She read 5 sentences in each of 10 blocks, randomly presented on a laptop screen through the booster's window. In order to induce the reading, instead of memorizing, each sentence appeared in a different spot on the screen. This procedure lasted 15 minutes and resulted in 50 observations, from which 10 were used to elaborate the stimuli.

After collecting data for the stimuli, one token was selected and copied 10 times, in order to be manipulated for the ten-step continua of burst duration, resulting in 10 identical tokens. Those tokens were the isolated /tipa/, which is what participants have to listen to in the discrimination task. Using Praat (BOERSMA; WEENINK, 2019), tokens of /tipa/ produced by female speakers that participated in the the experiment described in chapter 4 were selected and isolated, based on a continua from 15 to 60 ms. Those tokens were collected under similar experimental conditions to the procedure followed with the female additional participant. Then, each token's burst from the additional participant was replaced by the isolated bursts from those female speakers, resulting in 10 different tokens with ten-step continua of burst duration, having 5 ms of difference for each interval. The selection of the signal related to the frication burst was the same as described in the labeling process for the speech production experiment. The first token had 15 ms of frication burst and the last one had 60 ms. Also, the initial 5 steps were assumed to be variants of [t], while the others [tʃ], as shows Figure 6. As the rest of the signal was preserved, the unique difference between each continua was the frication burst. After elaborating the tokens, their amplitude were automatically normalized using a script written by the author, with the function *normalize*, from the package *tuneR* (LIGGES et al., 2018) in R (R CORE TEAM, 2019).

Figure 21 illustrates sound waves of [t] tokens and Figure 22 the [tʃ] ones. They are both in section 10.

After collecting all data from the experiment, a technical problem was found, what resulted in the elimination of the token 3. The third token, expected to have a 25 ms of frication burst, was wrongly replaced. Instead, it had the same burst as token 1, 15 ms, as shows Figure 21. Therefore, for this technical problem, token 3 was excluded in data analysis from this study. It means that all stimuli from the experiment that had the token

Figure 6 – Degree of frication burst and the phonetic boundary between [t] and [tʃ].



Source: Elaborated by the author.

3 in one of their pairs were excluded. Although they were not included in analysis and results, and as this issue was realized late, all procedures regarding this token are here be described.

The stimuli used in the discrimination test were the tokens combined with each other, except when the combination occurred twice, example: "2,1" and "1,2"; in this case, only one was used. Moreover, repeated tokens were used, like "1,1", "2,2", "3,3" ... "10, 10". This procedure resulted in 55 stimuli (10 + 9 + 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1). Given that the problem regarding token 3 was realized only after the data collection related to this experiment, the experiment was run with all pairs of tokens. The pairs with the token 3 were not included in the data analysis.

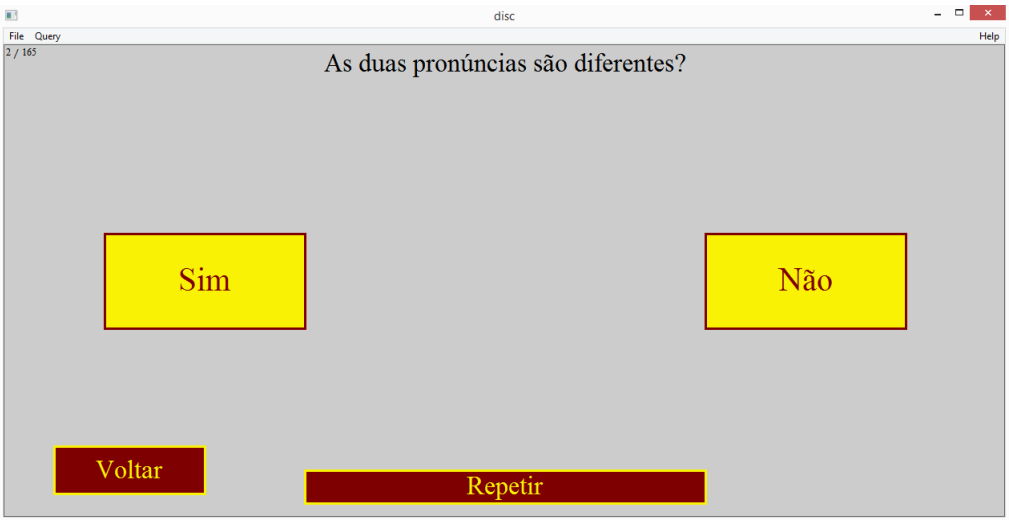
5.2.3 Data collection

The experiment was performed using an Asus X200M laptop, with an AKG K414P headphone. In a forced-choice task, they had to click on a button (yes or no) in order to answer the question: *As pronúncias são diferentes?* "Do the pronunciations differ?". Stimuli were presented at random, using the Praat script *ExperimentMFC 7*[2], which was modified by the author. The script was programmed to add intervals of 0.5 second of silence in the beginning, middle and end of stimuli. Each one was presented 3 times, resulting in 165 observations (55 x 3) for each participant. The total number of observations was 1650. Figure 7 shows the screen of the discrimination test. Before starting, each participant responded to a training test, an experiment that was similarly to the main one, in order to be familiar with the main experiment. After responding to a test with 10 stimuli, which were not included in the main test, the main experiment was performed. As shown in Figure 7, participants had to listen to two pronunciations of /tipa/ and had to indicate whether pronunciation were different (*Sim*) or not (*Não*). The following stimulus played

[2] A model for this script can be accessed in: http://www.fon.hum.uva.nl/praat/manual/ExperimentMFC.html

automatically after clicking on button. They could return (*Voltar*) to the previous stimulus or repeat (*Repetir*) it whenever and as much as they want. After 50 stimuli, they were encouraged by a message on the screen to have a break if they wanted. The total duration of this test was 18 minutes, on average.

Figure 7 – Screen from the discrimination test.



Source: Elaborated by the author.

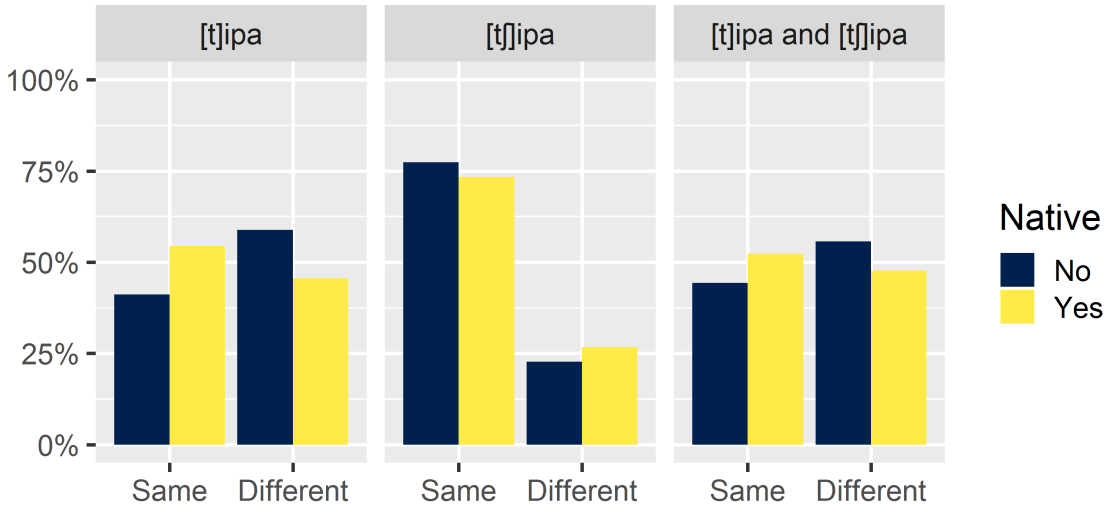
R (R CORE TEAM, 2019) was used to conduct the statistical analyses, adopting the significance level for all tests at 0.05.

5.3 Results

Figure 8 reports response percentages according to Nativeness, for different set of stimili. *[t]ipa* (n = 180) were pairs of stimuli from 1 to 5 degrees of /t/ frication burst duration, *[tʃ]ipa* (n = 300) from 6 to 10, and *[t]ipa and [tʃ]ipa* (n = 600) pairs of stimuli of [t]ipa with [tʃ]ipa. In percentage, when comparing [t]ipa with [tʃ]ipa, non-natives demonstrated more accuracy than natives. However, although the magnet effect seemed to distort listener's perception of auditory distance for prototype stimuli, Pearson's Chi-squared tests with Yates' continuity correction indicated that there was no significant response difference according to Nativeness, for *[t]ipa* (χ^2 (1) = 2.6942, p > 0.05), *[tʃ]ipa* (χ^2 (1) = 0.44846, p > 0.05), and *[t]ipa and [tʃ]ipa* (χ^2 (1) = 3.5306, p > 0.05) stimuli.

To look for evidence of the magnet effect, Figure 9 considers [t] as a prototype for natives and a non-prototype for non-natives, while [tʃ] as a non-prototype for natives and a prototype for non-natives. Thus, only pairs of variants of [t] or [tʃ], instead of [t] *and* [tʃ] were considered (n = 480). In percentage, data reveal that prototype targets were equated more often (68.8 %) than non-prototypes (61.3 %), suggesting the expected trend that in

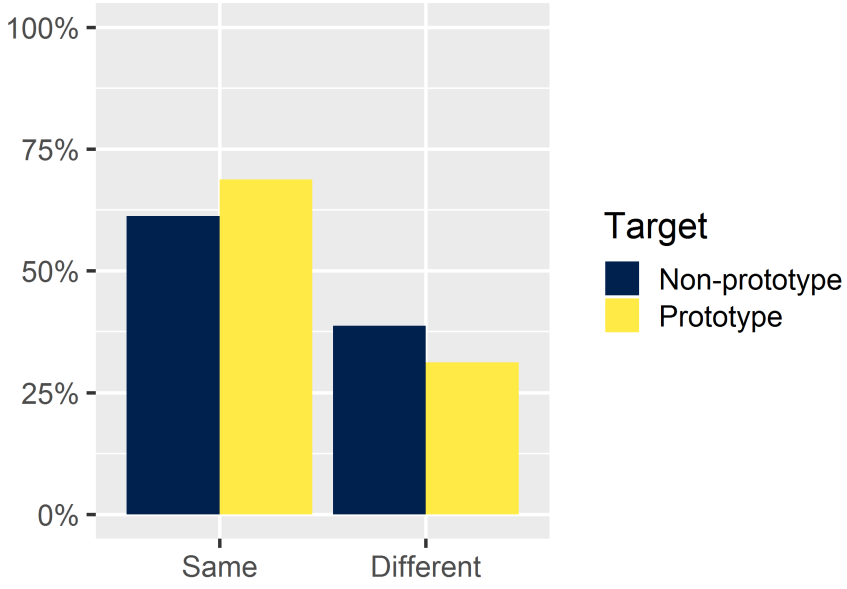
Figure 8 – Percentage of responses according to Stimuli and Nativeness.



Source: Elaborated by the author.

speech perception prototype stimuli tends to attract their variants. However, a Pearson's Chi-squared test with Yates' continuity correction reveals that this difference is still not statistically significant (χ^2 (1) = 2.6465, p > 0.05).

Figure 9 – Percentage of variants equal to target according to Target.

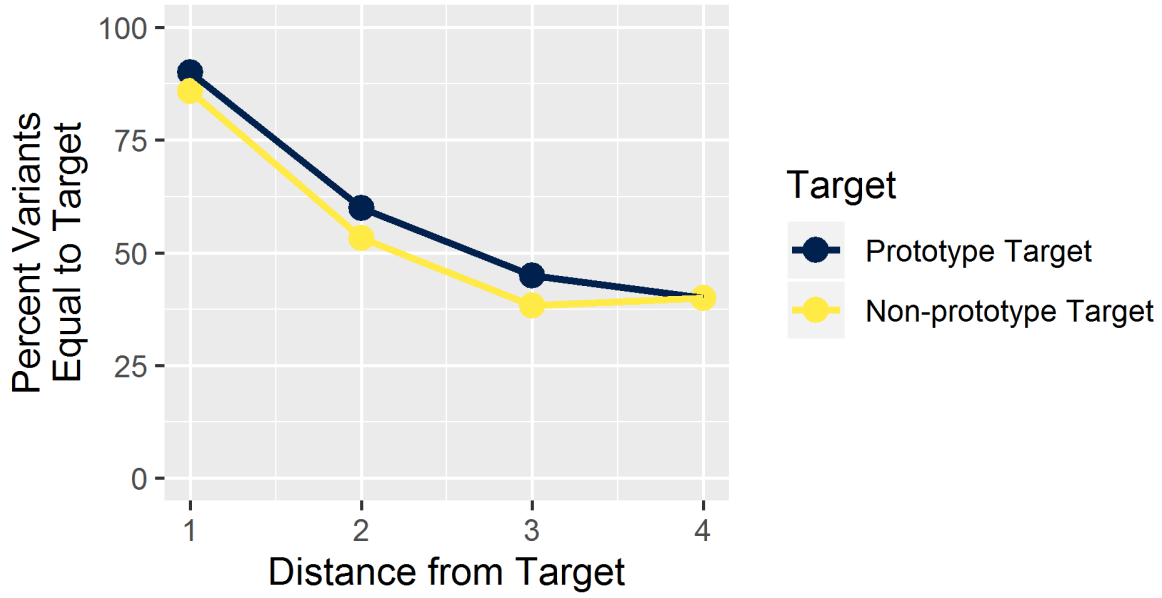


Source: Elaborated by the author.

A Pearson's Chi-squared test with Yates' continuity correction (χ^2 (1) = 14.115, p < 0.05) indicated that the duration of the /t/ frication bursts from the stimuli significantly

explains the differences in responses. Figure 10 shows that the responses depended on the variable Nativeness especially when stimuli were from 2 (10 ms) and 3 (15 ms) degrees of difference. The graph reveals that, when stimuli differed in more than 10 ms, "same" responses were below 50%. When the difference between two bursts was too subtle or to extreme, they tended to respond similarly. From this perspective, differences were found when distance between stimuli is around 10 and 15 ms, what would induce significant differences in responses.

Figure 10 – Percentage of variants equal to target according to Target and Distance. Each unit in Distance from Target refers to 5 ms of difference. 1 = 5 ms, 2 = 10 ms, 3 = 15 ms and 4 = 20 ms.



Source: Elaborated by the author.

Having Participant and Stimulus as random effects, in order to estimate the influence of Gender and Target on /t/ burst duration, a Generalized Linear Mixed model (Table 4) was fit to participants' responses to [t]ipa and [tʃ]ipa stimuli.

Table 4 – Generalized linear mixed model fit by maximum likelihood.

Fixed effects	Estimate	Std. Error	z value	p
Intercept	-0.4453	0.4319	-1.031	> 0.05
TargetPrototype	-0.6271	0.2358	-2.660	$\mathbf{< 0.05}$
GenderMale	0.4287	0.4724	0.907	> 0.05

Random effects: Participant and Stimulus. n = 480.

Source: Elaborated by the author.

With the reference value "same" for Response, "female" for Gender, and "non-prototype" for Target, the model predicts a significant effect of prototypes on participant's responses ($p < 0.05$). It implies that, independently from Gender and Native, prototype stimuli significantly influence responses. However, the model predicts that the Gender of the participants has no effect on the responses. Assuming a probability sampling for a representative sample, if further research find similar results, it reveals that there is statistical evidence that, at least under experimental conditions, perceptual magnet effect do influence discrimination of variants from different dialects of BP.

5.4 Discussion

The current experiment reveals that significant differences concerning listeners' discrimination of the duration of /t/ frication burst were found when the stimuli differed in 10 and 15 ms in relation to pairs of tokens. Regarding the discrimination of the pairs with differences of 5 and 20 ms, group differences were subtle and not significant, according to inferential analyses. The data obtained from this experiment shows that burst differences of 5 ms are too subtle to be perceived by listeners, while of 20 ms are too large. This finding is relevant for the literature on palatalization given that it reveals that listeners use this acoustic clue to discriminate this palatalization. As mentioned, Pozzani and Albano (2016), Amorim (2017) and Hora, Henrique and Amorim (2018) have already investigated the palatalization experimentally, but they did not address this process considering the duration of the /t/ frication burst. Furthermore, the differences that were observed in this study are consistent with the NLM theory (KUHL et al., 1992; IVERSON; KUHL, 1996), which predicts that the speech perception depends on previous language exposure. Therefore, the current research evidenced the magnet effect using data from the palatalization in BP.

In all of the current analyses, the descriptive statistics showed that the participants tended to give more equal responses to the stimuli assumed to be their prototypes, what is in line with previous studies on NLM theory (KUHL, 1993; KUHL et al., 2007). Considering that the alveolar plosive is the most common variant for the natives (HORA, 1997; HENRIQUE; HORA, 2012; AMORIM et al., 2019; AMORIM et al., 2019), and that the affricate for the non-natives, the participants were inclined to equate the variants of their expected prototypes more often, even when they were really different. The natives equated more frequently the stimuli with the lowest duration of /t/ frication burst, while the non-natives the ones with the highest duration. On the other hand, they discriminated more accurately the variants that are different from the ones that they are expected to produce. They responded more frequently that stimuli were different when the distribution of the duration of /t/ frication burst from the stimuli was distant to the distribution of the duration that is expected to be produced by their group.

A possible explanation for the similar rate of "same" for both groups when the difference was 5 could be the difficulty of the task. For the tokens that differed in 5 ms, when compared with the closest neighbor token, this difference could be extremely subtle to be perceived, at least to be observed using this type of experiment. If, different from expected, both groups gave similar responses, with no statistical difference among them, it is necessary to increase the distinction among stimuli in order to look for group differences. Also, further studies should be conducted in order to provide more evidence whether the findings related to stimuli with 10 and 15 ms of burst difference are real.

5.5 Summary, limitations, and future research

This experiment analyzed listeners' discrimination of /t/ frication bursts in a ten-step continua, from 15 ms to 60 ms, embedded in the nonce word *tipa* /tipa/, with differences of approximately 5 ms per token, when comparing with its closest neighbor. Each pair of /tipa/ had two tokens, which differed in 5, 10, 15 or 20 ms, since comparisons were made with tokens from different steps of the continua.

Although this study was limited to a small sample size, and due to a technical problem that resulted in the deletion of one of the tokens from the ten-step continua, it confirmed its main hypothesis when demonstrated the magnet effect (KUHL et al., 1992; KUHL et al., 2007). Results reveal that, although the acoustic difference among the variants was roughly the same, the responses depended on the variable Target, especially when the /t/ frication burst from the pairs differed in 10 and 15 ms. The descriptive analyses showed that prototypes were equated more often than non-prototypes for both groups. This implies that participants' perceptual space was distorted, and their responses were induced by the magnet effect. This trend, which is consistent with the NLM theory (KUHL et al., 1992; KUHL et al., 2007), was indicated to be statistically significant when stimuli differed in 10 and 15 ms. Moreover, a model fitted with the variables *Gender* and *Target* suggested that Gender is not a significant predictor, what is different from expected. Therefore, future studies on the palatalization of /t/ should consider differences of 10 and 15 ms of its frication burst in order to observe group differences.

A great contribution of this experiment is that it evidenced that listeners use the /t/ frication burst duration as an acoustic cue to discriminate the palatalization. Furthermore, this variable was empirically investigated, measured and modeled. Given that there is a lack of studies that attempt to analyze the palatalization from the current perspective, this dissertation broaden the understanding concerning the role of that acoustic cue on speech perception, since a range of duration was examined, from 15 to 60 ms.

6 An ABX experiment on the palatalization of /t/: a pilot study

6.1 Introduction

This study aims at analyzing listeners' discrimination regarding the palatalization of the alveolar plosive /t/ before /i/ in Brazilian Portuguese (BP), from a ten-step continua of /t/ frication burst's duration, embedded in the nonce word /tipa/. As previously explained, in BP, this palatalization is often characterized when, triggered by /i/, an alveolar plosive is produced as an affricate (BISOL, 1991; HORA, 1997; AMORIM et al., 2019). From an extensive literature developed in Brazil on palatalization (HORA, 1997; DUTRA, 2007; BATTISTI; ROSA, 2012; AMORIM et al., 2019; AMORIM et al., 2019), it is possible to state that the affricate is its most regular variant in most dialects of BP. However, there is a lack of studies that account for it within the scope of Acoustic Phonetics(KENT; READ, 1992; STEVENS, 2000; BARBOSA; MADUREIRA, 2015).

Considering this challenge, an ABX experiment was conducted to investigate listeners' discrimination from an acoustic perspective. Two groups participated in this study. The first group is the natives, individuals who have always lived in João Pessoa, where the alveolar plosive is the most frequent variant (HORA, 1997; HENRIQUE; HORA, 2012; AMORIM et al., 2019; AMORIM et al., 2019), whereas the second group is the non-natives, the ones who live in João Pessoa, but lived most of their life where the affricate is the most frequent variant. Similar to an AXB experiment (BEST; MCROBERTS; SITHOLE, 1988), in this ABX experiment, they had to listen to stimuli composed of three tokens of /tipa/, and to indicate whether the third token was similar to the first or second token from the stimuli. The unique difference concerning each stimuli was the /t/ frication burst, which varied in 5 ms[1]. The first token from the ten-step continua had 15 ms, while the last one had 60 ms of that burst.

The main hypothesis is that the variable Nativeness affects listeners' responses, since natives and non-natives differ in terms of language exposure. Based on the NLM model (KUHL et al., 1992; KUHL et al., 2007), it is expected to perceptual magnet effect significantly reduce discrimination near prototypical stimuli. Thus, the groups are expected to equate more often their prototypes and discriminate their non-prototypes. The prototypes are "speech sounds that are identified by adult speakers of a given language as ideal representatives of a given phonetic category", according to Kuhl et al. (1992)[p.

[1] This was decided arbitrarily because there was no study to date that investigated the palatalization of alveolar plosives in Brazilian Portuguese (BP) from the duration of the frication bursts.

255]. Moreover, the specific hypothesis is that the gender of the participant affects his or her responses, since prior research reported gender differences in relation to the use of palatalization in João Pessoa (HORA, 1997; HENRIQUE; HORA, 2012).

The current study contributes to the literature on palatalization of alveolar plosives in BP when it addresses the duration of /t/ frication burst as an acoustic cue used by listeners to discriminate variants of this process. Although this study failed in demonstrating the magnet effect on listeners' discrimination, it is relevant when suggests that 5 ms of difference regarding the burst duration of two tokens is too subtle to be perceived. Probably, more acoustic information is required in order to a difference be noted. Therefore, future studies should take this finding into consideration.

6.2 Methods

6.2.1 Location and participants

The recordings to elaborate stimuli were conducted in a sound-attenuated booth at Universidade Federal da Paraíba (UFPB), in JP, in 2019. The female speaker that was recorded was an academic student, from 20 to 30 years old, native speaker of BP, and had never lived outside of João Pessoa. Her unique participation in this research was in the elaboration of the stimuli.

The data collection regarding the experiment occurred in a silent room at UFPB, in JP, in 2019. Ten academic students responded to the experiment. They were 4 male and 6 female, native speakers of BP, from 20 to 30 years old and with normal hearing. They were categorized into two groups: "natives", for the 5 individuals who never lived outside João Pessoa, and "non-natives", for those 5 who were living in JP, but lived most of their life in any Brazilian city in which the affricate is the most frequent variant of /t/. There were two male and three female in both groups.

6.2.2 Stimuli

10 recordings of /tipa/ from the additional participant were used in order to manipulate the stimuli. She was recorded in the sound-attenuated booth with noise below 20 dB SPL. Praat (BOERSMA; WEENINK, 2019) was used to record in a sample frequency of 44.1 kHz and 16-bit quantization, with the Sennheiser E-835 recorder connected to the Behringer UMC 202 HD audio interface.

The most natural of those 10 recordings was selected and copied 10 times. Afterwards, /tipa/ productions of female speakers from the study presented in chapter 4 were selected and isolated considering a ten-step continua from 15 to 60 ms of the /t/ frication burst, having 5 ms of difference in respect to the closest neighboring token. Then the 10

identical tokens from the additional participant had the /t/ frication burst replaced by those from the other female speakers. They differed only in terms of the burst. Finally, each token had their amplitude normalized, using a script written by the author, with the function *normalize*, from the package *tuneR* (LIGGES et al., 2018) in R (R CORE TEAM, 2019). Figure 21 illustrates the sound waves assumed for [t] tokens and Figure 22 those for [tʃ] tokens that were used in the experiment. They are both in section 10.

All the data related to token 3 were excluded from the analyses due to technical problems. As Figure 21 shows, this token was equal to token 1, what was realized late.

The stimuli used in this test were 36 combinations of those 10 tokens, based on these four conditions: "x, y, x", "y, x, y", "x, y, y", and "y, x, x", where x = {1, 2, 3 ... 9}, and y = x + 1. Thus, the stimuli have differences of 5 ms regarding the /t/ frication burst.

6.2.3 Data collection

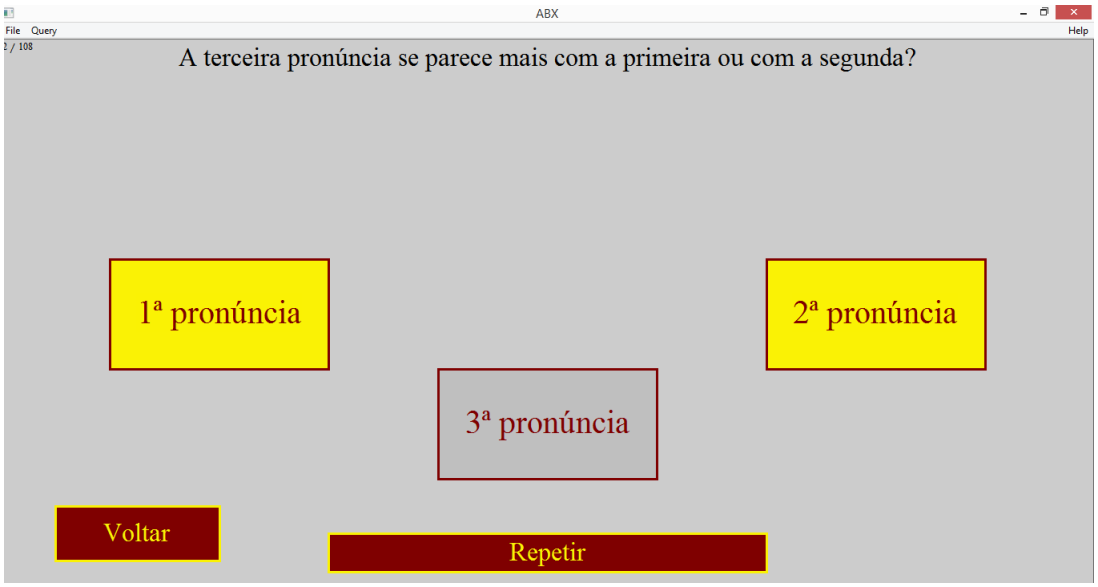
The experiment was carried out using an Asus X200M notebook, with an AKG K414P headphone. As a forced-choice task, listeners had to indicate whether the third stimulus is similar to the first or second stimulus. They had to respond to the question: *Com qual pronúncia a terceira pronúncia mais se parece?* 'With which pronunciation the third pronunciation is more similar to?', clicking on one of the two buttons: *Primeira Pronúncia* 'The first pronunciation' or *Segunda Pronúncia*, 'The second pronunciation', as shown in Figure 11. The stimuli were presented at random, using a Praat script programmed by the author. The stimuli played automatically after click, could be returned, repeated, and had a break after 50. Also, 0.5 seconds of silence intervals were added in the beginning, middle and end of stimuli. The total duration was 14 minutes, on average. Each stimulus was presented at random, repeated 3 times, resulting in 108 stimuli (36 combinations x 3) per participant and 1080 in total. However, taking into account that token 3 was excluded from data analysis, only 840 responses were considered.

After data collection, the statistical analyses were performed using R (R CORE TEAM, 2019), with the significance level at 0.05.

6.3 Results

Figure 12 represents the distribution of responses according stimuli and nativeness. The first panel (n = 240) groups tokens combinations from 1 to 5, the second (n = 480) from 6 to 10, and the third (n = 120) 5 and 6. The last panel had responses from the tokens 5 and 6. The present data reveal that participants tended to miss more often when stimuli were their prototypes. [t]ipa's stimuli were missed in 47.5% by non-natives, while in 50.8% by natives. [tʃ]ipa's stimuli were missed in 42.9% by non-natives, while in 35.8% by natives. [t]ipa and [tʃ]ipa's stimuli were missed in 48.3% by non-natives, while in 53.3% by natives.

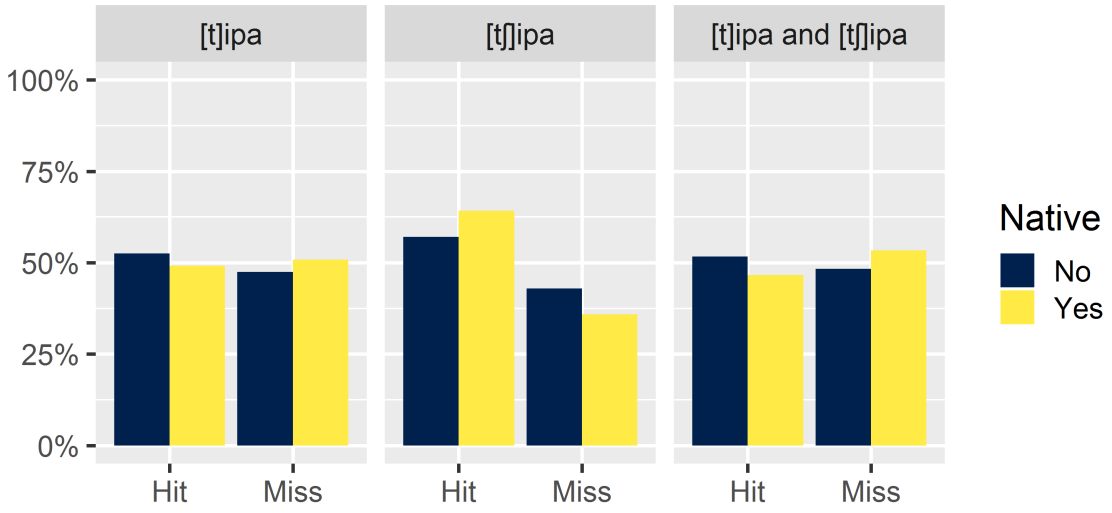
Figure 11 – Screen of the ABX test.



Source: Elaborated by the author.

Even though this trend is the expected by the NLM theory, Pearson's Chi-squared tests with Yates' continuity correction suggest that the observed difference is not statistically significant for *[t]ipa* (χ^2 (1) = 0.15004, p > 0.05), [tʃ]ipa (χ^2 (1) = 2.2342, p > 0.05) nor [t]ipa and [tʃ]ipa (χ^2 (1) = 0.13337, p > 0.05).

Figure 12 – Percentage of responses according to Stimuli and Nativeness.

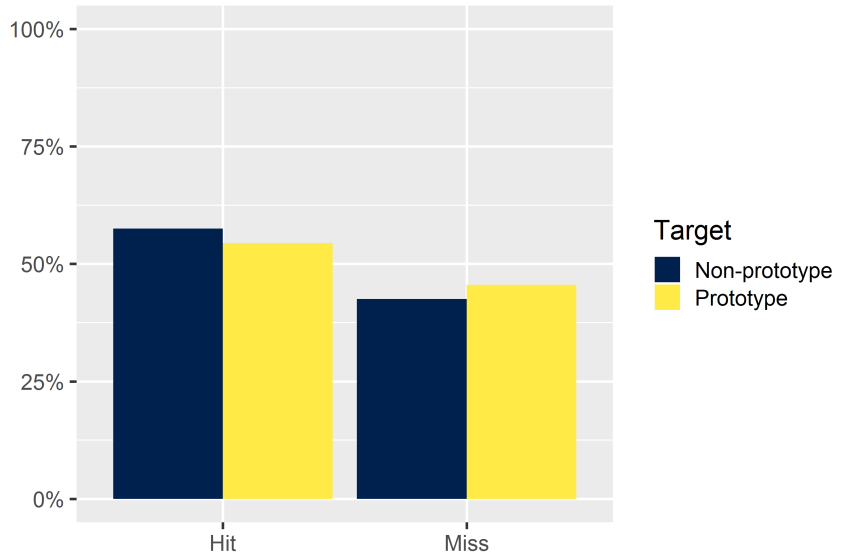


Source: Elaborated by the author.

Considering responses according to target (n = 840), that is, prototypes or not, Figure 13 shows that participants hit non-prototype stimuli (57.5%) more often than their

prototype variants (54.4%). However, a Pearson's Chi-squared test with Yates' continuity correction implies that responses do not differ significantly (χ^2 (1) = 0.66103, p > 0.05).

Figure 13 – Responses according to Target (%).



Source: Elaborated by the author.

To predict the effect of Gender and Target on /t/ burst duration, considering Participant and Stimulus as random effects, a Generalized Linear Mixed model was fit to participants' responses to [t]ipa and [tʃ]ipa stimuli. The model used as reference value "hit" for Response, "female" for Gender, and "non-prototype" for Target. Conforming to Table 5, the model estimates that no predictor significantly influences the response variable (p > 0.05). It implies that the observed data from the ABX test could not explain the magnet effect on participants' responses. Taking into account that stimuli used in the ABX test were too close in terms of auditory distance, that subtle difference could not be perceived by both groups. Their response thus did not vary significantly.

Table 5 – Generalized linear mixed model fit by maximum likelihood.

Fixed effects	Estimate	Std. Error	z value	p
Intercept	-0.392023	0.181997	-2.154	< 0.05
TargetPrototype	0.462352	0.255396	1.810	> 0.05
GenderMale	0.002359	0.254458	0.009	> 0.05

Random effects: Participant and Stimulus. n = 720.

Source: Elaborated by the author.

6.4 Discussion

In order to look for the magnet effect (KUHL et al., 1992; KUHL et al., 2007) on listeners' discrimination of the palatalization of /t/ considering the duration of its frication burst, this experiment could not confirm the main hypothesis. It was expected that listeners' responses would depend on their language exposure, assumed here by the variable Nativeness. This prediction is based on the assumptions from the NLM theory, which argues that speech perception is influenced by mental representations for phonetic categories emerged by linguistic experience (KUHL, 1991; KUHL, 1993; KUHL, 2000; IVERSON; KUHL, 1996). Whereas the descriptive analyses found the expected trend, since the listeners tended to miss more often when stimuli were their expected prototypes, the inferential analyses suggested that those differences were not significant, what was supported even by the generalized linear model. It seemed that 5 ms is a too subtle difference to be perceived by the listeners.

This result is in line with the findings from chapter 5, which conducted a AX discrimination experiment with the same tokens that were used in the current study. The differences was that listeners had to listen to a pair of tokens in a ten-step continua, which were combined with each other. Since tokens differed in each pair in 5, 10, 15 and 20 ms, it was possible to observe the amount of information that is required for listeners to discriminate that acoustic clue. The conclusion was that listeners can discriminate the /t/ frication burst when the pair of stimuli differs in 10 and 15 ms. Therefore, the results from the current study support the findings from that experiment described in chapter 5, evidencing that listeners can not discriminate differences of 5 ms concerning the /t/ frication burst.

6.5 Summary, limitations, and future research

This experiment investigated the discrimination of the participants regarding the palatalization, analyzed by means of a ten-step continua of frication burst's duration from 15 to 60 ms, embedded in the nonce word *tipa* /tipa/. General results showed that, although the responses followed the trend expected by the NLM theory (KUHL et al., 1992; KUHL et al., 2007), the group differences were not considered to be significant by inferential tests. As this study was limited by a small sample, it is harder to predict significant differences, especially considering the Chi-Square test, which depends on sample size to increase its power. Another limitation was due to the technical problem concerning the third token, given that the data related to this token were deleted. Also, the current findings can be accounted for the difficulty of the task, given that they are in line with those from the discrimination test of the study presented in chapter 5, which reported that participants tended to miss above 80% when difference in stimuli was only 5 ms.

According to the analyzes described in chapter 5, the magnet effect seems to be more evident when the acoustic distance between two tokens is from 10 to 15 ms, what should be taken into account by future research.

7 Listeners' goodness judgments towards the palatalization of /t/

7.1 Introduction

The goal of this study is to investigate the effect of duration of the /t/ frication burst on listeners' goodness judgments. The hypothesis is that the ratings depend on the duration, since, according to Kuhl (1991), the perceived goodness may decline as stimuli are further from the prototype. The object under analysis refers to the palatalization of /t/ before /i/ in Brazilian Portuguese (BP), which is here analyzed from the duration of its /t/ frication burst, in a ten-step continua from 15 ms to 105 ms.

Although Amorim (2017) and Hora, Henrique and Amorim (2018) have already investigated the goodness judgments of individuals from João Pessoa in relation to the palatalization of /t/, no study has examined it with the focus on the continua of frication burst's duration. Considering this, the current study intends to address the palatalization from goodness ratings of individuals from two groups: natives and non-natives. The first are individuals who have always lived in João Pessoa, where the alveolar plosive is the most used variant (HORA, 1997; HENRIQUE; HORA, 2012; AMORIM et al., 2019; AMORIM et al., 2019). The second are individuals who live in João Pessoa, but lived most of their life where the palatalization is the most frequent variant.

Based on (KUHL, 1991), the present experiment extends the studies on the palatalization by revealing that there is a certain location in the distribution related to the duration of the /t/ frication burst where listeners rated stimuli as prototypes, which are defined by her as the best exemplars of a given phonemic category. This supports the research of (KUHL, 1991), since she demonstrated that the goodness judgments were systematically affected by the distance of the stimulus when compared with its prototype. In the current study, the prototypes are expected to depend on listeners' language exposure, as predicts the NLM model (KUHL et al., 1992; KUHL et al., 2007). For the natives, it is expected that the prototype is an alveolar plosive, which is acoustically characterized by the /t/ frication burst around 27 ms, on average, according to the study of chapter 4. For the non-natives, it is expected that the prototype is an affricate, characterized by an average duration of 108 ms, as reported in that chapter.

7.2 Methods

7.2.1 Location and Participants

This research was conducted at *Universidade Federal da Paraíba*, in João Pessoa - Paraíba, Brazil, in 2019. Basically, data collection occurred in two different steps: (1) to elaborate the stimuli and (2) to run the experiment. In the first step, data were collected in a sound-attenuated booth, and in the second step they were collected in a silent room.

The number of individuals who participated in this research is 33: 1 was the additional participant, which did not participate in the experiment, but was used only to elaborate the stimuli, and 32 were the ones who did participate in the experiment and who have their responses analyzed by this study. The additional participant is a female, native speaker of BP, academic student, 26 years old, and has always lived in João Pessoa. Her profile is similar to the 32 participants, which were native speakers of BP, academic students, from 18 to 30 years old, and with normal hearing. They were recruited using quota sampling and responded to the experiment individually and under similar experimental conditions. As reported in Table 6, they were divided into two groups: native and non-native. The first group had 16 individuals who have always lived in JP. The second group had 16 individuals who have been living in JP for up to five years, but were born and used to live in any Brazilian city where the affricate is the most frequent variant in casual speech. In both groups, half of the participants is female, while the other half is male.

Table 6 – Participants by Gender and Nativeness.

Native	M	F	Total
Yes	8	8	16
No	8	8	16
Total	16	16	32

Note: M = Male. F = Female

Source: Elaborated by the author.

7.2.2 Stimuli

The objective of this subsection is to describe the procedures that were followed to elaborate the stimuli for the goodness judgment experiment, which are tokens of isolated /tiba/ in a ten-step continua of frication burst duration of /t/, from 15 ms to 105 ms,

having 10 ms of difference for each interval. All the recordings and procedures used to manipulate the stimuli were performed using Praat (BOERSMA; WEENINK, 2019) and are similar to those followed in the chapter 5 and chapter 6. The recordings were conducted in a sample frequency of 44.1 kHz and 16-bit quantization, using a Sennheiser E-835 recorder connected to a Behringer UMC 202 HD audio interface.

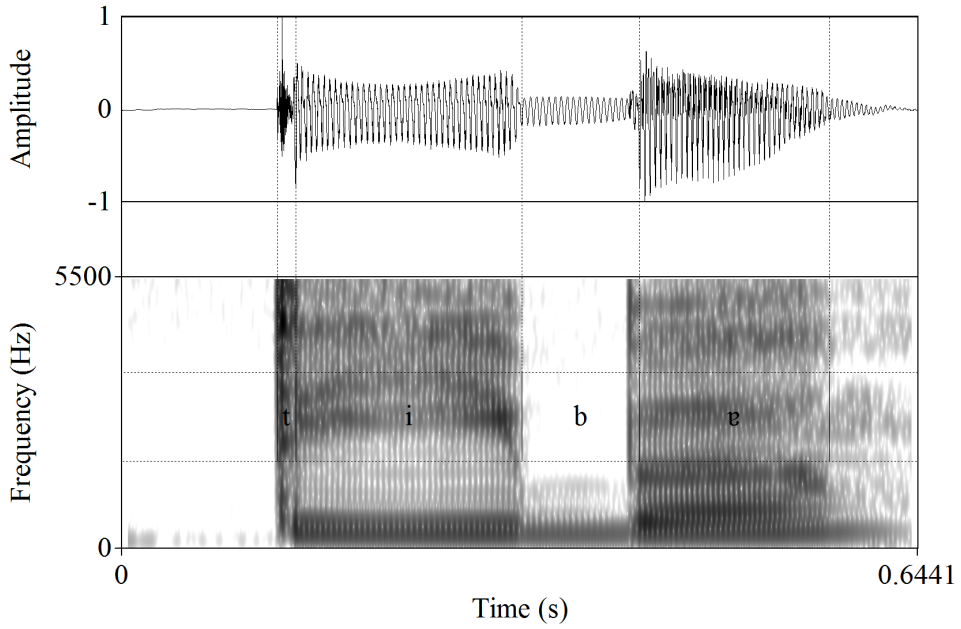
To elaborate the stimuli, a female additional participant produced words embedded in the carrier sentence "digo t*V*ba baixinho" (I say tiba in low voice) (BARBOSA; MADUREIRA, 2015), where *V* is /a, ɛ, i, ɔ, u/, five of the stressed vowels of Brazilian Portuguese. The words that she had to read, at a moderate speech rate, were "taba, teba, tiba, toba, tuba". The vowels besides /i/ were not analyzed, since they were fillers. The participant had to read the sentences, presented at random, on a laptop screen, through the booster's window. There were ten blocks, each one with five sentences. The duration of this procedure was around 20 minutes.

After gathering the speech samples, the next step was their manipulation. First, one token of /tiba/ was selected, which is what the participants will have to listen to in the experiment. Then the nonce word was isolated from the carrier sentence and the acoustic signal was replicated in order to produce 10 identical tokens. The next step was the production of the ten-step continua of frication burst duration of /t/, from 15 ms to 105 ms, in 10 ms of interval. For this purpose, tokens from female participants from the experiment described in chapter 4 were selected and isolated. After that, the frication burst of /t/ from the 10 tokens was replaced by the ones from the female participants from that experiment. Thus, the 10 tokens differed only in terms of the frication burst continua, since the rest of the signal was identical. Finally, the amplitude was normalized using a script written by the author, with the function *normalize*, from the package *tuneR* (LIGGES et al., 2018) in R (R CORE TEAM, 2019).

Figure 14 presents the fist token of the continua, with 15 ms of frication burst. The normalized sound wave is presented at the top of the figure and the spectrogram at the bottom. Each segment is phonetically transcribed. As mentioned, all the ten tokens were identical, with the exception of the frication burst of /t/. The difference among the other tokens is presented in the Figure 23 and Figure 24, in section 10, which show the sound wave of the segment /t/ (and part of the /i/) from the ten tokens.

Figure 23 illustrates the sound waves of the tokens 1 to 5, and Figure 24 the ones from 6 to 10. As described, when comparing with their neighbor, all the tokens differ in 10 ms regarding /t/ frication burst. The duration of the frication from the token 1 is 15 ms, while from the token 10 is 105 ms. Based on the findings from the study of chapter 4, "t2" corresponds to the stimulus with the closest mean of frication burst duration of natives (27.82), whereas "t10" with the mean of non-natives (108.34). It implies that in the goodness judgment test the stimuli that are closer to "t1" might be considered as the

Figure 14 – Sound wave, spectrogram, and segmentation tiers of /tipa/.



Source: Elaborated by the author.

ones that are more similar to the prototypes of natives, while less similar to non-natives, and "t10" less similar to the prototypes of natives and more similar to the prototypes of non-natives.

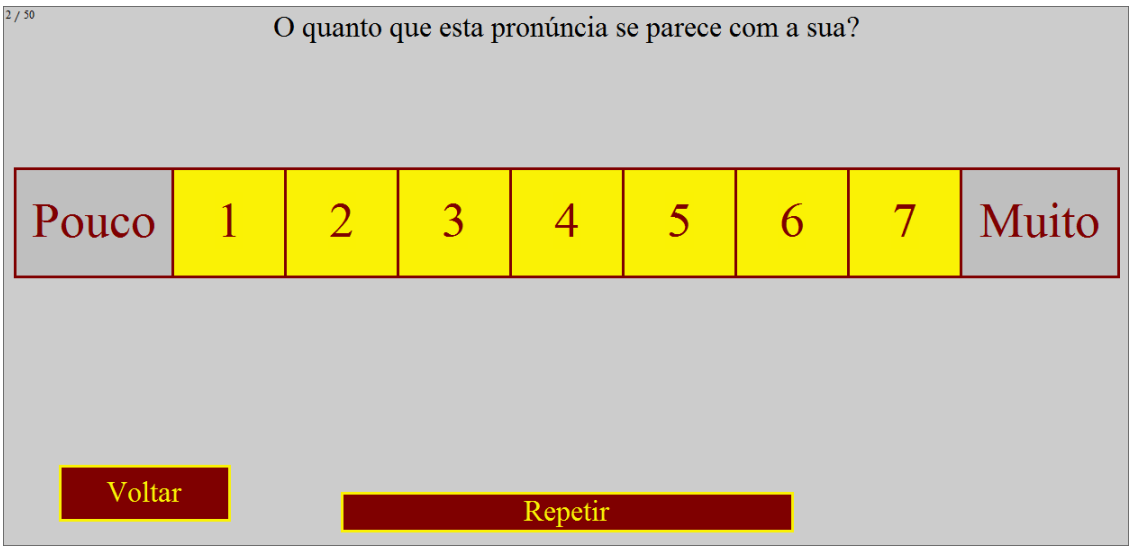
Note in the figure that the duration of the /t/ frication burst from the token 2 is slightly lower than expected. The actual duration is 23, whereas it should be 25. However, the duration of the original sample, from the female participant of the other experiment, is 25 ms. The difference of 2 ms was due to the manipulation of the tokens, since it was necessary to cut a small part of the signal to avoid the production of the sound of a "click". The same applies to the tokens 5, 6 and 10, which had a tiny difference. However, as described in the chapter 5, the present dissertation found statistical evidence that the responses from the participants of the discrimination experiment indicated that they could not adequately discriminate /t/ frication bursts when the difference between the pairs was below 10 ms. The results showed that the participants discriminated significantly only when the difference was 10 ms or 15 ms. For the present experiment, it implies that, although there is a small difference for those tokens, its effect on the validity of the experiment may be null or minimal.

7.2.3 Data collection

Using an Asus X200M laptop, with an AKG K414P headphone, the participants responded to a forced-choice task in which they were asked to rate the 10 tokens of /tiba/ on a 7-point integer scale. The experiment was presented in Praat using the script *ExperimentMFC 7*, which was programmed by the author. Before starting, each participant responded to a training test, an experiment that was similar to the main one, in order to advance possible questions and to understand the task. After responding to the test with 10 stimuli, which were not included in the larger test, the main experiment was conducted. As the Figure 15 shows, they had to click on a likert-type scale from 1 (a little, *pouco*) to 7 (a lot, *muito*) to respond to the question: "To which extent is this pronunciation similar to yours?" (*"O quanto que esta pronúncia se parece com a sua?"*). The script was programmed to add intervals of 0.5 second of silence in the beginning, middle and end of the stimuli, and to turn the screen blank while playing them, to avoid clicking on a wrong button by mistake. The participants were allowed to return (*Voltar*) to the previous stimulus and to repeat (*Repetir*) it. The stimuli were presented at random and played automatically after each judgment. Each stimulus was presented 5 times, resulting in 50 observations (10 x 5) for each participant. The total number of observations was 1600. The total duration of the task was 5 minutes, on average.

After data collection, data were exported to ".xlsx" files to be statistically analyzed using R (R CORE TEAM, 2019). The significance level adopted for all statistical tests was at 0.05.

Figure 15 – Screen of the goodness judgment task.



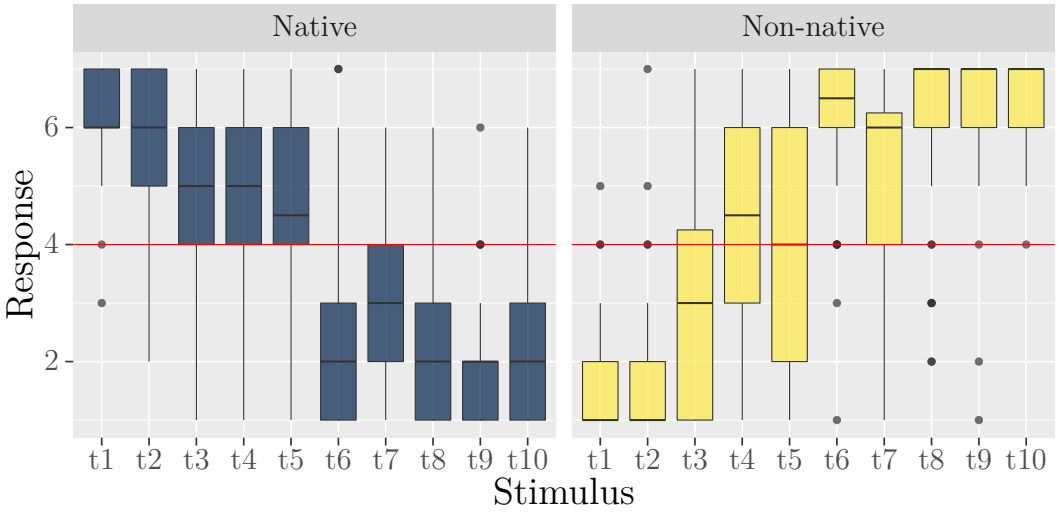
Source: Elaborated by the author.

7.3 Results

Each box-plot in this section illustrates responses from the experiment in the y-axis and the stimuli in the x-axis. Figure 16 shows the general results from the present experiment, with responses from natives in the left and from non-natives in the right panel. The red line indicates the middle of the rating scale. The box-plots suggest that, as expected, for both natives and non-natives, the further the stimulus was to the prototypes, the lower were the ratings. According to Spearman's rank correlation tests, this linear correlation was significant for both natives and non-natives. For the natives ($r = -0.72$, $p < 0.001$), the higher the duration of the /t/ frication burst, the lower were the ratings. For the non-natives ($r = 0.73$, $p < 0.001$), the higher the duration of the /t/ frication burst, the higher were the ratings.

After 55 ms ("t6") of /t/ frication burst, the Figure 16 shows that for both groups the ratings substantially differed from those with less than 55 ms. Considering the stimuli "t5" and "t6", for the natives, the medians were 4.5 and 2, respectively, while for the non-natives they were 4 and 6.5. This difference is statistically significant for both natives ($U = 5167$, $p < 0.001$) and non-natives ($U = 1109$, $p < 0.001$), according to Mann-Whitney tests. The graph also reveals that the variance of these stimuli are considerably different. For the natives, the first and third quartiles of "t5" were 4 and 6, while for the non-natives they were 2 and 6, respectively. For "t6", the quartiles were 1 and 3 for the natives, and 6 and 7 for the non-natives. Therefore, in relation to these two stimuli, the means and variability were considerably different.

Figure 16 – Boxplot of ratings by Stimulus and Nativeness.

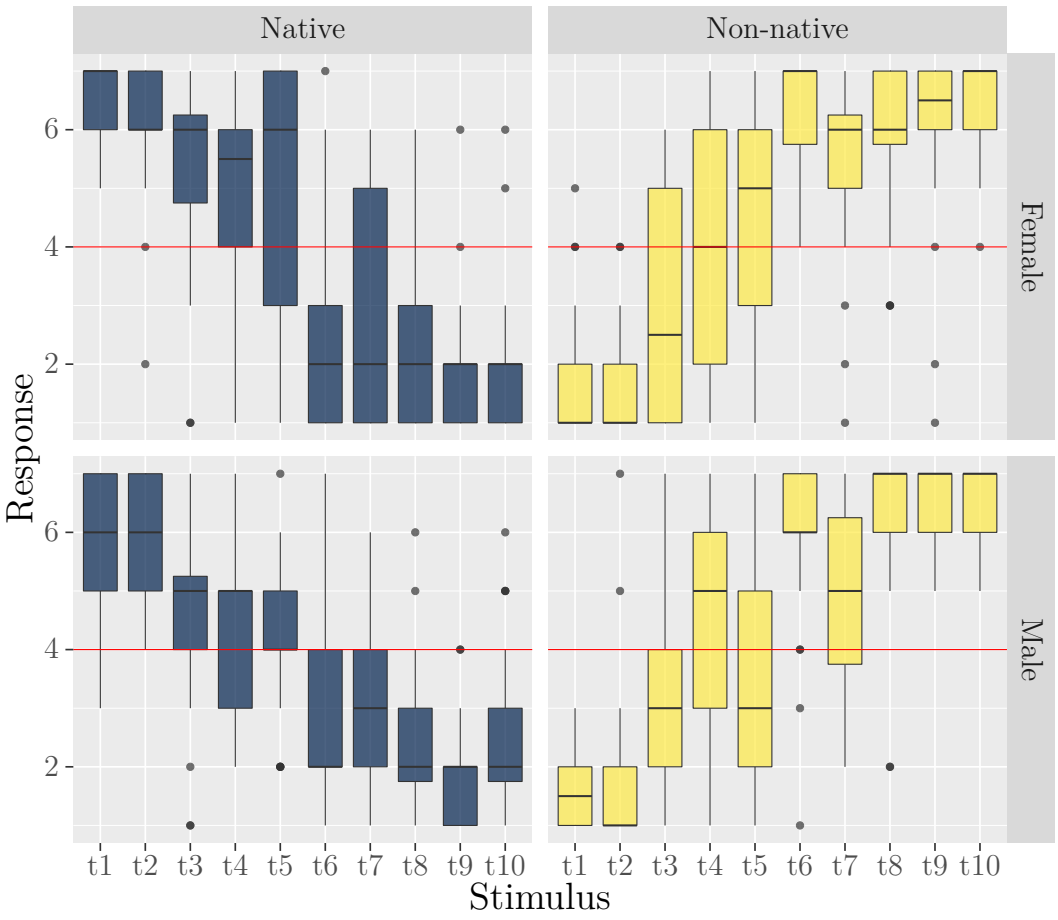


Source: Elaborated by the author.

The present research also found that the gender of listeners did not affect their

ratings, for both natives and non-natives. Figure 17 shows the responses from natives in the left and from non-natives in the right panels, and the responses of females in the upper and males in the bottom panels. The slight difference that can be observed from the graph is not significant for the natives ($U = 82976$, $p > 0.05$) and non-natives ($U = 77994$, $p > 0.05$), as suggest Mann-Whitney tests.

Figure 17 – Boxplot of the native participants' ratings by Stimulus, Nativeness and Gender.



Source: Elaborated by the author.

7.4 Discussion

The current experiment found significant linear correlations between the duration of the /t/ frication burst and listeners responses. It provides strong statistical evidences that this acoustic clue plays a role on speech perception, since the listeners rated stimuli that varied solely in terms of the duration. This corroborates with the study of Kuhl (1991), given that the ratings declined when stimuli were more distant to the prototypes. Thus, the present study evidences that, for both groups, the closer were the duration to the prototypes, the higher were the ratings.

The results also suggests that the boundary between an alveolar plosive and an affricate seems to be around 55 ms. The inferential analyses indicated that there is a significant difference between the ratings for both groups in relation to the stimuli "t5" (55 ms of burst) and "t6" (65 ms of burst). This is in line with the study from chapter 4, which indicated from a speech production perspective that the distribution of /t/ frication bursts from natives and non-natives overlaps when the duration is around 50 ms. A conclusion that can be drawn from that experiment and from the current study is that the boundary between the /t/ frication burst from an alveolar plosive and an affricate before /i/ is around 50 ms. This finding implicates that the speech perception studies from chapter 5 and chapter 6 did not adequately explore the real distribution. Because they used stimuli from 15 to 60 ms, they did not address the best exemplars of the affricate.

The findings also contribute to the study on palatalization of /t/ in BP. Amorim (2017), Hora, Henrique and Amorim (2018) investigated this palatalization in the same city of the current study, João Pessoa. They focused on the effect of the preceding phonetic context of /t/ on listeners' discrimination of the palatalization. Given that the authors did not explore the large impact of duration of the /t/ frication burst on listeners' discrimination, it is not possible to assume that their results were due to the preceding context alone. Therefore, in order to improve their experiment, future studies should consider the current findings when exploring the palatalization acoustically.

Although some studies in the domain of Variationist Sociolinguistics found some gender differences in relation to the use of the palatalization of /t/ (BATTISTI; FILHO, 2015; HENRIQUE; HORA, 2012; HORA, 1997), the inferential analyses imply that it does not affect listeners responses. It indicates that there is no evidence that gender affected the listeners responses. However, given that they had to compare the pronunciation of the tokens with their own, and that all the tokens to be judged by the participants were from a female speaker, it is not possible to measure from this study the effect of voice on responses. In order to investigate this question, an alternative is to replicate this study including male voices, what would make the experiment much longer.

7.5 Summary, limitations, and future research

This study demonstrated that the duration of /t/ frication burst from the palatalization of /t/ before /i/ in Brazilian Portuguese vary in perceived goodness. It also evidenced that there is a significant linear correlation between listeners' responses and the duration. For the natives, the higher were the duration, the lower were the ratings. For the non-natives, the higher were the duration, the higher were the ratings. Another finding from this study is that the boundary between an alveolar plosive and an affricate seems to be around 55 ms, a conclusion that was drawn from the current speech perception data

and from the speech production study described in chapter 4. Since few researchers have addressed the palatalization in BP from an acoustic perspective, the current study extends this investigation by examining it from the duration of the /t/ frication burst.

Although gender differences were expected, no difference was found for the current study. This may have been partially motivated by the stimuli, which were all produced by a female speaker. Because listeners had to compare their pronunciation with the stimuli, it is possible that voice played a certain role in responses. Therefore, this study was limited to investigating only stimuli with a female voice, instead of also including male voices.

Another limitation concerning stimuli is that they were manipulated, instead of synthesized. Although manipulated stimuli are more natural, they usually do not vary as expected, since other variables are not controlled. Using synthesized stimuli, it is possible to eliminate or reduce the effect of unwanted variables, and also to adequately control the variable under analysis. For example, the slight differences that were found in the manipulation of some stimuli (as "t2", that was with 23 ms, instead of 25), could have been easily avoided if the stimuli were synthesized. Another aspect is related to the stimulus "t7", which received widely distributed ratings. Given that the responses from this stimulus varied very differently from those from the most neighbor stimuli, it seems that other variable, probably related to burst frequency, influenced the results.

In relation to further research, supported by the present results, the current stimuli will be used in an ABX experiment based on the NLM model (KUHL et al., 1992; KUHL et al., 2007), which aims at investigating the role of language exposure on the discrimination of the /t/ frication burst. This experiment will replicate the study of chapter 6, but with the stimuli from the current experiment. Since the ten-step continua were rated for the participants as expected, the findings indicate that the current research was successful regarding the continua of /t/ frication burst that were manipulated for this study. Therefore, this work validated the stimuli that will be used in future research.

8 The magnet effect on the discrimination of /t/

8.1 Introduction

The objective of this study is to analyze the impact of language exposure on listeners' discrimination of the duration of /t/ frication burst, from the palatalization of /t/ before /i/ in Brazilian Portuguese (BP). The main hypothesis is that listeners' responses depend on their language exposure. This is based on the assumption of the Native Language Magnet (NLM) model (KUHL et al., 1992; KUHL et al., 2007), that speech perception is affected by linguistic experience. It is argued that good instances of phonetic categories yield special responses when compared with poor instances. A magnet effect may distort the perceptual distance of stimuli, even when their physical distance is constant. According to the model, the perceptual space may be shrunk near good instances (prototypes) and stretched near poor instances (non-prototypes). The specific hypothesis of the current study is that listeners' discrimination depends on gender, given that the literature on palatalization of /t/ suggests that its use depend on speakers' gender (BATTISTI; FILHO, 2015; HENRIQUE; HORA, 2012; HORA, 1997). Therefore, this experiment attempts to demonstrate that listeners' discrimination of the duration of /t/ frication burst depend on language exposure and on listeners' gender.

As already shown, a relatively tiny number of works has investigated the present palatalization from Acoustic Phonetics (KENT; READ, 1992; STEVENS, 2000; BARBOSA; MADUREIRA, 2015). For example, Pozzani and Albano (2016), when investigating the four spectral moments of the /t/ frication brust (mean, standard deviation, skewness and kurtosis), found that for some speakers the production of palatalization was influenced by language exposure. In the study presented in chapter 4, it was demonstrated that the palatalization can be explained by the duration of the /t/ frication burst. The longer the duration, the closer the /t/ is to an affricate. Also, it was reported that the palatalization is produced in theoretically infinituous stages, and that the longer an individual spends the years in a speech community, the closer his or her duration is to the members of that place. The study from the chapter 5 investigated the influence of language exposure on the perceptual discrimination regarding the duration of the /t/ frication burst. The findings reveal that group differences were found only when the burst duration from the pairs of tokens differed in 10 and 15 ms. The study from the chapter 6 failed to demonstrate that language exposure affects the perceptual discrimination of the duration of /t/ frication burst. This might be due to the stimuli, which differed only in 5 ms of the frication burst.

The study from the chapter 7 examined listeners' goodness ratings in relation to the same object of the last three studies. The linear correlation that was found revealed that the goodness depends on the distant to its prototype.

In order to further explore those issues, the current study replicated the ABX experiment from chapter 6, but using the stimuli validated in chapter 7. Those stimuli were used because the study of chapter 5 found group differences only when stimuli differed in 10 and 15 ms, instead of 5 ms, as in chapter 6. The stimuli were combinations from a ten-step continua of /t/ frication burst's duration, embedded in the nonce word /tiba/. Each token differed in approximately 10 ms in relation to its closest neighbor. The first token had 15 ms, while the last token had 105 ms of the burst. Each combination from the ABX task was three tokens of /tiba/ that differed only 10 ms of the /t/ frication burst (the rest of the stimulus was equal to all stimuli). The listeners had to indicate whether the third token was similar to the first or second token.

The listeners were from two groups. The individuals from the first group were called natives, which were those who have never lived outside of João Pessoa (JP), where [t] is mostly used (HORA, 1997; HENRIQUE; HORA, 2012; AMORIM et al., 2019; AMORIM et al., 2019), whereas the individuals from the second group were called non-natives, which were those who live in JP, but lived most of their life where [tʃ] is mostly used. The listeners from both groups are expected to more frequently miss their prototypes and hit their non-prototypes. Therefore, the natives may miss more often the stimuli with [t] and hit those with [tʃ], while the non-natives' responses may follow the opposite trend.

8.2 Methods

8.2.1 Location and Participants

This study was conducted at Universidade Federal da Paraíba (UFPB), in JP, in 2019. The recordings to elaborate stimuli were conducted in a sound-attenuated booth, while the ABX task was performed in a silent room. The participants were the same from the study of chapter 7.

Recruited using quota sampling, 33 individuals participated in this study, 1 only to elaborate stimuli and 32 to respond to the ABX task. The speaker used in the elaboration of stimuli was a female academic student, 26 years old, who had always lived in João Pessoa. The other participants were from a similar profile. The differences are related to gender and that they are from two groups: natives and non-natives. As shown in Table 7, the natives were 8 males and 8 females who have always lived in JP, whereas the non-natives were 8 males and 8 females who were living in JP for up to five years, but were from any Brazilian city where [tʃ] is mostly used in spontaneous speech.

Table 7 – Participants by Gender and Nativeness.

Native	M	F	Total
Yes	8	8	16
No	8	8	16
Total	16	16	32

Note: M = Male. F = Female

Source: Elaborated by the author.

8.2.2 Stimuli

The stimuli are combinations of the 10 tokens from chapter 7. They are shown in Figure 23 and Figure 24, in section 10. They refer to a ten-step continua of duration of the /t/ frication burst, from 15 ms to 105 ms, having 10 ms of difference for each interval. All the tokens were productions of /tiba/, which varied only in terms of the frication burst. Thus, the rest of the signal was identical for all tokens. According to the data from chapter 4, "t2" is the stimulus with the closest mean of frication burst duration of the natives (27.82), whereas "t10" of non-natives (108.34).

The current stimuli are 36 combinations of the 10 tokens from chapter 7. Similarly to the experiment from chapter 6, they follow these four conditions: "x, y, x", "y, x, y", "x, y, y", and "y, x, x", where x = {1, 2, 3 ... 9}, and y = x + 1. Therefore, each stimulus is combined with its closest neighbor stimulus.

8.2.3 Data collection

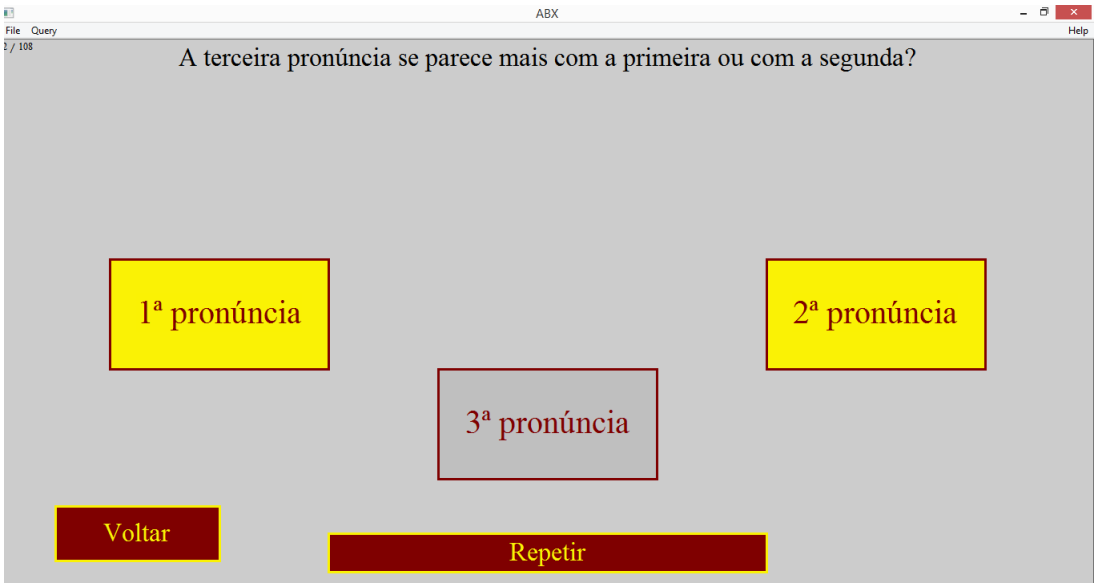
The data collection was similar to the experiment from chapter 6[1]. It was conducted with an Asus X200M notebook and an AKG K414P headphone. The experiment was performed in Praat (BOERSMA; WEENINK, 2019), using a script programmed by the author. The participants had to indicate clicking on a button on the screen whether the third stimulus is similar to the first or second stimulus. The stimuli were randomized, repeated 3 times, played automatically after clicking, could be returned and repeated. 0.5 seconds of silence intervals were added in the beginning, middle and end of stimuli. As the total duration was 15 minutes, on average, the participants were encouraged to have a

[1] The unique difference in relation to the experiment from chapter 6 is that here the screen was programmed to be turned blank while the stimulus was playing, in order to avoid responding before listening to it.

break after 50 responses. In total, the experiment had 108 stimuli (36 combinations x 3). As data from 32 participants were collected, 3456 observations were gathered.

Figure 18 shows the screen of the ABX test. The participants had to respond to the question *Com qual pronúncia a terceira pronúncia mais se parece?* "With which pronunciation the third pronunciation is more similar to?", clicking on *Primeira Pronúncia* "The first pronunciation" or *Segunda Pronúncia*, "The second pronunciation".

Figure 18 – Screen of the ABX test.



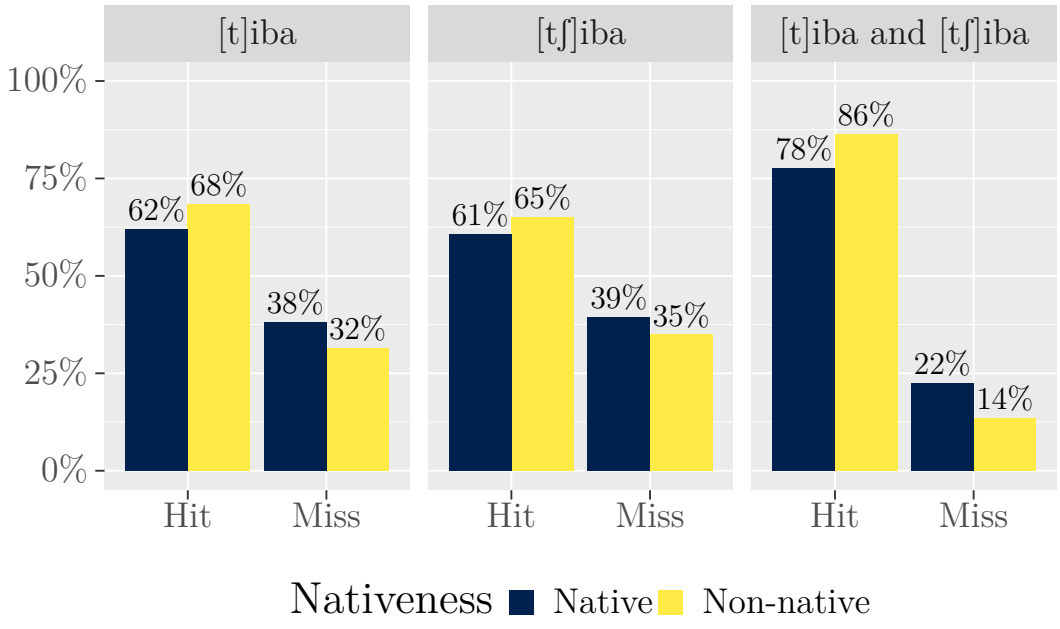
Source: Elaborated by the author.

The data were then exported to a ".xlsx" file to be analyzed using R (R CORE TEAM, 2019). The inferential tests were performed with the significance level at 0.05.

8.3 Results

Figure 19 reports listeners' responses according to Stimuli and Nativeness. The data suggest that language exposure affected listeners responses, since small but statistically significant differences were found. When compared with non-natives, in relation to the stimuli with *[t]iba*, the natives missed more frequently, in relation to those with *[tʃiba]*, the natives missed less often, and in relation to *[t]iba and [tʃiba]*, the natives missed more often. Therefore, the expected tendency was found for all group of stimuli. They missed more frequently when the group of stimuli was similar to their prototypes, and hit more regularly those similar to their non-prototypes. Pearson's Chi-squared tests with Yates' continuity correction evidenced that there is an association between responses and Nativeness. They indicated significant differences for *[t]iba* (χ^2 (1) = 6.89, p < 0.05) and *[t]iba and [tʃ]iba* (χ^2 (1) = 4.52, p < 0.05), but not for *[tʃ]iba* (χ^2 (1) = 3.03, p = 0.08).

Figure 19 – Responses according to Nativeness and Group of Stimuli (%). [t]iba = combination of tokens from 1 to 5 (n = 1536), [tʃ]iba = from 6 to 10 (n = 1536), [t]iba and [t]iba = 5 and 6 (n = 384).



Source: Elaborated by the author.

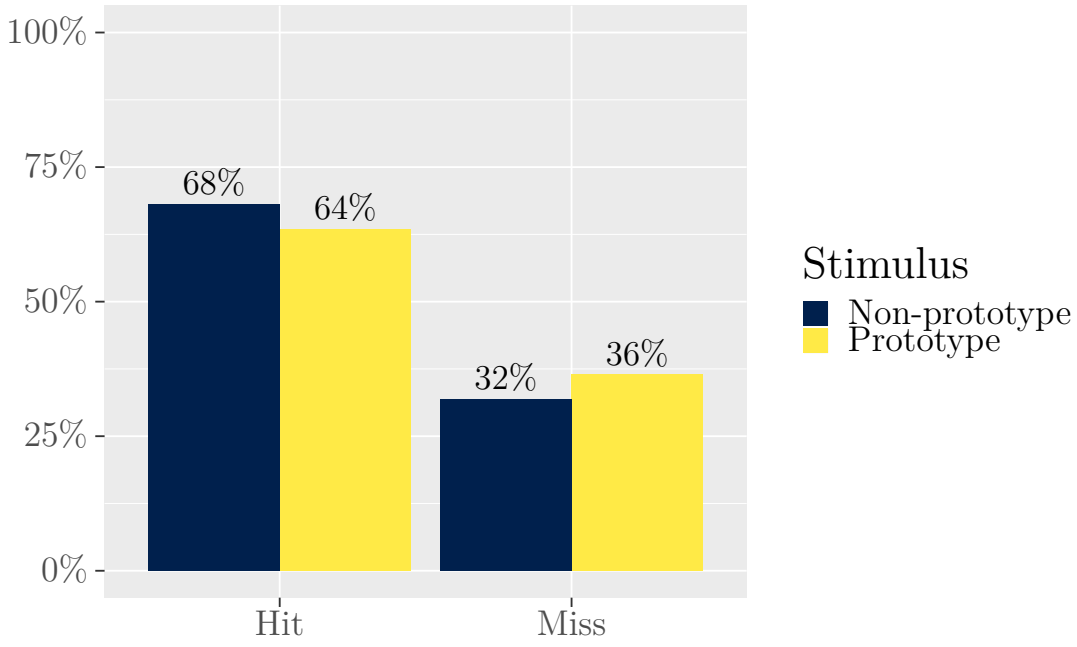
Figure 20 shows the responses according to Stimulus and Nativeness. As expected, the prototypes were missed more frequently than non-prototypes, and the non-prototypes were hit more often than prototypes. These findings were supported by a Pearson's Chi-squared test with Yates' continuity correction. It indicates that the responses depended on Stimulus (χ^2 (1) = 7.61, $p < 0.05$). Therefore, the current study found statistical evidence that the stimulus (prototype or non-prototype) significantly affected listeners' responses.

In order to further examine the role of Stimulus (prototype or non-prototype), and also to look for gender differences, a Generalized Linear Mixed model was estimated considering Participant as random effect (Table 8). The reference values were "hit" for Response, "female" for Gender, and "non-prototype" for Stimulus. In line with previous results, the model indicates that Stimulus significantly influences listeners' responses ($p < 0.01$). However, no significant effect was found in terms of Gender ($p > 0.05$).

8.4 Discussion

Based on the NLM model (KUHL et al., 1992; KUHL et al., 2007), which predicts a magnet effect on perceptual discrimination, the current study demonstrated that listeners' language exposure affected their responses, what confirms the main hypothesis of this

Figure 20 – Percentage of responses according to Stimulus.



Source: Elaborated by the author.

Table 8 – Generalized linear mixed model fit by maximum likelihood.

Fixed effects	Estimate	Std. Error	z value	p
Intercept	-0.808	0.106	-7.576	< 0.001
GenderMale	0.059	0.142	0.414	> 0.05
TargetPrototype	0.206	0.073	2.832	< 0.01

Random effect: Participant.

Source: Elaborated by the author.

research. Differently from the pilot from chapter 6, which failed to find group differences, the current inferential analyses evidenced that there is a significant association between the responses and the stimuli (if they are prototypes or not). Because of the magnet effect, the natives hit more often the stimuli with an assumed affricate, and the non-natives those with an assumed alveolar plosive. The present findings support previous research based on the NLM model (KUHL, 2000; IVERSON; KUHL, 1996; KUHL et al., 2007; KUHL; PADDEN, 1983; KUHL; PADDEN, 1982; KUHL, 1991; KUHL, 1993), which argues that the sensitivity to acoustic changes near the distribution of prototypes is reduced, whereas it is increased near the distribution of non-prototypes. However, the current study did not confirm the specific hypothesis, that gender affects the listeners' responses. Although previous research on the palatalization found gender differences related to the use of this variable (BATTISTI; FILHO, 2015; HENRIQUE; HORA, 2012; HORA, 1997), it seems

that gender does not play a significant role in terms of speech perception, at least under the experimental conditions of this work.

The current study corroborates with previous studies on the duration of /t/ frication burst related to the palatalization of /t/ before /i/ in BP, given that some predictions were found when extending the investigation concerning this variable. For example, the pilot study from chapter 6 failed because it considered only 5 ms of difference among the /t/ frication burst. As argued, this difference is too subtle or impossible to be perceived. Considering the predictions from the study of chapter 5, this experiment confirmed that group differences can be observed from 10 ms of /t/ frication burst. Another contribution to the literature is that the present study evidenced that the phonetic boundary between an alveolar plosive and an affricate seems to be around 55 ms. This has been supported by two studies, which are those from chapter 4 and chapter 7. From speech production data, the experiment presented in chapter 4 revealed that the distribution of /t/ frication burst from [t] and [tʃ] seems to be overlapped around 50 ms. This was supported by the study from chapter 7, which found statistical evidence that there is a significant difference in goodness between a stimulus with 55 ms and 65 ms of the burst. In the current work, a significant difference was found in relation to perceptual discrimination. The high rate of hits for the stimuli with tokens with 55 ms and 65 ms (*[t]iba and [tʃiba]*) suggests that listeners found little ambiguity between these two tokens. Considering the responses from the other groups of stimuli, it was much easier for them to perceptually discriminate them.

8.5 Summary, limitations, and future research

This study evidenced that language exposure affects listeners' discrimination of the duration of /t/ frication burst, related to the palatalization of /t/ before /i/ in BP. It confirmed preliminary predictions that this difference could be observed when using stimuli that differ only in 10 ms of frication burst. The findings from this research is in line with a number of studies on the NLM theory that attempt to demonstrate the magnet effect. One of the limitations regarding this study was that it considered only the voiceless alveolar plosive /t/, instead of including its counterpart /d/. If /d/ were used, the experiment would become much longer, what was not intended. In order to further analyze this process in its complexity, it is necessary to include /d/. Another limitation refers to stimuli, as mentioned in chapter 7. It is tougher for manipulated stimuli to be adequately controlled. A study with synthesized stimuli should be conducted in order to control unwanted variables and to be compared with the current findings. Further research should also investigate the stimuli that were used in this study to verify if other variables influenced the linear correlation found in chapter 7, which indicates that the further to the prototype the stimulus was, the lower were listeners' ratings. An interesting research is to consider the four spectral moments of the burst that were analyzed by Pozzani and

Albano (2016), when they studied the palatalization of /t/.

9 Discussion

The main objective of this master's dissertation was to investigate the magnet effect on the discrimination of the duration of /t/ frication burst from the palatalization of /t/ before /i/ in BP. As shown, there was a number of challenges to reach this goal. The main issue was that there was no prior description of this process in terms of the acoustic cue under study. This required a speech production experiment to be carried out before moving on to the speech perception experiments.

Five experiments were conducted to investigate the palatalization in terms of the duration of its /t/ frication burst. All of them considered two groups of participants: natives and non-natives. The first group is composed of individuals who have always lived in João Pessoa, where the alveolar plosive is the most common variant, whereas the second group is composed of individuals who live in João Pessoa, but lived most part of their life in a speech community where the affricate is the most regular variant.

The speech production experiment demonstrated that palatalization can be studied from the duration of its frication burst, what was evidenced by prior studies (SILVA et al., 2012; FREITAG; SOUZA, 2017). Based on this acoustic parameter, it was possible to observe group differences that have been documented by studies that adopt impressionistic methods. However, the current experiment went even further when it revealed small differences in speech that can not be perceived by studies like these (HAYWARD, 2000), what may provide more information for their analysis. For example, it could contribute to studies on language variation and change, such as Hora (1997), HENRIQUE and HORA (2012), AMORIM et al. (2019), that were about the dialect spoken in João Pessoa. Following the current method, it would be possible to analyze the continuum of the linguistic change. A second possible application for this method refers to studies on speech perception. As previously argued, an acoustic characterization could contribute to the reproducibility of studies like Amorim (2017), Hora, Henrique and Amorim (2018), Lopes and Lima (2015), Freitag and Santos (2016) and Ribeiro and Corrêa (2018), that investigated experimentally speech perception or language attitudes, since small effects of uncontrolled variables on the speech signal might bias results.

The findings from the speech production experiment revealed that the studied duration depends on speakers' language exposure. The higher was the duration of the /t/ frication burst, the closer to non-native was the distribution of /t/. It implies that the alveolar plosive [t] is associated with a lower duration of its burst, whereas the affricate [ʧ] is associated with a higher duration of the burst. This finding extends the evidence of Silva et al. (2012) and Freitag and Souza (2017) when they documented a continuum related

to the aspiration of /t/. Moreover, the findings also revealed that the distribution of the duration is somehow overlapped around 50 ms, which implies that the boundary between an alveolar plosive and an affricate is not so clear, at least in terms of speech production. This experiment also found that the female speakers produced /t/ frication bursts with a lower duration than male speakers. This gender effect was documented by previous studies in language variation related to the palatalization of /t/ in João Pessoa (HORA, 1997; HENRIQUE; HORA, 2012), what shows that gender differences are reflected in differences related to the current acoustic cue. Another important finding was that the longer the speakers of other dialects lived in João Pessoa, the more similar was their production of /t/ to the speakers of João Pessoa, what is in line with studies on dialects in contact (TRUDGILL, 1986). The major contribution of this finding is that there are at least two subgroups concerning the palatalization of /t/, which were called in this research by natives and non-natives. This acoustic characterization provided the distribution of the duration in which the current speech perception experiments are based.

Based on the distribution of the duration of the bursts provided by the speech production experiment, the speech perception studies of the current dissertation investigated the magnet effect on listeners' discrimination. The magnet effect induces listeners' responses if differences of prototypes' variants are equated more often than those of non-prototypes (KUHL et al., 2007; KUHL; PADDEN, 1982; KUHL; PADDEN, 1983; KUHL, 1991; KUHL, 1993; KUHL et al., 1992). As argued, the major challenge was the lack of studies that investigate this process acoustically, based on the same acoustic cue here analyzed. For that reason, it was difficult to understand how much of acoustic difference would be required for the listeners to perceive differences concerning the phonetic categories. If the acoustic differences were too large, the listeners would perceive them equally, since the differences would be too obvious. If they were too subtle, they would respond at random, since no difference would be perceived.

In the first speech perception experiment, described in chapter 5, differences in responses motivated by language exposure could not be observed when stimuli differed in 5 or 20 ms, but only in 10 and 15 ms of the /t/ frication burst. Therefore, 5 ms of difference seemed to be too subtle to be perceived, while 20 ms too evident. Considering the stimuli with 10 and 15 ms of difference, listeners' responses followed the pattern expected by the NLM theory (KUHL et al., 1992) and by the current research. However, these differences should be further investigated given that they were small despite of being statistically significant.

The second speech perception experiment, described in chapter 6, failed in demonstrating that language exposure affected listeners' responses. However, the lack of difference in responses should be associated with problems concerning stimuli, instead of a failure concerning the NLM theory (KUHL et al., 1992). As stimuli differed only in 5 ms of /t/

frication burst, this result was in line with what was expected by the discrimination test of chapter 5. Since this study was conducted on the same day as the discrimination test, it was not possible to use their results to design the ABX test. Nevertheless, the results from the ABX experiment support that 5 ms of difference in stimuli can not be perceived by those listeners.

Considering that the first two speech perception experiments were conducted with the duration of the /t/ frication burst from 15 to 60 ms, what would not be close to the mean of the distribution of both groups, a ten-step continua from 15 to 105 ms was elaborated to be analyzed by listeners in a goodness judgment task. This third speech perception experiment, which is shown in chapter 6, revealed that the duration of the /t/ frication burst varies in perceived goodness. A significant linear correlation was found between listeners' ratings and the duration of the burst. This study also suggested that a boundary between an alveolar plosive and an affricate is around 55 ms, in line with the study of chapter 4, given that there was a significant difference in ratings concerning the stimulus with this duration and the one that follows it. The results from this experiment imply that the stimuli used in the previous speech perception experiments include more variants associated with the natives than non-natives. It means that the category of the stimuli (prototype or non-prototype) assumed in these two studies is not what it really is. Although the results regarding the comparison between prototype vs non-prototype should not be validated, these two previous studies contributed to the current investigation when they revealed the acoustic differences that are discriminated by the listeners.

Using the stimuli validated in the experiment from chapter 7, a fourth speech perception experiment was carried out. It replicated the second speech perception experiment, from chapter 6. The present ABX test confirmed the hypothesis that language exposure affects listeners' discrimination regarding the duration of /t/ frication burst. With the same design from the first ABX test, but using different stimuli, this study demonstrated that group differences were found when stimuli differed in 10 ms, as expected by the discrimination test from chapter 5. Therefore, similarly to prior research on the NLM model (KUHL et al., 2007; KUHL; PADDEN, 1982; KUHL; PADDEN, 1983; KUHL, 1991; KUHL, 1993; KUHL et al., 1992), the magnet effect induced listeners' responses. Natives hit more often the stimuli with the duration close to the distribution of the non-natives' /t/ frication burst, and the non-natives those with the duration close to the distribution of the natives' /t/ frication burst. Therefore, the current experiment evidences that the magnet effect induced the listeners' responses.

10 Conclusions

This dissertation demonstrated that language exposure affects speech perception, as expected by the NLM model (KUHL et al., 1992; KUHL et al., 2007). For the participants, although the physical distance of stimuli was approximately the same, their responses imply that the perceptual distance seemed to be distorted. Their sensitivity to acoustic changes was reduced near prototypes and increased near non-prototypes. Moreover, this dissertation also contributed to the description of the palatalization of /t/ in BP from an acoustic perspective. It was investigated here in terms of speech perception and also production, and considering individuals of two groups: one composed of speakers that regularly palatalize and other composed of speakers that hardly ever palatalize.

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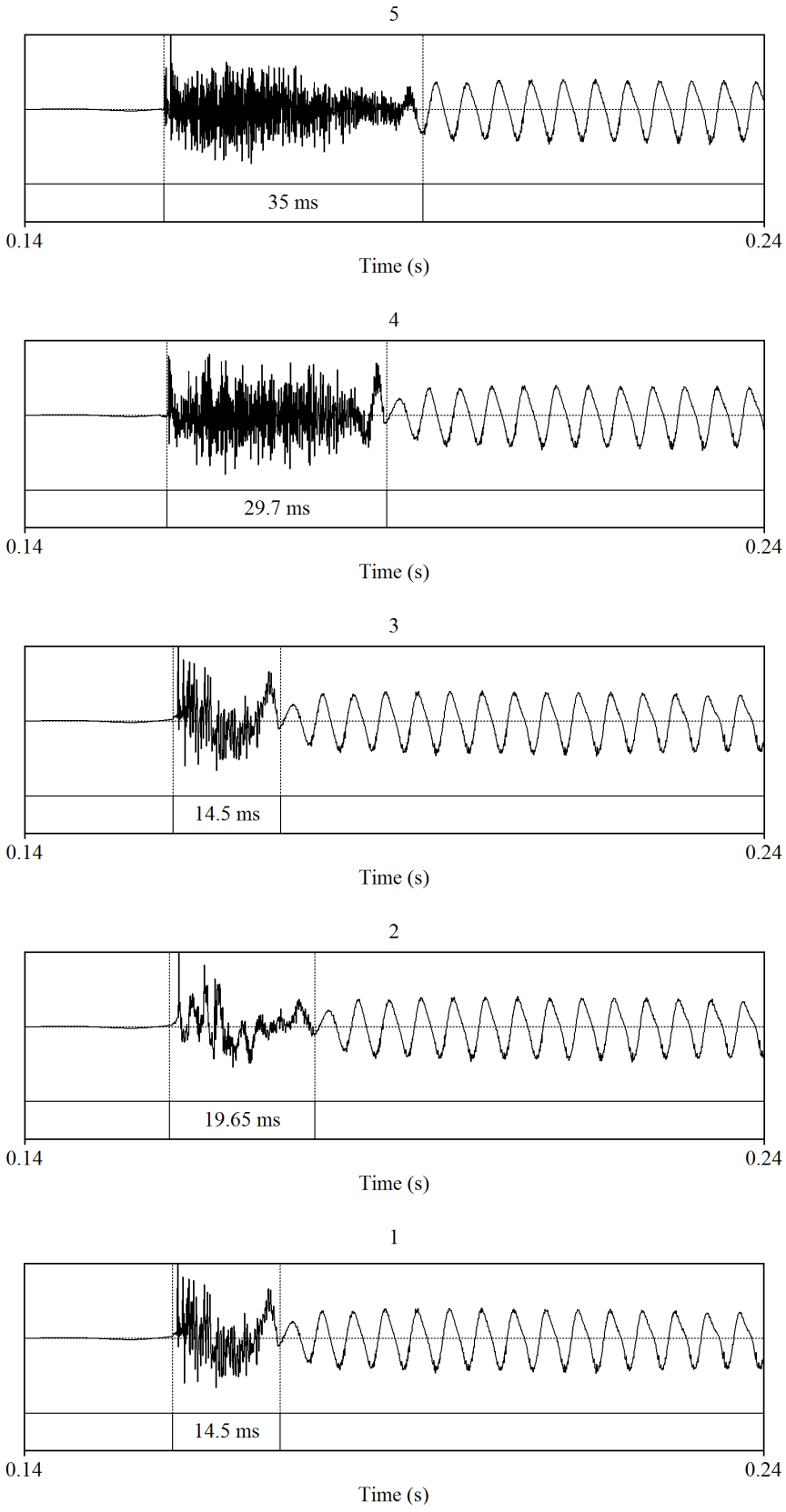
Appendix

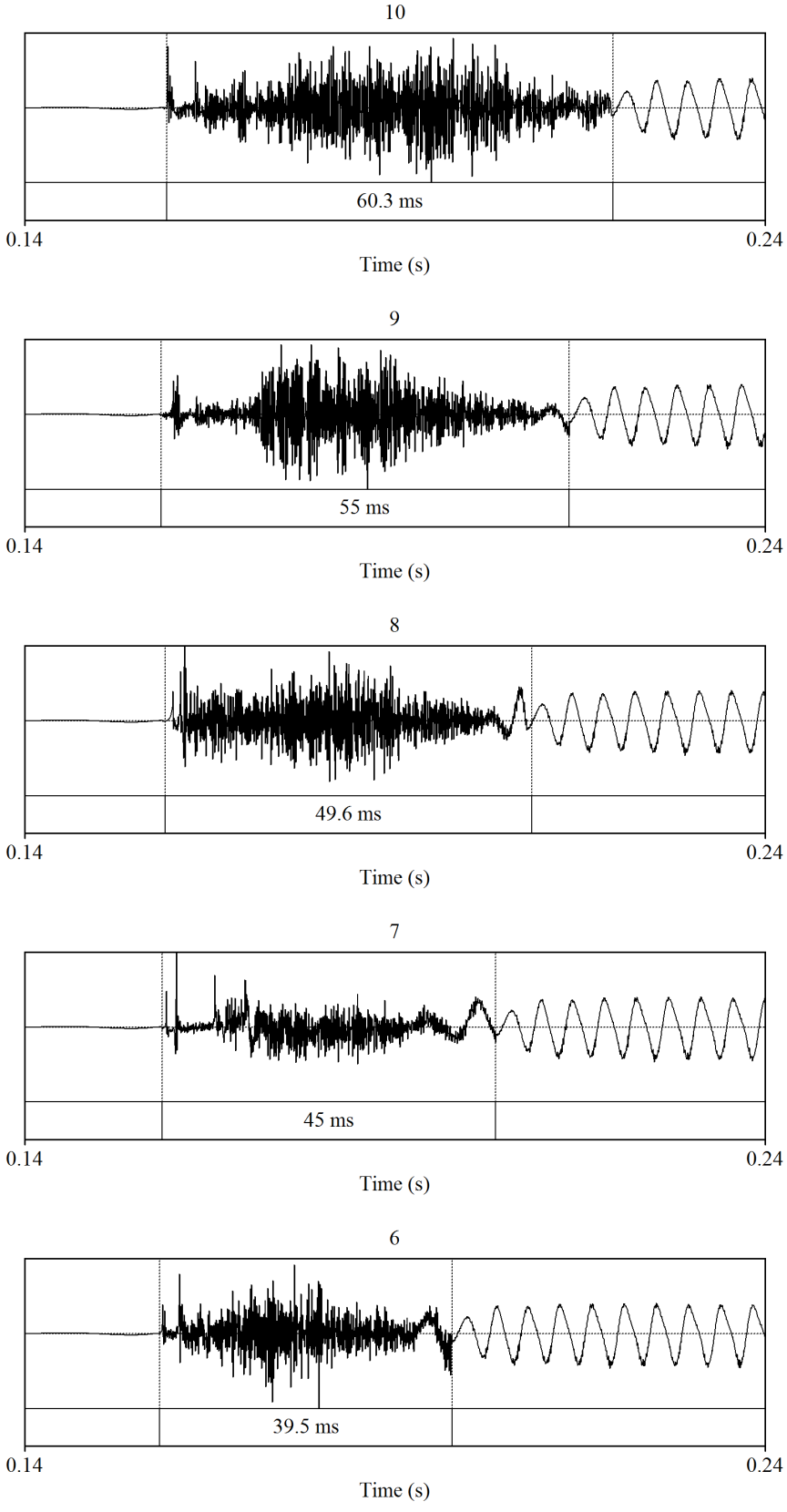
APPENDIX A – Sound waves of the tokens used in the experiments from chapters 5 and 6

Figure 21 – Sound waves of expected [t]ipa tokens.



Source: Elaborated by the author.

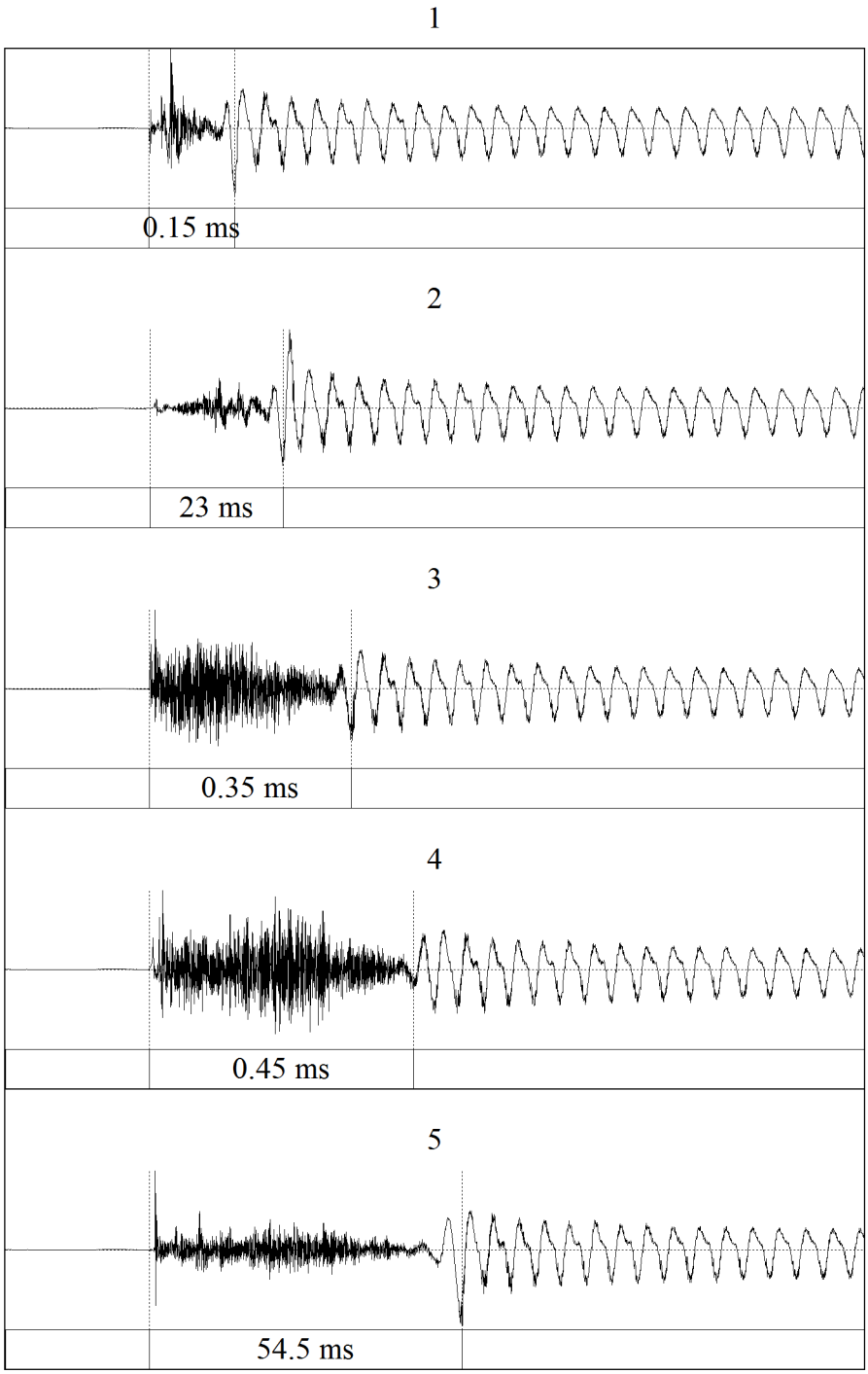
Figure 22 – Sound waves of expected [tʃ]ipa tokens.



Source: Elaborated by the author.

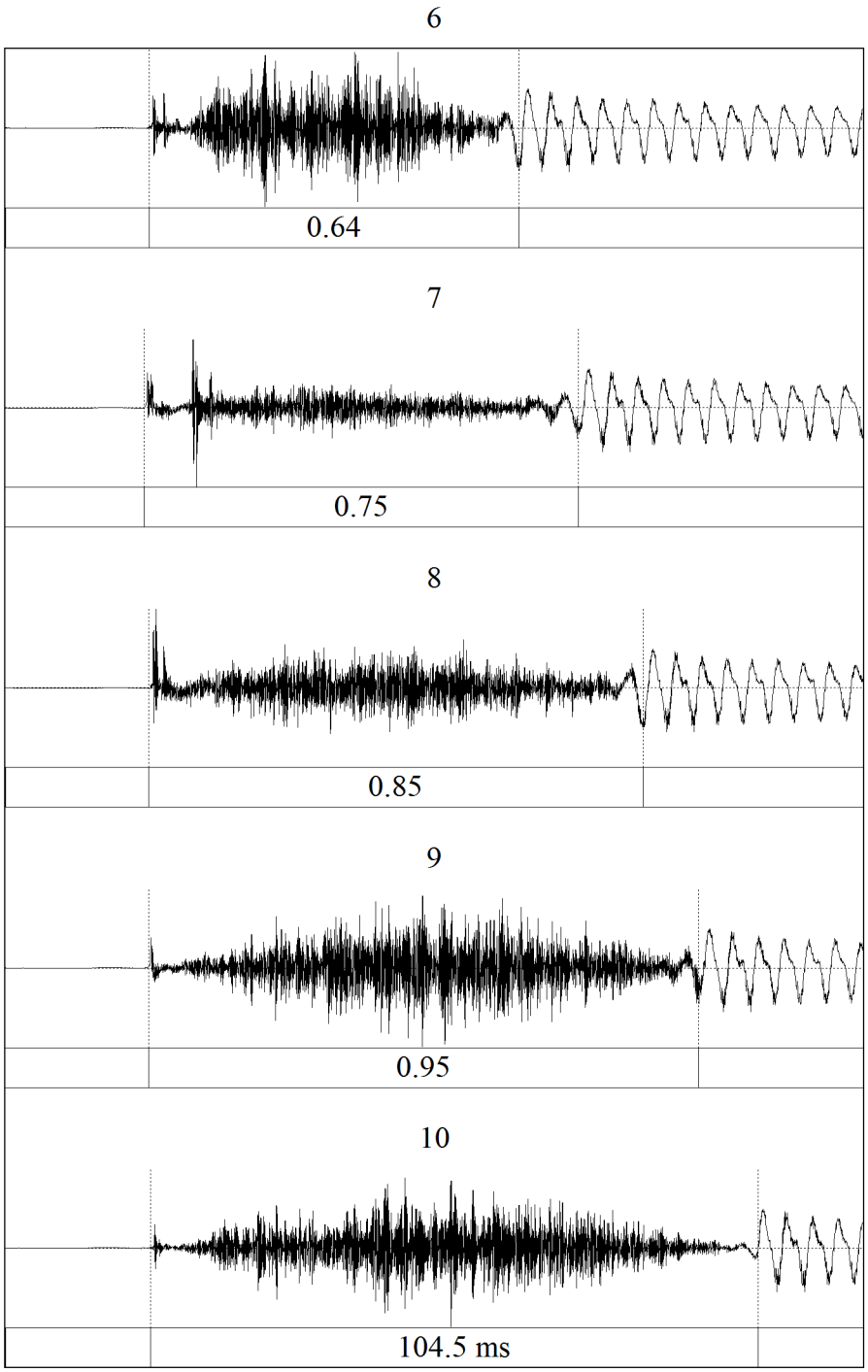
APPENDIX B – Sound waves of the tokens used in the experiments from chapters 7 and 8

Figure 23 – Sound waves of /tiba/ - tokens 1 to 5.



Source: Elaborated by the author.

Figure 24 – Sound waves of /tiba/ - tokens 6 to 10.



Source: Elaborated by the author.

Annex

ANNEX A – Linguistic Atlas of Brazil - palatalization of alveolar plosives

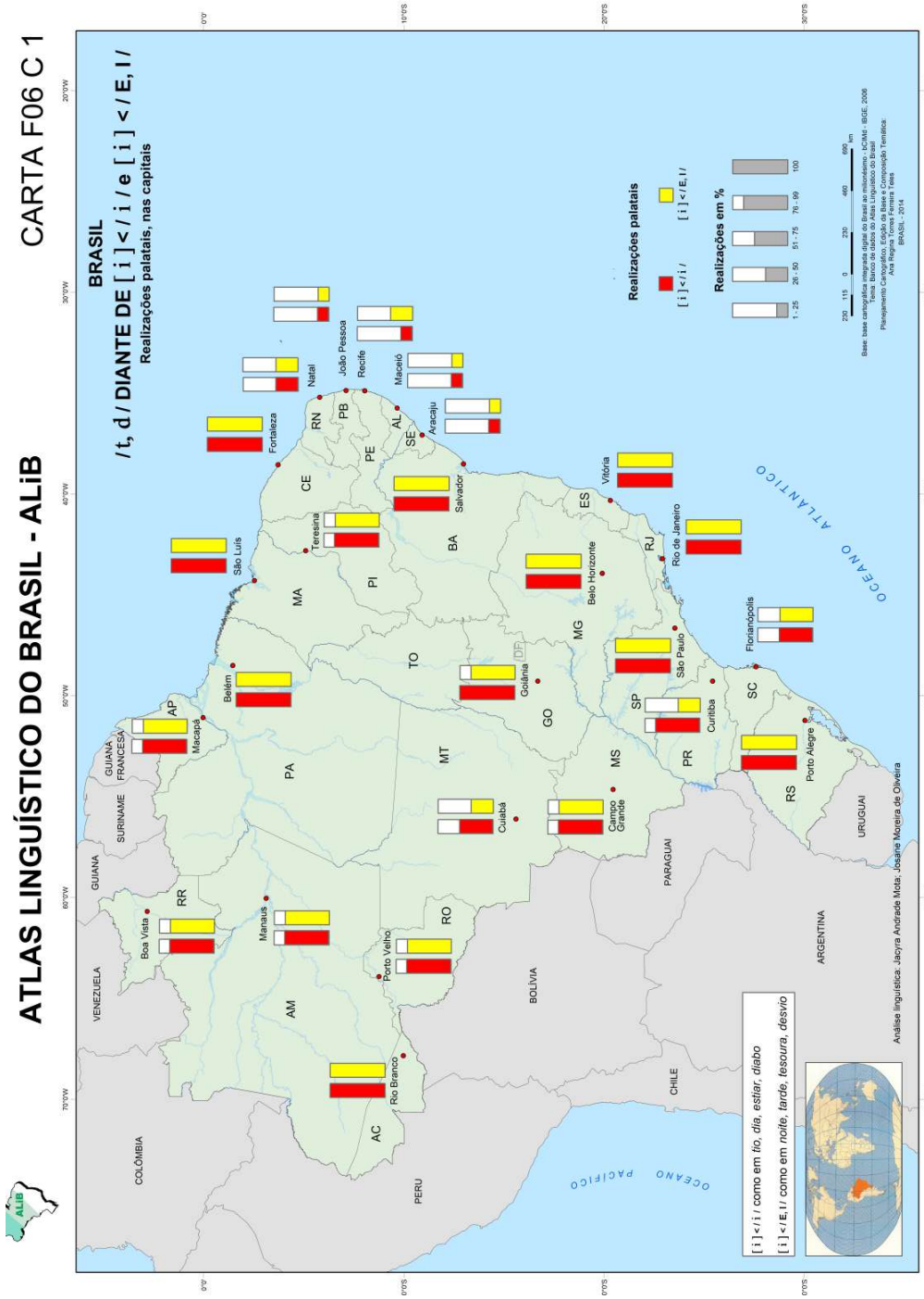


Figure 25 – Linguistic Atlas of Brazil - palatalization of alveolar plosives.

Source: Cardoso et al. (2014)