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ANTON MALMI

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Supervisors: Associate Professor Pärtel Lippus (University of Tartu)

Senior Research Fellow Einar Meister (Tallinn University of Technology)

Opponent: PhD Claire Nance (Lancaster University)

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FOREWORD

Never in my wildest dreams, I thought I would someday be writing a PhD thesis. My life has always been riddled with uncertainties, and constant change is something that I am now used to. Deciding to enroll at the University of Tartu has been one of the most significant and grounding decisions of my life. I have experienced enormous growth over the course of this time in academia. It is important to acknowledge that in life, anyone ever does anything without the help of others. I wish to take this opportunity to thank some of the wonderful people that have trusted and supported me on this journey.

Pärtel, to you, I owe my deepest gratitude. Thank you for being a mentor and a friend, and thank you for guiding me throughout the years at the University of Tartu. I could not have done this without you. Einar, thank you for looking out for me and being there when I needed your advice. I am happy that I have had the chance to collaborate with you; it means a lot to me. I would also like to thank the reviewers' Claire Nance and Alexei Kochetov. Your work has always inspired me, and I am so grateful and honored that you took the time to read and review my work.

University of Tartu Phonetics Lab as a whole has been instrumental in shaping me into who I am today as a young aspiring scientist. Thank you, Pire, Eva Liina, Tuuli, Katrin, and Helen, for creating a warm, open space that encourages critical and creative thinking. Your knowledge, suggestions, and guidance have helped me a lot throughout the years.

Heili, thank you for believing in me when I doubted myself, and thank you for supporting me over the course of our years together. Your intelligence, impeccable sense of ethics, and aesthetics of life set a standard for me that I wish to reach every day. Without you, I would not have found the balance that I needed in my life. I know that there were periods when all I could think about was work; at those times, I was out of touch with everything else. I am sorry for that. I dedicate this thesis to you and to our wonderful kids, August, Maru, and Elias. May this work remind them and us that when we work together, we can accomplish the unimaginable.

I am very happy that I have made some close friends over the course of my studies. Without you, Mari, and Mariann, handling the stress of writing and life, in general, would all have been a lot harder. I am grateful for every happy and a little bit less happy moment we shared, with or without cake. Marit, Siim, and Alvar – you have always been there for me and rooting for me in each step throughout my life and studies. Thank you for the support and for creating a trusting space where we could converse, share, and connect our minds. A piece of trivia: I wrote some parts of this foreword at your wedding Marit and Siim, while trying to put my kids to sleep.

And finally, I owe a huge thank you to my mother, Sirje. We have had some rough times together, but I am happy that we have always found a way to stay afloat in life. I believe that your kindness and investigative mind have led me to

this happy place where I am today. This work is also dedicated to you. You are the best mother I could ever wish for.

I am always in awe of the world that surrounds us. Academia, which celebrates the beauty of the inquisitive minds of the people in it, has given me the opportunity to explore and push the limits of my mental boundaries. For that, I am forever thankful. Life is always about contrast. At times of hardship, I cue the music of Bowie in my mind. It reminds me of the elusive control we seemingly have over our life and to never take yourself and life too seriously.

for here am I sitting in a tin can

far above the world

planet Earth is blue,

and there's nothing I can do

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LIST OF PUBLICATIONS

P1: Malmi, Anton. 2019. Spectral properties of Estonian palatalization. In: Sasha Calhoun, Paola Escudero, Marija Tabain & Paul Warren (Ed.). Proceedings of the 19th International Congress of Phonetic Sciences (3782–3786). International Congress of Phonetic Sciences, Melbourne, Australia, 5–9 August. Canberra, Australia: Australasian Speech Science and Technology Association Inc.

P2: Malmi, Anton, Pärtel Lippus & Einar Meister. 2022. Spectral and temporal properties of Estonian palatalization. Journal of International Phonetic Association, 1–26. DOI: https://doi.org/10.1017/S0025100321000360.

P3: Malmi, Anton & Pärtel Lippus. 2019. Keele asend eesti palatalisatsioonis [The position of the tongue in Estonian palatalization]. Eesti ja soome-ugri keeleteaduse ajakiri = Journal of Estonian and Finno-Ugric Linguistics, 10 (1), 105–128. DOI: https://doi.org/10.12697/jeful.2019.10.1.06.

P4: Malmi, Anton, Pärtel Lippus & Einar Meister. 2022. Articulatory properties of Estonian palatalization by Russian L1 speakers. Eesti ja soome-ugri keeleteaduse ajakiri = Journal of Estonian and Finno-Ugric Linguistics, 13 (2). 79–118. DOI: https://doi.org/10.12697/jeful.2022.13.2.03.

P5: Malmi, Anton & Pärtel Lippus. 2021. Russian L1 speakers' palatalization in Estonian and the effect of phonetic speech training. Eesti Rakenduslingvistika Ühingu aastaraamat = Estonian papers in applied linguistics, 17, 211–230. DOI: https://doi.org/10.5128/ERYa17.12.

1 INTRODUCTION

1.1 The goals and contribution of the thesis

The current thesis focuses on the secondary palatalization of Estonian alveolar coronal consonants /l, n, s, t/ in phonologically contrastive pairs and in *i*-stemmed nouns where it is not contrastive. Palatalization is a process in which the consonant typically assimilates with nearby front vowels /i/ or /e/ or a glide /j/ (Bateman 2007). In this coarticulatory process, the place of articulation of the consonant can become palatal, or it can acquire a secondary place of articulation on the hard palate. The process of palatalization is common in the world's languages, including Estonian, Russian, English, French, Japanese, and many others (Bateman 2011).

At the core of the current dissertation is the acoustic and articulatory analysis of palatalization in Estonian, a Finno-Ugric language of the Uralic language family. It focuses on two main research questions:

- What are the acoustic and articulatory properties specific to Estonian palatalization?
- How is Estonian palatalization realized by Russian L1 speakers of Estonian?

Palatalization in Standard Estonian has received some attention from Estonian phoneticians. Most of the literature is from the middle and end of the 20th century (Lehiste 1960; Lehiste 1965; Liiv 1965a; Liiv 1965b; Vihman 1967; Eek 1971; Remmel & Eek 1971; Eek 1973; Teras & Pajusalu 2014; Põld 2016; Piits & Kalvik 2019). A few empirical studies have also looked at the realization of Estonian palatalization in Southern Estonian (Org 2003; Org 2006) and in the Insular dialect (Niit 2005; Põld 2019). All of those studies have concluded that, acoustically, palatalization can be best described by the rise in F2 and fall in F1 in the vowel that precedes or follows the palatalized consonant[1]. Unfortunately, most of these studies have a small sample size and use descriptive statistics. More work with bigger sample sizes and up-to-date statistical methods is needed to supplement the previous research.

Most of the earlier studies are based on acoustic data (Lehiste 1960; Liiv 1965a; Liiv 1965b; Vihman 1967; Remmel & Eek 1971; Lehiste 1965; Org 2003; Niit 2005; Org 2006; Teras & Pajusalu 2014; Põld 2016; Piits & Kalvik 2019; Põld 2019), which is often used to make assumptions about articulation, but the relationship between acoustics and articulation is not always linear (Iskarous 2007).

[1] A reviewer suggested that as there is a phonemic contrast between non-palatalized and palatalized consonants in Estonian, the IPA symbols should be used whenever there is a reference to palatalized consonants in the thesis. I agree that this would make sense from the phonological perspective, however this is not how the consonants were annotated in the five publications that make up the thesis. I will refrain from using the symbols in the covering chapter of the thesis as well.

Therefore, the findings from acoustic studies need to be confirmed with with articulatory findings. A lot of the research has concentrated on the duration of the preceding vowel. However, there is a lack of data on the temporal characteristics of palatalized consonants themselves, and more research is needed.

All of the articulatory studies on palatalization in Estonian have used a pseudo-palate that registers the contact of the tongue on the hard palate and alveoli (Kutser 1935; Ariste 1943; Eek 1971; Eek 1973; Meister & Werner 2015). As mentioned above, palatalizing the consonant also affects the preceding vowel. An articulatory analysis of these vowels is not possible with this methodology because the vowels do not come in contact with the roof of the mouth. To overcome this shortcoming, the current thesis offers a view into the articulation of the palatalized consonants and preceding vowels using a Carstens AG501 electromagnetic articulograph. This device allows one to dynamically capture the movement of the tongue in a three-dimensional space, and it does not rely on the contact of the tongue on the roof of the mouth.

So far, research on Estonian and other languages (e.g., Kochetov 2002; Ní Chiosáin & Padgett 2012; Howie 2001) has described palatalization by measuring the quality of the consonants and the preceding vowels from one or a few measurement points within the segment. However, the scope of palatalization and the dynamic articulatory properties of vowels that precede palatalized consonants are mostly unclear. The current thesis implements a dynamic analysis of the vowel and consonant sequences to provide a broader acoustic and articulatory account of how palatalization is realized by Estonian L1 speakers and how it is realized by Russian L1 speakers of Estonian.

Russian L1 speakers are the most prominent language minority in Estonia, making up one-fourth of the total population (Stats 2017). Estonia became independent in 1918 and was ethnically homogenous. At that time, Russians constituted about 8% of the population. In 1940 Estonia was occupied by the Soviet Union, and a vast labor force of Russians was recruited and allocated to Estonia. By 1989 the Russian population reached around 30%, but the prestige of Russian remained low (Raun 2001). Three main concentrated areas emerged: bilingual Tallinn (capital), Russian-speaking north-east, and the rest of the Estonian, which was predominantly Estonian speaking. These regions have been retained, and two separate communities have existed ever since (Verschik 2008). In today's times, the older generation of Estonians knows Russian as well as the younger generation of Russians knows Estonian (Zabrodskaja & Kask 2017). However, there is a continuous effort to integrate Russian speakers into Estonian society and educate them in Estonian.

Studies on Russian-accented speech in Estonian have mainly been focused on the production and perception of Estonian ternary quantity contrasts and Estonian vowel categories (e.g., Meister 2011; Meister & Meister 2011; Lippus, Pajusalu & Allik 2009). The production of palatalization has not been studied in L2 Estonian and needs more attention because of its potential to contribute to having a foreign accent. L2 speakers are not expected to obtain a perfect native-like pronunciation. Still, this can be a problem for some learners as a foreign accent can

trigger stereotypes that may partially impede integration into the majority society as well as communication with native speakers (Gluszek & Dovidio 2010).

Problems with acquisition, production, and speech accent arguably arise because our native language affects the way we perceive and thus produce other languages. Speech learning models have shown that the similarities and differences between languages can reliably predict the outcomes of L2 speech (Flege 1995; Flege & Bohn 2021; Best 1995; Best & Tyler 2007). Although palatalization in both Estonian and Russian is accompanied by a secondary tongue raising, it is more salient in Russian, involving almost all consonants (Avanesov 1972; Ordin 2011). The difference is that in Estonian, palatalization is not marked in orthography as it is in Russian. For the Russian L1 speakers, these similarities and differences have the potential to interfere with their production of palatalization in Estonian.

The current thesis contributes to the previous research by providing an acoustic and articulatory account of palatalization by analyzing a large number of speakers and their productions. In addition, comparing native speakers to Russian L1 Estonian L2 speakers leads to a better understanding of Russian-accented speech in Estonian.

The main body of the thesis is divided into six chapters. Chapter 1 postulates the main objectives of the thesis and describes the theoretical background. After that, the research questions and hypotheses are outlined. Chapter 1 also describes the structure of and provides an overview of the publications that make up the thesis. Chapter 2 describes the materials and methods that are used in the thesis. Chapter 3 summarizes the main results and discusses them in light of relevant studies. Chapter 4 highlights the main conclusions of the study, and Chapter 5 gives an overview of the thesis in Estonian.

1.2 Theoretical background

In general, palatalization can be divided into two main types: full and secondary (Bateman 2007). The degree and type of the outcome of palatalization can be determined by looking at the articulatory changes in the target consonant. With full palatalization, the primary place of the articulation of a consonant is shifted to the palatal region – for example, /t/ → /tʃ/. With secondary palatalization, the primary constriction remains fairly unchanged, but the consonant acquires a secondary place of articulation on the hard palate – for example, /t/ → /tʲ/. Typologically, secondary palatalization is common in the world's languages, and it can involve labial, dorsal, or coronal consonants or a combination of them. It is not uncommon that coronal consonants are the only consonants that palatalize in a language (Bateman 2007).

Estonian /l, n, s t/ can be phonetically and phonologically palatalized in monosyllabic words after the first vowel or in disyllabic words at the boundary of the first and second syllables. For example, /l/ can be contrastively palatalized in the monosyllabic word *alt* [ɑlʲtː] ‘alto’ or non-contrastively in *null* [nulʲː] ‘zero’.

Phonetic palatalization can, in some cases, be optional and vary regionally (Teras & Pajusalu 2014; Põld 2016; Piits & Kalvik 2019). For example, /l/ in the word *album* [ɑlːpum] ‘album’ is not palatalized in Standard Estonian but can be in some southern dialects. Historically, the palatalization of the word-final consonant in monosyllabic nouns like *mutt* [mutʲː] 'mole' or *kott* [kotʲː] ‘bag’ was triggered by the final stem vowel /i/. After the apocope of the final vowel in the 13th–14th century, the consonant remained palatalized and is pronounced as such until this day (Kask 1972: 133). The apocope of the vowel resulted in phonologically contrastive pairs in nouns, in which palatalization is otherwise not contrastive. Palatalization is also common in Finno-Ugric languages (excl., Finnish and Izhorian). In addition to internal prosodic changes in Estonian, there were contacts from north-west and south from other Finno-Ugric languages like Karelian and Livonian from which Estonian might have acquired palatalization (Laanest 1975). Karelian and Livonian, in turn, had language contacts with other Slavic languages where palatalization is wide-spread.

It is important to note that palatalization of consonants is not marked in Estonian orthography. This is different from Russian, where palatalization is marked with a modifier letter ь. For example, the pronunciation of the Estonian homograph’s *pats* [pɑtːs] ‘pat’ or *pats* [pɑtʲːs] ‘braid’ is dependent on the surrounding context. The discord between orthography and pronunciation makes lexical and phonetic mapping difficult for the learner (Pallier, Colomé & Sebastián-Gallés 2001; Bassetti 2008; Escudero, Hayes-Harb & Mitterer 2008; Hayes-Harb, Nicol & Barker 2010; Rastle et al. 2011; Simonchyk & Darcy 2018). This has been shown to apply even more strongly when the languages use different writing systems, as in the case of Estonian (Latin alphabet) and Russian (Cyrillic alphabet) (Gottardo et al. 2001).

From the point of view of articulation, consonants in Estonian (Kutser 1935; Ariste 1943; Eek 1971; Meister & Werner 2015) and Russian (Avanesov 1972; Kochetov 2002; Ordin 2010) are palatalized by raising the back of the tongue to the hard palate while the primary constriction remains on the alveoli. The tongue is fronted and wider because it is pressed against the hard palate and the teeth. This cross-linguistic property of tongue raising is evident acoustically by a rise in the second formant (F2) and the third formant (F3) and a lowering of the first formant (F1) frequencies of the preceding vowel (Lehiste 1965; Teras & Pajusalu 2014 for Estonian; Derkach, Fant & de Serpa-Leitao 1970; Purcell 1979; Howie 2001; Kochetov 2002 for Russian; Kim 2012 for Korean; Cavar 2004 for Polish; Ní Chiosáin & Padgett 2012 for Connemara Irish). A study by Vihman (1967) compared the quality of Estonian and Russian palatalization in phonologically contrastive pairs. The results show that secondary palatalization is realized similarly in both languages. However, there are language-specific differences in the articulatory movements – for example, a difference in tongue height or anteriority that have to do with a higher degree of velarization of palatalized consonants in Russian. Vihman (1967) states that palatalization in Estonian and Russian can be directly compared to each other.

The acoustic characteristics of the palatalized consonants vary with the specific place and manner of articulation. For example, the palatalization of /l/ can be described by the higher F2 and F3, and lower F1 values (Lehiste 1965; Vihman 1967; Remmel & Eek 1971; Eek 1972), but the F2 values of /n/ are dampened by the anti-formant that forms in the oral and nasal cavities (Fant 1960; Derkach, Fant & de Serpa-Leitao 1970; Eek 1972; Tabain et al. 2016). /s/ and /t/ are usually analyzed by exhibiting a change in center of gravity (COG), and it has been shown that the COG is lower for fricatives (Padgett & Żygis 2003; Hamann & Avelino 2007; Kochetov & Radisic 2009) and higher for stop consonants (Shupljakov, Fant & De Serpa-Leitao 1968; Kochetov 2002; Kavitskaya 2006; Botinis, Chaida & Magoula 2011; Ní Chiosáin & Padgett 2012). It has been reported for Estonian that only the initial part of the consonant is affected by palatalization (Lehiste 1965; Liiv 1965a; Eek 1972; Eek 1973) and that palatalization in Estonian is weaker than in Russian (Bondarko & Verbitskaya 1987). Consonants with different manners and places of articulation need different methods of analysis, but the analysis of vowels is more straightforward, as they can all be analyzed by looking at the formant structure.

The palatalization of a consonant is accompanied by a longer duration of the vowel that precedes it. This lengthening occurs because of the tongue raising but also because it can enhance the perceptual distinctiveness of palatalization (Ordin 2010). The consonant itself lengthens in some cases too, but the evidence for this is contradictory and probably language-specific. For example, in Russian, the release bursts of palatalized consonants are longer than those of non-palatalized consonants (Kochetov 2006; Ordin 2010), presumably because Russian palatalized consonants are followed by an audible aspiration. At the same time, the duration of /s/ is shorter with palatalization (Bolla 1981). The results of measuring the duration of consonants in Estonian have shown that palatalization does not have an effect on duration (Lehiste 1960).

While there has been some research done to map the acoustic and articulatory properties of palatalization, the scope of palatalization is unclear. This is because the acoustic and articulatory properties of the preceding vowel and the consonant have mostly been studied from one or few measurement points (Lehiste 1965; Liiv 1965b; Liiv 1965a; Vihman 1967; Derkach, Fant & de Serpa-Leitao 1970; Purcell 1979; Howie 2001; Kochetov 2002; Cavar 2004; Kim 2012; Ní Chiosáin & Padgett 2012; Teras & Pajusalu 2014; Põld 2016; Piits & Kalvik 2019). The beginning of the vowel transition has usually been excluded in order to remove the effect of the surrounding context. The current thesis offers new insight into the realization of palatalization and its scope by dynamically analyzing the acoustic and articulatory properties of preceding vowels and consonants. In the current thesis, these novel findings on Estonian palatalization are also used to compare native speakers with Russian L1 speakers.

Nonnative speakers often have a native language accent in their L2 speech. The speech accent is even stronger and more persistent if the learners continue to frequently use their L1 while learning L2 (Flege, Frieda & Nozawa 1997). Some of the most well-known language learning models, such as the Speech Learning

Model – SLM (Flege 1995), and its revised version SLM-r (Flege & Bohn 2021), the Perceptual Assimilation Model – PAM (Best 1995), and the version of PAM that describes L2 learning – PAM-L2 (Best & Tyler 2007), converge on the idea that speech accents arise because the knowledge of the phonological and phonetic system from our native language affects the way we perceive and produce segments in L2. Consequently, problems with acquisition can be predicted using the phonetic and phonological similarity and dissimilarity of L1 and L2. At the same time, there are key differences between SLM(-r) and PAM(-L2) models. SLM-r posits that there is a tight link between perception and production, but PAM-L2 proposes that in some cases there is a divergence between the two. SLM(-r) suits the analysis of production better, while PAM(-L2) is more useful for perceptual aspects. Nonetheless, the assimilation pathways posited by PAM(-L2) are very similar to the *equivalence classification* proposed by SLM framework, which will be discussed below.

PAM-L2 proposes many different acquisition pathways for the learner, but only two are relevant to the current thesis. (1) Two-category assimilation in which the learner maps two contrasting L2 sounds to two different L1 categories. This is the easiest type of assimilation for the learners, and they should be able to discriminate between the two L2 sounds easily. (2) Single-category assimilation, in which two L2 sounds are assimilated to a single category in L1. This type of contrast should be difficult for the learner because the perceived sounds are not easily distinguishable.

SLM(-r) describes three main pathways of acquisition. (1) Identical – this occurs when an L2 phoneme is classified as being a good match for an L1 phoneme. (2) Similar – this occurs when two or even more distinct L2 phonemes are classified as being a similar match for a single L1 phoneme. (3) New – in this case, the segments in L2 are not similar to any of the L1 categories, and the learner has to establish a new category. (1) and (2) deal with equivalence classification, and (3) deals with the formation of new categories.

Members of the L2 group in the current study deal with palatalization contrast using a "similar" scenario (according to the SLM(-r) classifications) because secondary palatalization is used phonetically and phonologically in both Estonian and Russian. According to PAM(-L2), it is likely that a two-category or single-category assimilation will occur. An example of how the learners' native language affects their L2 perception and production comes from Spanish L1 Dutch L2 speakers. The Dutch contrast /ɪ/-/ɛ/ is acoustically similar to the Spanish /i/-/e/ contrast, and it has been shown that Spanish learners replicate their native contrast while producing Dutch (Burgos 2018). Another example of a "similar" scenario comes from Japanese L1 English L2 speakers. English /l/ and /ɹ/ are categories that do not exist in Japanese. According to SLM(-r), English /l/ is more difficult for Japanese learners than /ɹ/ because English /l/ is similar to Japanese /ɾ/. Thus, Japanese speakers have trouble differentiating between English minimal pairs like *bellies* and *berries* because they perceptually assimilate English /l/ and /ɹ/ (Aoyama et al. 2004; Shinohara 2014).

It is important to note that the way L2 learners map categories onto L1 differs because they take different learning paths and face different problems. So, naturally, there will be individual variation in the perception and production of nonnative segments. There will also be variation between learners because they are exposed to different inputs during their acquisition. SLM(-r) states that no L2 acquisition can match the production of a mature target language speaker. This means there will almost always be a divergence between L1 and L2 speakers. That being said, the learners are always improving, and there is no end-state to their learning.

In contrast to the lack of L2 studies on palatalization, numerous studies have analyzed the production and perception of the Estonian three-way quantity system and vowels by Estonian L2 speakers. In most languages, including Russian, the duration of consonants and vowels is not contrastive, and it usually acts as a cue for word stress. In Estonian, however, a ternary quantity contrast is realized within a short, long, or overlong foot. This is manifested through the duration ratio between stressed and unstressed syllables and, as a secondary feature, through fundamental frequency (Lippus 2011). Studies on the quantity system have found for Russian (Meister & Meister 2011; Meister & Meister 2012), Latvian (Meister & Meister 2014; Meister & Meister 2017), Finnish (Meister & Meister 2013), and Spanish L1 speakers (Leppik, Lippus & Asu 2020), that learners of Estonian usually differentiate between short and long or short and overlong categories but not between long and overlong categories. These studies have also found that learners tend to produce and perceive the Estonian vowel categories according to their native language. In line with SLM(-r) and PAM(-L2), L2 vowels that are not present in L1 are assimilated to fit the perceptual boundaries of the closest native vowel category of the speaker. Learners of Estonian mostly have trouble with [ɑ, y, ø, ɤ] (Meister 2011; Leppik, Lippus & Asu 2018; Nemoto, Meister & Meister 2015; Meister & Meister 2013). It can be argued that these temporal and segmental differences between Estonian and other languages can be a source of foreign-accented speech in L2.

Phonetic speech training can help learners to overcome problems with pronunciation. When the potential problems for the production of L2 have been identified, learners' pronunciation can improve through guidance. When learners of Russian that had classroom and immersion experience were tested while they produced Russian palatalization without any guidance, the results showed that they were unable to produce the palatalization contrast needed to differentiate consonants (Hacking et al. 2016). For example, although palatalization is not used in English to differentiate meaning as in Russian or Estonian, English L1 learners of Russian were able to produce the contrast after speech training with a pseudo-palate (Hacking, Smith & Johnson 2017). Similarly, Arabic L1 speakers' productions of novel Finnish vowels /y/ and /ø/ showed improvement after short phonetic speech training (Savo & Peltola 2019), and also English L1 speakers showed a significant improvement in the production of palatalization after they were familiarized with the articulatory nuances of palatalization through ultrasound (Roon, Kang & Whalen 2020).

1.3 Research questions and hypotheses

Based on the aims of the current thesis and the findings from previous research, the research questions and the hypotheses of this thesis are as follows:

a) What articulatory and acoustic properties describe Estonian native speakers' palatalization? It is hypothesized, based on previous research, that palatalization is articulatorily best described by the rising, fronting, and widening of the tongue. As a consequence, the apex of the tongue is also higher. This means that, acoustically, palatalization is manifested in the rise of F2 and F3 and in the fall of F1 frequencies of the preceding vowel. As a consequence of palatalizing the consonant, the duration of the preceding vowel is lengthened. It is also hypothesized that, because of sonority, the formant structure of /l/ is similar to the preceding vowel; /n/ might show a lowering in F2 because of the anti-formant; /s/ will have a lower center of gravity, and /t/ will have a higher center of gravity.

b) What is the scope of palatalization in Estonian? It is hypothesized, based on the findings from research on coarticulation, that speakers will anticipate the rising of the tongue that accompanies palatalization early on. This means that the F2 values (correlated with the fronting of the tongue) are higher from the beginning of the preceding vowel. Contrary to the previous findings for Estonian, it is expected that the formant and center of gravity values are affected up until the end of the consonant.

c) What are the articulatory and acoustic properties of Russian L1 speakers' Estonian palatalization compared to those of native speakers? This is the second study of Estonian in which the acoustic and articulatory properties of native and nonnative speakers' palatalization are analyzed together, the other being Vihman (1967). Based on that study, it can only be hypothesized that there are differences in tongue height and anteriority between Russian and Estonian palatalization. It is expected that Russian L1 speakers' Estonian consonants will have a longer duration because of the aspiration that usually accompanies palatalized consonants in Russian. Because of the fact that length is not contrastive in Russian (unlike in Estonian), the preceding vowels will be shorter in nonnative productions. This will be particularly clear because the test words in the current thesis are in an overlong quantity degree, and, as previous research has shown, L2 speakers have problems producing these. It can also be hypothesized that there will probably be variation in productions because palatalization is not marked in Estonian orthography, so non-native speakers will not always palatalize consonants where necessary.

Based on the predictions of SLM(-r) and PAM(-L2), it can be hypothesized that if there are differences between native and nonnative productions, then those differences will reflect the phonetic details of the native language of the speaker. Palatalization is a "similar" category for Russian speakers for which "two-category" or "single-category" assimilation will likely occur. In addition to the second language acquisition models' predictions, language-specific articulatory settings affect the realization of segments. As all segments are language-specific, these

specific details will carry over to L2. There will probably be variation between subjects because of orthographical differences between Estonian and Russian.

d) Does Estonian speech training affect Russian L1 students' productions of Estonian palatalization? It is hypothesized, based on previous research, that Russian L1 speakers' production of Estonian palatalization will get more native-like after attending speech training.

1.4 Overview of publications and the author's contributions

The first three publications in the current dissertation deal with the acoustic (P1, P2) and articulatory (P3) properties of native Estonian speakers' palatalization. The last two publications analyze the articulatory (P4) and acoustic (P5) properties of Russian L1 speakers' palatalization in Estonian and compare them to that of native Estonian speakers. In all of the publications, Malmi, as the first author, designed the experiments and carried out the recordings, authored the majority of the text in the papers, and did the statistical analysis.

P1 deals with the spectral center of gravity of Estonian palatalized consonants of native Estonian speakers. The objective of this paper was to find out whether the spectral center of gravity can be used to describe the effect of palatalization on the quality of four Estonian consonants.

P2 analyzes the spectral and temporal properties of the Estonian palatalized consonants and the preceding vowels. This paper aimed to study how the palatalization of a consonant is realized in Estonian and how far-reaching the effect of palatalization is. Lippus and Meister contributed to the various drafts of the paper and advised Malmi concerning the data analysis at each of the steps.

P3, which used the same participants and stimuli as P1 and P2, looked at the articulatory properties of Estonian palatalization. The main objective was to describe the articulation of Estonian palatalization by native speakers. Lippus analyzed the articulatory data, created the plots of the articulatory contours, and contributed to the drafts of the paper.

P4 used the same test materials and Estonian participants as P1–P3. In this paper, we analyzed the articulatory properties of Estonian palatalization by native Russian speakers, whose results were compared to those of native speakers. Lippus helped with the articulatory analysis and contributed to the drafts of the paper along with Meister.

P5 was based on data from Russian L1 high school students who were recorded before and after attending phonetic speech training for Estonian. The test subjects were different from those in P1–P4. Their data were compared to the control group of native Estonian speakers. The main objective was to study the realization of Estonian palatalization by Russian L1 speakers. Lippus created the formant plots and contributed to writing the article.

2 MATERIALS AND METHODS

The acoustic and articulatory data used in publications 1–4 were recorded in the Phonetics Laboratory at the University of Tartu, Estonia, and at the Tallinn University of Technology Phonetics Laboratory, Estonia, in 2018–2020. The data in P5 were recorded in a Russian-speaking high school in Tallinn, Estonia, in 2020. The Research Ethics Committee of the University of Tartu has approved the studies presented in the thesis.

2.1 Experiment 1: P1–4

2.1.1 Participants

43 native Standard Estonian speaking subjects (20 male, 23 female, aged 20–78) and 24 Russian L1 speakers of Estonian (7 male, 17 female, aged 18–44) were recorded. The data from all of the native speakers were analyzed in P1 and P2. A subset of 21 (10 male, 11 female, aged 20–52) native speakers were used in the articulatory studies P3–P4. All of the Russian L1 speakers were analyzed in P4.

Native Russian speakers in P4 reported that they spoke Russian at home with their parents; 17 of them had gone to a Russian preschool, seven to an Estonian or a bilingual preschool; 16 went to a Russian high school, five to a bilingual high school, and three to an Estonian-speaking high school.

2.1.2 Materials

The data consisted of 30 word pairs (see Appendix 1) and 31 *i*-stemmed nouns (see Appendix 2). The test words were placed in a carrier sentence. In total, there were 91 sentences where the sentence medial test word was in a focal position followed by a comma and a word starting with the syllable *mi-*.

2.1.3 Procedure

The data were recorded in two trials. The first trial was recorded with an electromagnetic articulograph; for the second trial, only the acoustic signal was recorded. The articulatory data were recorded with a Carstens AG501 articulograph using a 200 Hz sampling frequency. Five sensors were glued on the tongue (positions 1–5 in Figure 1) and one just below the lower incisors (position 6 in Figure 1). Alongside the articulatory data, acoustic recordings were made in order to match the phoneme boundaries with articulatory contours.

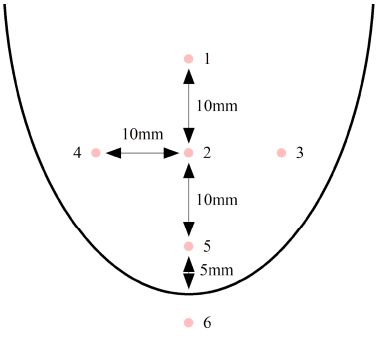

Figure 1. Schematic overview of the placement of the sensors on the tongue and the lower incisors; here, the curved black line represents the tongue, and the dots show where the sensors were placed.

The carrier sentences were presented to the test subjects on a computer screen in a randomized order using SpeechRecorder software (Draxler & Jänsch 2004). For the articulatory experiment, this was done using Praat (Boersma & Weenink 2021). The participants were not introduced to the materials beforehand. They had the opportunity to correct their pronunciation immediately if they felt they had misread something.

Some of the recorded test words and individual tokens had to be excluded because the test subjects did not produce any palatalization at all in some contexts, or there were problems with the sensors. Malmi listened to all of the recordings and determined whether the consonant was palatalized or not. This was done by listening to the /i/-like quality in the preceding vowel and a change in quality in the consonant. Spectrograms were also checked where necessary. In the few borderline cases where it was hard to assess the degree of palatalization, the consonants were classified to be palatalized. In total, 18 contrastive pairs were used for the analysis in P1 and P2 and 11 pairs in P3 and P4. 26 *i*-stemmed nouns were analyzed in P4. Ten additional articulatory recordings that were made in Tallinn, Estonia, were not analyzed as they were recorded with a different articulograph (an NDI Wave (Northern Digital Inc.)). However, the acoustic recordings of those ten subjects were analyzed alongside the data recorded in Tartu, Estonia.

2.1.4 Acoustic analysis

All recordings were initially segmented with an ASR-based forced aligner (Alumäe, Tilk & Asadullah 2018); following this; the segmental boundaries were manually checked for any possible misalignments. For the acoustic studies P1 and P2, the center of gravity (COG), the standard deviation of COG, F1–F3 values, and the duration of the segments were extracted with Praat and analyzed in R (R Core Team 2021).

For the F1–F3 analysis of the vowels and /l/, an Optimized Formant Ceiling method (Escudero et al. 2009) with modifications was implemented in Praat. Thirty equidistant time points were extracted from the duration of each vowel and consonant. For each segment, a formant ceiling was determined between 4000 and 8000 Hz with 10 Hz intervals. The ceiling with the smallest variance within each segment was selected for the analysis.

2.1.5 Statistical analysis

Statistical analyses were carried out with the R software. In P1, a Generalized Linear Mixed Model (GLMM) was used with the package *glmm* (Knudson 2018) to study the effect of palatalization, gender, and vocalic context on the COG. In P2, a Generalized Additive Mixed Model (GAMM) with the package *mgvc* (Wood 2017) was used to study the effect of palatalization, gender, and vocalic context on the formant values of the vowels and /l/. A Linear Mixed Model (LMM) with the package *lme4* (Bates et al. 2015) was also used with the same dependent variables to analyze the mean formant values of /n/, the COG, the standard deviation of the spectrum of /s/ and /t/, and the duration of the segments. In P3, a combination of GAMM and LMM was used to study the effect of palatalization, vocalic context, and duration on /l, n, s, t/ and the preceding vowels. In P4, a combination of GAMM and LMM was used to study the effect of palatalization, vocalic context, native language, and the duration of the consonants and preceding vowels. In all of the articles, a series of post-hoc tests were also carried out by changing the intercept of the statistical model and then running it again. The p-values were adjusted with a *p-adjust* function and corrected with Benjamini-Hochberg or Bonferroni-Holm methods in R.

2.2 Experiment 2: P5

2.2.1 Participants

Eight Russian L1 speakers (4 male, 4 female, aged 17–18) and 7 native Estonian (3 male, 4 female, aged 17–18) subjects participated in P5. This study was designed to look at the acoustic properties of Estonian palatalization before and after phonetic speech training. In the pre-test, around 40 test subjects were recorded, but only 8 of them returned for the post-test. Russian L1 speakers reported that they spoke Russian at home and had gone to a Russian-speaking preschool. They had Estonian classes at high school five days a week. A control group of 7 Estonian L1 speakers of the same age range and level of education who did not participate in the training were recorded at an Estonian-speaking high school in Tartu.

2.2.2 Materials

The data consisted of 31 sentences with *i*-stemmed nouns (the same as in Experiment 1, see Appendix 1) and 20 sentences where the palatalization of word-initial consonants was studied (see Appendix 3).

2.2.3 Procedure

P5 aimed to investigate the production of Estonian palatalization by Russian L1 speakers as well as the effect of speech training on their production of palatalization. A 12-week phonetic speech training course for Estonian that took place once a week for 1.5 hours was conducted by a speech and pronunciation coach at a Russian-speaking high school in Tallinn, Estonia. The training covered various topics on Estonian pronunciation. The correct usage of palatalization was covered in two of the twelve lessons. Alongside the lessons, the teacher made instructional videos on the topics covered so that the students had the chance to practice on their own at any given time.

A reading task was carried out twice in a quiet classroom: once before and once after the training. The carrier sentences were presented to the test subjects on a computer screen in a randomized order via SpeechRecorder software. The participants were not introduced to the carrier sentences before the pre-test. They had the opportunity to correct their pronunciation immediately if they felt they had misread the sentence.

2.2.4 Acoustic analysis

All recordings were initially segmented with an ASR-based forced aligner (Alumäe, Tilk & Asadullah 2018); following this; the segment boundaries were manually checked for any possible misalignments. The same Optimal Formant Ceiling method as in Experiment 1 was implemented to extract 30 F1 and F2 values for each vowel that preceded palatalized and non-palatalized consonants. The formant values were transformed into z-scores in order to normalize the differences in vocal tract length between male and female speakers. After that, the standard deviation of 30 measurement points within each of the individual vowel were calculated. The duration of the vowels was also extracted and analyzed.

2.2.5 Statistical analysis

LMM was used from the *lme4* package in R to estimate the effect of vowel and trial (pre-test, post-test, and control group) on the standard deviations of normalized F1 and F2 values (z-scores) within the 30 measurement points and the duration of vowels. A Benjamini-Hochberg corrected Tukey post hoc test was conducted for a pairwise comparison in R.

3 RESULTS AND DISCUSSION

This section is divided into two parts. In 3.1, the realization of Estonian consonants /l, n, s, t/ and the preceding vowels are analyzed and discussed. It summarizes the findings from P1–P3 and discusses the acoustic and articulatory realization of Estonian palatalization. Section 3.2 summarizes the findings from P4–P5 and compares the acoustic and articulatory properties of Russian L1 speakers' palatalization with native speakers.

3.1 The quality of Estonian vowels and palatalized consonants by native speakers

The results of P2, where the acoustic data from phonologically contrastive pairs were analyzed, showed that the F2 values of vowels that preceded palatalized consonants were consistently higher than in a non-palatalized context, just as hypothesized. F1 tended to be lower, but F3 values did not show a systematic variation. These results are mostly in line with previous research on Estonian (Lehiste 1965; Liiv 1965b; Liiv 1965a; Teras & Pajusalu 2014) as well as on Russian (Avanesov 1972; Bolla 1981; Kochetov 2002), Polish (Cavar 2004), Ocotepec Mixe (Hamann & Avelino 2007), Korean (Kim 2012), Connemara Irish (Ní Chiosáin & Padgett 2012), and Latvian (Urek 2016). Contrary to the hypothesis, however, the F3 values were not affected by palatalization. The higher F2 and lower F1 values with palatalization are clearly shown in Figure 2, where the vowels that precede /l/ are plotted.

P2 also aimed to offer a more dynamic view of the realization of palatalization by looking at the formant movements throughout the whole duration of the vowel. The 100 equidistant time points are plotted in Figure 2. This approach is rather novel because previous research in the field has measured the quality from a single or just a few timepoints (Lehiste 1965; Liiv 1965a; 1965b; Vihman 1967; Derkach et al. 1970; Purcell 1979; Howie 2001; Kochetov 2002; Cavar 2004; Kim 2012; Ní Chiosáin & Padgett 2012; Teras & Pajusalu 2014; Põld 2016; Piits & Kalvik 2019). The results in P2 showed that the F2 values were usually higher from the beginning of the vowel, while the change in F1 started later; this is also evident in Figure 2. The high value of F2 at the beginning of the vowel is probably due to the speech economy principle, according to which speakers adjust to the following segments early on. Thus, places of articulation of adjacent segments become similar, as has been shown in studies that look at vowel-consonant-vowel sequences (Lindblom 1963a; Lindblom 1963b; Öhman 1966; Amerman, Daniloff & Moll 1970; Hammarberg 1976; Lisker 1978; Farnetani & Recasens 2013; Malmi 2014; Malmi 2016).

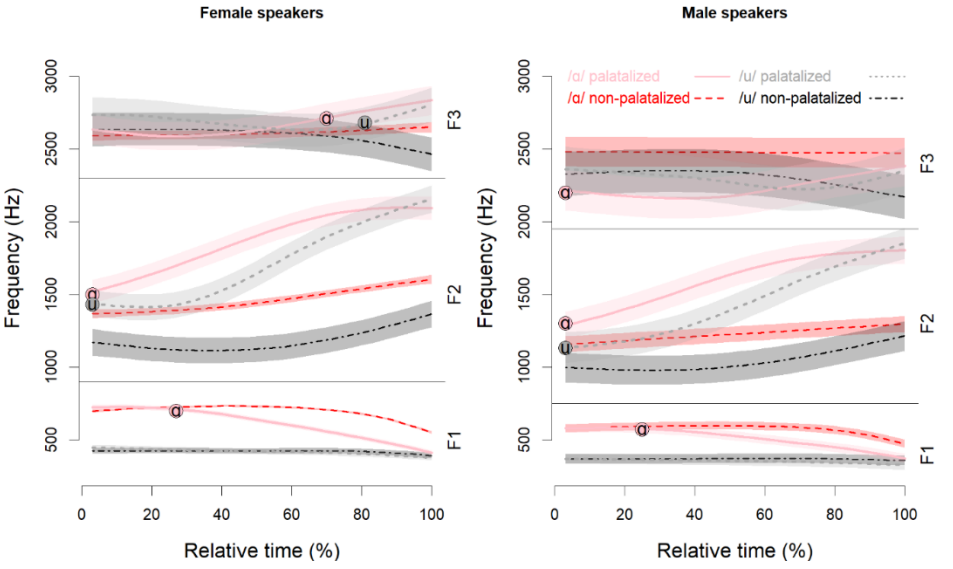

Figure 2. Fitted F1, F2, and F3 values from the GAMMs for the vowels preceding /l/ in test words produced by female (left panel) and male (right panel) speakers. The light colors represent the vowels in a palatalized context and the dark colors in a non-palatalized context: /ɑ/ - red, /u/ - black. The relative location of the timepoint from where the difference between the palatalized and non-palatalized conditions occur is marked with a dot.

The results from P3 showed that the formant movements in the vowels could be correlated with the actual articulatory gestures. The rise in the F2 values with palatalization is linked to the rising and fronting of the tongue body. This is also illustrated in Figure 3 (the upper row in each of the panels). For example, when the tongue moves up and forward in the oral cavity, the F1 values are lower because the pharyngeal cavity becomes longer and wider (Fuchs, Winkler & Perrier 2008; Lee, Shaiman & Weismer 2016). This was consistent throughout all consonant contexts. The rise in F2 in the preceding vowel can be used as a good indicator of consonant palatalization. This is also clearly visible in Figure 3 from P3, where the articulatory contours are plotted. The results from P3 also showed that the tongue body is raised and fronted during palatalization, and the tongue stays higher almost until the end of the consonant in all contexts. This contradicts the previous finding that palatalization only affects the initial part of the consonant in Estonian (Eek 1973).

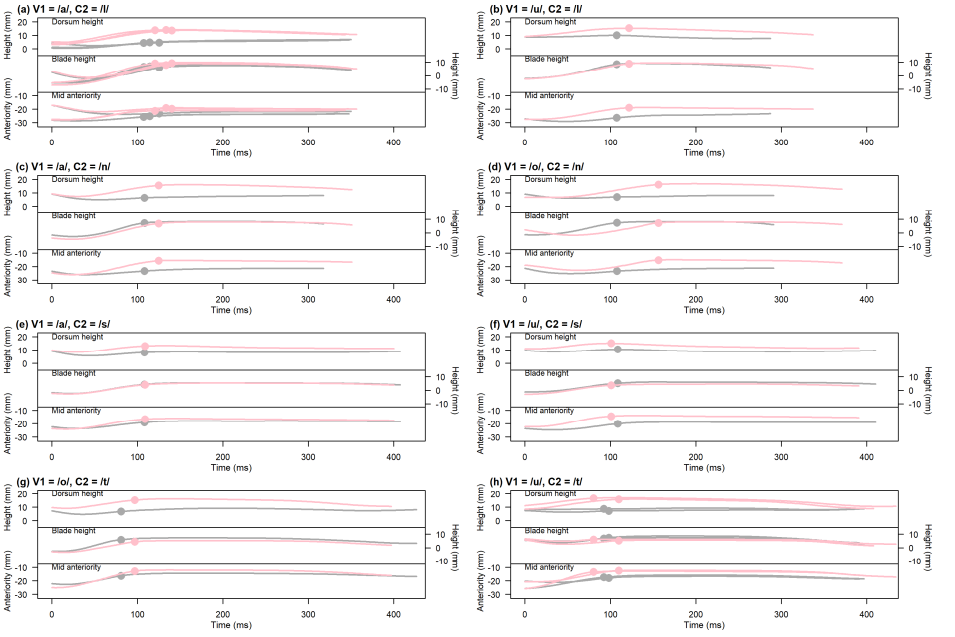

Figure 3. The height of the anteo-dorsum (Sensor 1) and the tongue blade (Sensor 5), and the anteriority of the tongue (Sensor 2) in millimeters when producing the VC sequence of the words with palatalized (pink) and non-palatalized (gray) consonants. The dot marks the acoustic boundary between the vowel and the consonant. Word-initial consonants are marked with a letter at the beginning of the lines. The panels are grouped by V1 and C2. The contours are averaged over all the speakers.

The problem with analyzing consonants with different manners of articulation is that they need different methodological approaches. For example, /l/ is quite sonorous and has a stable formant structure, but the formant values of /n/ are dampened by the anti-formant that forms in the nasal and oral cavities (Eek 1972; Tabain et al. 2016). At the same time, /s/ and /t/ do not have a clear formant structure and can be analyzed through spectral moments. However, an articulatory analysis of these consonants is more straightforward because it measures the tongue movements directly and does not rely on estimation, unlike acoustic analyses.

As hypothesized, the results from P2 showed that the F2 and F3 values of /l/ were higher with palatalization, while F1 was lower throughout. The effect of palatalization on /n/ was weak, and the F2 values, which were lower with palatalization, had to be averaged. The results for /s/ showed that with a higher tongue position, the mean spectral energy was lower. The effect of palatalization on /t/ had a weak lowering of the COG effect in the beginning. The results from P1 showed that it is possible to overcome the constraints posed by the acoustic analysis of Estonian palatalized consonants by using COG as a unified spectral measure. When Figure 2 from P2 and Figure 4 from P1 are compared, it is evident that the COG values of /l/ (bottom left panel) and /n/ (bottom right panel) behave in a similar manner as F2 values.

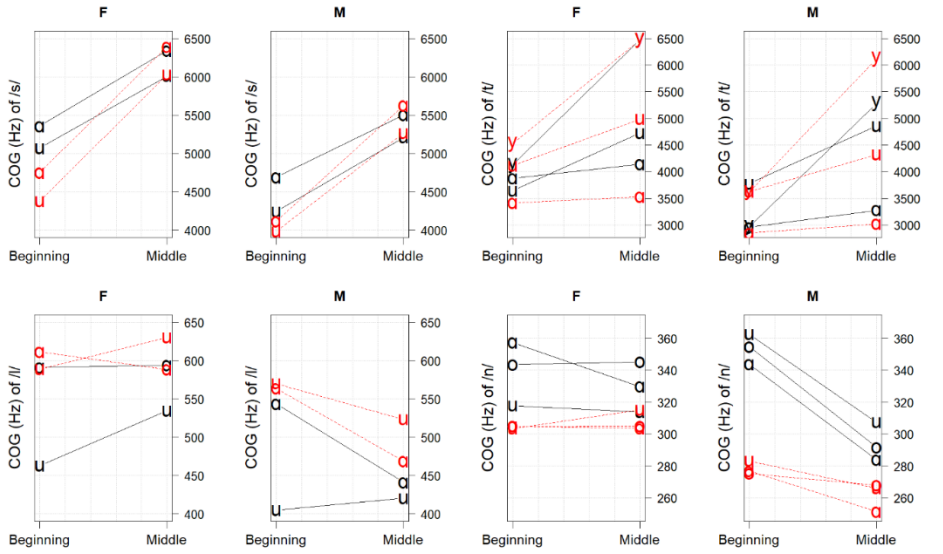

Figure 4. The center of gravity of the palatalized and non-palatalized /s/ (upper left), /t/ (upper right), /l/ (bottom left), /n/ (bottom right) of female (F) and male (M) speakers. Dashed lines represent palatalized productions, and solid lines non-palatalized productions.

As hypothesized, the results from P2 and P3 showed that the vowels in phonologically contrastive pairs were always longer with palatalization. This is in line with earlier findings for Estonian (Lehiste 1965; Liiv 1965a; Teras & Pajusalu 2014) and Russian (Ordin 2010; Stoll, Harrington & Hoole 2015). The vowel is lengthened because of the articulatory gesture of the tongue raising and fronting which occurs during consonant palatalization. This longer duration can also enhance the perception of palatalization (Ordin 2010). There were differences in the results in P2 and P3; specifically, in the latter, there was a weaker effect on duration. Presumably, the sensors on the tongue or any obstruction in the mouth has a hindering effect on pronunciation (Malmi 2016). P2 and P3 failed to find any effect of palatalization on the consonant itself. This is in line with a study by Lehiste (1960). The results from earlier studies demonstrate that the duration of the consonant is inconsistently affected by palatalization. For example, it has been found that there is a lengthening effect of palatalization on the duration of /s/ and on the burst of /t/ in Russian (Zsiga 2000; Kavitskaya 2006; Stoll, Harrington & Hoole 2015). At the same time, Russian /s/ has also been shown to have a shorter duration when palatalized (Bolla 1981). It seems that the effect of palatalization on the duration of the consonant itself is language-specific.

3.2 The quality of Estonian vowels and palatalized consonants produced by Russian L1 speakers

P4 looked at the articulation of Estonian palatalization by Russian L1 speakers in phonologically contrastive pairs and *i*-stemmed nouns. P5 analyzed the acoustic properties of palatalization for *i*-stemmed nouns and word-initial consonants.

The results of P4 showed that, in a phonologically contrastive context, Russian L1 speakers' tongue dorsum was higher and more anterior with palatalization than without. This is consistent with the production of palatalized consonants by Estonian L1 speakers in P2 and P3 and other languages and indicates that Russian L1 speakers used palatalization to differentiate meaning. Compared to the Estonian control group, the Russian L1 speakers' tongues were lower. This is also evident in Figure 5, where the height of the tongue is plotted. This effect was consistent in all consonant contexts. The results also showed that the tongue was more posterior than for the Estonian L1 speakers. This result is also shown in Figure 6, where the tongue anteriority in different consonant contexts is plotted. The result is consistent throughout all consonant contexts. The width of the tongue was similar between the groups.

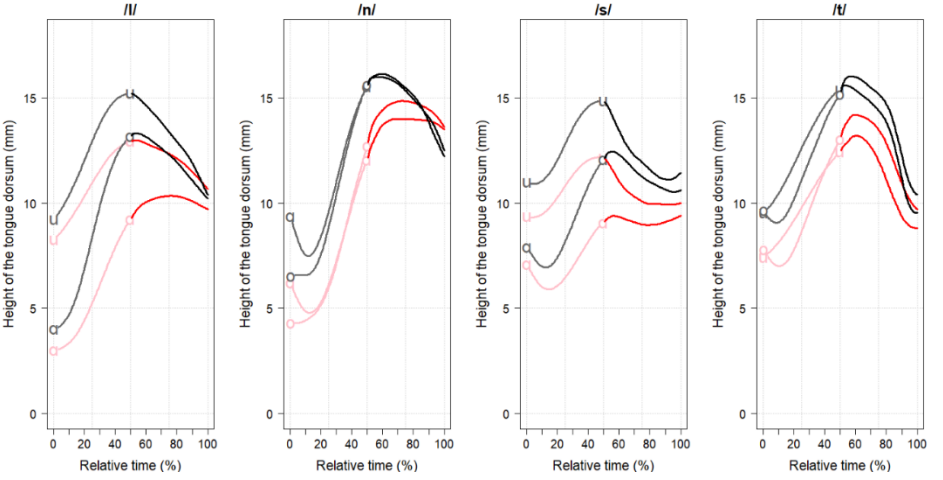

Figure 5. The height of the tongue dorsum (mm) within the sequence of a vowel and a consonant of Russian L1 speakers (pink/red) and Estonian L1 speakers (gray/black). The beginning of the vowel and the vowel-to-consonant boundary is marked with the vowel character. The measurements were time-normalized in reference to the segment duration so that the boundary between the vowel (lighter color) and the consonant (darker color) is always at 50%.

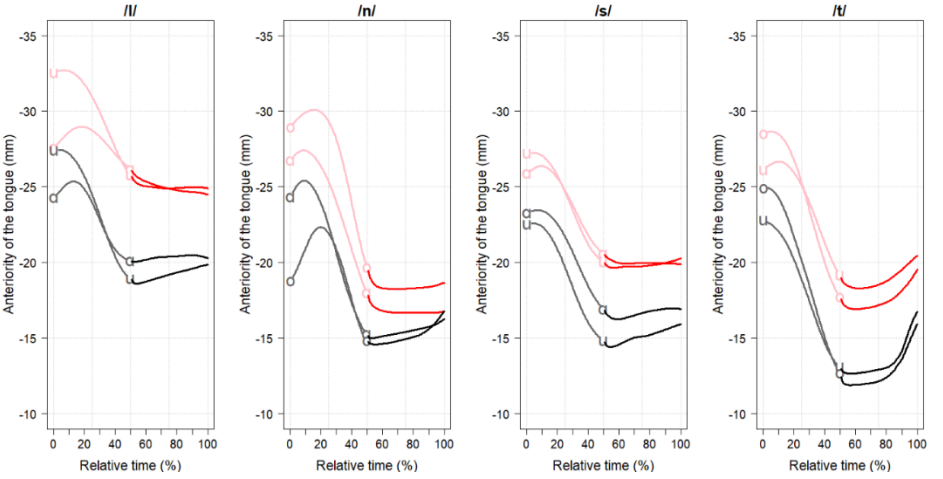

Figure 6. The anteriority of the tongue (mm) within the sequence of a vowel and a consonant of Russian L1 speakers (pink/red) and Estonian L1 speakers (gray/black). The beginning of the vowel and the vowel-to-consonant boundary is marked with the vowel character. The measurements were time-normalized in reference to the segment duration so that the boundary between the vowel (lighter color) and the consonant (darker color) is always at 50%.

The acoustic analysis of the preceding vowels in P5 found that the Russian group tended not to palatalize consonants in *i*-stemmed nouns. P4, which concentrated on articulation, showed, on the other hand, that their tongue dorsum was lower than for the Estonian L1 speakers, but the anteriority and width were similar. This means that the Russian speakers did palatalize consonants in this context but did so in a slightly different way than the native speakers. The results from P5 also showed that, while word-initial consonants can be palatalized in Russian, the learners did not palatalize these consonants in Estonian. A possible reason why the results between P4 and P5 differed could be because the Russian groups were of different levels of education and age.

The high school students in P5 were recorded before and after attending phonetic speech training to see if the training would affect the production of palatalization in Estonian. Previous studies have shown that phonetic speech training can help students of various ages and backgrounds to learn new contrasts (Taimi et al. 2014; Hacking, Smith & Johnson 2017; Savo & Peltola 2019). Contrary to the hypothesis, the voluntary speech training that they attended once a week for three months did not affect their production. The reason may lie in the fact that the training did not specifically concentrate on palatalization. Many topics were covered during the training, and the students might have been overwhelmed. It is possible that the training had a positive effect on something that was not measured.

As mentioned above, palatalization in Estonian and other languages is accompanied by a longer duration of the preceding vowel. For Russian L1 speakers in

P4, the duration of the vowels in contrastive pairs was not longer with palatalization, but the consonants showed a tendency to be longer. Compared to the control group, the duration of the Russian L1 speakers' productions were significantly shorter. In P5, there were no temporal differences between the groups. In Russian, palatalized consonants are accompanied by an audible aspiration, which adds to the duration. Natively, Estonian consonants are not pronounced with aspiration (Asu & Teras 2009).

The differences in duration between the native speakers and the Russian group might be due to the structure of the test words that contained mostly overlong consonants in a stressed position. In Russian, duration is mainly used to indicate stress, and length is not phonologically contrastive. As previous research has shown, the Estonian quantity system can be difficult for learners in that they have trouble differentiating between overlong and short or long quantity degrees (for example, Meister & Meister 2011; Nemoto, Meister & Meister 2015; Leppik, Lippus & Asu 2020).

A possible reason why there were differences in duration and articulatory movements between native speakers and Russian L1 speakers is that palatalization is not marked in Estonian orthography, unlike in Russian orthography. The palatalization of consonants in contrastive contexts and in *i*-stemmed nouns is dependent on the context that the test word is in. There were a lot of production errors in P4 by the Russian group, and around 50% of the productions in the contrastive context had to be discarded because the correct contrast was not produced. Although they had the option to re-read the previous sentence in the test, they rarely used it. It might have been difficult for the test subjects to concentrate and naturally produce palatalization in a laboratory setting. Ultimately, the results from P4 and P5 indicate that Estonian palatalization can be a problem for Russian L1 speakers.

Although Russian L1 speakers managed to produce a contrast between non-palatalized and palatalized Estonian consonants, the articulatory and acoustic properties of palatalization differed. As was hypothesized on the basis of SLM(-r) and PAM(-L2) models that were referred to in Chapter 1.1, it is likely that the learners were faced with two-category assimilation of similar contrast. PAM(-L2) has shown that two-category assimilation is easy to perceptually differentiate for the learner because the contrast is similar to one in their native language. This similarity might be problematic because speakers of different languages are bound by language-specific articulatory configurations. This means that they all have a different starting point from which the segments are produced (Gick et al. 2004; Wilson & Gick 2013), making it harder for the learner to combine different segments into a continuous native-like speech stream in L2. As the results from P4 and P5 show, because of the similarity of the contrast, Russian L1 speakers might not be sensitive to the fine phonetic details that differentiate palatalization in Estonian from that of Russian. Naturally, the learners face different problems, and they receive different inputs while learning a language, and this causes variation in production. Because many of the participants did not recognize palatalization from the context, a lot of tokens had to be discarded in P4 and P5.

SLM also states that while L1 has an effect on L2, the effect is bidirectional. Palatalization is said to be stronger in Russian and weaker in Estonian (Bondarko & Verbitskaya 1987). It could be the case that Russian L1 speakers' palatalization is weakened in Estonian, or they are hesitant when producing palatalization in Estonian.

SLM(-r) and PAM(-L2) have shown that there is a link between perception and production. If learners cannot perceive the difference between contrasts or sounds, they will probably not produce the difference correctly either. One limitation of the current thesis is that it only concentrated on production and not on perception. A possible research route that could validate the results in the current thesis would be to test the perception of palatalization of Estonian and Russian L1 speakers, thus assessing whether perception also contributes to speech accent. Another limitation is that only short vowels that preceded palatalized consonants were analyzed. It might be possible that the rise in F2 starts later in the relative duration of the longer vowel, and the scope of palatalization might not be as far-reaching as was found in the current thesis. It would be reasonable to test whether the scope of palatalization reaches further than the preceding vowel and/or further than the segment following the palatalized consonant. It would also be useful to test the learners of Estonian prior to and after phonetic speech training which concentrates on fewer topics and exclusively on palatalization.

4 CONCLUSIONS

The current thesis investigated the acoustic and articulatory realization of Estonian palatalization in phonologically contrastive pairs and in words where palatalization is phonetically conditioned. The thesis consists of five publications (P1–P5) and had two aims. First, to study the acoustic (P1–P2) and articulatory properties (P3) of palatalization by native speakers of Estonian. Second, to study the acoustic (P5) and articulatory (P4) properties of Estonian palatalization by Russian L1 speakers of Estonian.

The results from the acoustic study of native Estonian speakers (P2) showed that the F2 values of the preceding vowels were consistently higher from the beginning of the vowel than in the non-palatalized context. F1 tended to be lower, and the lowering started later. The data from the articulatory study (P3) showed that the rise in F2 and the lowering of F1 of the preceding vowels are connected to the higher and more anterior tongue position brought about by the palatalization of the following consonant.

The F2 and F3 values of /l/ were higher, while the F1 value was lower in P2. The F2 values of /n/ were lower with palatalization. The mean spectral energy (COG) of /s/ was lower at the beginning of the consonant. Palatalization on /t/ had a weak lowering of the COG effect only at the beginning of the consonant. The results showed that spectral energy moved in a similar manner as the F2 values. The data from the articulatory study were in line with the acoustic findings. The tongue body was raised and fronted during palatalization, and the tongue stayed higher almost until the end in all consonant contexts.

The durations of the vowels in phonologically contrastive pairs were always longer with palatalization. In the articulatory study (P3), the effect was weaker. Although the vowel tended to be longer, there was no effect of palatalization on the duration of the consonant itself.

The results from the articulatory study of Estonian L2 speakers (P4) showed that the tongue dorsum of the Russian L1 speakers producing phonologically contrastive pairs was higher and more fronted with palatalization, just as it was for the Estonian L1 speakers. However, compared to the native speakers, Russian speakers' tongues were lower and more posterior. The width of the tongue was similar between the groups.

The results from the *i*-stemmed nouns in the acoustic study (P5) and in the articulatory study (P4) showed different results. The acoustic study (P5) found that Russian L1 speakers tended not to palatalize consonants in *i*-stemmed nouns. The articulatory study (P4) found that the tongue dorsum of the Russian L1 speakers was lower in *i*-stemmed nouns than that of the Estonian L1 speakers, but the anteriority and width were similar. This means that Russian L1 speakers did palatalize consonants in that context, but differently than native speakers. The results from the acoustic study (P5) showed that the L2 speakers did not palatalize word-initial consonants in Estonian as they do in Russian.

In P4, the durations of the preceding vowels in contrastive pairs were not longer with palatalization, but the consonants showed a tendency to be longer. Compared to the control group, the duration of Russian L1 speakers' vowels and consonants were significantly shorter, but in the acoustic study P5, there were no temporal differences between the groups. The high school students in P5 were recorded before and after phonetic speech training to see if the training would affect the production of palatalization in Estonian. Contrary to expectations, attending speech training once a week for three months did not have this effect.

The current thesis contributes to the body of knowledge about the articulatory and acoustic process of palatalization in Estonian by analyzing its dynamic realization. Most of the previous studies have used only a few or even just one measurement point, but in the current thesis, one hundred measurement points were used for each of the segments. Articulatory studies with as many participants as in the current thesis are not common. This allowed broader generalizations to be made and affirmed the findings of previous studies on the acoustic and articulatory properties of palatalization. As of today, the phonetic realization of Estonian palatalization by non-native speakers has not been extensively studied in Estonian. The current thesis also contributes to the discussion about second language acquisition and its intricacies by showing how the acquisition of a similar category in L2 can be problematic.

In summary, the results showed that the palatalization of a consonant in Estonian is a process that affects the quality of the previous vowel already from the beginning of that vowel. Speakers anticipate the tongue rising that accompanies palatalization early on. The tongue stays high until the end of the consonant. Palatalization is a common feature of Russian, but it can be difficult for Russian L1 learners of Estonian to acquire it. This was evident from the more anterior and lower tongue position and from the temporal differences between Estonian L1 and Russian L1 Estonian L2 groups.

5 KOKKUVÕTE. EESTI JA VENE EMAKEELEGA KÕNELEJATE EESTI KEELE PALATALISATSIOONI HÄÄLDAMINE

5.1 Sissejuhatus

Palatalisatsioon on artikulatoorne protsess, mille käigus konsonandi häälduskoht assimileerub lähedal asuva vokaali /i/, /e/ või konsonandiga /j/ (Bateman 2007). Vokaali või /j/-i ja konsonandi koartikuleerimisel võib konsonandi peamine häälduskoht muutuda palataalseks või ta omandab sekundaarse häälduskoha kõval suulael. Eesti keele alveolaarsed konsonandid /l, n, s, t/ muutuvad läbi assimilatsiooni sekundaarselt palataliseerituks. Palatalisatsiooni võib leida paljudes maailma keeltes, näiteks vene, inglise, prantsuse, jaapani jm (Bateman 2011).

Käesolev väitekiri keskendub kahele peamisele uurimisküsimusele. Esiteks uuritakse, millised on eesti keele konsonantide /l, n, s, t/ palatalisatsiooni iseloomustavad akustilised ja artikulatoorsed omadused. Teiseks küsitakse, kuidas vene keelt emakeelena (L1) kõnelejad, kes räägivad eesti keelt teise keelena, produtseerivad eesti keele palatalisatsiooni?

Eesti keele palatalisatsiooni on peamiselt uuritud eelmise sajandi teises pooles, kuid leidub ka töid sellest sajandist. Varasemates eesti ühiskeele (Lehiste 1960; Lehiste 1965; Liiv 1965a; Liiv 1965b; Vihman 1967; Eek 1971; Remmel 1971; Eek 1973; Teras 2014; Põld 2016; Piits 2019) ja murdeuurimustest (Org 2003; Niit 2005; Org 2006; Põld 2019) on leitud, et akustiliselt kirjeldab palatalisatsiooni peamiselt teise formandi (F2) tõus ja esimese formandi (F1) langus. Nende uurimuste puudusteks aga on see, et neis on väikesed valimid ja neis esitatakse põhiliselt ainult deskriptiivset statistikat. Suur osa palatalisatsiooni puudutavatest uurimustest kasutavad kirjeldamiseks akustiliste salvestuste põhjal saadud andmestikke. Akustika põhjal saab küll teha oletusi artikulatsiooni kohta, kuid seos akustika ja artikulatsiooni vahel pole lineaarne. Palju on uuritud konsonantidele eelnevate vokaalide kestust, kuid andmeid konsonantide enda kohta on vähe.

Artikulatoorsed uurimused eesti keele kohta on peamise meetodina kasutanud palatograafiat, et uurida keele kontakti suulael (Kutser 1935; Ariste 1943; Eek 1971; Eek 1973; Meister & Werner 2015). Kuna palatalisatsioon mõjutab ka talle eelneva vokaali häälduskoht, siis palatograafiga selle kohta andmeid ei ole võimalik koguda. Käesolevas doktoritöös kasutatakse elektromagnetilist artikulograafi (Carstens AG501), mis võimaldab salvestada keele liikumist kolmemõõtmelises ruumis. Selle meetodiga saame me koguda ka andmeid keele liikumise kohta vokaalide hääldamisel.

Varasemates akustilistes uurimustes eesti keele ja ka teiste keelte kohta (näiteks Howie 2001; Kochetov 2002; Ní Chiosáin & Padgett 2012) on kaashäälikute ja neile eelnevate vokaalide kvaliteeti mõõdetud ainult ühest või paarist mõõtmispunktist. Ei ole selge, milline on palatalisatsiooni mõju ulatus ja milline on palataliseeritud kaashäälikutele eelnevate vokaalide dünaamiline realiseerumine. Käesolevas töös analüüsitakse vokaalide ja konsonantide häälдust dünaamiliselt, see

uudne lähtepunkt aitab näha, kuidas eesti keele palatalisatsioon realiseerub eesti L1 ja vene emakeelega eesti keele kõnelejate kõnes.

Vene emakeelsed kõnelejad moodustavad suurima vähemuskeele kõnelejate kogukonna Eestis. Nende integreerimiseks Eesti ühiskonda on oluline, et nad oskaksid rääkida enesekindlalt ja head eesti keelt. Vene aktsendiga tegelevad foneetilised kakskeelsuse uurimused on peamiselt tegelenud eesti keele väldetega ja vokaalikategooriatega (Meister 2011; Meister & Meister 2011; Lippus, Pajusalu & Allik 2009). Enamikus keeltest, sealhulgas vene keeles, ei ole konsonantide ja vokaalide kestus fonoloogiliselt kontrastiivne, vaid seda kasutatakse pigem rõhu märkimiseks (Avanesov 1972; Ordin 2010). Eesti ja vene keeles esinevad palataliseeritud konsonandid, kuid vene keeles hõlmab palatalisatsioon peaaegu kõiki konsonante, aga eesti keeles ainult nelja. Pole selge kas ja kuivõrd valmistab eesti keele palatalisatsiooni kasutus vene emakeelega õppijatele probleeme.

Peamised keele omandamise mudelid on näidanud, et sarnasused ja erinevused emakeele ja õpitava keele vahel mõjutavad seda, kui keeruline või kerge on teise keele omandamine. Näiteks sarnase foneemi või kontrasti omandamine on õppija jaoks raskem, kui täiesti uue õppimine (Best, 1995; Best & Tyler, 2007; Flege, 1995; Flege & Bohn, 2021). Vene emakeelega õppijad peavad ära tundma eesti keele palatalisatsiooni kirjeldavad tunnused ning seejärel seda eesti keelele omaselt hääldama. See on keeruline, sest neil on väga lähedane näide selle moodustamiseks oma emakeelest kohe võtta. Samas on uurimused näidanud, et kui õppijaid treenitakse kuulama vähe eristuvaid kontraste, siis neil tekib oskus neid kiiremini ja paremini omandada (Hacking, Smith & Johnson 2017, Savo & Peltola 2019).

Üks oluline erinevus eesti ja vene keele vahel on ka see, et eesti keele ortograafias ei märgita konsonantide palatalisatsiooni, kuid vene keeles tähistatakse seda pehmendusmärgiga ь. Grafeemi ja foneemide vastavus või mittevastavus keeltes võib negatiivselt mõjutada seda, kuidas õppijad foneemikategooriaid tajuvad ning põhjustada võõrkeele aktsenti (Bassetti 2008; Escudero, Hayes-Harb & Mitterer 2008; Hayes-Harb, Nicol & Barker 2010; Rastle jt 2011). Ortograafiliselt sarnased ja fonoloogiliselt kontrastiivsed paarid moodustavad käesolevas väitekirjas võrreldava andmestiku, mille põhjal saab hõlpsasti uurida palatalisatsiooni akustilisi ja artikulatoorseid tunnuseid.

Doktoritöös püstitatud kahele peamisele uurimisprobleemidele vastuste leidmine annab parema ülevaate sellest, kuidas palatalisatsioon eesti keeles realiseerub ja kuidas saadud tulemused on kooskõlas teiste keeltega. Doktoritööst teadmisi saab kasutada ka selleks, et võrrelda eesti emakeelega kõnelejate ja vene emakeelega õppijate eesti keele häälдust. Seda selleks, et näha, mis tekitab õppijale raskusi, ning et anda suuniseid keeleõpetajatele.

Käesolev väitekiri koosneb sissejuhatusest ja viiest publikatsioonist. Doktoritöö põhiosa on jagatud kuueks peatükiks. Doktoriväitekirja viis publikatsiooni käsitlevad kahte alamteemat. Publikatsioonid 1–3 uurivad eesti keele palatalisatsiooni akustilisi (P1 ja P2) ning artikulatoorseid (P3) tunnuseid. Publikatsioonid 4–5 uurivad vene L1 eesti keele palatalisatsiooni artikulatoorseid (P4) ja akustilisi tunnuseid (P5).

5.2 Materjalid ja meetodid

Doktoritöö jaoks läbi viidud akustilised ja artikulatoorsed katsed andmete kogumiseks publikatsioonidesse 1–4 toimusid Tartu Ülikooli foneetika laboris ja Tallinna Tehnikaülikoolis foneetika ja kõnetehnoloogia laboris aastatel 2018–2020. P5 jaoks salvestati materjal 2020. aastal Tallinna vene õppekeelega gümnaasiumis. Tartu Ülikooli inimuuringute eetikakomitee on doktoritöös kasutatavad uuringud heaks kiitnud.

5.2.1 Eksperiment 1: P1–P4

Katsete käigus koguti andmeid 43-lt eesti emakeelselt kõnelejalt (20 meest, 23 naist). Publikatsioonides 1–2, mis analüüsivad akustilisi andmeid, kasutati salvestusi kõigilt 43-lt kõnelejalt. Artiklites 3–4, mis analüüsivad artikulatoorseid andmeid, kasutati nendest 21 (10 meest, 11 naist) kõneleja andmeid. Artikulatsiooni uuriva P4 jaoks salvestati 24 (7 meest, 17 naist) vene emakeelega eesti keele kõnelejat.

Uurimismaterjaliks oli kokku 91 lauset, millest 60-s (vt täpsemalt Lisast 1) oli fookuspositsioonis testsõnaks üks fonoloogiliselt kontrastiivne palataliseeritud või palataliseerimata sõna. Ülejäänud 31-s lauses (vt täpsemalt Lisast 2) oli fookuspositsioonis palataliseeritud konsonandiga *i*-tüveline testsõna.

Materjal koguti kahes osas. Esiteks salvestati Carstens AG501 artikulograafiga katseisikute keele liikumist testlausete lugemisel. Katseisikutele liimiti ristikujuliselt 5 sensorit keelele (vt täpsemalt Jooniselt 1). Sensoritevaheline kaugus oli 1 cm ja keeletipu sensor oli keele tipust 0.5 cm kaugusel. Lisaks liimiti üks sensor alumise igeme peale. Artikulogaafi andmed salvestati 200 Hz kvantimissagedusega. Pärast seda salvestati ainult kõne, kui katseisikud lugesid neid samu lauseid helikindlas salvestuskabiinis ilma artikulograafi sensoriteta.

Salvestuste automaatseks segmenteerimiseks kasutati Tallinna Tehnikaülikoolis välja töötatud segmenteerijat (Alumäe, Tilk & Asadullah 2018). Pärast seda käidi kõik salvestused käsitsi üle ja kohandati segmentide piire, kui seda vaja oli. Praati skriptiga eraldati andmetest F1–F3 väärtused, kestus, spektri keskmine väärtus ja selle standardhälve. Formantide analüüsiks kasutati Optimaalsete Formantlagede meetodit (Escudero et al. 2009), mille käigus otsiti iga kõneleja igale häälikule vahemikust 4000–8000 Hz optimaalne formantlagi, mille puhul oli andmetes kõige vähem varieeruvust.

Statistiline analüüs ja joonised tehti programmis R (R Core Team 2021). P1-s kirjeldati üldistatud lineaarse segamudeli (GLMM) abil paketiga *glmm* (Knudson 2018) palatalisatsiooni mõju konsonandi spektraalsetele tunnustele. P2–P4 kasutati üldistatud aditiivset segamudelit (GAMM) paketiga *mgvc* (Wood 2017) ja lineaarset segamudelit (LMM) paketiga *lme4* (Bates et al. 2015), et kirjeldada palatalisatsiooni, häälikulise konteksti ja kestuse mõju konsonandi ja talle eelneva vokaali spektraalsetele ja artikulatoorsetele tunnustele. Kõikides artiklites tehti ka post-hoc teste kasutades *p-adjust* funktsiooni R-is, et erinevate faktorite tasemeid omavahel võrrelda.

5.2.2 Eksperiment 2: P5

P5 uuriti palatalisatsiooni akustilisi tunnuseid ja hinnati ka foneetilise kõnetreeningu mõju õppijate palatalisatsiooni hääldusele. Vene emakeelega õpilaste eesti keele hääldust salvestati enne ja pärast hääldustreeningut vaikses klassiruumis, et näha, kuidas häälduстreening mõjutab nende eesti keele palatalisatsiooni häälda-mist. Eesti kontrollgrupp salvestati vaikses klassiruumis Tartus. Enne treeningu algust salvestati andmeid 40-lt vene emakeelega katseisikult, kuid pärast treenin-gut tuli ainult 8 neist tagasi järelsalvestusele. Seega, analüüsiti andmeid ainult 8 (4 naist, 4 meest) vene emakeelega keskkooliõpilaselt ja 7 (3 naist, 4 meest) eesti emakeelega keskkooli õpilaselt.

Materjaliks kasutati samu 31 *i*-tüvelise testsõnaga lauseid, mis eksperimendis 1 (vt Lisa 2), ning 20 lauset, kus uuritav konsonant oli testsõna alguses, et uurida kas vene emakeelega õpilased palataliseerivad eesti keeles palataliseerimata sõna-algulisi konsonante (vt Lisast 3).

Kõik salvestused segmenteeriti TTÜ autosegmenteerijaga ning kõik segmen-tide piirid kontrolliti käsitsi üle. Andmetest eraldati Praati skriptiga kestus ja 30 mõõtmispunkti iga vokaali kohta kasutades Optimaalsete Formantlagede mee-todit. Formantväärtused transformeeriti z-skoorideks, et vähendada soost tingitud kõnelejatevahelisi erinevusi, mis tulenevad erinevatest kõnetrakti pikkustest. Pärast seda arvutati iga üksiku vokaali 30 mõõtmispunkti standardhälve.

Statistiliseks analüüsiks kasutati lineaarset segamudelit paketiga *lme4*, et uurida katsekonditsiooni (enne ja pärast treeningut, kontrollgrupp), palatalisat-siooni ja kestuse mõju normaliseeritud vokaalide F1 ja F2 väärtustele. Seejärel viidi läbi hulk post-hoc teste, et võrrelda omavahel erinevaid õppijagruppe ja testi-konditsioone, kasutades Benjamini-Hochberg korrektuuri p-väärtustele.

5.3 Tulemused ja diskussioon

P2 analüüsiti eesti keelt emakeelena kõnelevate katseisikute akustilisi andmeid. Andmetest ilmnes, et fonoloogilistes paarides palataliseeritud konsonantidele eelnevates vokaalides oli F2 alati kõrgem ja seda juba vokaali algusest peale (vt täpsemalt Jooniselt 2). F1 väärtus oli madalam ning langus algas pigem vokaali esimese kolmandiku juures. F1 ja F2 väärtused kirjeldavavad keele liikumist. F1 seostatakse keele kõrgusega ja F2 keele ees- ja tagapoolsusega. Kõrgem F2 väär-tus juba vokaali algusest võib viidata kõne ökonoomsuse printsiibile, mis ütleb, et seotud kõnes kõnelejad planeerivad alateadlikult eesolevat kõnet ja seega kohandavad rääkides oma artikulaatoreid, et üleminek ühelt foneemilt teisele oleks sujuvam. (Lindblom 1963a; Lindblom 1963b; Öhman 1966; Amerman, Daniloff & Moll 1970; Hammarberg 1976; Lisker 1978; Farnetani & Recasens 2013; Malmi 2014; Malmi 2016)

Konsonantide formantanalüüs näitas, et /l/-i F2 ja F3 väärtused olid palatali-satsiooniga suuremad kuni konsonandi lõpuni. /n/-i F2 väärtus oli madalam, kuid palatalisatsiooni mõju oli nõrk, sest antiformant, mis tekib nina- ja suuõõnes,

summutab formantväärtusi F2 piirkonnas. /s/-i ja /t/ puhul vaadati keskmist spektraalset energiat (COG) konsonandi algusest ja keskelt, sest kuna nad on helitud, pole nende puhul formantanalüüs võimalik. Tulemused näitasid, et COG oli mõlema konsonandi puhul ainult alguses madalam, keskosa ei olnud mõjutatud. Konsonantide keskmist spektraalset energiat analüüsiti ka P1 (vt Joonist 4), milles saadi /s/ ja /t/ puhul samad tulemused nagu P2 ning lisaks leiti, et /l/-i ja /n/-i oli keskmine spektraalne energia sarnase suunaga nagu F2 väärtused. Arvo Eegi (1973) tulemused on osutanud, et palatalisatsioon mõjutab eesti keele konsonandi kvaliteeti ainult selle algusosas. P3 saadud tulemuste põhjal võib aga öelda, et keele asend oli palatalisatsiooniga kõrgem kuni konsonandi lõpuni, mitte ei langenud tagasi alla (vt Jooniselt 3).

Erinevate keelte puhul on leitud, et palataliseerimisega kaasneb ka konsonandile eelneva vokaali pikenemine (Lehiste 1965, Liiv 1965a, Kochetov 2006, Ordin 2011, Teras & Pajusalu 2014, Stoll et al. 2015, Piits & Kalvik 2019). Seda näitasid ka käesoleva doktoritöö tulemused. See on seetõttu, et füüsiline liigutus mis hõlmab keele tõstmist suulae poole lisab vokaalile kestust juurde. Ilse Lehiste (1960) artiklis mõõdeti lisaks kõigele muule ja palataliseeritud ja palataliseerimata konsonantide kestusi. Tema andmetest selgus, et palatalisatsioonil ei ole eesti keele konsonantide kestusele mõju. Käesoleva doktoritöö P2 ja P3 saadud tulemused kinnitavad seda.

P4 leiti, et vene emakeelega eesti keele kõnelejad palataliseerivad eesti keele palatalisatsioonipaarides olevaid sõnu, aga nende keele asend on madalam ja tagapoolsem kui eesti emakeelsetel kõnelejatel (vt täpsemalt Jooniselt 5). Vene L1 kõnelejate keele asend oli ka madalam *i*-tüvelistes sõnades, aga mitte tagapoolsem. Oluline on siin märkida, et artiklis kasutati analüüsiks ainult neid paare, milles kõnelejad tundsid konteksti kaudu ära, et seal peab konsonanti palataliseerima. Umbes 50% sõnadest jäid analüüsist välja, kuna õiget kontrasti ei produtseeritud.

P5, kus uuriti lisaks palatalisatsiooni akustilistele tunnustele ka hääldustreeningu mõju, leiti, et vene emakeelega katseisikud pigem ei palataliseerinud konsonante *i*-tüvelistes sõnades. Artiklist selgus ka, et nad ei palataliseerinud sõnaalgulisi konsonante. Erinevus tulemustes kahe uurimuse vahel võib tuleneda sellest, et katsetes osalejad P4 ja P5 olid erinevate haridustasemetega ja vanusega. Foneetilisel hääldustreeningul ei olnud mõju vene emakeelega katseisikute eesti keele palatalisatsiooni hääldusele.

Kui palatalisatsiooniga kaasneb tavaliselt eelneva vokaali pikem kestus, siis vene emakeelega katseisikute andmetest seda ei leitud. Küll aga leiti, et nende konsonandid näitasid palatalisatsiooniga pikenemise tendentsi. Selle põhjuseks võib olla fakt, et vene keeles lisandub palataliseeritud konsonandile aspiratsioon, mis omakorda pikendab konsonandi kestust. Eesti keeles pole leitud, et konsonandi kestus oleks palatalisatsioonist mõjutatud. P4 võrreldi vene emakeelega katseisikute andmeid kontrollgrupiga ja leiti, et vene grupi produktsioonid olid oluliselt lühemad. P5 ei leitud, et eesti ja vene L1 produktsioonide vahel oleks olnud kestuserinevusi.

Keeleomandamise mudelid nagu SLM (Flege 1995), SLM-r (Flege & Bohn 2021), PAM (Best 1995) ja PAM-L2 (Best & Tyler 2007) on leidnud, et uusi kontraste või kategooriaid on keeltes lihtsam õppida, kui sarnaseid, sest sarnaste puhul on oma emakeeles lähedane näide kohe võtta. Õppijad ei kohanda kohe oma häälduslikke mustreid ümber, vaid nad kasutavad teadmisi oma emakeele häälikusüsteemi toimimisest teise keele produtseerimisel. Kuna palatalisatsioon realiseerub nii eesti kui vene keeles sekundaarsete omaduste kaudu, siis on selle produktsioon artikulatoorselt sarnane. Seetõttu on oht, et õppijad ei ole pane tähele foneetilisi peennüansse, mis palatalisatsiooni realiseerumist kahes keeles eristab. Doktoritööst selgus, et vene keelt emakeelena kõnelejate hääldus oli keel tagapoolsem ja madalam ning nende konsonantidele eelnevate vokaalide kestus oli lühem kui eesti keelt emakeelena kõnelejatel.

5.4 Kokkuvõte

Käesolevas doktoriväitekirjas uuriti eesti keele palatalisatsiooni akustilisi ja artikulatoorseid tunnuseid fonoloogiliselt kontrastiivsetes paarides ja sõnades, kus palatalisatsioon on ei erista tähendust. Saadud tulemusi võrreldi vene keelt emakeelega eesti keele kõnelejate häälduse.

Eesti keelt emakeelena kõnelejate akustilise uurimuse tulemused näitasid, et palataliseeritud kaashäälikutele eelnenud vokaalide F2 väärtused olid vokaali algusest peale püsivalt suuremad kui palataliseerimata kontekstis. F1 oli väiksem ja langus algas hiljem. Artikulatoorsed andmed näitasid, et vokaalide F2 suurenemine ja F1 vähenemine on seotud konsonandi palatalisatsioonist tingitud keele kõrgema ja eespoolsema asendiga.

Palataliseerimine mõjutas ka konsonandi kvaliteeti. /l/-i F2 ja F3 väärtused olid suuremad, F1 väärtused olid aga väiksemad. /n/-i F2 väärtused olid palatalisatsiooniga väiksemad. Keskmine spektraalne energia (COG) oli /s/-i ja /t/ puhul konsonandi algusosas madalam. /l/-i ja /n/-i formantide liikumine näitas sama suunda mis COG, mis tähendab, et seda saab edukalt kasutada, et kirjeldada konsonandi kvaliteeti palataliseerimisel. Artikulatsiooniuuringu andmed olid suuresti kooskõlas tulemustega akustilisest uurimusest. Palataliseerimisel tõuseb keel juba konsonandile eelneva vokaali algusest kõrgemale ja püsib kuni konsonandi lõpuni kõrgena.

Palataliseeritud konsonandile eelnev vokaal oli kestuselt alati pikem, kuid konsonant ise mitte. Esines lahknevus akustilises ja artikulatoorses uurimuses saadud tulemustes, kus viimases ei olnud kestusel nii suur olulisus palatalisatsiooni kirjeldava tunnusena.

Vene emakeelega eesti keele kõnelejate keeleselg oli fonoloogiliselt kontrastiivsetes sõnapaarides kõrge ja eespoolne, kuid kui nende andmeid võrreldi eesti emakeelega kõnelejatega, siis selgus, et see oli madalam ja tagapoolsem. Akustilises uurimuses leiti, et vene keelt emakeelena rääkijad pigem ei palataliseerinud konsonante *i*-tüvelistes sõnades, aga artikulatoorses uurimuses seda ei leitud.

Keel oli küll natuke madalam, aga mitte tagapoolsem. Nad palataliseerisid konsonante, kuid mitte nii nagu emakeelsed kõnelejad. Andmetest selgus ka, et vene keele kõnelejad ei palataliseeri sõnaalgulisi konsonante nii nagu nad seda teevad oma emakeeles.

Kui tavaliselt kaasneb palataliseerimisega konsonandile eelneva vokaali pikenemine, siis vene grupis seda ei leitud. Konsonandid ise aga näitasid neil pikenemise tendentsi. Kui vene keelt emakeelena kõnelejate tulemusi artikulatoorsest uurimusest võrreldi eesti emakeelsetega, siis selgus, et vene kõnelejate kestused olid oluliselt lühemad. Akustilises uurimuses rühmade vahel kestuse erinevusi ei olnud.

Vene emakeelega venekeelse õppekeelega keskkooli õpilased osalesid ka foneetilisel häältdustreeningul, kus muuhulgas harjutati eesti keele palatalisatsiooni hääldamist. Õpilased osalesid kord nädalas kolme kuu jooksul häältdustreeningul ja et hinnata nende edasijõudmist, salvestati neid enne ja pärast treeningut. Tulemused näitasid, et kõnekoolitusel ei olnud mõju nende eesti keele palatalisatsiooni häältdusele.

Käesolev doktoritöö täiendab teadmisi palatalisatsiooni toimimisest, näidates kuidas see dünaamiliselt realiseerub. Varasemates uurimustes on mõõdetud häälikute kvaliteeti ainult ühest või paarist mõõtmispunktist. Vastupidiselt varasematele artikulatoorsetele uurimustele erinevates keeltes, on käesolevas doktoritöös kasutatud suurt valimit, et teha täpsemaid üldistusi palatalisatsiooni toimimise kohta. Doktoritöö tulemused täiendavad ka peamiseid keele õppimise ja omandamise teooriaid, näidates, et emakeeles ja õpitavas keeles olevate sarnaste häälikute õppimine võib valmistada keeleõppijatele probleeme.

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APPENDIX 1.
Sentences recorded for P1–5: contrastive pairs

Non-palatalized	Palatalized
Ta küsis minult **kas**, mitte kus ma töötanud olen.	Mul oli punane **kass**, mitte must.
Tahtsin teada, **kus**, mitte kas sul töö on.	Palun ole **kuss**, mitte ära räägi kogu aeg.
Kevadel sündis väike **tall**, mitte vasikas.	Hobustele ehitati uus **tall**, mis pakub neile peavarju kogu aasta.
Külmal hommikul oli maas **hall**, mida oli ilus vaadata.	Minu auto on **hall**, mitte valge.
Mu sõbranna on **Mall**, mitte Anu.	Joonestamiseks on vajalik **mall**, mitte joonlaud.
See raamat oli **mul**, mitte sul.	Vee alt tuli pinnale **mull**, mis valjult lõhkes.
Tehtes eraldas arve **sulg**, mis tegi arvutuse võimalikuks.	Linnult kukkus küljest **sulg**, mis maandus mu jalgade ette.
Temas see miski **on**, mida ma ei oska kirjeldada.	Mul oli metsas **onn**, mida ma ehitasin terve suve.
Kastmiseks on meil rauast **kann**, mida olen juba kaua kasutanud.	Mänguasja kohta öeldi vanasti **kann**, mitte lelu.
Targal poisil oli silmapaistev **nutt**, mis teda elus edasi viis.	Mul oli kurgus **nutt**, mida ma hästi varjasin.
Mul tuli jalast puidust **kott**, mis viis mu tasakaalust välja.	Maas lebas suur **kott**, mis jäi kõikidele ette.
Külmal hommikul oli maas **hall**, mida oli ilus vaadata.	Minu auto on **hall**, mitte valge.
Vasakul oli arvudega **tulp**, mitte sõnadega.	Minu lemmiklill on **tulp**, mitte liilia.
Lambal oli pehme **vill**, millest hiljem tehti kampsun.	Nahal punetas **vill**, mis läks kergesti katki.
Mu sõbranna on **Mall**, mitte Anu.	Joonestamiseks on vajalik **mall**, mitte joonlaud.
See raamat oli **mul**, mitte sul.	Vee alt tuli pinnale **mull**, mis valjult lõhkes.
Meeldib puhuda suuri **mulle**, mis lendavad kaugele.	Ütle seda **mulle**, mitte talle.
Ta tuli **alt**, mitte ülevalt.	Ta saksofon oli **alt**, mitte tenor.
Temas see miski **on**, mida ma ei oska kirjeldada.	Mul oli metsas **onn**, mida ma ehitasin terve suve.

Kastmiseks on meil rauast **kann**, mida olen juba kaua kasutanud.	Mänguasja kohta öeldi vanasti **kann**, mitte lelu.
See võrk kiiresti valmis **punu**, mitte ära vahi niisama.	Lapsel oli ees armas **punu**, mis meid naerma ajas.
Mõtlesin mitmeid **tunde**, mis temast küll on saanud.	Üritasin tekitada temas **tunde**, mis jääks temaga kauaks.
Sa teda eesnimega **kutsu**, mitte hüüdnimega.	Mulle meeldis see väike **kutsu**, mitte kiisu.
Targal poisil oli tõeline **nutt**, mis teda elus edasi viis.	Mul oli kurgus **nutt**, mida ma hästi varjasin.
Mul tuli jalast puidust **kott**, mis viis mu tasakaalust välja.	Maas lebas suur **kott**, mis jäi kõikidele ette.
Õues käis vali **müts**, mis ehmatas meid kõiki.	Mul oli villane **müts**, mille ma kahjuks ära kaotasin.
Kindlustus neid kulusid ei **kata**, mis sa oled ise põhjustanud oled.	Mu on naabritüdruk **Kata**, mitte Mari.
Tal on alati kuskile mujale **rutt**, mitte minu juurde.	Tema nimi on **Rutt**, mitte Kadi.
Mu seljal käis kõva **pats**, mis ehmatas mind väga.	Talle punuti ilus **pats**, mis hiljem lahti tuli.

APPENDIX 2.
Sentences recorded for P1–4: i-stemmed nouns

Tal oli kaelas **sall**, mitte kett.

Saalis toimus suur **ball**, mitte lihtsalt pidu.

Voodi all elas hirmus **koll**, mitte kass.

Tema arust oli ta **loll**, mitte minu arust.

Mu veregrupp on **null**, mis sobib kõigile.

Mul oli üks sinine **pall**, mis lõpuks kaduma läks.

Karjamaal seisis suur **pull**, mitte lehm.

Talle sobib hästi see **roll**, milles ta täna oli.

Aiamaal kasvas **till**, mitte petersell.

Vanasti oli igas korteris **vann**, milles sai tihti käidud.

Kuumal pliidil seisis **pann**, milles praadisin sibulaid.

Veini pudelil oli peal **punn**, mis ei tahtnud üldse lahti tulla.

Ta oli väike **põnn**, mitte suur poiss.

Mu ema tähtkuju on **sõnn**, mitte jäär.

Muld kaalus üks **tonn**, mitte üks kilo.

Keldrist kõlas madal **bass**, mis pani seinad värisema.

Liiklemiseks on kõige parem **buss**, mitte sõiduauto.

Alatskivil on ilus **loss**, mis on seal olnud juba kaua.

Kasvamisel suureneb su **mass**, mitte ei vähene.

Iga aasta toimub suur **mess**, kus saavad kõik jälle kokku.

Mul on kodus ikka veel aegunud **pass**, millega ei saa midagi teha.

On olemas ainult üks **rass**, milleks on inimrass.

Mul on nimeline **tass**, mis on mul alati kaasas.

Mul on kaelas **kett**, mitte sall.

Ta oli pikk nagu **latt**, mitte lühike.

Poes oli kaupa täis **lett**, millelt võis leida kõike.

Lapsel oli suus **lutt**, mitte näpp.

Ukse ees oli must **matt**, millel pühitakse jalgu.

Selle augu on kaevanud **mutt**, mitte koer.

Pliidi peal podiseb **pott**, millega ma keedan suppi.

Tal oli kodus karvane **rott**, mitte kass.

Ta nahk oli pehme nagu **vatt**, mitte kare.

Metsas lendas ilus **vutt**, mitte metsis.

APPENDIX 3.
Sentences recorded for P5: palatalization of word-initial consonants

Ütlesin **legend**, mõtlesin võitja

Ütlesin **läbi**, mõtlesin sees

Ütlesin **liblikas**, mõtlesin koer

Ütlesin **lürpima**, mõtlesin jooma

Ütlesin **lörts**, mõtlesin lumi

Ütlesin **negatiivne**, mõtlesin positiivne

Ütlesin **nägema**, mõtlesin kuulma

Ütlesin **Nigeeria**, mõtlesin nigeerlane

Ütlesin **nüri**, mõtlesin terav

Ütlesin **nördinud**, mõtlesin kurb

Ütlesin **sebra**, mõtlesin hobune

Ütlesin **sädelev**, mõtlesin läikiv

Ütlesin **siga**, mõtlesin notsu

Ütlesin **sürrealism**, mõtlesin modernism

Ütlesin **sörkima**, mõtlesin jooksma

Ütlesin **tegema**, mõtlesin magama

Ütlesin **tädi**, mõtlesin onu

Ütlesin **tigu**, mõtlesin tegu

Ütlesin **tögama**, mõtlesin narrima

Ütlesin **Türgi**, mõtlesin türklane

PUBLICATIONS

CURRICULUM VITAE

Name:	Anton Malmi
Citizenship:	Estonian
Date of birth:	10th April 1987
Address:	University of Tartu, Institute of Estonian and General Linguistics Ülikooli 18, 50090 Tartu, Estonia
Telephone:	+372 5323 1224
E-mail:	anton.malmi@ut.ee

Education

2017–2022	University of Tartu, doctoral studies in Estonian and Finno-Ugric Linguistics
2016	University of Tartu, MA in Estonian and Finno-Ugric Linguistics
2014	University of Tartu, BA in Estonian and Finno-Ugric Linguistics

Professional experience

2020–	Junior Researcher, University of Tartu, Institute of Estonian and General Linguistics

ELULOOKIRJELDUS

Nimi:	Anton Malmi
Kodakondsus:	Eesti
Sündinud:	10. aprill 1987
Aadress:	Tartu Ülikool, Eesti ja üldkeeleteaduse instituut Ülikooli 18, 50090, Tartu
Telefon:	+372 5323 1224
E-post:	anton.malmi@ut.ee

Haridus

2017–2022	Tartu Ülikool, doktoriõpe eesti ja soome-ugri keeleteaduse erialal
2016	Tartu Ülikool, MA eesti ja soome ugri keeleteadus
2014	Tartu Ülikool, BA eesti ja soome ugri keeleteadus

Teenistuskäik

2020–	Nooremteadur, Tartu Ülikooli eesti ja üldkeeleteaduse instituut

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