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The Effect of Duolingo on L2 Learners' Pronunciation: Analysis of Minimal Pairs in Russian Speakers

MA thesis

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VILNIUS

2024

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ABSTRACT

The present paper focuses on the acoustic analysis of Russian speakers' vowel production before and after using Duolingo application. The aim of this study is to investigate the impact of Duolingo application on Russian speaking learners of English, focusing on phonetic acquisition in the context of minimal pairs. The method chosen to achieve this objective is experimental analysis, using phonetic acoustic variables – formant frequencies (F1 and F2) and vowel duration, which were evaluated through spectrograms. Ten Russian speaking volunteers, divided into experiment and control groups participated in Pre and Post-Tests. The results observed in this experiment show that Duolingo application contributed to Russian speakers' production of tense/lax vowel pairs /u/-/ʊ/ and /i/-/ ɪ/, with F1 and F2 frequency values closer to those of native American English, but no improvements were seen with a vowel sound /æ/. The duration of vowels did not see significant improvements, apart from vowel pair /u/-/ʊ/. This research contributes to the understanding of Duolingo's phonetic training impact on L2 learners' pronunciation. As language learning platforms' aid for learners' pronunciation is still under-researched area, this paper offers valuable insights into the phonetic influence of technology, and the need to study it further, employing various languages for the analysis.

Keywords: Duolingo, L2 learning, pronunciation, vowels, formant frequencies, Russian, English

INTRODUCTION

One of the most important skills that language learners wish to acquire is speaking, nevertheless mastering the pronunciation of a second language (L2) is an extremely challenging task. Learner's perception is strongly conditioned by the phonological system of their first language (L1) (Best & Tyler, 2007; Flege, 1995), consequently this brings difficulties when perceiving foreign language's phonology adequately. Pronunciation learning activities have always been included in the language learning classrooms, nevertheless mobile-assisted language learning (MALL) applications, such as Duolingo, only recently have started implementing phonological instruction in its features.

A particular manner of pronunciation in L2 learners reflects their linguistic background, which is composed of their mother tongue and a level of proficiency in the second language, so when a learner speaks, foreign language principals typical of the first language can be seen in their manner of pronunciation as well. This can be observed when contrasting highly phonetic and non-phonetic languages, such as Russian and English. For example, the system of Russian vowels consists of five vowel sounds, not differentiated by length or tenseness. Whereas English vowel system is more complex, with around fifteen vowel sounds, which can be long or short, tense, or lax, also includes various diphthongs which typically are not found in Russian language. According to Swan and Smith (2001) absence of a sound or a pattern in the first language in one's mother tongue and its presence in English sound system affects the non-native pronunciation. Within this contrast, Russian learners of English are inclined to reach for the familiar production of their L1 vowels and apply them to L2.

To overcome phonetic interference, phonetic training has emerged in classrooms. Firstly, ever since the International Phonetic Alphabet (IPA) development, in one way or another it has been included in the textbook to be used by teachers and students alike (O'Connor, 1967). The aim of the IPA is to provide distinct phonological and visual symbols for each sound articulated in any given language. According to Haycraft (1978), this is beneficial as numerous mistakes made by students stem from minute differences in sound production. Jarrah (2012) adds that phonological differences are foundational to the variations in sound systems, stemming from the diverse placements of speech organs and breath control. Teachers must have a thorough understanding of the target language, their students' native languages, and articulatory phonetics. This knowledge enables them to identify the physiological reasons behind students' inaccurate pronunciation of foreign language sounds and offer precise guidance to help students improve their pronunciation. In general, instructors need a thorough understanding of articulatory phonetics, a well-trained ear, and knowledge of the phonological contrasts, significant allophones, processes, prosodies, orthography, and pronunciation in both the target language and the native language.

Today, technology integration is being increasingly used in instruction, and autonomous learning. MALLs available in various forms, such as Duolingo language learning application, provide a platform for learning any language without being fixed to a pre-determined location. The ability to learn a new language anywhere appeals to many people, and not surprisingly, Duolingo has over 500 million registered users. Previous studies indicate that Duolingo is an effective tool in learning new languages, especially vocabulary and grammar of the target language.

Novelty of the research

While many studies have been done to highlight the positive learning outcomes from MALL (Chen et al., 2020; Noyan et al., 2023), research attention to the effect of these apps on learners' pronunciation is scarce, and instead most of the research is focused on vocabulary and grammar (Kusumadewi, 2018; Loewen et al., 2019; Irawan et al., 2020). Since MALL is one of the most convenient tools, especially in adult learning, and achieving intelligible pronunciation is essential in order to obtain a comprehensible conversation (Morley, 1991), it is necessary to extend learners' knowledge of the phonological advances in the language learning apps. Findings of this study will be able to offer an insight into the effectiveness of the app and suggest future modifications, if needed, which can be implemented for the more competent application.

The purpose of the research

The aim of this study is to analyze Duolingo's impact on Russian-speaking English learners' vowel pronunciation through the analysis of minimal pairs. Subject to the aim of this research, following objectives can be seen below:

1. To analyze the differences in Russian and English vowel systems and determine common English vowel pronunciation difficulties experienced by Russian speakers.
2. To investigate types of phonetic training employed in Duolingo application.
3. To study changes in Russian-speaking learners vowel pronunciation, after administering Duolingo treatment, through the acoustic analysis of minimal pairs contrasts.

Hypothesis

The pronunciation accuracy of Russian-speaking English learners should be positively influenced by Duolingo's language learning platform, specifically when measured through minimal pair analysis.

To address the hypothesis, two additional research questions are answered in this study:

1. What are specific vowel difficulties experienced by Russian learners of English?
2. Which phonetic training strategies are employed in Duolingo app to aid Russians learning English?

1. A COMPARISON OF RUSSIAN AND ENGLISH VOWEL PHONOLOGICAL PROPERTIES

This chapter describes main categories of the Russian and English vowel systems. Russian phonetic consistency contrasts with English language's variability and irregularities. While Russian vowel system is considerably simple, the English vowel system is more complicated in comparison. Russian speakers experience phonological interference and common errors, discussed in this chapter, arise in their pronunciation.

1.1. Russian Vowel system

The Russian language is formed of only five vowel phonemes /i, u, e, o, a/, which can be found in accented syllables. This paper will not consider /ɨ/ phoneme, due to long standing dispute among linguists, as to whether it should be considered as an allophone or independent phoneme. As it can be seen in Figure 1 all of the vowels are monophthongs. Vowels marked with black dot are considered the Russian vowel phonemes, whereas vowels marked with red dot are allophones.

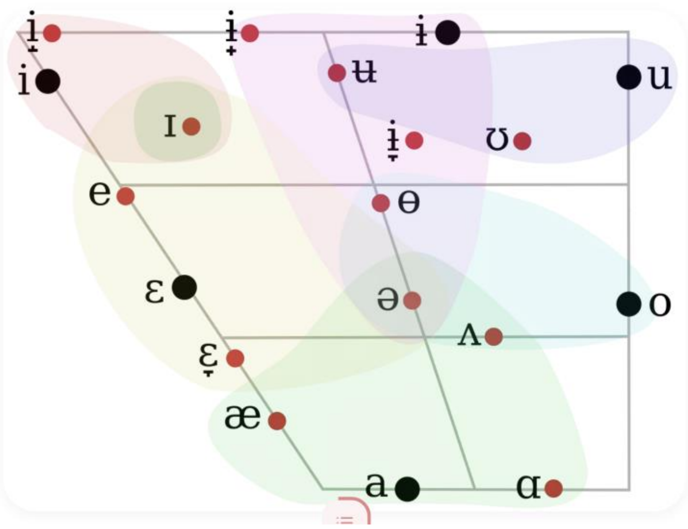

Figure 1. Russian vowel chart by Jones & Trofimov (1923)

Table 1 shows Russian vowel phonemes categorized into high-front vowel /i/, mid-front vowel /e/, low-middle vowel /a/, high-back vowel /u/ and mid-back vowel /o/.

Table 1. Russian Vowel Phonemic System. (Byun, K., Hong, SH. & Ahn, H, 2018)

	Front	Middle	Back
High	i		u
Mid	e		o
Low		a	

Allophony

Russian vowels are susceptible to a significant allophony. For this reason, linguists, such as Jakobson (1939), Jones (1969) and Halle (1971) name ten vowels in the Russian vowel system – five soft vowels and five hard vowels. According to Swan (2011) vowel allophones in Russian occur depending on whether they are positioned next to a hard or a soft consonant and the position relative to the stressed syllable. This can be seen in Table 2. The phonemes that differ in the minimal pair of *мать* /ˈmatʲ/ (mother) and *мять* /ˈmʲætʲ/ (crumple), are not the vowels *a* and *я*, but rather soft and hard consonants *м* /m/ and *м* /mʲ/. Vowel letters *a* and *я* are just orthographic representations of a single phoneme /a/.

Table 2. Russian Vowel Orthography.

After a hard consonant	а	э	ы	о	у
	(a)a	(e)	(y)	(o)	(u)
After a soft consonant	я	е	и	ё	ю
	(ja)	(je)	(ji)	(jo)	(ju)

The realization of the vowels varies according to the consonantal context. For example, vowels are more fronted when found in the palatalized consonant environment. Thus, for example vowel /a/ gets steadily more front CVCʲ, CʲVC, and CʲVCʲ contexts relative to CVC context, as seen in *сад* /ˈsɑt̪/ (garden) and *сядь* /ˈsʲætʲ/ (sit).

Vowel Reduction

In Russian, just like in English, reduction of vowels occurs in unstressed syllables. However unlike in English, where reduced vowels are usually replaced by the sound /ə/ and sometimes /ɪ/ (Wells, 1982), Russian reduction is much more complicated. Avanesov and Sidorov (1970) describe two degrees of reduction. The first degree, also referred to a moderate reduction, happens in the syllable just before the stressed syllable and the second-degree reduction– which takes place in all other unstressed positions. For example, the only vowels which can undergo first degree reduction are /o/ and /a/, and if the preceding consonant is non-palatalized, these vowels undergo the reduction process with an end result of /a/. In other words, the phonetic contrast between /o/ and /a/ is neutralized. Vowels /a, o, e/ appearing before palatalized consonant undergo even stronger neutralization, and an outcome of this reduction is always /iᵊ/, which is a substantially more centralized vowel /i/. In the second-degree reduction all vowels are realized as /ə/.

1.2. English Vowel system

The English Language, on the other hand, consists of fifteen vowel sounds (Gildersleeve-Neumann & Wright, 2010). This, of course, is a very broad calculation, as the number varies, according to accents and dialects. As it can be noted in Figure 2, for most speakers of American English there are fourteen pure vowels, that is, monophthongs.

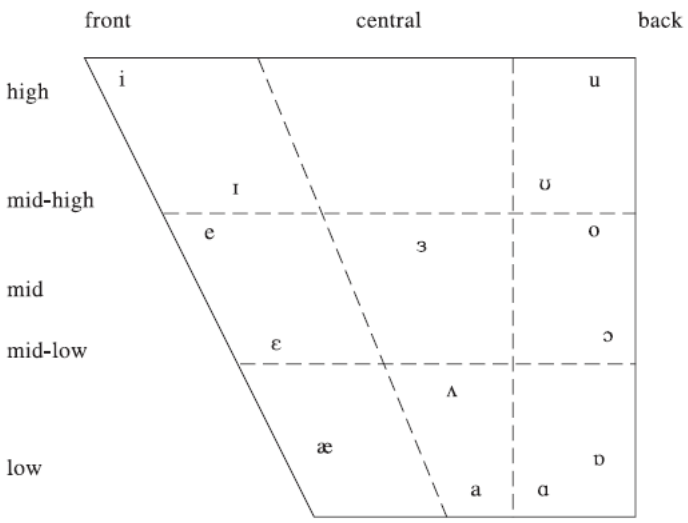

Figure 2. American English pure vowels.

English vowels can be separated by various features, such as tongue height and advancement, lip rounding, and whether the vowels are lax or tense (Small, 2016:56).

Table 3. American English Vowel Phonemic System.

	Front	Middle	Back
High	i, ɪ		u, ʊ
Mid	e, ɛ	ɜ, ə	o, ɔ
Low	æ	a, ʌ	ɒ, ɑ

As it can be seen in Table 3, the larger number of English phonemes can be classified according to the height and the backness, yet due to the amount of these phonemes in the language, it can also be classified according to other categorization methods, which are discussed next.

Tense and Lax Vowels

English vowel phonemes can be divided into tense and lax vowels (Jones, 1956). This is a distinction that separates vowels like those in sheep /ʃi:p/ and ship /ʃɪp/. Traditionally, they are separated by the difference in the tension or tightness of the muscles of the tongue or lips while saying the sound. Lax vowels are more centralized, meaning that the tongue is not pushing out towards the extreme edges of the mouth, so in other words they are more relaxed. Lax vowels are /ɪ/, / ɛ/, /æ/, /ʊ/, /ʌ/ and /ə/ and they are usually shorter than tense vowels. One standard argument is that in monosyllabic words is not possible to have lax vowels in the final position. Thus, /ʃɪ/ (she) is ill formed. However tense vowels and diphthongs can occur at the final position of a monosyllable.

Long and short vowels

English vowels are often separated into two length categories, short and long. Phonetically, short vowels in American English /ɛ/,/ɪ/,/ʌ/ and /ʊ/ are not only shorter than their long vowel counterparts, but also more centralized in the vowel space and for this reason short vowels sometimes might be called lax, and long vowels - tense. According to Wang and J. van Heuven (2006) even though /æ/ is phonologically a lax vowel, as it cannot occur at the end of a word, various phonetic reasons, such as it being clearly longer than any other short vowel and it being not centralized allow sound /æ/ to be considered as a tense vowel, therefore a long vowel. As it happens, duration of the vowel varies a lot as it depends on whether the syllable is stressed or the consonants proceeding it are voiced or unvoiced. Pavlik (2003) observes that short vowels’ duration is decreased if followed by voiceless consonants, and not affected by voiced consonants. On the other hand, long vowels’ duration is decreased if followed by voiceless consonants, and not affected by voiced consonants.

Diphthongs

English has eight diphthongs, sounds which involve a glide between two vowels and are usually considered as long vowels. Gimson (2008) divides them into three groups: those with glide to /ɪ/, so diphthongs /eɪ/ /aɪ/ and /ɔɪ/, those with glide to /ʊ/ - diphthongs /əʊ/ and /ɑʊ/, and those with glide to /ə/ - /ɪə/, /eə/ and /ʊə/.

1.3. Phonotactic constraints on Russian learners’ L2 speaking skills

According to Freeman, Blumenfeld & Marian (2016) phonotactic constraints can be different across languages, in turn, some issues arise for language learners during L2 acquisition and use stages. This can be noticed when the phonological patterns of L2 are not similar to, or even absent, in the native language, causing L2 learners to encounter interference from the non-target language.

In Russian language, pronunciation of letters can be derived from print. However, the information about position of the letter and the surrounding phonemes is crucial for determining how the letter is pronounced in each particular case, since Russian phonology is rich in phonotactic rules, therefore phonemes are phonotactics-dependent (Ulicheva et al. 2016).

In Marian, Blumenfeld & Boukrina (2007) study, experiment was conducted to determine whether unique non-native phonemes affect lexical access for words in Russian and English speakers. The findings of this experiment showed that the access to unique non-native phonemes took longer, compared to words with phonemes shared between native and non-native languages. This suggests that bilinguals exhibit interference effects when processing words that are phonologically similar across languages. In other words, phonological representations of words are active from both languages, which in turn can influence each other during language processing.

Another similar study was done by Mikhaylova (2009), which explored L2 learners' sensitivity to phonotactic constraints of their target language. This study found that legal nonwords (those not violating phonotactic constraints of L2) were recognized by English speakers and Russian-English bilinguals faster and more accurately than those words that did not follow phonotactic patterns of L2. This experiment provided an insight into L2 learners' ability to develop phonotactic knowledge similar to that of a native speaker, therefore influencing the recognition of non-words in target language.

1.4. Palatalization as a contrastive feature in Russian

As mentioned before, the Russian language uses a simple 5-phoneme vowel system, absent of diphthongs, opposition of tense and lax vowels, and phonological contrasts in length. Nevertheless, Russian can be defined as a language, in which palatalization may occur as a contrastive feature, and, as a consequence of phonological processes, the five vowel phonemes can be expressed as ten vowel phones. Ghabanchi (2017) discusses the front open vowel /æ/, which can be found in English words *bat* or *cat*. Russian speakers are likely to replace it with /ɛ/, as it can be seen in a word *bet*. Sound /æ/ is found in Russian language, but only due to allophony. Back vowel /a/ becomes /æ/, only between two soft consonants, for example in a word *пять* /pʲætʲ/ (five). In English there is no soft/hard consonant distinction, therefore it is not rendered phonemic. In turn, Russian speakers might encounter troubles pronouncing words, such as *cat* /kæt/, since /k/ is not palatalized.

Ordin (2011) also argues that interaction between vowels and palatalization context is significant. His study analyzes front and back vowels, and reanalyzes the structure of the Russian vowel system into two allophonic subsystems. First subsystem is combined to fit after non-palatalized consonants and include allophones [ɨ], [ɛ], [a], [o], [u], whereas second system fits into palatalized contexts and formed of allophones [i], [e], [æ], [ɵ], [ʉ]. Russian speakers, when it comes to loan words, can keep the typical pronunciation of a source language, for example non palatalized consonant and allophone [ɛ], like in a word /bɛt/, or change it to the norms of Russian phonotactics, therefore palatalize the consonants and make the vowel higher and more fronted.

Palatalization also affects the vowel duration. This depends on the backness of the vowels. Ordin (2011) study found that Russian back vowels' /a, o, u/ duration increases when the preceding consonant is palatalized, or if both consonants, surrounding the vowel, are palatalized. On the other hand, front vowels' /e, i/ duration is reduced when both consonants are palatalized. This can explain the pronunciation of English word *you* /juː/, where Russian speakers increase the length of the back vowel phoneme /u/ due to /j/ being the only palatal consonant in English language.

1.5. Tense and Lax vowel contrast in Russian and English

Another difference that comes up when comparing English and Russian is tense and lax vowel contrast (Gildersleeve-Neumann & Wright, 2010; Panasyuk, & Gorlovsky, 2019). Such distinctive feature of English phonemic system presents a major difficulty for Russian learners of English, as it is not present in Russian language. An outstanding study has been done by Panasyuk, & Gorlovsky (2019), which has found that difficulties can be clearly seen in monosyllabic consonant-vowel-consonant (CVC) words, when tense vowels are shortened by the fortis consonant /biːt/, and lax vowels are lengthened before the lenis consonant /bɪd/. The data collected in this research showed that Russian listeners responded mainly to the durational characteristics of the vowels and paid less attention to the quality. There was a marked tendency in words with a lax vowel and fortis consonant to be substituted for tense vowels, for example /bɪt/ -> / biːt/, and overall Russian speakers identified tense vowels better than lax vowels.

Dmitrieva, Jongman & Sereno (2010) study, which has analyzed Russian final devoicing, has found that vowels were on average 6 milliseconds longer when preceding voiced final obstruents, compared to voiceless final obstruents. Monolingual Russian speakers produced similar results to speakers of Russian with some knowledge of English, except for the most experienced speakers of English, who produced significantly greater differences in vowel duration compared to monolingual Russian speakers.

Interestingly, Kharmlamov (2014) has found that vowel lengths are not relevant to the proceeding voiced versus voiceless obstruents. It was deduced that this has happened due to a fact that previous research done on vowel duration in relation to voiced and voiceless obstruents has only looked at a small data set. It was also observed that phonotactic restriction, such as short vowels are usually found before voiced coda obstruents, does not exist in Russian , therefore it is impossible to claim that vowel durations are sensitive to consonantal voicing.

1.6. Vowel acoustic distance in Russian and English.

Formants are crucial in distinguishing vowels from each other and providing an insight into the acoustic characteristics of speech sounds. Ladefoged (2006) claims that each vowel has three formants. The major acoustic representation of the auditory property of the vowel height, therein high, mid-high, mid, mid-low, low, is the first frequency of the formant, or in other words the first formant (F1). The second formant (F2) combines three traditional vowel features, highness, backness and roundness, and according to him can be described as brightness. In simplified terms, high front unrounded vowels portray the highest value of brightness and high back rounded vowels have the lowest value.

Leonov et al. (2009) has looked into frequency modulations in speech signals and have mentioned that it is almost impossible to accurately determine set formant frequencies in vowels. This can be due to many factors, such as the speakers themselves, the type of vowel, the sound quality, microphone used in the research and so on.

Nevertheless, studies which have focused on frequencies as a contrasting feature in vowels, have found some average means, which can be applied loosely to a language. For example, English formant values for /ɛ/ and /æ/ are exceptionally similar to one another (at least in some English dialects) and are closest to values of Russian /e/. Hence it is less likely, that L2 vowels that are similar to one another in both F1 and F2 values will be acquired as two separate vowel categories. Ivanova (2016) mentions that the greatest challenge for the perception and production of L2 vowels is in creating new phonetic categories similar to or extending over the existing categories. Comparing Russian and English languages, it was found that the most challenging pairs of vowels for Russian Speakers speaking English as L2, are /i - ɪ/, /u- ʊ/, /ɛ - æ/, /ɑ - ʌ/, since features and contrasts of these pairs are not present in Russian. Makarova (2011) indicates the overreliance on vowel duration in Russian speakers, with the greatest degree of dependance seen in the vowel pair /ɛ-æ/, followed by /i - ɪ/ and /u- ʊ/ respectively. Researcher adds that phonetic perception is better when speaker’s concentration is on the contrasts, and lexicon involvement is less required. Therefore, natural speech environments turn out to be trickier for native Russian speakers.

2. PHONETIC TRAINING STRATEGIES IN L2 LEARNING

This section discusses a few phonetic training strategies, which can be seen employed in Duolingo app. Even though Duolingo explicitly states that they use IPA as their tool for teaching sound pronunciation, other tools such as high variability phonetic training can be noticed in this app. This chapter will look at these strategies and previous research discussing their efficiency.

2.1. The role of phonetic training in L2 speech learning

Many researchers and linguists agree that acceptable pronunciation, or being understood by native speakers, is one of the main problems that English as a second language (ESL) learners face today. Ghorbani et al. (2016) agree that while L2 learners might achieve native-like proficiency in other aspects of the language, acquiring and producing non-native phonemes provides difficulties to learners. Following other researchers' claims that vowel-recognition instruction helps L2 learners identify and produce phonemes, they have conducted an experiment on vowel instruction and found that implicit teaching of vowels, in other words, raising learner's awareness of different phonemes, has shown better results than intuitive- imitative approach, otherwise known as listening to vowel pronunciation drills and imitating them.

Aliaga-Garcia and Mora (2011) conducted an experiment with Romance language users, to determine the efficacy of phonetic training, which included lessons focused only on pronunciation, such study of the English vowel system, focusing on tense/lax vowel contrasts and descriptions of tongue movement and lip position. Assessments were taken prior and after the course. The results provided showed that phonetic training indeed had some significant short-term effects on learners' pronunciation, such as an improved vowel contrast discrimination.

2.2. Employment of IPA in phonetic training

Sulukiyyah & Mardiningsih (2018) research focused on improving on students' pronunciation ability. Researchers provided phonetic exercises in two cycles. Test material was given to the students as IPA transcriptions of vocabulary. They found that in the first cycle, students still produced some pronunciation errors, but second cycle saw significant improvements, due to accustomedness to the phonetic symbols. This shows that using transcription exercises can be a valuable training strategy for improving learner's pronunciation.

Yusuf's (2019) research on English pronunciation based on the Phonetic transcription application, has shown positive improvement, particularly in students' pronunciation, as phonetic transcription voids them from any mispronunciation. An app Top Phonetics was used to facilitate learners' English pronunciation acquisition, where students were able to look up phonetic transcription of target words, thus, in turn, allowing them to better understand the pronunciation of the wanted language.

Of course, not all research agrees that IPA is an indispensable tool in phonetics training. Some researchers, such as Putri (2018) and Najmuddin (2017) found that using the phonetic symbols can become an additional difficulty for learners of English. Students of a new language must already learn many new aspects, such as grammar, vocabulary, and new phonological system of the target language. Additionally, having to learn IPA symbols might become to burdensome for students, and jeopardize the whole learning process.

2.3. Effects of High Variability Phonetic Training

High variability phonetic training (HVPT) is an effective technique, nevertheless, unfortunately, it is not widely used by educators in language classrooms. It is a technique used to improve the perception and production of non-native speech sounds in L2 learning. It uses multiple voices to help learners perceive sounds in a more target-like manner. Thomson (2018) has investigated 32 research articles and found that 97% report significant improvements in L2 learners' perception and/or production of L2 sounds. One of these studies looked at /e/ and /æ/ production before and after the intervention of HVPT and found that experiment and control groups both produced both phonemes with F1 values closer to the phoneme /e/. After the HVPT intervention, HVPT group produced /æ/ with higher F1, which was closer to native-like performance. This improvement also extended to a more native-like vowel duration.

The paper by Grenon, Kubota, and Sheppard (2019) explored the phenomenon of adult learners creating a new vowel category through high variability phonetic training. Study was done with Japanese speakers, who similarly to Russian speakers, do not have tense/lax vowel distinction, therefore they often perceive English vowel sounds based on their duration, and not spectral cues (formant frequencies), which native English speakers use. A cue-weighting task confirmed adult Japanese learners' ability to create a new vowel category along spectral dimension for lax vowel /ɪ/. Even though most of Japanese learners still relied on vowel duration to distinguish English vowels, the results of this study proved that it is possible for late learners to create new phonetic categories, even if they were subject to phonetic category dissimilation, and with further phonetic training, these categories could be improved.

3. PREVIOUS RESEARCH ON THE INCORPORATION OF TECHNOLOGY FOR DEVELOPING LINGUISTIC SKILLS

Modern world relies heavily on technologies to aid in every aspect of human's life, including language learning. The current chapter discusses technology's influence on the way L2 learners learn new language's pronunciation, specifically focusing on the previous research that focused on effects of Duolingo application on L2 learners.

3.1. MALL's contribution to language acquisition

The term Mobile Assisted Language Learning, or MALL, originated in Chinnery's (2006) paper, who claimed that mobile devices can be used as an effective pedagogical tool for language learning and teaching. Arvanitis & Krystalli (2021) provide a list, accumulated from previous research, which shows the uses of Mobile Assisted Language Learning, which states that MALL is used to not only encourage the use of the target language, promote learning, and enhance the motivation, but also to give more opportunities for students to develop various communication skills, including comprehension and production of a spoken language. Surprisingly, in the same study Arvanitis & Krystalli (2021) found that out of 340 studies done between years 2010 and 2020, only 20 were conducted in the theme of speaking/pronunciation, which shows that pronunciation aspects of the learning apps are still under-researched.

Burston (2014) criticized MALL applications on the notion of them being behaviorist and teacher centered. He noted that the issue of response feedback and learner monitoring needs to be addressed, as this is a worry in most of the MALL programs. Even though there are some issues with MALL, such as accessibility for everyone and absence of suitable feedback, the overall findings in MALL studies report positive learning outcomes. In Zhen & Hashim (2022) study, they claimed that MALL contributed to the instructional approach in English speaking skills, while also increasing learner's motivation and self-confidence, which is often associated with poor communication skills, when using non-native language. Nur, Sahril & Makassar et al (2022) also add that MALL significantly contributes to various language components, such as vocabulary, grammar, and pronunciation.

3.2. Duolingo – a modern tool for learning pronunciation

Quite a few studies have been done on the advantages of using Duolingo in various language learning and teaching, especially related to English language learning. Most of the research has shown positive findings, proving that using a MALL system can be fruitful to learner's goals. Vesselinov & Grego (2012) claimed that statistically significant improvements were shown in learners' language abilities due to using this app. More recent study by Syafrizal et al. (2022) adds to Duolingo's efficacy in enhancing English proficiency. This article suggests that students' vocabulary can be expanded, and students are able to "talk more clearly" (Syafrizal et al. 2022, p.1048). Experiment done by Niah & Pahmi (2019) also shows that using Duolingo helps improve learner's English skills, specifically listening and speaking skills.

Nevertheless, not all studies agree on the efficiency of the app in question. Many drawbacks have been discovered and analyzed by researchers. One of the most noticeable setbacks in this mobile application is the practice of speaking skills. There is a lack of dialogue practice, in turn, there are limited opportunities to develop your speaking skills. (Sakalauske & Leonavičiūtė, 2022) Secondly, conversations that are being taught in the app often sound unnatural, therefore speakers are at risk of forming sentences which would sound strange to native speakers of that language. (Nushi & Eqbali 2017) Loewen et al. (2019) study has found that even though some gains were made in L2 learning on Duolingo, participants in this study scored lowest on the speaking skills. This could be due to Duolingo, just as most MALL applications, employing grammar-translation and audiolingual-type activities.

3.3. Russian speakers learning English on Duolingo

Unfortunately, only limited research can be found on the effects of Duolingo in Russian speakers learning English.

Mospan (2018) organized a survey-based study, where students from universities in Poland and Ukraine (75.5 % from Ukraine) have reviewed various mobile applications for learning English. Duolingo was chosen as the most used one. When asked if they believed that using apps, such as Duolingo, contributed to improving their language skills, 77.5% of the participants answered positively. Unfortunately, as it is survey-based study, answers might be biased as they have not been proven by any suitable experiment.

Kemalova et al. (2021) conducted a six-month long study, where they have provided pre and post-tests to sixty students from Kazan Federal University in Russia, after studying English language on Duolingo. Students' average scores improved after using Duolingo, and conclusion, that Duolingo with "its repetitions of sentence structure has contributed to better understanding lexis, grammar and syntax as a whole" (Kemalova et al., 2021, p.636) was made. Unfortunately, this research does not provide which specific components were improved, and the absence of a control group makes it questionable whether these improvements were due to Duolingo or other sources.

4. DATA AND METHODOLOGY

4.1. Participants and research background

The study was administered at an IT company in Vilnius. 10 employees were chosen for this study, which were divided into two groups – control group (CG) and experiment group (EG). Both of these groups were attending English language lessons at a B2 level (CEFR, 2020) twice a week during the experiment. 8 of the participants were males and 2 were females. Equal number of women and men were distributed into each group – 4 males and 1 female in EG and CG. Recruitment of the subjects was performed following a selection criterion:

1. Participants must be native Russian speakers and use Russian language daily, both at home and at work.
2. Participants must be 18+ years of age.
3. Participants must have a B2 level of English at the time of the experiment and have a strong need for English language skills.
4. Participants must be comfortable in using technology and own a smartphone.

Recruitment was conducted via contacting various companies in Vilnius, which are known to have employed workers from Belarus, Russia, and Ukraine, with a proposal to perform an experiment to determine employees' English skills. One of these companies has agreed to participate, as the company is already providing English lessons to its workers for business purposes. 10 employees were chosen, after meeting the criteria mentioned above, and informed consent was obtained from all participants prior to their involvement in this study. They were randomly assigned to either EG or CG using a random number generator, in order to ensure an objectivity of the results.

4.2. Data collection and procedure

Data collection was performed in two stages. Firstly, pre-tests (see appendix) were administered individually to each participant in both EG and CG. Participants were asked to read sentences out loud without prior preparation. Nevertheless, a small conversation, such as about the weather or news, was made prior to the test to activate the code switching and get them ready to use the L2 (participants mainly converse in Russian at work). Participant's readings were then recorded on the electronic device with a voice recording function. Both groups took a pre-test and continued attending English Language course at their workplace (attendance rates are inconsistent, as some of the participants got sick, or were on holiday at that time).

While CG were informed that another test will be performed in four-week time and no extra treatment was administered to this group, EG has agreed to use Duolingo app for those 4 weeks. EG was instructed to use Duolingo app for at least 15 minutes every day, focusing on both general training and the phonetic training in the app. No extra instructions were provided. At the end of those four weeks, post-test was administered to both CG and EG.

Participants' recordings along with the test material were then transferred to WebMAUS web application to perform automatic phonemic segmentation, in order to align speech recordings with their corresponding text transcriptions. This data was then transferred to Praat speech analysis software for the data to be analyzed by the researcher.

The rationale for the selection of the target language vowels is warranted. Minimal pairs comparison was chosen, as it is the main tool in learning phonemic contrast in vowels and consonants (April, 2016). As discussed in the section 2 Russian speakers struggle with a vowel sound /æ/ and tend to change it to /ɜ/, therefore minimal pairs of /æ/ and /ɜ/, and pairs of /ʌ/ and /æ/ were chosen, to distinguish whether the mistake happens only in close proximity to one another, or just generally. Another difficulty that Russian speaking English language learners experience is the contrast of lax/tense vowels, therefore minimal pairs of /ɪ/ and /i:/, along with /u:/ and /ʊ/ were included in the test.

4.3. Methodology

The design for the experiment used in this study, which can be seen in Table 4, is quasi-experiment with non-equivalent pretest-posttest control group design. (Kenny, 1975; Peláez-Sánchez & Velásquez Durán, 2023)

Table 4. Quasi-Experiment with non-equivalent pretest-posttest control group design.

Group	Pre-test	Treatment	Post-test
Experimental group	Y1	X	Y2
Control group	Y1	-	Y2

Description:
Y1 = Pre-test (dependent variable or conditions before treatment).
X = Using Duolingo (independent variable).
Y2 = Post-test (dependent variable or conditions after treatment)

Due to the insufficient number of volunteers, this study employed a qualitative-contrastive analysis to accomplish its objective. As Lado (1957) claims that components acquired in L2 which are similar in learner's native will be simple for the learner, and those that are different will be difficult, and contrastive analysis allows to predict and describe the patterns that will cause difficulties, by systematically comparing those two languages, As this research went deep into the L1 interference in the learners' pronunciation acquisition, this type of analysis was chosen to provide an explanation for these specific difficulties that are met by Russian speaking learners of English.

The phonological model, following Escudero and Williams (2014) and Flemming (2009) example was used to analyze and to interpret the data by using phonetic acoustic variables- formant values (F1 and F2) and vowel duration, detected and measured using a spectrogram, as manual phonetic transcription itself is error-prone due to the subjective judgment of human transcribers, and automatic phonetic transcription is not void of errors. The following two sections (4.3.1 and 4.3.2) describe how vowel duration and vowel quality were defined and analyzed for this experimental procedure.

4.3.1. Vowel Quality

Vowel quality is determined by analyzing formant frequencies, which are visible in the spectrogram. Although no human is the same, therefore no resonances of frequencies are the same, expected formant frequency ranges are observed in all speakers, certain for women and for men. Changes in these formant patterns provide an insight into the unique characteristics of each vowel. A composite measurement of frequencies, such as F1, F2, F3 can be referred to as vowel quality.

Most of the research (Neel, 2004; Carlson et all, 1975) agrees that frequencies corresponding with tongue height (F1) and tongue advancement (F2) are enough to adequately determine the characteristics of the vowel, hence a vowel with a low F1 frequency and high F2 frequency will be considered a high close vowel /i/. F1 and F2 measurements of the vowel were taken from the steady state of the vowel. Shadle's (2016) research claims that there are difficulties in determining which point represents the correct vowel frequency, but since this experiment was more inclined to compare two phonemes in the same environment, the steady state of the vowel was chosen as a pinpoint, as it can be seen in the figure 3.

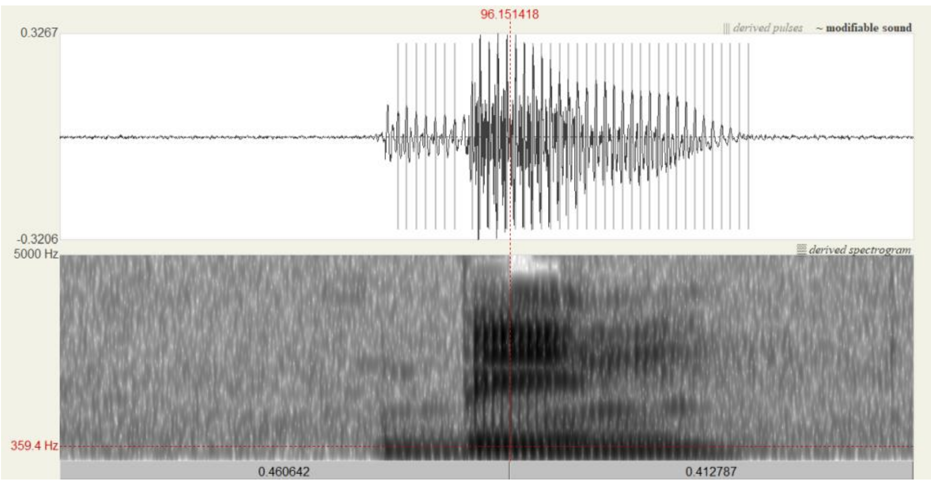

Figure 3. Illustration of participant's Pre-Test pronunciation of the word **Bin**.

Vowels produced by Russian speakers were then contrasted with American English vowel frequencies as found in Hillenbrand et al. (1995) As mentioned before, frequencies vary from person to person, but Hillenbrand's averages appear to be similar to other researchers, such as Ladefoged & Johnson (2011) and employ a larger number of speakers to extract a median, therefore these frequencies were chosen for accuracy measurements in Russian speakers' vowel production. Frequencies of vowels examined in the research can be seen in table 5.

Table 5. American English Vowel Phonemes (Hillenbrand et al. 1995)

Vowel	Male		Female	
	F1	F2	F1	F2
ɪ	427	2034	483	2365
i:	342	2322	437	2761
æ	588	1952	669	2349
ɛ	580	1799	731	2058
u:	378	997	459	1105
ʊ	469	1122	519	1225
ʌ	623	1200	753	1426
ɒ	497	910	555	1035

4.3.2. Vowel Duration

Vowel duration can vary substantially due to many factors such as syllable stress, voicing of a following consonant or vowel height. Acknowledging this , phonetically identical targets were chosen for the experiment, e.g. comparing bean /bi:n/, and bin /bɪn/. Vowel duration helps learners to place vowels in categories such as lax vs. tense (Kent & Yunjung, 2009), so analysis of the duration of these vowels were expected to show some insight into Russian learners' differentiation between these categories.

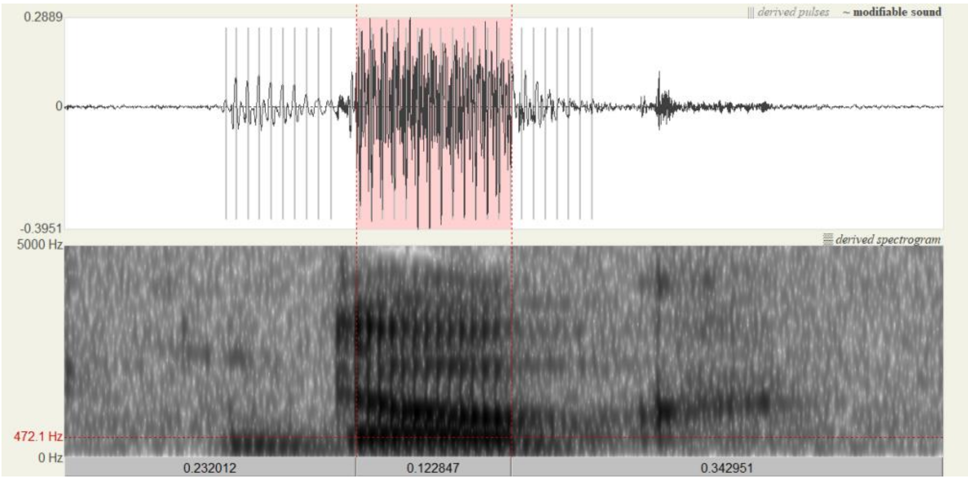

Figure 4. Illustration of vowel duration: participant's pronunciation of the word **Dock**.

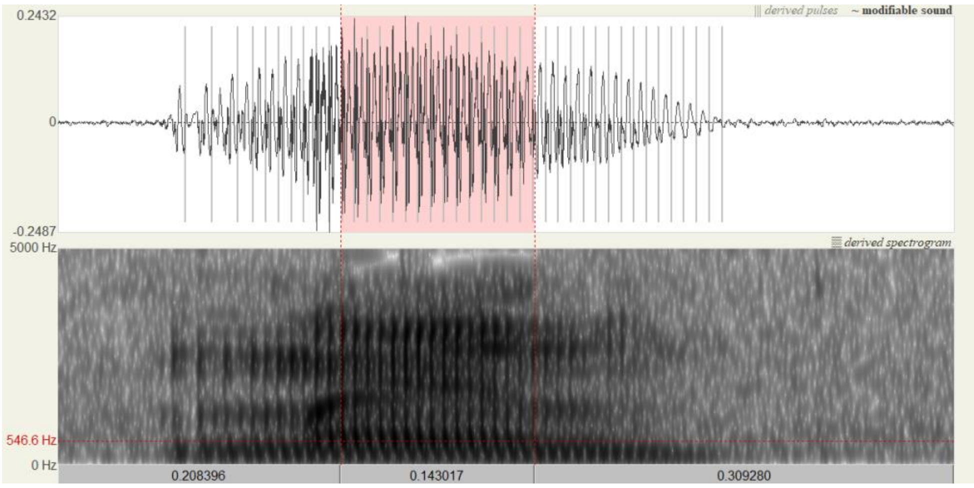

Figure 5. Illustration of vowel duration: participant's pronunciation of the word **Man**.

Vowel length was determined through spectrogram analysis from the boundary between the consonant and vowel. As some consonants pose more difficulties in determining where the vowel ends and consonant begins, regularity of a waveform was also observed. As it can be noted in Figure 4, boundaries between consonants and vowel are quite clear, whereas Figure 5 shows the wavelength of the word *man*, where vowels are surrounded by nasal consonants, so boundaries become blurred. Regularity of the waveform allows us to better understand where one phoneme ends and the other begins.

5. RESULTS AND DISCUSSION

This section presents the results of the analysis of speech samples from 10 volunteer subjects, to empirically determine if acoustic phonetic vowel features varied between the group which has been using Duolingo, and the control group. The results of this experiment are organized into two sections. Section 5.1 offers the results of vowel quality from each group. This section presents the comparison between the two groups and discusses changes in F1 and F2 frequencies that were visible after the experiment. Section 5.2 presents the results of vowel duration analysis. A summary of the results is presented at the end of this section.

5.2.Vowel Quality analysis

5.2.1. Pre-test results

Vowel charts, as can be seen in figure 6 and figure 7, depict the vowel positioning of American English and experiment and control group male participants' vowels produced prior to the treatment. Russian speakers' vowels are presented in light grey font, American English phonemes in dark grey. The vertical axis represents F1 measurements, which corresponds to tongue height, and horizontal axis represents F2 measurements, which corresponds with tongue advancement. All measurements are presented in Hertz (Hz).

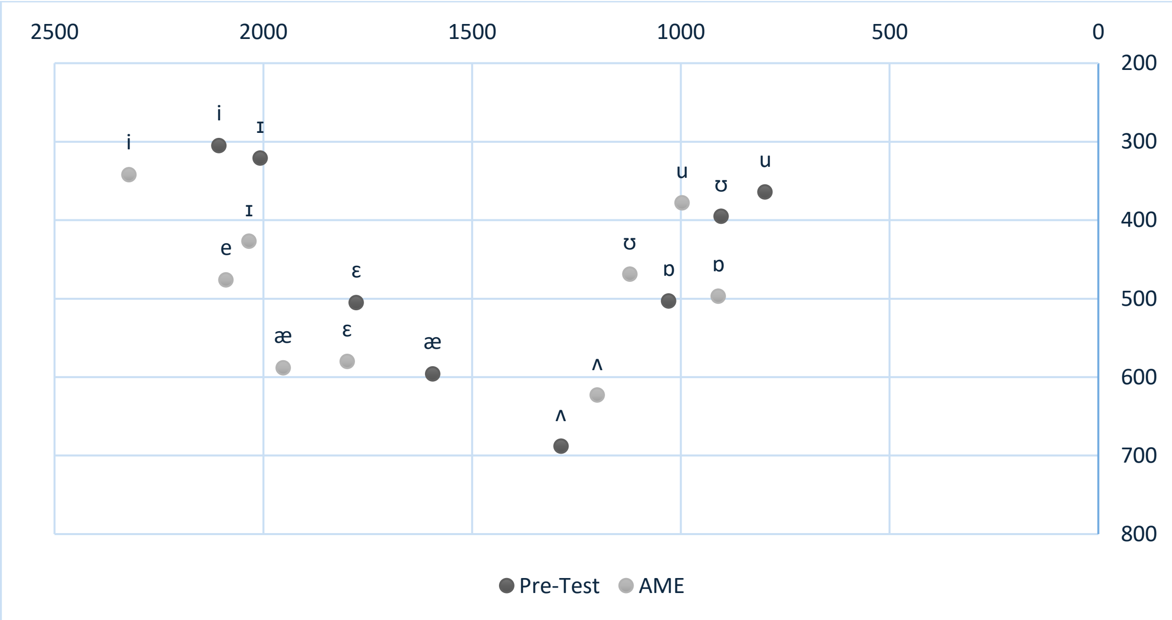

Figure 6. Male Experiment group Pre-Test vowel quality and American English vowel phonemes.

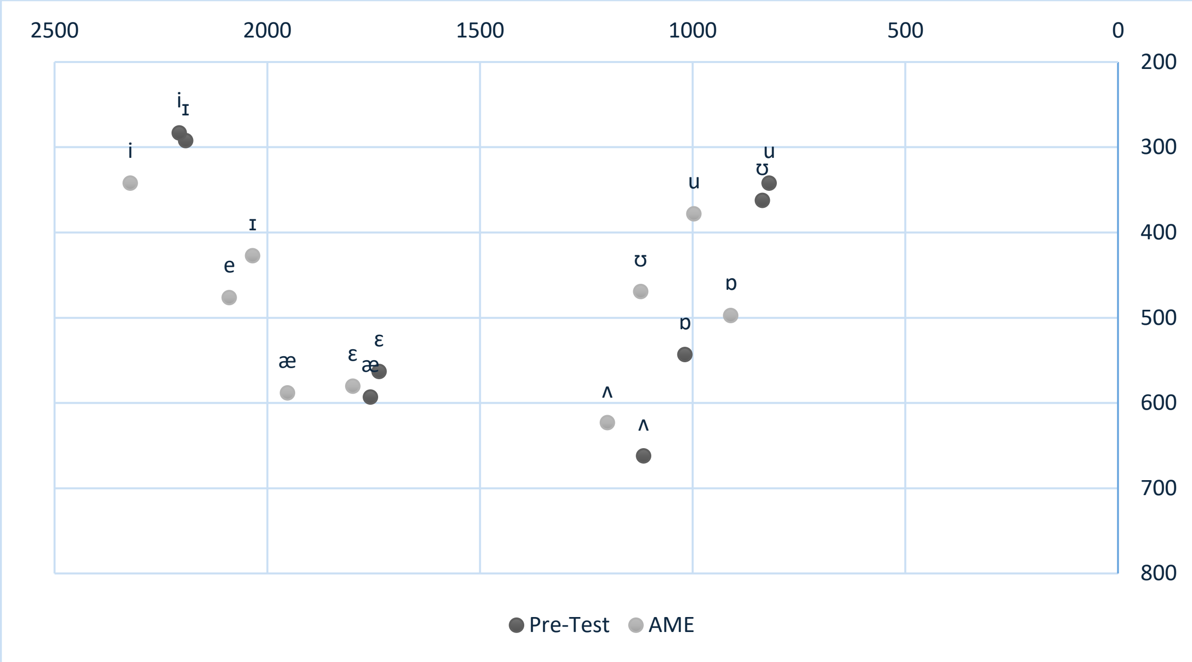

Figure 7. Male Control Experiment group Pre-Test vowel quality and American English vowel phonemes.

The relationships of vowels in this space represent typical Russian acoustic inventory. According to Halle (1971) contemporary standard Russian phoneme's /i/ F1 is quite low, often reaching 150-300 Hz, therefore /i/ is a high front vowel. Pre-Test results of the experiment align with the common errors produced by Russian speakers. Both control and experiment groups vowel production showed minimal acoustic distances between tense and lax vowel pairs /i/- /ɪ/ and /u/ - /ʊ/. F1 for the vowel /i/ was between 285Hz-305Hz on average, while F1 for the vowel /ɪ/ - 290-315Hz in both groups. This shows that while producing both /i/ and /ɪ/ tongue vertical position was similarly high. Similarly, vowel sound pair /u/ and /ʊ/ did not differentiate in F1, with /u/ ranging between 340Hz and 360Hz and /ʊ/ between 360Hz and 390Hz, while F2 was in a range of 798Hz and 820Hz for /u/ and 840Hz-900Hz for /ʊ/. This shows that both /u/ and /ʊ/ were produced in the back of the mouth, even though /ʊ/ is a near-back vowel, meaning that it should differentiate from /u/ in the horizontal position of the tongue.

Vowel /æ/ can be distinguished from sound /ɛ/ more so by backness than height of the tongue position. Traditionally, F1 for these sounds is similar frequenting at around 580Hz-588Hz, yet /æ/ is produced more in the front, than /ɛ/. Pre-Test results show that F2 for these vowel sounds was very close ranging between 1594Hz and 1757Hz for /æ/, while /ɛ/ saw ranges of 1737Hz and 1777Hz. Russian speakers producing /æ/ sound more in the back found themselves pronouncing it more like /ɛ/.

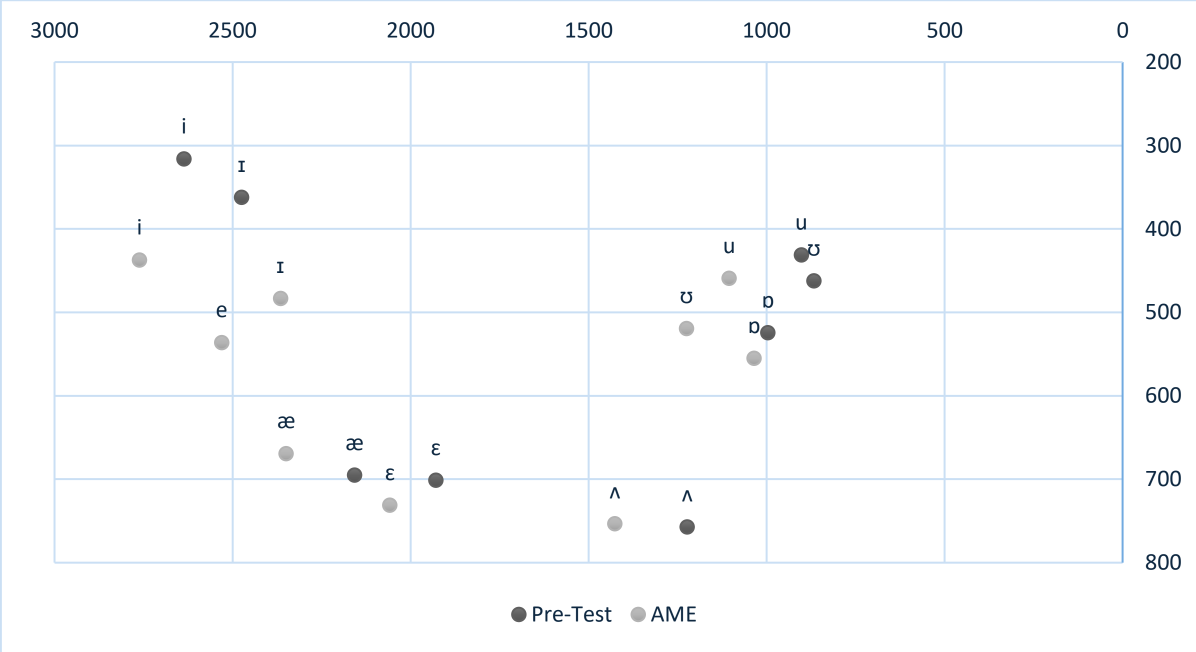

Figure 8. Female Experiment group Pre-Test vowel quality and American English vowel phonemes.

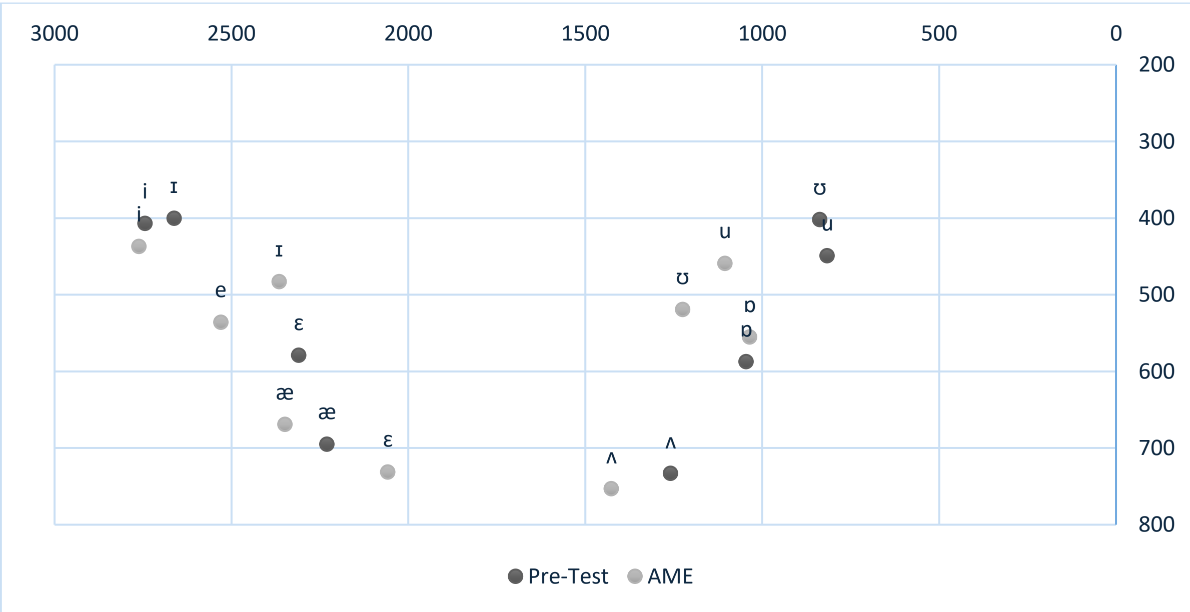

Figure 9. Female Control group Pre-Test vowel quality and American English vowel phonemes.

Female participants produced similar errors prior to the treatment, as it can observed in figures 8 and 9. Prior to the experiment F1 for vowel sound /u/ was around 440Hz, and F2 around 850Hz, and F1 values averaged at around 430Hz for /ʊ/, with F2 around 830Hz. Vowel's /ɪ/ F1 and F2 midpoints were around 362 Hz and 2474Hz in the experiment group, and 400Hz and 2662Hz in the control group. While /i/ F1values in the experiment group averaged at about 316Hz, and 407Hz in the control group. F2 values for this vowel sound in the experiment and control group were around 2636Hz and 2744 respectively.

F1 values for the vowel sound /æ/ in the experiment and control groups were averaging at the similar 695Hz, which is somewhere in the middle of American English /æ/ and /ɛ/ sounds. The F2 values for this sound were about 2157Hz for the experiment group, and 2230Hz for the control group. /æ/ in the female groups was not as inaccurate as in the male groups, nevertheless it was still dangerously close to /ɛ/ sound.

5.2.2. Post-Test Results

The experiment group used Duolingo for a month in an attempt to improve their pronunciation. They did not know the focus of this study; therefore, the results were quite surprising. The most noticeable difference, seen in figure 10, is the difference between tense and lax vowels. Experiment group's vowel sound's /i/ F1 value was averaging at 283Hz, while /ɪ/ was now around 350Hz. The pair /u/ - /ʊ/, saw F1 frequencies of around 385Hz and 435Hz, while backness for this pair improved substantially, with /u/ F2 being around 847Hz, and /ʊ/ - around 1053Hz. Control group did not show this difference, as it can be observed in figure 11.

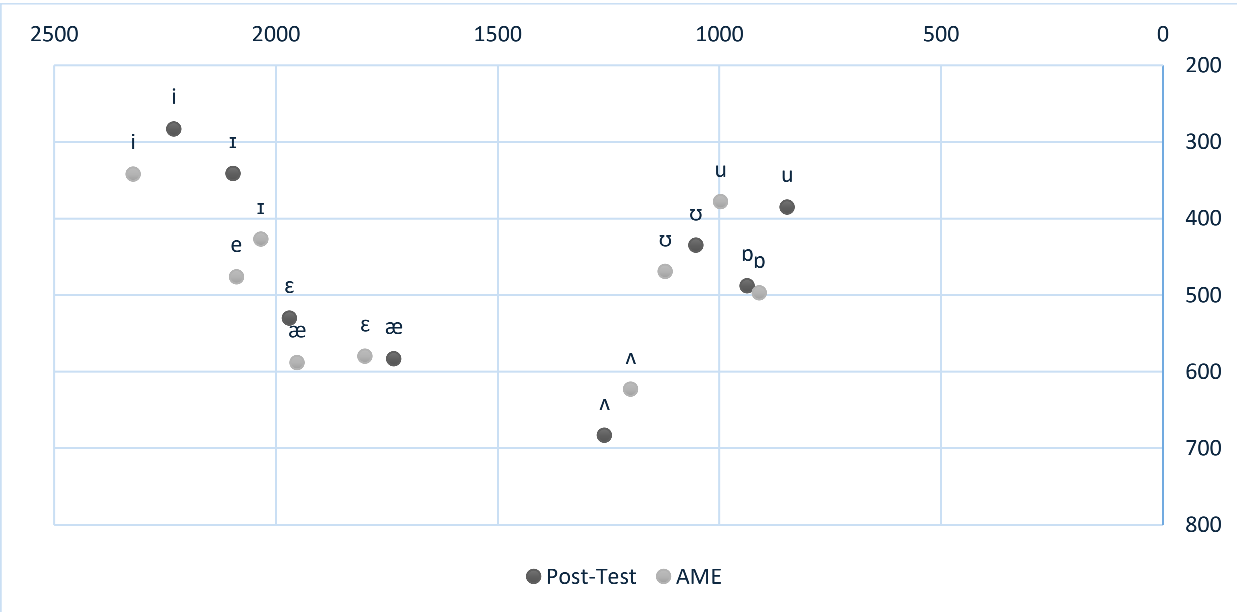

Figure 10. Male Experiment group Post-Test vowel quality and American English vowel phonemes.

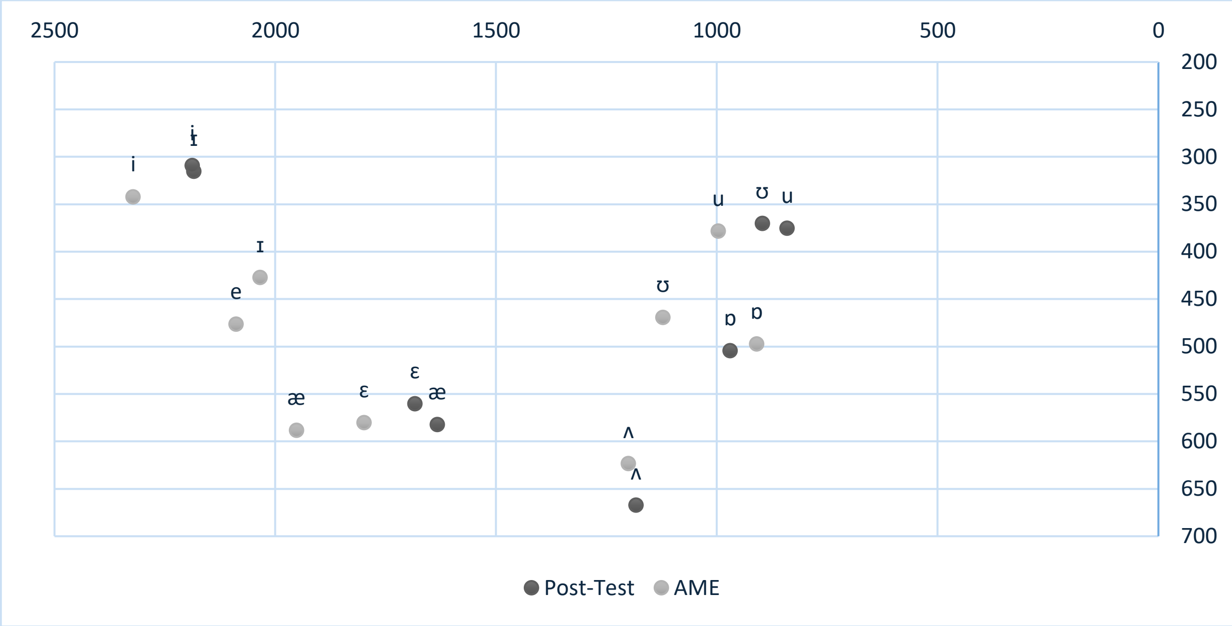

Figure 11. Male Control group Post-Test vowel quality and American English vowel phonemes.

Vowel sound /æ/ was produced a little bit more in the front, but not enough for it to be considered an unmistaken pronunciation of this vowel sound. Experiment group's F2 for this vowel averaged at about 1734Hz, but as the backness was closer to the sound /ɛ/, it was still considered not improved. Control group proved similar to the experiment group, with too low F2 frequencies of around 1633Hz

As can be seen in figures 12 and 13, female participants showed similar improvements in vowel pair /u/ - /ʊ/. After the use of Duolingo, experiment group's F1 was 441Hz for /u/, with F2 of 915Hz, while /ʊ/ was produced with F1 of 503Hz and F2 of 1012Hz. It can be noted that height and backness improved in /ʊ/ production, while control group produced /ʊ/ more in the front, yet at the same height as /u/. F1 for vowels /i/ and /ɪ/ were 324Hz and 388Hz respectively, while F2 were 2697Hz and 2407Hz. Even though acoustic distance was more prominent, the vowels' /i/ and /ɪ/ height remained quite high, which is typical in Russian pronunciation of /i/ sound. Control group's frequencies for height and backness remained in the close proximity for this vowel pair.

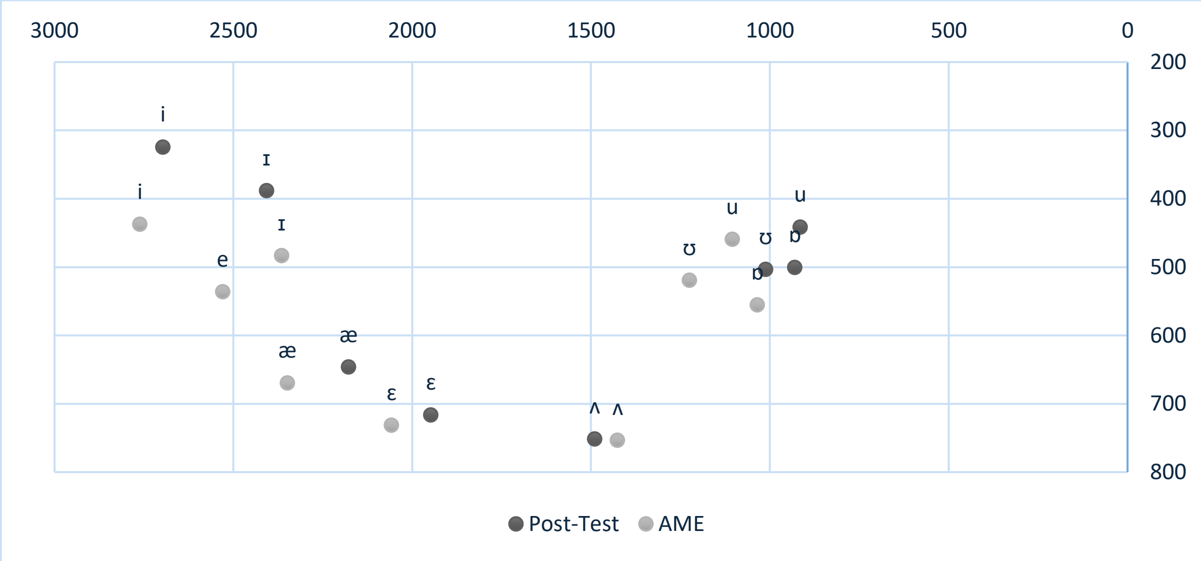

Figure 12. Female Experiment group Post-Test vowel quality and American English vowel phonemes.

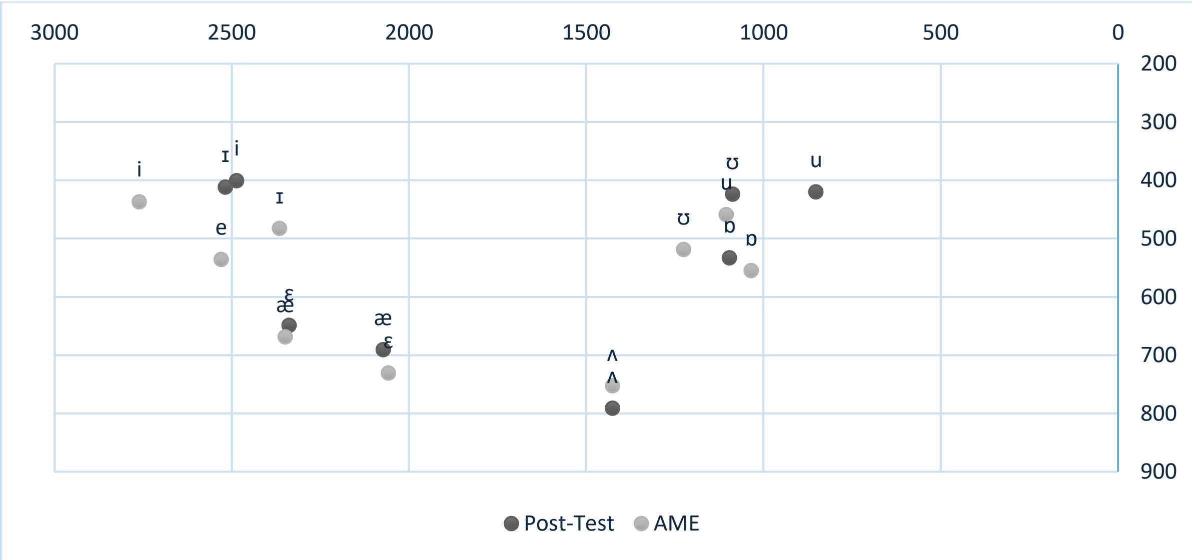

Figure 13. Female Control group Post-Test vowel quality and American English vowel phonemes.

No significant differences were observed for the vowel sound /æ/ in either of the groups. F1 values were around 646Hz for the experiment group, and 691Hz for the control group. F2 in the experiment group averaged at about 2178Hz and 2073Hz in the control group.

5.3.Vowel Duration Analysis

This section is concerned with vowel duration. As noted before there is no distinction between short and long vowels in Russian language, therefore minimal differences were expected between pairs such as /ɪ/ and /i/, and /ʊ/ and /u/. As it can be seen in figure 14, prior to the treatment, experiment group's average vowel /i/ duration was 165ms, vowel /ɪ/ - 115ms, /u/ - 195ms, /ʊ/ - 148ms, /æ/ - 129ms, /ɛ/ - 161ms, /ʌ/ - 116ms, /ɒ/ - 112ms.

After using Duolingo there were some changes in the average durations of the vowels. /i/ duration was 158ms, vowel /ɪ/ - 112ms, /u/ - 245ms, /ʊ/ - 105ms, /æ/ - 128ms, /ɛ/ - 135ms, /ʌ/ - 118ms, /ɒ/ - 112ms.

Pre-Test vowel duration ratio for /i/ and /ɪ/ is 1.4:1, and post-test – 1.4:1, so no changes were observed. Ratio for /ʊ/ and /u/ in pre-test averages was 1.3:1, whereas post-test ratio was 2.3:1. Vowel /æ/ duration remained the same, and vowel /ɛ/ duration was shorter by 26 ms.

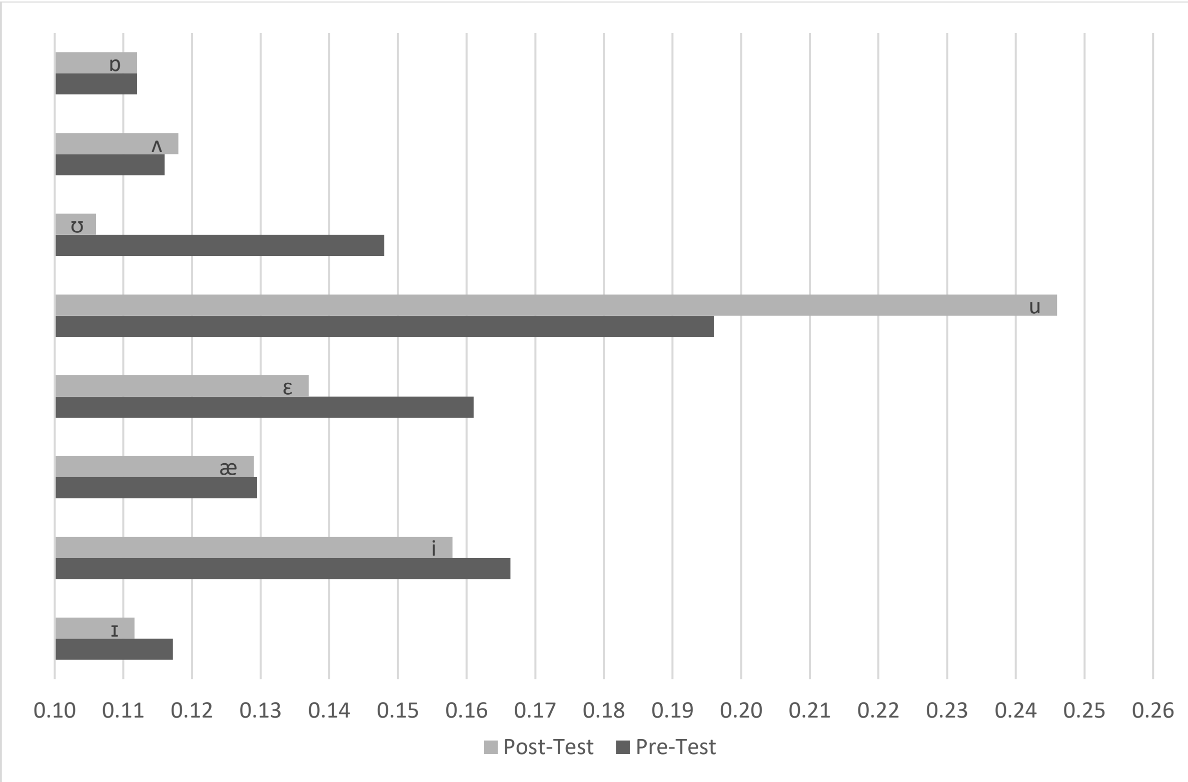

Figure 14. Experiment group vowel duration Pre and Post-Test.

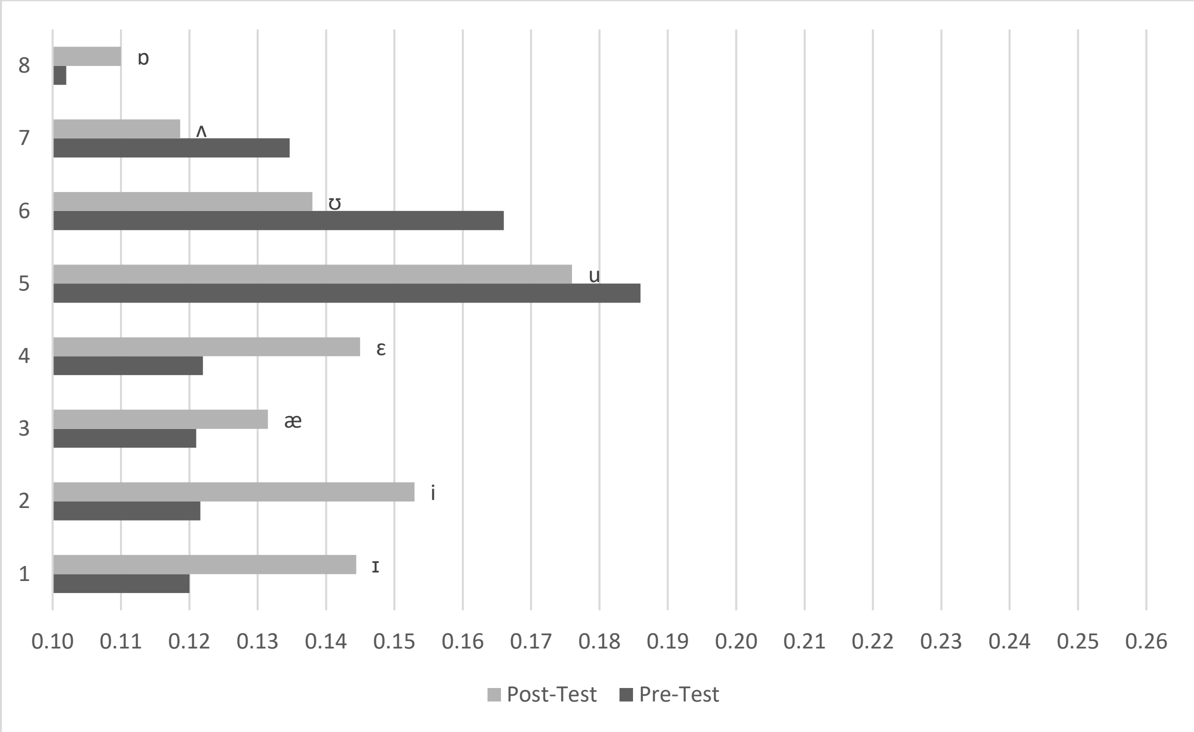

Figure 15. Control group vowel duration Pre and Post-Test.

During the pre-test control group's average vowel /i/ duration was 121ms, vowel /ɪ/ - 120ms, /u/ - 185ms, /ʊ/ - 165ms, /æ/ - 121ms, /ɛ/ - 122ms, /ʌ/ - 115ms, /ɒ/ - 102ms, which can be noted in figure 15. Post-test results are as follows: /i/ duration - 153ms, vowel /ɪ/ - 144ms, /u/ - 176ms, /ʊ/ - 138ms, /æ/ - 131ms, /ɛ/ - 145ms, /ʌ/ - 119ms, /ɒ/ - 110ms.

Pre-Test vowel duration ratio for /i/ and /ɪ/ is 1:1, and post-test – 1.1:1. Ratio for /ʊ/ and /u/ in pre-test averages was 1.1:1, whereas post-test – 1.3:1. Vowels' /æ/ and /ɛ/ duration increased by 10ms and 23ms respectively.

5.4.Discussion

A growing number of second language acquisition researchers note the interference of L1 in second language acquisition. There are two assumptions that are shared in this field. First of all, the degree of similarity between the two languages shows the degree of simplicity. Secondly, the degree of difference shows the degree of difficulty. Therefore, if two languages are different in certain aspects, such as phonological patterns of L2 are not similar to the native language of a learner, it causes L2 learners to encounter interference from their mother tongue.

Chapter 2 discussed English and Russian vowel phonological systems and issues that are often found in Russian speaking pronunciation. Firstly, vowel sound /æ/ does not exist in Russian phonological system, therefore many Russian speaking learners are met with a problem on how to pronounce it. As a result, learners tend to reach for their native phonological system, and employ a vowel sound /ɛ/, therefore words ‘men’ and ‘man’ is pronounced in a very similar manner of /mɛn/. This could be seen in both control and experiment groups, where /æ/ was produced more in the back, closer to the expected frequencies of a phoneme /ɛ/. Experiment and Control groups produced sound /ɛ/ similarly to the American English pronunciation, except experiment group tended to lower the vowel height, therefore bringing it closer to /e/ sound. It seems that /æ/ remained in the close proximity of /ɛ/ in both groups post-test, and experiment group haven't improved /ɛ/ sound, still pronouncing it more as /e/.

Phoneme /ɪ/ in Russian language is an allophone which can only be found in unstressed syllables, and if the consonant is preceding it, it must be soft. Most of the participants pronounced the word *bin* /bɪn/, as *bean* /bin/, due to rarity of this phonetic category in their phonological system. Similar observations were made with phonemes /ʊ/ and /u/. The space between these two phonemes is minor in the pre-test production in both experiment and control groups, due to near-close, near-high phoneme /ʊ/ being an allophone of /u/, only in unstressed syllables in Russian language. As all of the stimuli were monosyllabic words, therefore stressed syllables, Russian speakers pronounced near-close phoneme /ʊ/ as a closed-high phoneme /u/. Post-Test results showed differences in the experiment groups' vowel production after using Duolingo, but not the control group's. Larger distance in height and backness could be clearly seen in vowels/ɪ/,/i/ and /ʊ/,/u/ in the experiment group.

Similar observations were made in female control and experiment group participants. There was a minimal differentiation between vowel sounds /ɪ/ and /i/, and also /ʊ/ and /u/. /æ/ tended to be produced more in the back, therefore becoming closer to /ɛ/.

Female participants produced similar results regarding /ɪ/ and /i/, and /ʊ/ and /u/, nevertheless more so with the vowel pair /ʊ/ and /u/. The experiment group showed greater acoustic distance between these vowels, whereas control group's results remained the same. Interestingly, female experiment group participant improved /æ/ and /ɛ/ to some extent, bringing it closer to expected frequencies of these vowels. Control group did not show this result.

Vowel duration was used to determine the Russian speakers' ability to differentiate between long and short vowels. It should be noted that there is no set duration for vowels, as they vary according to their phonetic environment and other factors. Jones (1960) has found that the average ratio between long and short vowels is 1.9 to 1. The ratios for long and tense vowels were quite minimal in the Pre-Test phase. The only noticeable change found after the experiment was in the experiment group's /u/ - /ʊ/ pair, with a long/short vowel ration of 2.3 to 1.

The findings of this experiment support the hypothesis raised at the beginning of this paper, that Duolingo positively impacts Russian speaking L2 learners of English, at least in the vicinity of tense/lax vowels. Duolingo incorporates IPA as part of its teaching methodology, to help learners to understand actual sounds, regardless of their native phonological categories. Flege's (1995) speech learning model (SLM) proposes that with time even adults retain the capacity to perceive and establish new phonetic categories. This was observed in the improvement of formant frequencies of vowels/i/ and /ɪ/ and /u/ and /ʊ/. However, the likelihood of phonetic categories formation of L2 speech sounds depends on perceived cross-language phonetic distance and the state of development of L1 phonetic categories. As vowel sound /æ/ is not found in Russian language, it could explain why there were no improvements in this sound after using Duolingo. Differentiation of vowel duration did not show any significant results, except for /u/ and /ʊ/ sounds, though this could also relate to the acquired ability to contrast tense and lax vowels.

CONCLUSION

This study analyzed the complexities and difficulties that Russian speaking learners of English face when attempting to master the pronunciation of the target language. Pronunciation, a paramount part of any intelligible speech, often can be influenced by learner's native phonological system, which in turn leads to complications in perceiving and reproducing target language. Difficulties often come from the absence of certain phonological categories in the native phonological system, which leads learners to rely on the familiar phonological inventory of their native language. Through the inspection of the Russian and English vowel systems, it became apparent that pronunciation errors which are repeatedly present in Russian speakers' vowel production are the differentiating between tense and lax vowel and specifically vowel sound /æ/.

Using technology to facilitate the language learning process is not a new concept, yet phonetic training in mobile applications is more of a recent addition. This offers new strategies for pronunciation instruction and practice. Duolingo application specifically, employs IPA and minimal pair contrast as its phonetic training technique, and previous research suggests that phonetic training is an effective way to enhance learner's vowel production. This study focused on analyzing the impact of Duolingo on the vowel production in Russian speaking English learners. By providing minimal pair contrasts and employing qualitative acoustic analysis techniques, which measured formant frequencies and vowel duration, it was found that Duolingo positively influenced learners' pronunciation, especially in tense/lax vowel pairs /i/-/ɪ/ and and /u/-/ʊ/.

The findings of this research support the hypothesis, which predicted that Duolingo should have a positive effect on Russian speaking learners' English vowel pronunciation. Duolingo was shown to facilitate the development of new phonetic categories, as proposed by Flege's speech learning model. Despite these improvements, certain challenges remain. Vowel sound /æ/ did not show any significant developments, which could be due to this vowel sound being completely absent in Russian language.

Study Implications.

There are few implications that arose while conducting this experiment. First of all, the size of the data was relatively small, therefore statistical analysis could not be performed to determine whether the changes were statistically significant. While formant analysis proved some changes in Russian speakers' pronunciation, a larger data set would have been preferable. Of course, to ask participants to use a program which they haven't used before for a set amount of time and without compensation proved more challenging than expected. Another difficulty was controlling how much time participants used Duolingo application for. Therefore, no set time was set, though participants seemed to engage with this app daily.

Directions for Future Research

As mentioned before, Duolingo studies mainly focus on vocabulary and grammar achievements, while pronunciation is not so widely studied. The studies that focus on Duolingo's impact on pronunciation usually involves Roman languages, especially Spanish and French, or Eastern Asian languages, such as Chinese or Korean. There are approximately 7000 spoken languages in the world, though the focus of researchers always lands on selected few. When it comes to focus language of this research, Russian, a larger data sample taken over a longer period of time should be investigated to determine and prove significantly whether the Duolingo app can be considered as a valuable aid in learning L2 pronunciation. This study only analyzed a limited data set, so a similar study of another Slavic language, such as Bulgarian, would provide more context for this data analysis. In addition, only a small amount of vowel sounds was analyzed, therefore this gives an opportunity to analyze other vowels in different contexts, consonants, whole syllables, and various other properties. The directions for future study are numerous, but this study lays a foundation for further comparative phonetic investigations of mobile applications for language learning, such as Duolingo.

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SANTRAUKA

Šiame darbe daugiausia dėmesio skiriama rusų kalbos vartotojų balsių darybos akustinei analizei prieš ir po Duolingo programos naudojimo. Šio tyrimo tikslas - ištirti Duolingo programos poveikį rusakalbiams besimokantiesiems anglų kalbos, daugiausia dėmesio skiriant fonetiniam įsisavinimui minimalių porų kontekste. Šiam tikslui pasiekti pasirinktas eksperimentinės analizės metodas, naudojant fonetinius akustinius kintamuosius - formantų dažnius (F1 ir F2) ir balsių trukmę, kurie buvo vertinami naudojant spektrogramas. Dešimt rusakalbių savanorių, suskirstytų į eksperimentinę ir kontrolinę grupes, dalyvavo prieš ir po testuose. Eksperimento metu gauti rezultatai rodo, kad Duolingo programa padėjo rusakalbiams išgauti atsipalaidavusiųjų/įtemptųjų balsių poras /u/-/ʊ/ ir /i/-/ ɪ/, kurių F1 ir F2 dažnių reikšmės priartėjo prie gimtosios amerikiečių anglų kalbos, tačiau nepastebėta jokių pagerėjimų, susijusių su balsiu /æ/. Balsių trukmė reikšmingai nepagerėjo, išskyrus balsių porą /u/-/ʊ/. Šis tyrimas prisideda prie Duolingo fonetinio mokymo poveikio L2 besimokančiųjų tarimui supratimo. Kadangi kalbų mokymosi platformų pagalba besimokančiųjų tarimui vis dar yra nepakankamai ištirta sritis, šis straipsnis pateikia vertingų įžvalgų apie fonetinę technologijų įtaką ir poreikį ją toliau tirti, analizei pasitelkiant įvairias kalbas.

APPENDICES

Appendix 1. Test Stimuli

Say these sentences:

1. A man cannot do much for the humanity, but men can.
2. I don't really like beans, so I threw them in the bin.
3. A fool is that person who is full of anger and resentment.
4. One of the UK's gems is their elderflower jam!
5. I fell over the most annoying peach pit in the pitch on my last game.
6. For the World Cup 2024 I will wear my new cap with Spain's flag on it.
7. I can't believe I found a bug in my bag! That is so disgusting.
8. The duck attacked me suddenly while I was strolling down the dock.
9. Samsung has made their chips very cheap after the scandal.
10. I live in Barcelona, until I decide to leave forever.
11. Rich people usually reach for more and more, as they cannot stop.

Say these sentences:

1. Rich people usually reach for more and more, as they cannot stop.
2. A man cannot do much for the humanity, but men can.
3. A fool is that person who is full of anger and resentment.
4. I fell over the most annoying peach pit in the pitch on my last game.
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9. I live in Barcelona, until I decide to leave forever.
10. I can't believe I found a bug in my bag! That is so disgusting!
11. One of the UK's gems is their elderflower jam!

Appendix 2. Experiment group Pre-Test Male

Sound	F1	F2	Sound	F1	F2	Sound	F1	F2
/ʌ/	664	1195	/ɪ/	313	2100	/ʌ/	637	1443
/ʌ/	651	1207	/ɪ/	308	2098	/uː/	381	810
/ʌ/	754	1274	/ɪ/	365	2122	/uː/	403	792
/ʌ/	604	1090	/ɛ/	411	1785	/uː/	330	883
/iː/	319	1961	/ɛ/	522	1609	/uː/	341	708
/iː/	343	1923	/ɛ/	459	1994	/ʊ/	379	816
/iː/	301	1973	/ɛ/	565	1577	/ʊ/	371	1010
/iː/	318	2078	/æ/	559	1551	/ʊ/	414	1011
/iː/	307	2215	/æ/	553	1613	/ʊ/	415	774
/iː/	348	2024	/æ/	566	1679	/iː/	257	2017
/iː/	290	2046	/æ/	580	1577	/iː/	324	2050
/iː/	297	2183	/æ/	491	1763	/iː/	353	1943
/ɪ/	301	1960	/æ/	553	1712	/iː/	263	2060
/ɪ/	304	2001	/æ/	765	1602	/iː/	317	2090
/ɪ/	338	2089	/æ/	737	1399	/iː/	301	2094
/ɪ/	357	2000	/æ/	703	1462	/iː/	296	2445
/ɪ/	383	1993	/æ/	558	1628	/iː/	262	2396
/ɪ/	288	1988	/æ/	541	1571	/iː/	296	2341
/ɪ/	255	2133	/æ/	598	1501	/iː/	276	2120
/ɪ/	301	2212	/ ɒ/	499	1092	/iː/	298	2022
/ɪ/	296	1976	/ ɒ/	484	1072	/iː/	324	2132
/ɪ/	355	1463	/ ɒ/	521	1002	/ɛ/	468	1929
/ɪ/	304	1809	/ ɒ/	509	950	/ɛ/	561	1818
/ɪ/	295	2046	/ʌ/	676	1227	/ɛ/	474	1944
/ɪ/	373	2053	/ʌ/	659	1372	/ɛ/	576	1557
/ɪ/	341	2104	/ʌ/	739	1256	/æ/	561	1580
/ɪ/	343	2015	/ʌ/	608	1426	/æ/	493	1899
/ɪ/	336	1942	/ʌ/	737	1352	/æ/	735	1451
/ɪ/	267	2037	/ʌ/	836	1557	/æ/	549	1522
/ʌ/	687	1043						

Appendix 3. Control group Pre-Test Male

Sound	F1	F2	Sound	F1	F2	Sound	F1	F2
/ɪ/	330	2176	/ɛ/	578	1672	/uː/	364	932
/ʌ/	707	1005	/ɛ/	516	1742	/ʊ/	303	823
/ʌ/	665	1072	/ɛ/	644	1663	/ʊ/	362	711
/ʌ/	616	875	/ɛ/	575	1663	/ʊ/	333	741
/ʌ/	616	875	/æ/	580	1876	/ʊ/	449	1069
/iː/	318	2320	/æ/	786	1513	/iː/	246	2412
/iː/	282	2295	/æ/	529	1581	/iː/	264	2426
/iː/	225	2089	/æ/	617	1930	/iː/	232	2432
/iː/	287	2091	/æ/	541	1772	/iː/	253	2157
/iː/	249	2151	/æ/	709	1404	/iː/	304	2260
/iː/	421	1629	/æ/	623	1889	/iː/	282	2137
/iː/	280	2151	/æ/	478	1922	/iː/	257	2233
/iː/	356	1999	/æ/	568	1927	/iː/	260	2254
/ɪ/	255	2266	/æ/	591	1889	/iː/	302	2158
/ɪ/	282	2324	/æ/	520	1922	/iː/	299	2233
/ɪ/	260	2394	/æ/	568	1927	/iː/	260	2254
/ɪ/	364	2350	/ ɒ/	580	1148	/iː/	287	2456
/ɪ/	275	1851	/ ɒ/	598	945	/ɛ/	593	1726
/ɪ/	272	2130	/ ɒ/	515	975	/ɛ/	511	1672
/ɪ/	269	2416	/ ɒ/	480	1005	/ɛ/	542	1878
/ɪ/	289	2059	/ʌ/	691	1126	/ɛ/	542	1878
/ɪ/	335	2070	/ʌ/	647	1212	/æ/	577	1665
/ɪ/	283	2183	/ʌ/	664	1333	/æ/	571	1622
/ɪ/	261	2248	/ʌ/	657	1320	/æ/	605	1633
/ɪ/	269	2168	/ʌ/	632	1070	/æ/	630	1633
/ɪ/	300	2170	/ʌ/	709	1209	/ɪ/	279	2168
/ɪ/	308	2134	/ʌ/	632	1070	/ɪ/	300	2170
/ɪ/	300	2183	/ʌ/	709	1209	/ɪ/	308	2134
/ɪ/	305	2248	/uː/	319	970	/uː/	321	717
/uː/	364	662						

Appendix 4. Experiment group Post-Test Male

Sound	F1	F2	Sound	F1	F2	Sound	F1	F2
æ	585	1804	ɪ	302	2012	iː	283	2206
ɒ	498	826	ɪ	408	1609	iː	288	2081
ɒ	469	800	ɪ	304	2040	iː	265	2083
ɒ	485	1122	ɪ	396	2236	iː	266	2424
ɒ	499	1001	ɪ	316	2142	iː	225	2277
æ	598	1666	ɪ	396	1983	iː	259	2247
æ	544	1851	ɪ	466	1966	iː	300	2304
æ	564	1637	ɪ	321	2393	iː	241	2310
æ	601	1616	ɪ	348	2260	ʊ	362	798
æ	569	1537	ɪ	242	2194	ʊ	446	1001
æ	632	1412	ɪ	318	2175	ʊ	487	1203
æ	611	1707	ɪ	371	2047	ʊ	446	1209
æ	554	1796	ɪ	374	1947	uː	395	616
æ	549	1904	ɪ	353	2188	uː	343	822
æ	673	1245	ɪ	275	2239	uː	399	980
æ	557	1726	ɪ	289	2049	uː	401	969
æ	541	1992	ɪ	381	1980	ʌ	696	1309
æ	591	1893	ɪ	300	2221	ʌ	654	1219
æ	581	1893	iː	290	2283	ʌ	679	1408
æ	610	2072	iː	323	2305	ʌ	797	1383
ɛ	557	2052	iː	306	2193	ʌ	657	1148
ɛ	454	2384	iː	323	1926	ʌ	717	1418
ɛ	609	1908	iː	286	2012	ʌ	697	1188
ɛ	448	1875	iː	258	2350	ʌ	677	1234
ɛ	559	1714	iː	239	2457	ʌ	714	1352
ɛ	540	1812	iː	279	2403	ʌ	657	1022
ɛ	589	1995	iː	351	2077	ʌ	614	1176
ɛ	485	2020	iː	288	2360	ʌ	667	1250
ɪ	330	2180	iː	301	2100			
ɪ	325	2083	iː	285	2210			

Appendix 5.

Sound	F1	F2	Sound	F1	F2	Sound	F1	F2
æ	576	1737	ɪ	323	2480	iː	347	2174
ɒ	503	1089	ɪ	382	2291	iː	351	2044
ɒ	474	839	ɪ	324	2301	iː	316	2176
ɒ	548	952	ɪ	233	2334	iː	297	2235
ɒ	489	999	ɪ	258	2247	iː	293	2169
æ	579	1908	ɪ	273	2088	iː	301	2345
æ	650	1489	ɪ	317	2016	iː	278	2044
æ	611	1504	ɪ	276	2000	iː	316	2176
æ	446	1662	ɪ	319	2106	ʊ	363	1024
æ	584	1698	ɪ	289	2221	ʊ	330	655
æ	559	1483	ɪ	291	2194	ʊ	352	820
æ	510	1502	ɪ	339	2185	ʊ	435	1090
æ	609	1509	ɪ	342	2107	uː	383	977
æ	573	1777	ɪ	299	2106	uː	354	664
æ	567	1568	ɪ	289	2221	uː	381	725
æ	614	1719	ɪ	291	2194	uː	381	998
æ	609	1509	ɪ	339	2185	ʌ	723	1090
æ	573	1777	ɪ	333	2107	ʌ	635	1130
æ	567	1568	iː	439	1991	ʌ	733	1312
æ	614	1719	iː	294	2468	ʌ	631	1228
ɛ	578	1827	iː	309	2600	ʌ	612	1078
ɛ	595	1526	iː	359	2120	ʌ	582	1310
ɛ	529	1461	iː	285	2389	ʌ	664	1209
ɛ	455	1546	iː	248	2136	ʌ	730	1010
ɛ	599	1690	iː	248	2221	ʌ	676	1303
ɛ	570	1865	iː	280	2056	ʌ	664	1209
ɛ	583	1690	iː	297	2053	ʌ	730	1010
ɛ	570	1865	iː	264	2015	ʌ	676	1303
ɪ	422	2077	iː	364	2184			
ɪ	359	2210	iː	293	2169			

Appendix 6. Experiment group female pre and post-test

Pre-Test			Post-Test		
Vowels	F1	F2	Sound	F1	F2
/æ/	723	1857	ɒ	500	930
/ɛ/	749	1966	æ	709	2243
/iː/	308	2462	æ	593	2359
/iː/	237	2949	æ	622	2204
/iː/	330	2572	æ	683	1911
/ʊ/	462	867	ɛ	730	1991
/uː/	431	902	ɛ	702	1904
/ʌ/	748	1272	ɪ	326	2409
/ʌ/	795	1337	ɪ	363	2679
/ ɒ/	524	996	ɪ	387	2421
/æ/	468	2783	ɪ	461	1961
/æ/	868	2191	ɪ	404	2567
/æ/	721	1798	iː	375	2461
/ɛ/	653	1892	iː	250	2949
/ɪ/	409	2291	iː	310	2971
/ɪ/	327	2540	iː	367	2357
/ɪ/	287	2610	iː	317	2725
/ɪ/	384	2531	ʊ	503	1012
/ɪ/	402	2398	uː	441	915
/iː/	374	2621	ʌ	790	1284
/iː/	329	2575	ʌ	732	1509
/ʌ/	727	1061	ʌ	732	1677

Appendix 7. Control group female pre and post-test

Pre-Test			Post-Test		
Sound	F1	F2	Sound	F1	F2
/æ/	771	2057	ɒ	533	1096
/ɛ/	488	2539	æ	690	2040
/iː/	332	2717	æ	700	2047
/iː/	452	2961	æ	695	2043
/iː/	432	2721	æ	678	2162
/ʊ/	402	837	ɛ	732	2389
/uː/	449	816	ɛ	565	2287
/ʌ/	710	1202	ɪ	473	2540
/ʌ/	778	1376	ɪ	397	2886
/ ɒ/	587	1045	ɪ	355	2466
/æ/	739	2065	ɪ	428	2610
/æ/	780	2189	ɪ	409	2089
/æ/	490	2609	iː	420	2619
/ɛ/	670	2080	iː	349	2861
/ɪ/	413	2323	iː	448	2218
/ɪ/	348	2760	iː	394	2266
/ɪ/	465	2443	iː	398	2468
/ɪ/	363	2904	ʊ	424	1087
/ɪ/	410	2881	uː	420	852
/iː/	372	2502	ʌ	756	1484
/iː/	445	2821	ʌ	755	1362
/ʌ/	712	1200	ʌ	863	1433

Appendix 8. Experiment group pre-post vowel duration

Sound	Duration	Sound	Duration	Sound	Duration
ɪ	0.09	ɪ	0.1	ʌ	0.08
æ	0.1	æ	0.2	æ	0.1
ɛ	0.25	æ	0.21	æ	0.12
i	0.13	ɛ	0.24	ɛ	0.16
i	0.17	ɛ	0.22	ɛ	0.12
i	0.09	i	0.2	i	0.19
i	0.23	i	0.22	i	0.18
i	0.26	i	0.16	i	0.14
u	0.22	i	0.1	i	0.22
u	0.3	i	0.21	i	0.23
ʊ	0.17	u	0.11	u	0.2
ʊ	0.09	u	0.15	ʊ	0.1
ʌ	0.11	ʊ	0.2	ʌ	0.11
ʌ	0.09	ʊ	0.18	ʌ	0.09
ʌ	0.12	ʌ	0.18	ʌ	0.1
ʌ	0.11	ʌ	0.18	ɒ	0.09
ɒ	0.1	ɒ	0.17	ɒ	0.11
ɒ	0.09	æ	0.13	æ	0.1
æ	0.13	æ	0.1	æ	0.08
æ	0.11	æ	0.16	æ	0.12
æ	0.17	æ	0.18	æ	0.13
æ	0.08	æ	0.1	æ	0.16
æ	0.11	ɛ	0.08	ɛ	0.1
ɛ	0.16	ɛ	0.09	i	0.14
ɛ	0.19	i	0.11	i	0.13
i	0.12	i	0.17	i	0.12
i	0.22	i	0.18	ɪ	0.1
i	0.13	i	0.11	ɪ	0.09
ɪ	0.12	ɪ	0.11	ɪ	0.13
ɪ	0.16	ɪ	0.15	ɪ	0.14
ɪ	0.12	ɪ	0.25	ɪ	0.09
ɪ	0.09	ɪ	0.1	ɪ	0.14
ɪ	0.05	ɪ	0.09	ɪ	0.14
ɪ	0.09	ɪ	0.11	ɪ	0.11
ɪ	0.08	ɪ	0.17	ʌ	0.08
ɪ	0.11	ʌ	0.1	ʌ	0.11
ʌ	0.1	ʌ	0.18		

Appendix 9. Control Group pre-post vowel duration.

Sound	Duration	Sound	Duration	Sound	Duration
ɪ	0.1	ɪ	0.09	ʌ	0.09
æ	0.16	æ	0.14	æ	0.11
ɛ	0.13	æ	0.09	æ	0.09
i	0.08	ɛ	0.15	ɛ	0.11
i	0.12	ɛ	0.15	ɛ	0.15
i	0.15	i	0.16	i	0.1
i	0.16	i	0.15	i	0.16
i	0.13	i	0.13	i	0.15
u	0.22	i	0.09	i	0.13
u	0.21	i	0.13	i	0.11
ʊ	0.11	u	0.19	u	0.19
ʊ	0.19	u	0.12	ʊ	0.2
ʌ	0.14	ʊ	0.2	ʌ	0.3
ʌ	0.12	ʊ	0.13	ʌ	0.1
ʌ	0.13	ʌ	0.3	ʌ	0.09
ʌ	0.09	ʌ	0.1	ɒ	0.1
ɒ	0.08	ɒ	0.12	ɒ	0.12
ɒ	0.09	æ	0.11	æ	0.09
æ	0.13	æ	0.11	æ	0.11
æ	0.16	æ	0.13	æ	0.13
æ	0.1	æ	0.15	æ	0.15
æ	0.11	æ	0.12	ɛ	0.12
æ	0.14	æ	0.09	i	0.1
ɛ	0.1	ɛ	0.12	i	0.12
ɛ	0.1	ɛ	0.09	i	0.1
i	0.11	i	0.09	ɪ	0.1
i	0.08	i	0.12	ɪ	0.09
i	0.15	i	0.1	ɪ	0.1
ɪ	0.16	i	0.12	ɪ	0.16
ɪ	0.13	ɪ	0.1	ɪ	0.12
ɪ	0.13	ɪ	0.16	ɪ	0.14
ɪ	0.1	ɪ	0.12	ɪ	0.12
ɪ	0.09	ɪ	0.14	ɪ	0.09
ɪ	0.17	ɪ	0.12	ɪ	0.1
ɪ	0.12	ɪ	0.1	ʌ	0.08
ɪ	0.15	ʌ	0.13	ʌ	0.12
ʌ	0.11	ʌ	0.12		

Appendix 10. Experiment group post-test vowel duration.

Sound	Duration	Sound	Duration	Sound	Duration
ɒ	0.13	ɒ	0.12	i	0.08
æ	0.14	ɒ	0.15	ɒ	0.07
æ	0.12	æ	0.1	ɒ	0.09
æ	0.13	æ	0.15	æ	0.12
æ	0.12	æ	0.13	æ	0.06
æ	0.17	æ	0.25	æ	0.1
æ	0.16	æ	0.09	æ	0.12
æ	0.12	æ	0.15	æ	0.12
æ	0.13	ɛ	0.1	æ	0.1
ɛ	0.12	ɛ	0.13	ɛ	0.07
ɛ	0.21	ɛ	0.09	ɛ	0.14
ɛ	0.13	ɛ	0.2	i	0.07
ɛ	0.18	i	0.16	i	0.12
i	0.18	i	0.1	i	0.14
i	0.09	i	0.18	i	0.12
i	0.13	i	0.25	i	0.3
i	0.09	i	0.1	i	0.21
i	0.11	i	0.2	i	0.1
i	0.2	i	0.2	i	0.22
i	0.22	i	0.2	ɪ	0.09
ɪ	0.11	i	0.16	ɪ	0.1
ɪ	0.09	ɪ	0.07	ɪ	0.08
ɪ	0.05	ɪ	0.07	ɪ	0.09
ɪ	0.09	ɪ	0.13	ɪ	0.09
ɪ	0.11	ɪ	0.16	ɪ	0.11
ɪ	0.13	ɪ	0.12	ɪ	0.09
ɪ	0.14	ɪ	0.17	ɪ	0.09
u	0.15	ɪ	0.11	ɪ	0.16
u	0.27	ɪ	0.13	u	0.27
ʊ	0.12	ɪ	0.21	ʊ	0.15
ʊ	0.07	u	0.24	ʌ	0.11
ʌ	0.11	u	0.3	ʌ	0.08
ʌ	0.11	ʊ	0.09	ʌ	0.09
ʌ	0.1	ʊ	0.1	ʌ	0.1
ʌ	0.12	ʌ	0.17	ʌ	0.11
ʌ	0.1	ʌ	0.23	ʌ	0.11
ʌ	0.11	ʌ	0.12		

Appendix 11. COntrol group post-test vowel duration.

Sound	Duration	Sound	Duration	Sound	Duration
ɒ	0.09	ɒ	0.09	i	0.8
æ	0.11	ɒ	0.13	ɒ	0.11
æ	0.12	æ	0.15	ɒ	0.13
æ	0.13	æ	0.13	æ	0.13
æ	0.14	æ	0.12	æ	0.12
æ	0.14	æ	0.12	æ	0.15
æ	0.15	æ	0.13	æ	0.13
æ	0.12	æ	0.12	æ	0.12
æ	0.18	ɛ	0.12	æ	0.12
ɛ	0.14	ɛ	0.19	ɛ	0.12
ɛ	0.16	ɛ	0.1	ɛ	0.19
ɛ	0.13	ɛ	0.13	i	0.12
ɛ	0.17	i	0.13	i	0.09
i	0.1	i	0.09	i	0.11
i	0.14	i	0.09	i	0.11
i	0.14	i	0.11	i	0.21
i	0.08	i	0.21	i	0.15
i	0.13	i	0.15	i	0.11
i	0.12	i	0.11	i	0.1
i	0.16	i	0.1	ɪ	0.8
ɪ	0.08	i	0.12	ɪ	0.12
ɪ	0.12	ɪ	0.15	ɪ	0.09
ɪ	0.13	ɪ	0.08	ɪ	0.09
ɪ	0.09	ɪ	0.1	ɪ	0.12
ɪ	0.11	ɪ	0.12	ɪ	0.17
ɪ	0.1	ɪ	0.17	ɪ	0.15
ɪ	0.16	ɪ	0.15	ɪ	0.12
u	0.24	ɪ	0.12	ɪ	0.09
u	0.15	ɪ	0.09	u	0.18
ʊ	0.09	ɪ	0.09	ʊ	0.18
ʊ	0.12	u	0.18	ʌ	0.11
ʌ	0.16	u	0.13	ʌ	0.1
ʌ	0.1	ʊ	0.18	ʌ	0.09
ʌ	0.13	ʊ	0.12	ʌ	0.13
ʌ	0.16	ʌ	0.13	ʌ	0.11
ʌ	0.11	ʌ	0.11	ʌ	0.13
ʌ	0.08	ʌ	0.13		