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THE PRODUCTION OF RUSSIAN VOWELS /i/ AND /ɨ/ BY RUSSIAN-ENGLISH BILINGUAL CHILDREN

by

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This manuscript has been read and accepted for the Graduate Faculty in Linguistics for satisfaction of the thesis requirement for the degree of Master of Arts.

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ABSTRACT

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This study is the first to investigate the production of the Russian vowel contrast /i/-/ɨ/ by Russian-English bilingual children living in New York City. This contrast is interesting because the vowel /ɨ/ is not unanimously recognized as an independent phoneme, based on e.g. its limited occurrence and distribution (Kodzasov & Krivnova, 2010; Matusevich, 1976). Additionally, Russian-speaking children acquire /ɨ/ relatively late in production. Therefore, this contrast's acquisition may be particularly challenging for bilingual children with more limited exposure and variability in their input and is an interesting test case and contribution to the debate regarding the contrast's phonological status. In this study, I collected production samples from 11 Russian-English bilingual children from New York City (mean age 10 years) as well as two 10-year-old Russian monolingual children from Russia. Participants completed a picture-naming and sentence-repetition task via Zoom while parents recorded their speech via iPhones. Productions of /i/ and /ɨ/ (~120 tokens per participant) were acoustically analyzed focusing on formant frequencies at 5 points in time. Results showed that overall bilingual children's formant values were similar to monolinguals, although bilinguals tended to produce high mid vowel /ɨ/ with higher F2 values than monolinguals. Moreover, differences were observed within

the bilingual group: participants with more Russian input showed patterns of production more similar to monolinguals than children with less Russian input.

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1. Introduction

People who have been exposed to two languages from an early age tend to be successful in establishing language-specific-contrastive categories and demonstrate more 'nativelike' pronunciation for both the first and later-learned languages (Flege, Schirru, & MacKay, 2003). This phenomenon has been linked to factors like age of acquisition and the amount of daily use of these languages. The purpose of this study is to explore whether Russian-English bilingual children form separate categories for high front /i/ and high central /ɨ/ vowels in Russian. All children in this study were born in America, have either one or two Russian-speaking parent(s), and were exposed to Russian from birth. The contrast under investigation was chosen because it could present a problematic case for bilingual children with presumably limited Russian input. Vowel /ɨ/ is not unanimously accepted by phonologists as a separate phoneme in Russian, although it has independent articulatory and acoustic properties. The examination of how bilingual children approach the contrast could contribute to the debate regarding the status of the /ɨ/.

It has been widely recognized that children's early experience with speech is crucial for later language development (Tsao, Liu, & Kuhl, 2004; Kuhl, Padden, Conboy, Nelson & Pruitt, 2005; Conboy, Rivera - Gaxiola, Klarman, Aksoylu, & Kuhl, 2005). Even repeated passive exposure to a language in early childhood, such as overhearing, seems to be beneficial for later language learning, primarily as it pertains to phonology. In a study where "childhood overhearers" were compared to late L2 learners, the first group demonstrated better pronunciation as the result of "incidental" childhood learning (Knightly, Jun, Oh, & Au, 2003). Specifically, participants who were exposed to Spanish in childhood by virtue of hearing it from a parent or a relative or being spoken to in Spanish

occasionally, produced voiced-initial stops (/p/, /t/, /k/) with shorter voice-onset-time (VOT) hence more nativelike than L2 learners.

A large body of research has demonstrated that monolingual and bilingual infants are capable of discriminating a wide range of native and non-native phonemic contrasts during their first year of life. With increasing age, the become progressively more selective and attuning to the sounds of their native language or languages (Bosch & Sebastian-Galles, 2000; Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992; Rivera-Gaxiola, Silva-Pereyra & Kuhl, 2005; Werker & Tees, 1984). This "Perceptual Attunement" or "Perceptual Narrowing" to the language-specific sound units is often linked to increased native language experience (Maurer & Werker, 2013; Werker, 2018). The ability to discriminate non-native contrasts declines by the time infants are around 6-month-old for vowels (Kuhl et al., 1992; Polka & Werker, 1994) and by 10-month-old for non-native consonants (Werker & Tees, 1984; Rivera-Gaxiola et al., 2005). However, several studies have reported that the decline in sensitivity to nonnative contrasts doesn't necessarily happen in the same fashion for all contrasts (Best, McRoberts, & Sithole, 2003), and sensitivity to some contrasts require a longer period of exposure (Narayan, Werker, & Beddor, 2010).

When it comes to bilingual children, it is not exactly clear how this transition from universal to native language-specific discrimination occurs, but some evidence indicates that bilingual children undergo a different developmental trajectory compared to monolingual children. For instance, when 4-, 8-, and 12-month-old Catalan-Spanish bilingual infants were tested on discrimination of Catalan vowels /e/-/ɛ/, the results indicated that only 4-, and 12-month-old infants were capable of discriminating the

contrast, but not 8-month-olds (Bosch & Sebastian-Galles, 2003). The contrast is phonemic only in one language (Catalan) and there is a level of acoustic-phonetic overlap between the vowels of Catalan and Spanish. The same U-shaped pattern was observed in a follow-up study examining a contrast that is phonemic in both Catalan and Spanish (/o/-/u/) (Sebastian-Galles & Bosch, 2009). Eight-month-old bilingual infants failed to discriminate the /o/-/u/ contrast, unlike 4- and 12-month-olds. However, all three age groups showed successful discrimination of the acoustically more distant vowels /e/-/u/ which are common in both Spanish and Catalan (Sebastian-Galles & Bosch, 2009).

In contrast, no difference between bilingual and monolingual developmental patterns was observed in other studies. For example, in a study of the English /e/- /ɛ/ contrast, 4- and 8-month-old English and Spanish-English learning infants, both were successful at discriminating the contrasts (Sundara & Scutellaro, 2010). The authors noted that English and Spanish are rhythmically different languages as opposed to Catalan and Spanish, indicating that this could be a factor affecting the developmental trajectory in speech perception by bilingual infants (Sundara & Scutellaro, 2010).

The U-shaped pattern also was not observed in studies examining the discrimination of consonant contrasts by other bilingually exposed infants. For example, 6 to 8, 10 to 12, and 14 to 20-month-old French-English learning bilingual infants in Canada demonstrated the ability to discriminate a three-way voice onset time (VOT) consonant contrast (Burns, Yoshida, Hill, & Werker, 2007). Among the age-matched English monolingual infants in the same study, only 6- to 8-month-olds were able to discriminate the three-way VOT contrast, but not the older monolingual group (Burns, Yoshida, Hill, & Werker, 2007). In another study, 10 to 12-month-old Canadian French-English learning bilingual infants, but

not age-matched French monolingual infants were capable of discriminating English /d/-/ð/ (Sundara, Polka, & Molnar, 2008). These results suggest that bilingual infants discriminate the sounds in both their native languages in a relatively similar fashion to monolingual infants. Furthermore, the studies show that if two languages are present in the ambient environment, bilingual infants exhibit sensitivity to sound contrasts in both languages.

Additionally, researchers who employed neural measures, such as ERP, show that input from two language sources modulates the neural discrimination of speech sounds differently than when it comes from one language (Garcia-Sierra, Rivera-Gaxiola, Percaccio, Conboy, Romo, Klarman, Ortiz, & Kuhl, 2011; Shafer, Yan, & Datta, 2011) For example, Garcia-Sierra et al. (2011) observed that 6-9 month-old Spanish-English learning bilingual infants did not exhibit the neural response indicating discrimination of the VOT contrast in neither of the languages. However, 10-12 months bilingual infants showed discrimination of the contrast in both languages. On the contrary, similar previous study with monolingual infants showed that they were able to discriminate the contrasts in both languages at 7 months (Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005). However, 11-month-old monolingual infants in the study only discriminated the contrast in their native language. The authors suggested it should not be interpreted as a developmental delay but could indicate that perceptual narrowing takes place later in the development of bilingual children.

In sum, previous studies have shown that infants undergo drastic changes in their perceptual organization of speech sounds during their first year of life and these changes are correlated with the input that they receive. Although bilingual infants' developmental trajectory might show a slight divergence from monolinguals' development, both groups

demonstrate the transition from a “universal” pattern of perception to language-specific perception as their experience with the language(s) in their environment increases.

It is unclear, however, how language experience affects production patterns during the first year of life. There is some debate over whether infants produce universal babbling patterns during the first year of life independent of their language experience or whether language specific experience affects first vocalizations (Boysson-Bardies, Halle, Sagart, & Durand, 1989; Boysson-Bardies & Vihman, 1991; Boysson-Bardies, Halle, Sagart, & Durand, 1987; Lee, Davidson & MacNeilage, 2009). A universal pattern could be explained by anatomical constraints in infants (Oller, 2000). However, cross-linguistic examination of acoustic properties of vowels in babbling revealed that systematic differences in vowel productions emerge in 10-month-old infants across different language communities (Boysson-Bardies et al., 1987).

Research exploring babbling in bilingual children has demonstrated different patterns as well. Some studies failed to observe the effect of the ambient languages on babbling productions (Oller & Eilers, 1982; Poulin-Dubois and Goodz, 2001). On the other hand, some report differences in the types of syllables used in bilingual children depending on the interlocutor (Maneva & Genesee, 2002; Sundara, Ward, Conboy, & Kuhl, 2019). Sundara et al. (2019) demonstrate that these differences emerge even after a few hours of exposure to another language. However, these studies generally have small number of participants and it is very difficult to measure babbling acoustics. Thus, more studies are needed to fully document how exposure to two languages affects the production patterns during the first year of life.

1.1 Phonology in adult bilinguals

Understanding the developmental differences in perception and production between monolingual and bilingual children is paramount for understanding the organization of the phonological system in bilingual speakers in general. The question of the organization of the phonological systems has extensively been studied among adult bilinguals. For instance, Flege, Schirru, and MacKay (2003) examined the production of English mid-front diphthong /e^{i}/ by Italian Canadian bilinguals who were born in Italy and moved to Canada at various stages of life. Bilinguals were divided into four groups depending on the age of arrival to Canada and the amount of experience with English (Early/Late, High/Low bilinguals). The results revealed that early bilinguals with a low amount of language experience produced the target vowel with more tongue movement and both groups of late bilinguals produced it with less tongue movement than native English speakers. More tongue movement was expected because English /e^{i}/ is diphthongized whereas Italian /e/ is not. The authors suggested that bilingual speakers employed different strategies: assimilation (merger) and dissimilation. When the vowel was produced with less tongue movement, the participants treated the vowel closer to Italian /e/, described as a merger with or assimilating to the Italian vowel. When the vowel was dissimilated from Italian /e/, it suggested that they had established a new category, different from Italian /e/. In general, early bilinguals with a low amount of experience in L2 were more successful at establishing new categories than both late bilingual groups. This finding indicated that age of acquisition played a more important role than language experience in establishing new categories. Additionally, the results supported the idea of language interaction of two languages through different mechanisms: assimilation and dissimilation.

The fact that age of acquisition plays an important role in forming vowel categories in production was supported by Guion (2003). They reported that among three groups of Quichua-Spanish bilinguals only early (those who acquired Spanish between 5 and7 years of age) and mid (those who acquired Spanish between 9-13 years of age) bilinguals were able to acquire Spanish vowels (Quichua vowel system consists of three vowels /i/, /ʊ/, /a/ and Spanish is a 5-vowel system /i/, /e/,/a/,/o/,/u/); the late bilinguals (those who acquired Spanish at 15- 25 years old) showed less Spanish-like productions of Spanish vowels. Moreover, speakers who had acquired the Spanish vowels produced Quichua vowels with higher formant value as opposed to those who had not. Guion suggested that those who produced the Quichua vowels with higher formant values employed a dissimilation strategy to perceptually enhance the differences between vowels in both languages.

Early French-English bilingual adults in the study by MacLeod, Stoel-Gammon, & Wassnik (2009) also demonstrated accurate production of language-specific vowel phonemes, even for vowels that were close in acoustic space, such as tense/lax vowel contrasts /i, ɪ, u, ʊ/. While in English these vowels are phonemes, in Canadian French lax /ɪ/,/ʊ/ are allophones of tense vowels /i/ and /u/. In Canadian French the distribution of tense and lax vowels is phonetically conditioned (tense vowels can only occur in open syllables or syllables with voiced fricatives in the coda, lax vowels occur in all other environments). Moreover, acoustically these vowels tend to differ in both languages: lax vowels in French are higher (produced with lower F1) than in English. Comparison of the formant values revealed that bilinguals produced these vowels in both languages in a manner similar to French and English monolinguals, maintaining the differences in height in advancement. However, bilingual speakers produced English lax vowels with lower F1

than English speakers which could indicate a possible influence of French vowels and interaction between two languages. The authors argued that overall successful establishment of language-specific vowel phonemes for acoustically-overlapping vowels by early French-English bilinguals in the study could have been attributed not only to the age of acquisition but also to continuous daily use of both languages in various contexts.

Taken together these studies indicate that bilingual adults can be successful at establishing language-specific vowel contrasts, even for acoustically similar vowels, but their productions may still be slightly different from those of monolinguals. Moreover, the quality of bilinguals' vowel productions depends on the time of exposure to both languages and experience using them.

1.2 Phonology in bilingual children

Previous studies with children show more mixed results. The majority of studies examining productions in young bilingual children focus on single-case studies and broad transcriptions (Yung, Fox & Jacewicz, 2014; Kehoe, 2002; Keshavarz & Ingram, 2002). The principal questions previous researchers have attempted to address were whether there was a delay in acquiring vowels in both languages in bilingual children and how accurate early productions were. For instance, Kehoe (2002) longitudinally examined productions of vowels by three German-Spanish bilingual children (from one to approximately three years of age) and compared them with productions by monolingual German and monolingual Spanish children. The results from this study indicate that bilingual children were successful at acquiring Spanish vowels. However, bilingual children had not yet acquired the German vowel length contrast by three years of age, while German monolingual

children in the study showed successful length distinction by the ages of 2;3- 2;6 years. Kehoe's interpretation was that the German vowel system is more marked than Spanish and, thus, harder to acquire and caused the bilingual children to exhibit a slight delay in the acquisition of that vowel system. Two groups of younger (39- to 57- months of age) and slightly older (60- to 65- months of age) bilingual Russian-English children also demonstrated a higher rate of errors in their productions of English vowels compared to age-matched monolingual children (Gildersleeve-Neumann & Wright, 2010). However, both monolingual and bilingual groups had similar phonetic inventories and error patterns in productions. The errors tended to decrease by 5 years of age. However, Russian-English bilinguals continued to have more difficulty compared to the monolinguals with producing tense/lax vowel contrast, which is absent in Russian. Taken together, these studies indicate that the acquisition of the more "marked" vowel system (Kehoe, 2002) or the vowel system with a larger inventory (Gildersleeve-Neumann & Wright, 2010) might take longer for bilingual children to acquire.

Additionally, it has also been argued that when a vowel system with a larger phonemic inventory is introduced, the phonological system of the first language undergoes a reorganization in young children: Spanish-English sequential bilingual children (mean age =3 years) showed an increase in error rates (such as diphthong reduction or vowel neutralization) in the production of Spanish vowels when English was introduced (Gildersleeve-Neumann & Peña, 2009). This increase in errors might indicate the reorganization of the L1 (in this case, Spanish) phonological system.

The question of whether the phonetic systems of sequential bilingual children are reorganized was further investigated in Korean-English 5- and 10-year-old bilingual

children (Lee & Iverson, 2012). English and Korean vowel productions were acoustically analyzed. The results revealed that bilingual children, even 5-year-olds with only 2 years of exposure to English, produced both Korean and English vowels similar to Korean-speaking and English-speaking children, respectfully. However, some exceptions were observed; for example, bilingual children produced Korean /u/ and /o/ with higher F2 (which corresponds to more fronted), which could indicate the influence of English. Another difference observed between 5 and 10-year-old bilinguals was the merger of English /ɔ/ and Korean /ʌ/ by 10-year-olds. Korean /ʌ/ is phonetically close to English /ɔ/, with a slight difference in that the English vowel is more retracted (lower F2). The younger but not the older group of bilinguals produced these two vowels similar to monolinguals of each language. The authors suggested that this difference in the production of the two vowels could have been caused by the influence of English on Korean after a longer exposure to L2. Overall, bilingual children showed production of English vowels similar to English monolinguals, and no significant difference was observed between the vowel formants in bilingual and monolingual children in both languages.

In summary, previous research demonstrates that early experience with speech as well as linguistic input received during the first year of life has a profound long-lasting effect. Bilingual adults exposed to more than one language in the early period of life demonstrate vowel productions that are more native-like (Flege et al., 2003). Additionally, extended daily experience with two languages enables early bilingual speakers to produce sounds that are acoustically similar within the two languages (MacLeod et al., 2009). Nevertheless, the productions of bilingual speakers tend to differ from the productions of monolinguals (Flege et al., 2003; MacLeod et al., 2009). The studies with bilingual children also

demonstrate successful acquisition of language-specific vowels; however, these productions show some degree of interaction between languages and reorganization of phonetic system when the second language is introduced (Gildersleeve-Neumann & Wright, 2010; Gildersleeve-Neumann & Peña, 2009; Kehoe, 2002; Lee & Iverson, 2012).

1.3 The Russian vowel system

The Russian vowel system inventory is relatively small and consists of five vowels: /i/, /a/, /o/, /u/ and /ɛ/ (Table 1) (Halle, 2011; Jones & Ward, 1969). Some phonologists argue that there is an additional sixth mid-high vowel /ɨ/ in Russian (Kodzasov & Krivnova, 2010; Matusevich, 1976), whereas others suggest that /ɨ/ is an allophone of /i/ (Jones & Ward, 1969). Despite the small number of phonemes, a striking feature of the Russian vowel system is a large number of allophones, which are determined by a phonetic context and, in particular, adjoining consonants as well as stress (Jones & Ward, 1969).

Each of the five vowel phonemes can occur either in palatal or non-palatal environments, depending on the preceding consonant (Table 2) (Byun, Hong, & Ahn, 2018; Hickey, 1986).

Table 1. The Russian vowel phonemic system.

	Front	Middle	Back
High	i	ɨ	u
Middle	ɛ		o
Low		a	

Table 2. The variants of Russian vowels after hard and soft vowels and their orthographic letters.

After a hard consonant	a(а)	ɛ(э)	u(у)	o(о)	ɨ(ы)
After a soft consonant	ja(я)	jɛ(е)	ju(ю)	jo(ё)	ji(и)

These environments are determined by the consonants which in Russian are divided into hard and soft ('palatalized') (Jones & Ward, 1969; Matusevich, 1976). Soft or palatalized consonants are pronounced by raising the front of the tongue and almost or completely (in the coronal sounds /t,d,n/) touching the hard palate (Jones & Ward, 1969; Matusevich, 1976). Palatalized consonants are normally followed by a glide that sounds like /j/ and is known as "off-glide", which is fully realized when followed by a stressed vowel, and which is represented phonetically as C^{j} e.g 'мять' /$m^{j}at^{j}$/ *crush* (Byun, Hong & Ahn, 2018; Jones & Ward, 1969). Russian vowels are subject to "vowel reduction", when in an unstressed syllable (Iosad, 2012; Matusevich, 1976). The vowels in Russian diphthongs are falling in term of sonority: a vowel with greater sonority is followed by the semi-vowel /j/ with lesser sonority, for example /aj/ as in 'дай' /daj/ *give* or /oj/ as 'чай' /tʃæj/ *tea* (Jones & Ward, 1969).

The unresolved question among Russian phonologists remains whether there are five or six vowels. Although a consensus on the status of the vowel /ɨ/ has not been achieved, /ɨ/ is phonetically distinct from /i/ in both acoustic and articulatory properties. The vowel /ɨ/ is a high, central, unrounded vowel (Jones & Ward, 1969). Its phonetic

realization is highly dependent on the preceding consonant. For example, /ɨ/ can be produced further forward in the mouth (after dental, alveolar, post-alveolar, and velar consonants) or it can be more retracted and lightly diphthongized (after labial, labio-dental, and /l/) (Jones & Ward, 1969). On the acoustic level, /ɨ/ is characterized by a gradual rise of the initially low F2 value of around 1600-1800 Hz for an adult male and eventually reaches F2 value equivalent to /i/ (Derkach, Gumetskyi, Gura & Chaban, 1983; Matusevich, 1976). The phoneme /i/ has a comparatively high F2 value from the beginning of the vowel (2500 Hz). The gradual increase in F2 is a typical feature of /ɨ/ in terms of the spectral dynamics, and it demonstrates the diphthong-like nature of the vowel; thus /ɨ/ is often perceived as /ɨi/ especially when followed by a soft consonant (Derkach et al., 1983). The initially low F2 value and diphthongization of the vowel were claimed to be the result of the secondary articulation when the back of the tongue is raised and known as velarization. Velarization functions to enhance perceptual distinctiveness between two sounds (Padgett, 2001). According to Padgett (2011), the contrast should not be understood as /i/ vs /ɨ/ but as a palatalized consonant followed by /i/ versus velarized consonant followed by/ i/ (Ci vs Cˠi). Velarization can especially be observed when the preceding consonant is bilabial and F2 is significantly lower at the beginning of the vowel. However, it is worth noting that phoneticians have not come to an agreement on which non-palatalized consonants are velarized in Russian and which not, and whether velarization is an inherent feature of non-palatalized consonants (Bogoroditsky, 1930; Ladefoged & Maddieson, 1996; Matusevich, 1976).

There are two main phonological schools of thought in Russia: the Moscow and Saint Petersburg (or Leningrad) schools, which differ in their view of how the description

of phonemic inventory in any given language should be approached (Byun, Hong, & Ahn, 2018; Kodzasov & Krivnova, 2010; Matusevich, 1976). The Moscow School's main principle is the application of morphological criteria when describing the phonemic inventory of a language (Kodzasov & Krivnova, 2010). The phoneme is understood to be the minimal sound unit within a morpheme, which in turn represents a minimal semantic unit; the phonemes alternate within a morpheme according to phonetic rules (Kodzasov & Krivnova, 2010).

On the other hand, at the core of the Saint Petersburg Phonological School are experimental phonetics and methods of speech analysis. Under this view, the phoneme is considered to be autonomous and independent from a morpheme entity used in the processes of speech perception and production (Kodzasov & Krivnova, 2010; Matusevich, 1976). This approach doesn't attempt to minimize the number of phonemes to describe a sound system, and if a sound occurs in all positions, it will be considered a separate phoneme regardless of its semantic function (Kodzasov & Krivnova, 2010).

Whether /ɨ/ should be considered an allophone of the vowel /i/ (under the view of the Moscow school) or independent from /i/, albeit with limited distribution (the approach of the Saint Petersburg school) has been debated for a long time (Byun, Hong, & Ahn, 2018; Kodzasov & Krivnova, 2010; Matusevich, 1976). The Moscow view was first proposed by a Russian linguist Baudouin de Courtenay (1917), who referred to /ɨ/ as *i- mutabile* ('changing ') and suggested three main arguments to support his point of view: (1) /ɨ/ never occurs word-initially, (2) /ɨ/ never occurs after soft consonants, and (3) /ɨ/ and /i/ vowels alternate in the process of derivation. The Moscow Phonological School later adopted his views, according to which vowels /i/ and /ɨ/ are the variants of one phoneme alternating

depending on the phonetic context (palatal/non-palatal), where /i/ is the main phoneme because it can occur word-initially and independently (e.g. preposition ‘и’ /i/ *and*). (Matusevich, 1976). Thus, according to this approach, in words where the vowel seems to occur in contrastive distribution (e.g. as in ‘мило’ /mila/ *cute* and ‘мыла’ /mɨla/ *washed*), the difference lies not in the vowels but in the hard versus soft consonants, while the vowel remains the same. Crucially, these vowels can therefore only occur in complementary distribution.

The opposing view (the Saint Petersburg School) was first offered by Shcherba (1957), who offered four main arguments for considering /ɨ/ an independent phoneme; (1) although they are infrequent, words beginning with /ɨ/ are possible (e.g. the name of the Russian village ‘Ындин’ *Yindin*, or the verb ‘ыкать’ *ykat* ‘to pronounce the sound /ɨ/’), (2) /ɨ/ is in contrastive distribution with other vowels and serves as a semantically differentiating unit (e.g. ‘bak’ /bak/ *barrel*, ‘bok’ /bok/ *side*, ‘byk’ /bɨk/ *bull),* (3) historically, /ɨ/ was an independent phoneme that later became associated with /i/; however, a complete merger of the two vowels never happened (but did in other languages such as Czech). Finally, (4) native Russian speakers treat /ɨ/ as an independent entity and can pronounce it in isolation as opposed to other allophones that are not pronounced without a preceding consonant.

Overall, both approaches present compelling reasonings. However, the status of the high central phoneme /ɨ/ remains unclear. In general, the Russian vowel system is smaller in comparison to English, although not without certain nuances.

1.4 The current study

The overarching goal of this study is to examine acoustic-phonetic properties of Russian high front and high central vowels /i/ and /ɨ/, in bilingual Russian-English children and to identify whether bilingual children form separate categories for this vowel contrast. The debate in the literature regarding the status of the high central Russian vowel /ɨ/ makes it an especially interesting test case.

The vowel has a limited distribution and rarely occurs word-initially (Byun et al., 2018), except in the few cases discussed above. Russian-speaking children in monolingual environments start producing it accurately later than other vowels, at around three years old (Gvozdev, 1949; Zharkova, 2005). Until this age, children show a tendency to substitute it with /i/ even after mastering the hard and soft consonant contrast (Gvozdev, 1949). An important question is whether bilingual children, who have higher variability in the input and relatively limited exposure to the language, show evidence of /ɨ/ as a separate phoneme to /i/ or whether in contexts where /ɨ/ is expected, the produce a vowel with a quality similar to /i/.

Another question I aim to explore is whether the high front and front central vowels produced by Russian-English children differ from the monolingual norm. Acoustic measures of the first formant (F1) and the second formant (F2) are calculated to address whether the bilingual children produce two, separate vowel categories and whether these values differ from monolingual norms. Finally, I investigate how the children's language experience, primarily the age of exposure and their daily use of Russian, affects the quality of their vowel productions.

In general, vowel development is an important milestone for children. Children reach a high degree of accuracy in the production of vowels earlier than consonants (Irwin

& Wong, 1983; Otomo & Stoel-Gammon, 1992), and vowels are paramount for establishing a phonological system. Moreover, vowels are important units of speech and acoustic measurements of vowels can reveal developmental processes (Vorparian & Kent, 2008).

To answer these questions, I remotely collected speech production data from eleven 8- to 13-year-old Russian-English bilingual children living in New York City. Additionally, I obtained speech production data from two 10-year-old native Russian speakers living in Siberia, Russia, to establish a normative baseline for the vowels, because, to my knowledge, there is no known previous investigation of the production of the high central vowel /ɨ/ by Russian children. Children in this study had to perform two tasks: a Naming task and a Repetition task. The vowels produced in these tasks were extracted and acoustically analyzed, and F1 and F2 were obtained at five time points of the vowel.

A previous study addressing Russian-English children's production focused on preschool children (Gildersleeve-Neumann & Wright, 2010), and there are no studies exploring production in older bilingual children, to date. School children for whom Russian is an earlier language, but English is the dominant societal language, the question of how they produce this Russian vowel contrast is of considerable interest. Specifically, Russian-English bilingual children in the US might potentially undergo a language dominance shift due to longer exposure to American English at school. This situation may lead to phonological reorganization for the L1, Russian.

In this thesis, I hypothesize the following:

1) Children's early exposure to Russian and their language experience should enable them to accurately produce both vowels; however, the quality of the vowel productions will not be the same as that seen for monolinguals. This prediction is derived from the previous acoustic investigation of vowel production by older (10-year-old) bilingual Korean-English children (Lee & Iverson, 2012).

2) If the bilingual children in the study successfully establish the contrast, the F2 values for /ɨ/ should be lower than /i/. Alternatively, if they do not form the contrast, this will be seen as F2 values which are higher, similar to /i/.

3) There is a relationship between amount of input and the distinctness of F2 measures for /i/ versus /ɨ/. This hypothesis is based on research revealing that the amount of input in the L1 modulates how similar the phonetic patterns are to monolingual L1 speakers (Bosch & Ramon-Casas, 2011).

2. METHODS

2.1 Participants

A total of 14 children participated in the study: 12 Russian-English bilingual children (4 female) between the of age 8-13 years (mean age: 10 years) living in New York City area and two native Russian-speaking 10-year-olds (1 female and 1 male) living in Siberia, Russia. Parents of bilingual participants were asked to fill out a Language Background Questionnaire (LBQ) via Qualtrics to provide detailed information about their child's experience with both languages. After analyses answers on the LBQ one participant was excluded from the study: The LBQ revealed that English was the child's third language. Her mother was Russian, and father was Ecuadorian, and the child's home

languages were exclusively Russian and Spanish (English was the child's language outside of the home only).

All participants, except one (P03), were born in the United States. P03 was born in London, was exposed to both English and Russian from birth, and moved to the United States at the age of 5 years. All children attended school 5 days a week where the primary language of instruction was English. Parents of P01 indicated that the child attended English-Spanish bilingual school. Among the 11 participants, eight had two Russian-speaking parents and three had one Russian-speaking parent (mothers). Additionally, eight children attended Russian classes outside the school once or twice a week. According to the parent reports, all children were exposed to Russian from birth. Five children were exposed to both Russian and English from birth, and the rest of the participants acquired English later before the age of five. None of the children had reported speech, language, or hearing issues. Table 3 provides a summary of the participant information. Children were compensated with a $10 Barnes and Noble gift card for participating.

Table 3. Participants' Gender, Age in years, Age of Acquisition (AoA) in years to Russian and English, and number of parents speaking Russian.

Participant #	Gender	Age	AoA of Russian	AoA of English	# of Russian speaking parents
1	female	9	from birth	birth	1
2	male	8	from birth	3 years	2
3	female	12	from birth	birth	1
4	male	9	from birth	3 years	2
5	male	9	from birth	3 years	2
7	female	9	from birth	birth	1
8	male	11	from birth	2 years	2
9	male	10	from birth	at 2.5 years	2
10	female	10	from birth	birth	2
11	male	13	from birth	at 4 years	2
12	male	12	from birth	birth	2

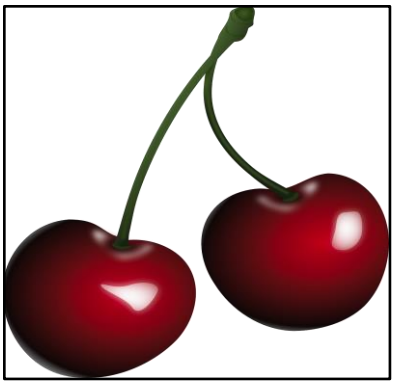
2.2 Stimuli

To elicit the production of the Russian vowel sounds /i/ and /ɨ/, participants were tested in a picture-naming and a repetition task. The words selected for the study were mono-, bi-, and trisyllabic real words from Russian that contained target vowels /i/ and /ɨ/. A total of 40 words were selected for the experiment: 10 words for each vowel were chosen for the picture-naming task and 10 words per vowel for the repetition task. In addition, an equal number of words containing non-target Russian vowels were used as fillers. All target words selected for the study were high-frequency items representing the names of animals, food items, and everyday objects or actions. In terms of grammatical class, the majority of target words were nouns, with a few exceptions: numerals (1), adjectives (4), and verbs (3). The whole list of target words used in the study is illustrated in Table 4.

Table 4. Target words with translations and phonetic transcriptions.

Words with /ɨ/	Russian transcription	English Translation	Words with /i/	Russian transcription	English Translation
dynya	[ˈdɨnʲa]	melon	kit	[kit]	whale
mysh	[mɨʃ]	mouse	odin	[ɐˈdʲin]	one
syr	[sɨr]	cheese	grib	[grip]	mushroom
tykva	['tɨkvə]	pumpkin	ris	[ris]	rice
lyzhi	[lɨʒɨ]	skis	apel'sin	[ɐpʲɪlʲˈsʲin]	orange
mylo	['mɨ lə]	soap	sinij	[ˈsʲinʲɪj]	blue
ryba	['rɨ bə]	fish	ptitsa	[ˈptitsə]	bird
krysa	['krɨsə]	rat	kniga	[ˈkniga]	book
krysha	['krɨʂə]	roof	tigr	[ˈtʲig(ə)r]	tiger
chasy	[t͡ɕɪˈsɨ]	watch/clock	krokodil	[kr ʌ k ə ˈdiɬ]	crocodile
rytsar'	[ˈrɨt͡sərʲ]	knight	vilka	[ˈvʲilkə]	fork
plyt'	[plɨtʲ]	to swim	pit'	[pʲitʲ]	to drink
dym	[dɨm]	smoke (n)	prints	[prʲint͡s]	prince
byk	[bɨk]	bull	liliya	[ˈlʲilʲɪjə]	lilly
myt'	[mɨtʲ]	to wash	kartina	[kɐrˈtinə]	painting
usy	[ʊˈsɨ]	mustache	vishnya	[ˈvʲiʂnʲə]	cherry
malysh	[mɐˈlɨʂ]	baby	klubnika	[klʊbˈnʲikə]	strawberry
prygat'	[ˈprɨgətʲ]	to jump	gorillla	[gɐˈrʲil(ː)ə]	gorilla
dyrka	[ˈdɨrkə]	hole	sil'nyj	[ˈsʲilʲnɨj]	strong
kryshka	[ˈkrɨʂkə]	lid	dlninyj	[ˈdlʲinːɨj]	long

All visual stimuli were colorful pictures or photos taken from open-access databases (Pixabay or Google images), see Figure 1 for two examples.



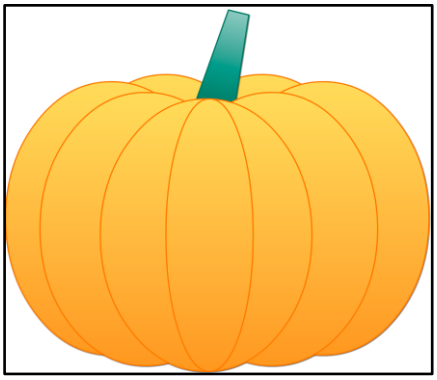


Figure 1. Examples of illustrations of experimental items. Left: illustration representing the word ‘vishnya’ *cherry* that contains target vowel /i/. Right: illustration representing ‘tykva’ *pumpkin* that contains target vowel /ɨ/.

Since vowels in Russian are subject to vowel reduction in unstressed positions, the target vowels occurred only in stressed positions in all words. The target vowel /ɨ/ was embedded into the first stressed syllable of mono- or bi-syllabic words. In the majority of items selected to elicit the production of /i/, the target vowel was embedded in the first syllable but occurred in the third stressed syllable of a trisyllabic word on two occasions (‘kroko'dil’ *crocodile* and ‘apel''sin’ *orange)*. Since /ɨ/ is never used word-initially, items featuring a word-initial /i/ were excluded from the experiment as well.

2.3 Procedure

The experiment was conducted online via Zoom since in-person data collection was not possible due to COVID-19. The experimenter (the author of this thesis) was a native Russian speaker with experience teaching Russian to young children in person and over Zoom. Prior to conducting the experiment, parents of the participants were asked to fill out

the LBQ via Qualtrics, which asked detailed information about children's language experience.

Parents were instructed to have their child participate in the study in a quiet room, with doors and windows closed and no additional mechanical devices (such as air conditioners) running for the duration of the experiment. They were also instructed to use a voice recording application on their iPhone (e.g., VoiceMemos), and place the phone flat on the table next to the child's computer screen. Parents were allowed to be in the same room with the participant but were instructed not to interfere with the experiment.

The experiment consisted of two tasks: the picture-naming and the repetition task. At the beginning of each task, children were given detailed instructions by the experimenter via Zoom, first in English to ensure their understanding of the instructions and then in Russian to encourage the children to shift to a Russian language mode (Grosjean, 2020). Each task began with three practice trials to ensure participants understood the task. During the picture-naming task, children were instructed to name images they saw on the screen in Russian. They were instructed to give just one name for the image. If they did not know the name, they were instructed to say "Ya ne znayu" (*I don't know*) and the experimenter would skip the image and show the next one. In total, the task consisted of 10 words for each target vowel and 20 fillers. Each image was presented twice, so a total of 40 tokens were collected in the first task. The first task lasted approximately 10 minutes.

During the repetition task, children saw an image on the screen and heard the (native Russian speaker) experimenter say a sentence of the format 'Ya mogu skazat [target], [target]' (*I can say [target], [target]*) containing the name of the image repeated

twice, for example: ‘Ya mogu sazat syr, syr’ *I can say cheese, cheese*. The participants were instructed to repeat the entire sentence including the repetition of the target word after the experimenter. The stimuli in the repetition task consisted of the same 10 words per vowel that were used in the first task, plus an additional 10 words per vowel and 40 fillers which provided an opportunity for participants to name the words they did not know in the first task. In total, there were 20 target words per vowel, and since each word was repeated twice, 80 tokens were collected per vowel in this task. The session lasted roughly 20 minutes. The total number of tokens collected for each participant was 120 per vowel, if the participant successfully named all the images during the first task. At the end of the task, parents were instructed to end the recording session, save the audio, and were instructed how to attach the audio file to the Qualtrics questionnaire.

2.4 Acoustic analyses

The audio files were converted into .wav files and analyzed using Praat (Boersma and Weenink, 2019). The onset and offset of the vowel were identified by the presence of stable formant traces in the spectrogram. Once the onset and offset were identified, the boundaries were added to a text tier in Praat (see Figure 2 for an example). The segmented vowel was additionally checked by listening and if an intruding consonant (especially in the case of liquids or fricatives) was identified, the boundaries were adjusted. Some of the measurements were obtained using Praat script and some hand measured. The measures obtained with the help of the script were double-checked and re-measured by hand.

Once the vowel boundaries were identified, vowel duration, F1, F2, and fundamental frequency (F0) values were obtained at 10%, 20%, 50%, 70%, and 80% of the

duration of the vowel. The formant settings were individually adjusted for every participant. In particular, Maximum Formant (Hz) was increased to 6000 - 9000 (Hz) (occasionally up to 10 000 Hz). The Pitch range was set to 500 Hz. The window length used for analysis was 0.005s and the dynamic range was set up at 30(dB). The default temporal resolution was used: 1000 Time steps with 250 Hz Frequency steps.

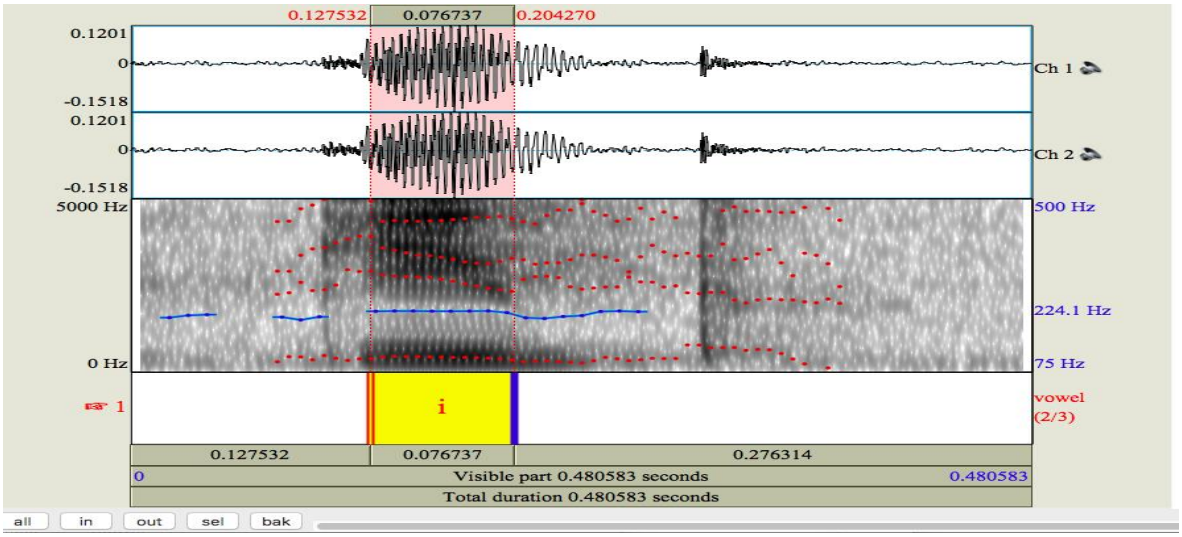


Figure 2. An example of segmentation of Russian /i/.

3. RESULTS

The design of the experiment yielded the production of 120 tokens for two vowels per participant, a total of 1560 words would have been collected for all participants. Not all participants were able to correctly name all the target words in the picture-naming task and, as a result, 1447 tokens were collected successfully. A total of 1357 tokens were included

in the analyses: 90 tokens had to be excluded from the analysis due to excessive noise in the recording, poor quality of the recording, or too much creaky voice. The number of tokens excluded per child varied from 1 to 6 for most of the participants, except P12 (10 tokens had to be excluded due to poor quality), P01 (30 tokens had to be excluded due to too much creaky voice), and P07 (25 tokens had to be excluded due to background noise).

3.1. Russian monolinguals

Figure 3 illustrates the overall distributions of the first two formant values in the productions of the Russian monolingual participants. Based on the figure, both participants produced vowels with F1 at around 300 - 400 Hz with F1 for /i/ being slightly lower than for /ɨ/. For both participants, F2 begins high for /i/ at around 3000 Hz and gradually decreases throughout the duration of the vowel, but still remains relatively high. Although there is more variability in the production of /ɨ/ for both speakers, the F2 median values are lower, especially in the first part of the vowel (below 2000 Hz), after which they gradually increase, reaching their peak at 50% for RU2 (Figure 3b) and at 70% for RU1 (Figure 3a). The F2 values rarely go above 2000 Hz. These Russian monolingual speakers' formants were taken as a baseline to which the productions by bilingual children were compared.

3.2. Russian-English bilinguals

Three patterns were identified for the Russian-English bilingual participants, illustrated in Figures 5, 6, and 7 below. The first pattern shows participants with formant values similar to those of the monolinguals' (Figure 4). The second pattern shows formant

values somewhat close to those of the monolinguals (Figure 5). The third pattern exhibits formant values that are different from those of the monolinguals (Figure 6).

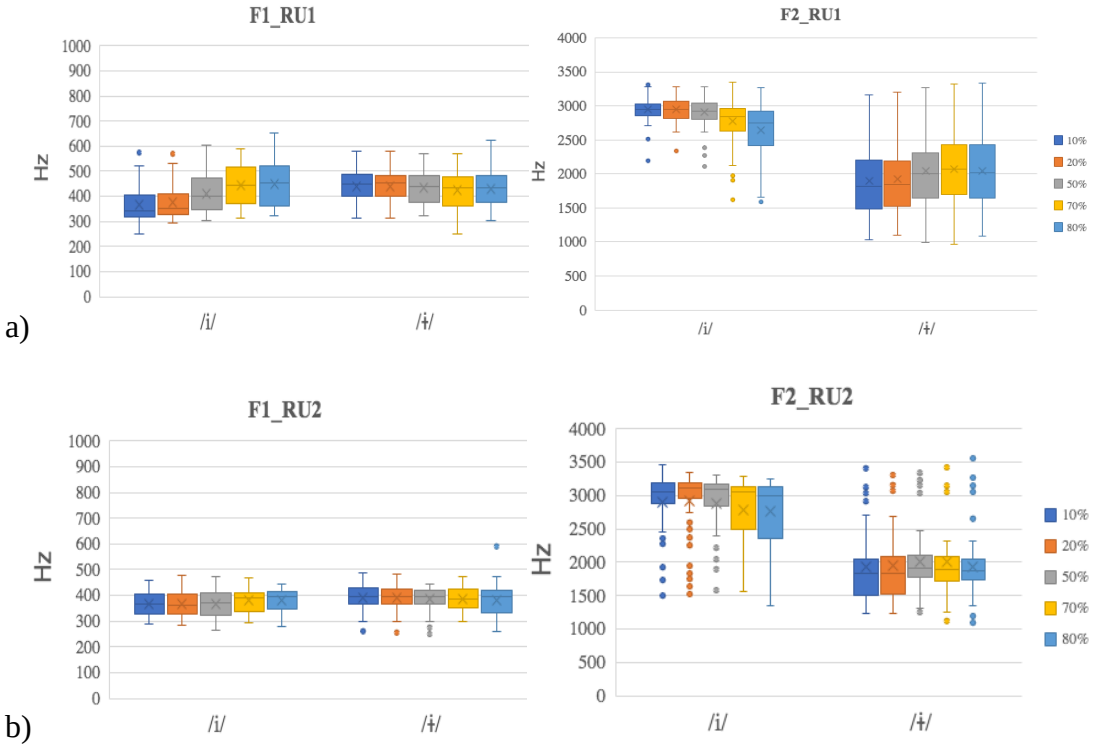
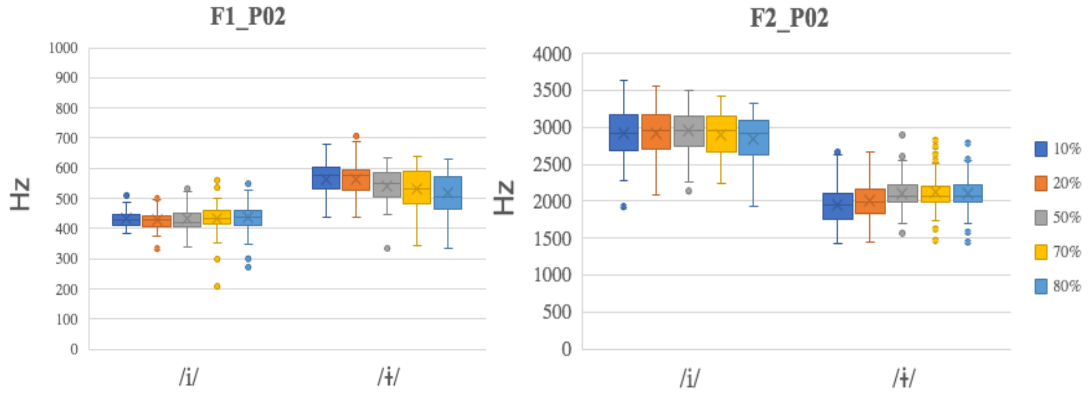


Figure 3. Boxplots for formant frequencies to vowels produced by Russian monolinguals (n=2). Distributions of F1 (left panels) and F2 (right panels) (in Hz) in /i/ and /ɨ/, with whiskers from 1.5 times the interquartile range below and above the first and third quartiles. Distributions are plotted at five-time points in the vowel: 10%, 20%, 50%, 70%, and 80% of the vowel duration. Dots represent outliers.

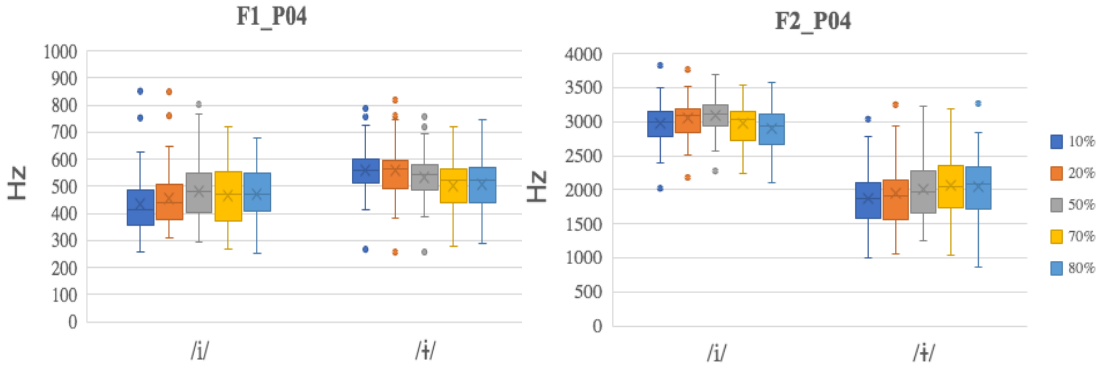
Figure 4 illustrates data from four bilingual participants who demonstrated production patterns that were similar to monolinguals. For all four participants, the F2 for /i/ begins high at around 3000 Hz and decreases throughout the duration of the vowel. F2 for the vowel /ɨ/ was different. It began low at a little below 2000 Hz and increased throughout the duration of the vowel, reaching a peak at around 2000 Hz for all participants except P09 (Figure 4d) at 50-70% of the vowel.

These bilingual participants did show a slight difference in the way these participants produce F1 values: the values were around 400 Hz for /i/ and 500 Hz for /ɨ/ and 600 Hz for P02, which is higher than the F1 observed for monolinguals.

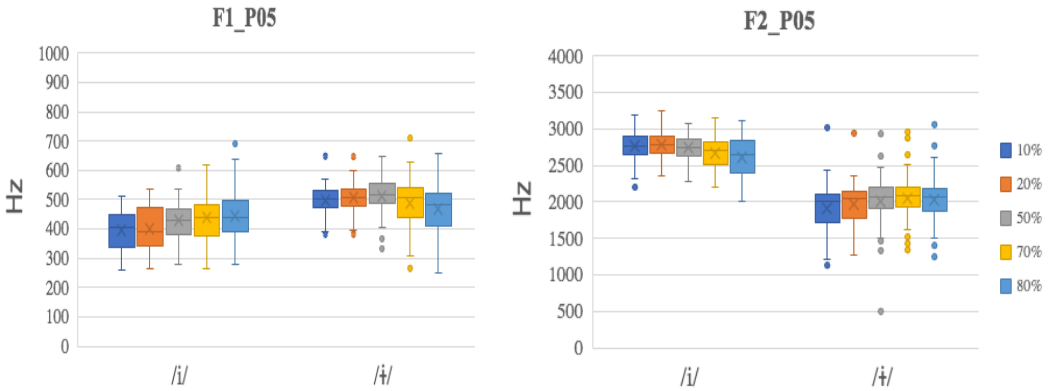
a)

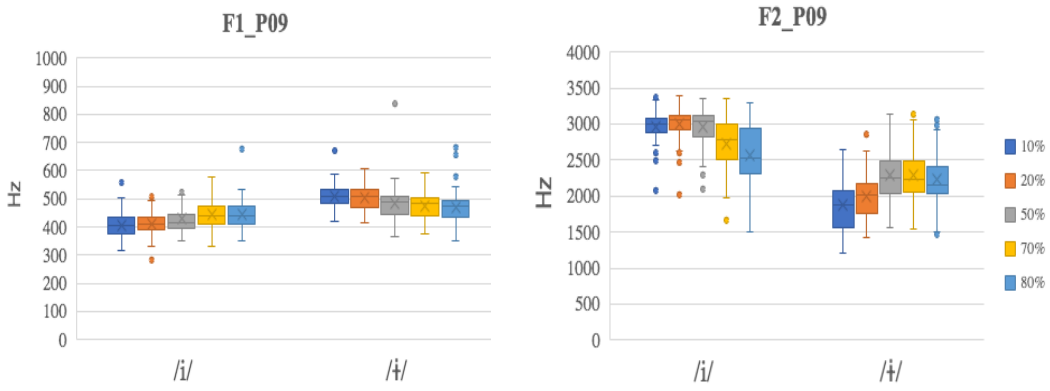


b)



c)



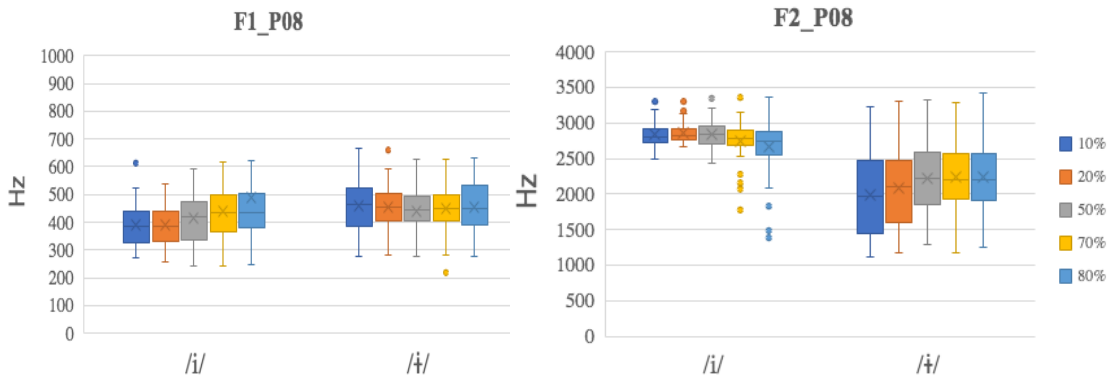


d)

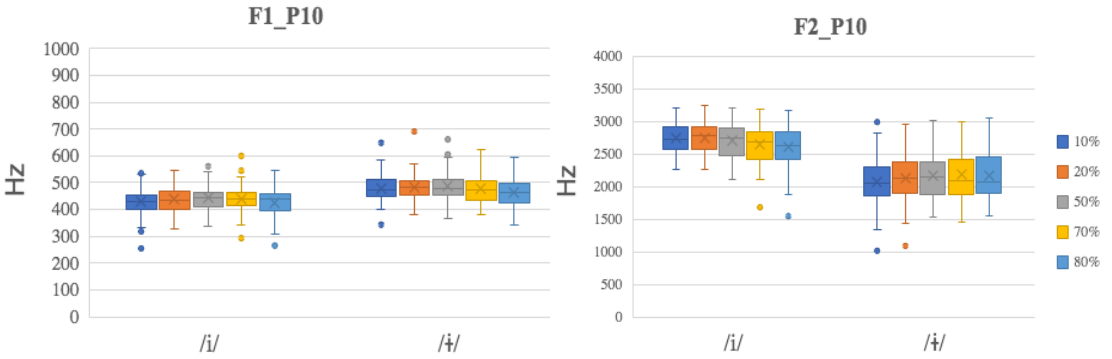
Figure 4. Boxplots for formant frequencies to vowels produced by bilinguals who demonstrate production patterns similar to monolinguals (n=4). Distributions of F1 (left panels) and F2 (right panels) (in Hz) in /i/ and /ɨ/, with whiskers from 1.5 times the interquartile range below and above the first and third quartiles. Distributions are plotted at five-time points in the vowel: 10%, 20%, 50%, 70%, and 80% of the vowel duration. Dots represent outliers.

Figure 5 illustrates data from four bilingual participants who demonstrated production patterns that are approaching the frequencies of monolinguals: these participants are producing a vowel contrast, although not quite in the same way the Russian monolinguals. Although F2 values show that all four participants begin the vowel /i/ high, it begins lower than 3000 Hz for two participants (Figure 5 a,b) or much higher than 3000 Hz (Figure 5d). P11 (Figure 5c) shows values much lower values than for the rest of the participants. This could possibly be due to the fact that he was the oldest participant (13 years old) and his formant values began to approach the adult range. For the high mid vowel /ɨ/, the productions of all four participants show more variability than the other participants or monolingual speakers. F2 begins higher at 2000 Hz for P08, P10, and P12 (Figures 5a, b, and d) and reaches its peak at 50% at a little above 2000 Hz. As far as F1 values, they are lower for /i/ for all participants and begin at around 300-400 Hz, and F1 for /ɨ/ is slightly higher and begins at around 500 Hz, except for P11 (Figure 5c).

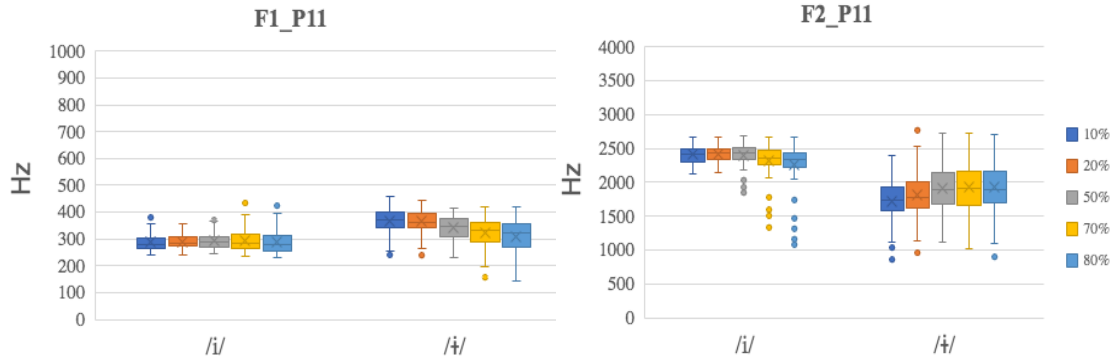
a)

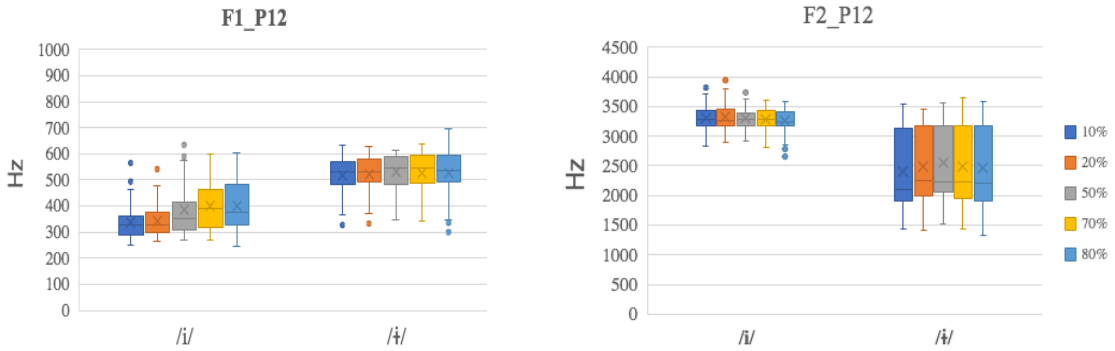

F1_P08
F2_P08
Hz
/i/
/ɨ/
10%
20%
50%
70%
80%

b)


F1_P10
F2_P10
Hz
/i/
/ɨ/
10%
20%
50%
70%
80%

c)


F1_P11
F2_P11
Hz
/i/
/ɨ/
10%
20%
50%
70%
80%



d)

Figure 5. Boxplots for formant frequencies to vowels produced by bilinguals who contrast the vowels, but less distinctly than the Russian monolinguals(n=4). Distributions of F1 (left panels) and F2 (right panels) (in Hz) in /i/ and /ɨ/, with whiskers from 1.5 times the interquartile range below and above the first and third quartiles. Distributions are plotted at five-time points in the vowel: 10%, 20%, 50%, 70%, and 80% of the vowel duration. Dots represent outliers.

Figure 6 illustrates data from three bilingual participants who demonstrate production patterns that are very different from the formant frequencies of Russian monolinguals: these participants are not producing a clear vowel contrast. F2 values for /ɨ/ for these three participants are relatively high at around 2500 Hz, almost as high as for /i/, which indicates a lack of separate categories for the vowel contrast. Moreover, there is no particular difference in the F1 values between the two vowels for these participants. P01 produced both vowels with much higher F1 than the rest of the participants, most likely because she is the youngest participant and her F1/F2 are higher than for the rest of the children due to a smaller vocal cavity.

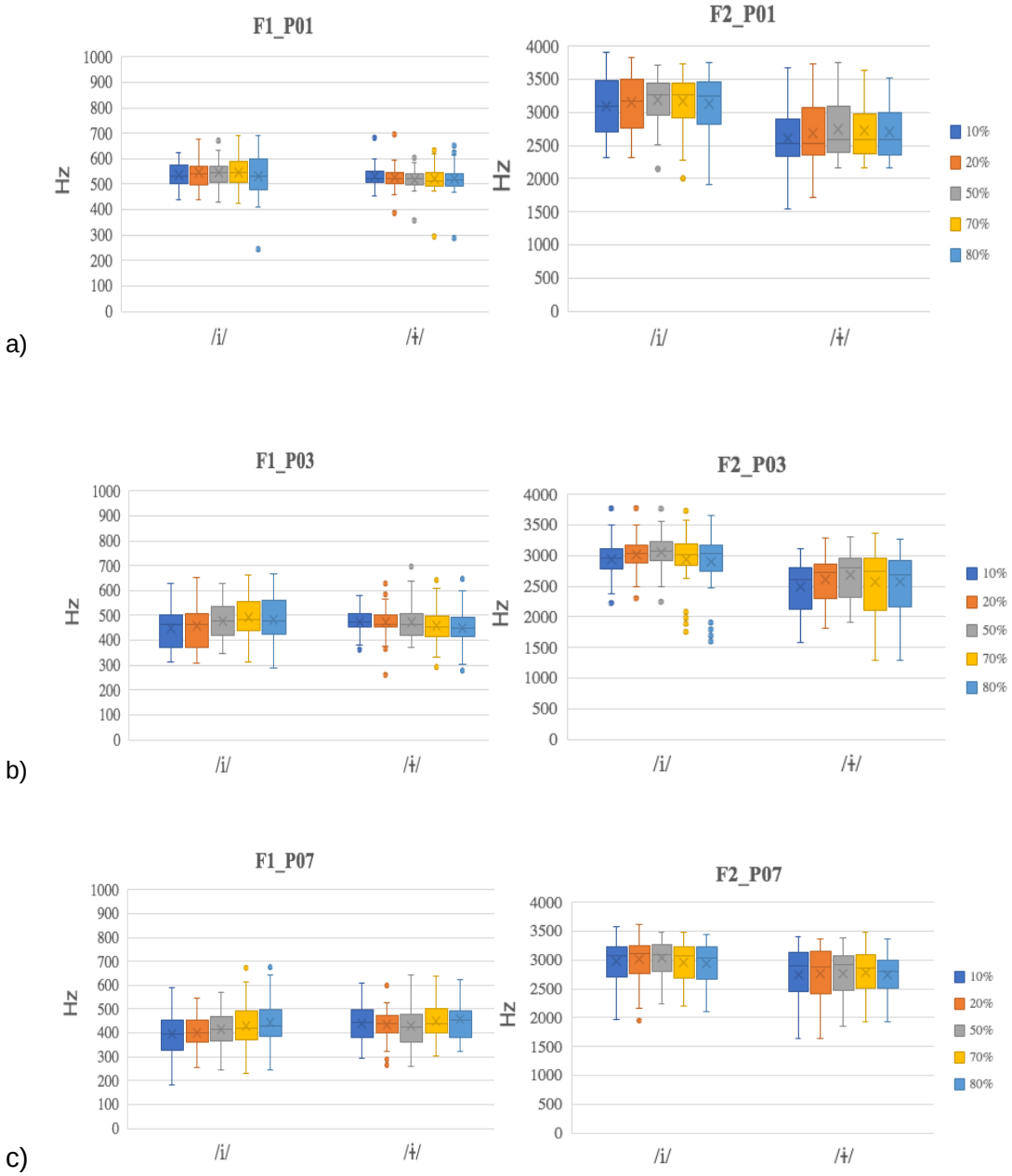


Figure 6. Boxplots for formant frequencies to vowels produced by bilinguals who do not show the contrast (n=3). Distributions of F1 (left panels) and F2 (right panels) (in Hz) in /i/ and /ɨ/ with whiskers from 1.5 times the interquartile range below and above the first and third quartiles. Distributions are plotted at five-time points in the vowel: 10%, 20%, 50%, 70%, and 80% of the vowel duration. Dots represent outliers.

To understand the potential causes of these differences in productions among bilingual participants, the responses on the LBQ were analyzed. Multiple factors were assessed, such as the age of exposure to both languages (AoA), frequency, contexts of use, competence in different skills such as reading and writing, and the amount of language they hear and produce daily. All answers were organized into subgroups (e.g., language history; daily language use) and responses tabulated as follows: for yes/no a numerical value of 1/0 was assigned. For the questions using a 5-point Likert scale, each answer was assigned a minimum value of 0 and a maximum value of 5. Open-ended and multiple-choice questions were assigned a numerical code 0-4 depending on the answer. A percentage of use of each language was calculated from the total score (Figure 7). Based on the visual inspection of Figure 9, two general patterns were identified: (1) participants who have low Russian experience (Participants 1,2,3,7,11,12) and 2) participants with a relatively high Russian experience (Participants 4,5,8,9,10).

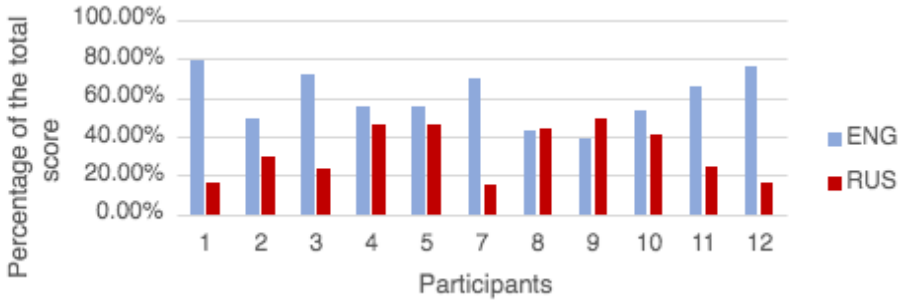


Figure 7. Language experience in English and Russian based on the questionnaire responses. Each bar represents the percentage of total input for each participant in English and Russian.

Next, for further analyses, all formant values were converted from Hertz to an auditory scale in Bark, to reduce the variation within the vowel tokens among different speakers, using the following formula: Zi = 26.81/(1+1960/Fi) - 0.53 (Traunmuller &

Hartmut,1997). Mean F1 and F2 values were obtained for each participant, and mean values and standard deviations in Hz and Bark were computed for both groups of participants (see Table 5).

Figure 8 illustrates individual F1/F2 means in Bark plotted in the vowel space for bilinguals versus monolinguals. This visualization shows that /i/ is more fronted for most of the bilingual participants than for monolinguals. The figure illustrates that /i/ and /ɨ/ are not well-separated for three participants; these are the same participants in Figure 7. However, it is evident that for the majority of the participants the vowels are clearly separated in the vowel space.

Table 5. Mean and standard deviation of F1 and F2 in Hz and bark, for /i/ and /ɨ/ for bilingual and monolingual groups.

		/i/		/ɨ/	
		F1(SD)	F2(SD)	F1(SD)	F2(SD)
Bilinguals	Hz	426.5 (59)	2882 (237)	480 (54)	2774 (315)
	Bark	4.2 (0.59)	15.3 (0.57)	4.6(0.54)	13.5(0.92)
Monolinguals	Hz	391(31)	2848(93.8)	4102 (24.5)	1981(59.5)
	Bark	3.85(0.28)	15.1(0.42)	4.05 (0.25)	12.8 (0.35)

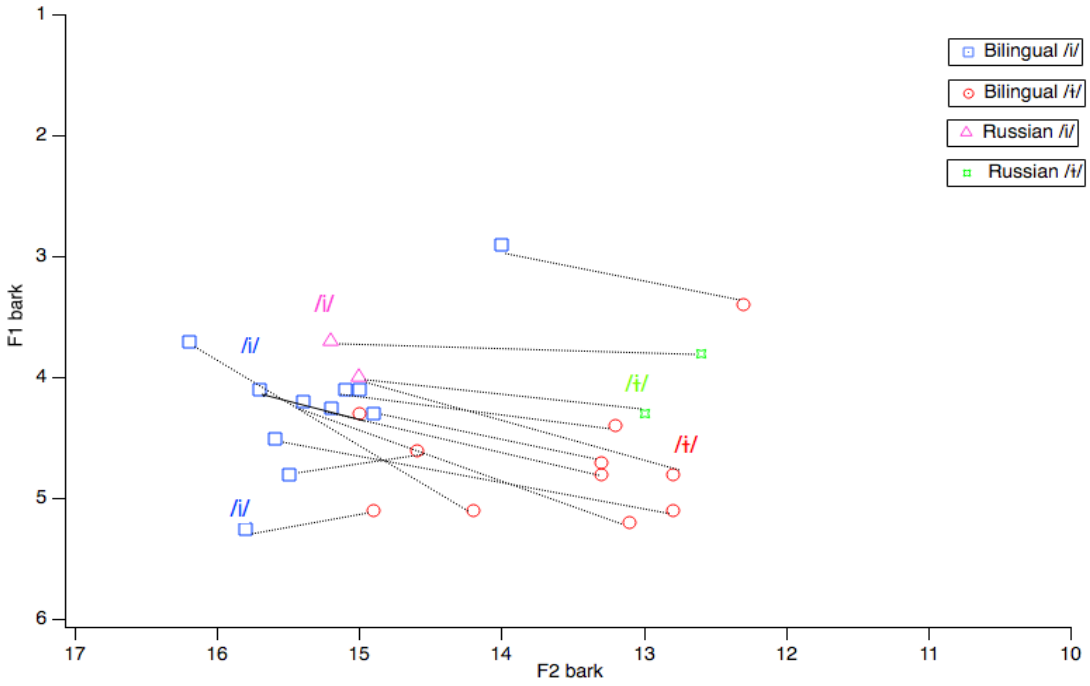


Figure 8. Individual mean F1 and F2 values in Bark for the target vowels /i/ and /ɨ/ produced by bilingual and monolingual children. Individual values for each participant are connected by lines.

The relationship between the different groups and their vowel productions were next investigated in a planned comparisons repeated measures three-way 2 x 2 x 2 ANOVA with group (bilingual, monolingual) as a between-subjects factor and vowel (/i/, /ɨ/) and formant (F1, F2) as within-subjects factors. There was a main effect of formant, $F(1,11) = 1606.5$, $p = <.0001$, but no three-way interaction, $F(1,11) = 0.48$, $p = .4$), nor were there significant interactions between group and vowel, $F(1,11) = 1.19$ $p = 0.2$ or group and formant, $F(1,11) = 0.04$, $p = 0.8$. However, there was a significant interaction between vowel and formant, $F(1,11) = 12.1$, $p = .001$. Specifically, the two vowels showed greater separation for F2.

To directly compare the formant values between the two groups of bilinguals with low and high Russian experiences, a repeated measures 2 x 2 x 2 ANOVA was conducted with Russian Experience (low, high) as between-subjects factor and vowel (/i/, /ɨ/) and formant (F1, F2) as within-subjects factors. A main effect of formant was found, $F(1,9) = 2562.79$, $p = <.0001$, as well as a main effect of vowel, $F(1,9) = 9.77$, $p = .003$ but no significant three-way interaction, $F(1,9) = 0.81$, $p = 0.3$ There was a significant interaction between vowel and formant, $F(1,9) = 30.95$, $p = <.0001$, and a marginally significant interaction between Russian Experience (low, high) and formant, $F(1,9) = 3.3$, $p = .007$, but no significant interaction between vowel and the two groups with low and high Russian experience, $F(1,9) = 0.6$, $p = 0.4$. The interaction between groups that approached significance was related to the low input group showing higher F2.

Next, to further investigate differences in the mean formant values for F1 and F2 in productions of the two bilingual groups with low and high Russian experience, /i/, and /ɨ/, were compared for F1 and then for F2 using unpaired two-sample two-tailed *t*-tests. No significant difference was observed for F1 values in /i/, $t(9) = 0.2$, $p = 0.8$, or /ɨ/, $t(9) = 0.4$, $p = 0.6$ between the two groups. For F2 values, there was a marginally significant difference for /ɨ/, $t(9) = 1.8$, $p = 0.09$ between the group with low ($M = 14$, $SD = 1$) and high Russian experience ($M = 13$, $SD = 0.2$), but no significant difference in the F2 values for /i/, $t(9) = 0.7$, $p = 0.4$.

A single sample two-tailed *t*-test was conducted to compare the F1 and F2 values of the two vowels of the bilingual children using the values of the Russian monolinguals to represent the population mean. The F1 values for /ɨ/ were significantly higher for bilinguals ($M = 4.6$ bark, $SD = 0.5$) than the monolingual norm, $t(10) = 4$, $p = 0.02$. The F2 values for

/ɨ/ were significantly higher for bilingual group as well (M = 13.5 bark, SD = 0.9) than the monolingual norm, $t(10) = 2.8$, $p = 0.01$. For /i/, there was no significant difference for either the F1 values, $t(10) = 1.9$, $p = 0.07$, nor the F2 value , $t(10) = 1.1$, $p = 0.2$ from the Russian monolingual norm.

Next, the values for the two groups of bilinguals with low and high Russian experience were each compared with the monolinguals. F1 values for vowel /i/ were significantly higher for the group with high Russian experience (M = 4.2, SD = 0.16) than the monolingual norm, $t(4) = 5.3$, $p = 0.005$. F1 values for /ɨ/ were also higher for the group with high Russian experience (M = 4.7, SD = 0.2), than the monolingual norm, $t(4) = 6.3$, $p = 0.003$. No significant difference was observed for F1 values between groups with low Russian experience and monolinguals neither for /i/, $t(5) = 0.9$, $p = 0.4$, nor for /ɨ/, $t(5) = 2$, $p = 0.1$. As far a F2 formant, F2 values of /ɨ/ were higher for the group with low Russian experience (M = 14, SD = 1) than the Russian norm, $t(5) = 2.7$, $p = 0.04$, but not difference in F2 values for /i/ between the groups was found, $t(5) = 1$, $p = 0.3$. There was no difference between monolinguals and the group with high Russian experience for F2 values of /i/, $t(4) = 0.4$, $p = 0.6$, and /ɨ/, $t(4) = 2$, $p = 0.07$.

In summary, the results show that the patterns of production of the two high Russian vowels /i/ and /ɨ/ by bilingual children are similar to monolinguals' patterns. However, there is a degree of variability in the production of the high mid vowel /ɨ/ among the bilinguals, which seems to be related to the amount of language experience children receive on the daily basis. Test results confirmed that the bilingual group produces /ɨ/ with higher F1 and F2 values than the Russian monolingual value, but no difference in formant values was observed for the production of /i/. Furthermore, bilinguals with low Russian

experience produce /ɨ/ with higher F2 values than the high input bilingual group and bilinguals with high Russian experience produce both vowels with higher F1 values than monolinguals.

3.3 Comparison to American English vowels

One question that was not investigated in this study is how the values produced by bilingual children are compared to the English vowels such as /i/ or /ɪ/. Future research is needed to compare the production of these vowel contrasts in both languages. Figure 9 illustrates individual means in Hz produced by bilingual and Russian speaking children in the study and the mean values for /i/ and /ɪ/ taken from Hillenbrand et al. (1995). According to the visual inspection of the graph, two participants produced Russian /ɨ/ with values close to English /ɪ/. Moreover, the vowel plot shows that six participants produced Russian /i/ with values closer to English /i/. Thus, it is possible to speculate that the differences in productions could be explained by assimilation to English vowels and the possible influence of English on Russian. These observations provide reasoning to further explore the production of these two contrasts in addition to the Russian contrast with a larger number of participants.

Figure 9. Individual mean F1 and F2 values in Hz for the target vowels /i/ and /ɨ/ produced by bilingual and monolingual speakers that participated in the study (empty symbols) and mean F1 and F2 for English /i/ and /ɪ/ for children (filled symbols) taken from Hillenbrand et al. (1995).

4. DISCUSSION

This study examined the productions of two high Russian vowels, high front /i/ and high mid /ɨ/, by Russian-English bilingual and Russian monolingual children. The main goals of the study were to investigate whether bilingual children form separate categories for these two vowels, how their formant values are compared to the Russian monolingual norm, and the effect of the language experience they receive on a daily basis on their acoustic realization of the two target vowels. In addition, the study provides additional findings that can contribute to the debate regarding the status of the phoneme /ɨ/ in the Russian language.

To my knowledge, this is the first study that investigates the production of the /i/ - /ɨ/ vowel contrast in children. The debate on the phonological status of the vowel has not

been settled, with some researchers considering /ɨ/ to be an independent sixth vowel in the Russian vowel system (Matusevich, 1976; Shcherba, 1957), while others consider it to be an allophone of /i/ (Avanesov, 1956; Kodzasov & Krivnova, 2010). As discussed in the Introduction, /ɨ/ has a limited distribution and only occurs after hard consonants (Byun, Hong, & Ahn, 2018). From the previous literature, we know that it has a particular acoustic pattern that is different from /i/ (Derkach, Gumetskyi, Gura & Chaban, 1983). One of the purposes of the study was to investigate whether Russian-English bilingual and Russian monolingual children demonstrate the same acoustic patterns in their productions of these vowels. To answer the questions posed in this study, word productions containing the target vowels were obtained from 11 bilingual Russian-English children and two Russian monolingual children. The productions of the vowels were acoustically analyzed, and the formant characteristics were compared between the mono- and bi-lingual groups, as well as within the bilingual group.

4.1 Production of /i/ versus /ɨ/

Overall, the results demonstrated that there were no significant differences between the bilingual and monolingual groups in their production of /i/. The F2 values were relatively high for both groups with a relatively low F1, the pattern that is typical for Russian /i/. However, a difference was observed between the bilingual and monolingual groups in their productions of both F1 and F2 formants for the high mid vowel /ɨ/. The values for both formants tended to be higher for bilingual participants compared to the two monolingual controls. Moreover, the examination of individual patterns of production revealed a high degree of variability in the production of this vowel among bilingual

participants. These findings were consistent with my predictions. Differences in the production of /i/ were not expected and were not found in this study. For the vowel /ɨ/, I predicted that if bilingual participants showed a difference, they would produce this vowel with higher F2 values. As a result, there would be a tendency towards producing /ɨ/ closer to /i/. Overall, however, most bilinguals (8/11) had formed separate categories for these two vowels.

4.2 Amount of Russian input

When the responses on the LBQ were analyzed, results showed that bilingual participants could be divided into two categories, with low versus high Russian experience. Low versus high experience was seen as less than 30% Russian for the low group and more than 40% Russian input for the high group. Not surprisingly, the three participants with only one Russian-speaking parent were in the low-input group and it is these three children who did not show a clear distinction between the two vowels (Figure 7). The comparison of formant values between these two groups of bilinguals, and between each of the groups with the monolinguals revealed that the group with low Russian experience tended to produce higher values for F2 for high mid vowel /ɨ/ than the monolingual speakers. No such difference was observed between the group with high Russian experience and monolinguals. In fact, 4 of the 6 children from the low group showed F2 values for /ɨ/ that overlapped with American English /ɪ/ or /i/ (see Figure 10). Additional participants will be needed in order to confirm these results.

These preliminary findings indicate that there is a correlation between the quality of the vowel productions (i.e., matching the Russian monolingual's vowels and maintaining contrastiveness) and the amount of Russian language experience in bilinguals. Note that all

bilingual participants were exposed to Russian since birth, however, the groups differed in the way the language was used on a daily basis. Thus, in order to account for differences between productions of young bilingual speakers, not only age of exposure should be considered as an important factor, but also the quantity of the input and daily use of both languages. The quality of input may also be a factor, but the current study did not examine this.

The findings from the current study are in line with the findings by McLeod et al. (2009), who suggested that the early French-English bilinguals in their study were successful in the establishment of language-specific contrasts in both languages not only due to the early age of exposure but due to the continuous use of both languages on a daily basis. However, in this study children receiving less than 30% input by a native-Russian speaker may fail to acquire or maintain an L1 contrast. A future study is needed that follows children longitudinally from birth to determine whether the pattern is one of failure to acquire the contrast versus failure to maintain an earlier-acquired contrast. In addition, it is possible that the children from the low-input group will achieve this contrast at a later age if input in Russian continues.

4.3 Influence of English

One unexpected finding in this study was the difference between the production of F1 values for /i/ and /ɨ/ by the group with higher Russian experience and by the monolinguals. It is unclear where this difference comes from, especially because no difference was observed between the F2 values of the vowels in the same groups. One

possible source is that some children are producing vowels more like American-English /i/ versus /ɪ/, which have to appear to have a lower F1 than for the Russian vowels /i/ and /ɨ/ (see Figure 10). Future research involving comparison with English vowels and a larger number of participants is needed to investigate this difference in more detail.

4.4 Individual differences

When individual patterns were examined, participants with more Russian language experience showed more similar productions to Russian monolinguals, although the match was not perfect. For instance, P04, P05, and P09 showed patterns that were similar to monolinguals and showed over 40% Russian input on the LBQ. However, P02 had lower Russian experience according to the LBQ but also showed production patterns similar to monolinguals. As mentioned above, the three participants (P01, P03, P07) with only one Russian-speaking parent all showed a different pattern from the monolingual Russian children. Although there is not enough statistical power in this study to make any hard claims, this finding could lay the foundation for future research investigating if having one versus two L1-speaking parents has an effect on the quality, as well as quantity, of sound productions by bilingual children. Ideally, such a study would have an equally matched number of participants in the group of children with two Russian-speaking parents, one Russian-speaking parent, and would include a group of English monolinguals as well as Russian monolingual children.

4.5 Status of /ɨ/ in Russian

The last question we attempted to answer in this study was whether studying the production of the two vowels could provide a contribution towards the debate regarding the status of the phoneme /ɨ/. We observed that participants with lower Russian experience struggled to produce the high mid vowel /ɨ/ in a similar fashion to monolinguals, compared to participants with more Russian experience. If /ɨ/ indeed is an allophone and is linked to a specific phonetic environment (in this case, occurring only after hard consonants), then it is plausible that children who struggled with the vowel might not be employing all phonetic cues and contextual information. Another way to approach the question of the status of the phoneme is to investigate whether children also have mastered the difference between soft and hard consonants. If the comparison shows that they are able to produce the difference between consonants, but fail to produce the difference between the vowels, then it could be indicative of the fact that /ɨ/ is an allophone and not a separate phoneme since only contrastive sounds are stored in representations (Shea & Curtin, 2011). Future research is needed to further examine the use of contextual factors in implementing phonetic cues by bilingual and monolingual speakers. In addition, it will be interesting to examine the production of other Russian allophones to provide a complete picture of the acquisition of the Russian vowel system in bilingual and monolingual speakers.

4.6 Limitations

One of the main limitations of this study was the small number of participants due to the time constraints of the project. We currently have only 11 bilingual participants and

2 Russian monolinguals. The numbers need to be expanded, with a goal of at least 12 low-Russian input and 12 high-Russian input bilinguals and 12 monolingual Russian children, to allow confidence in the pattern of findings described in this report. Another limitation of the current study was that recordings for acoustic analysis were made with an iPhone. This could have affected the quality of the production analyses. However, iPhone recordings proved to be quite reliable. During this time, when participants' visit to the laboratory was not possible due to COVID-19, iPhone recordings proved to be an excellent solution. Even so, some factors were out of the experimenter's control, such as background noise. In future studies, recordings will ideally be made with professional equipment in a soundproof or sound-attenuated booth room in a lab.

5. CONCLUSIONS

This study demonstrates that bilingual Russian-English children can produce the phonetic contrast between /i/ and /ɨ/. It also suggests, however, that less than 30% input in Russian can lead to failure to acquire or maintain this contrast. Although much work remains to be done to understand vowel organization in Russian-English bilingual speakers, the work in the thesis has important implications. First, it provides the first investigation of acoustic properties of the Russian vowel /ɨ/, not only by bilingual children but also by native monolingual Russian speaking children. It also provides the first attempt to approach the debate regarding the status of the phoneme /ɨ/ by studying the productions and the acquisition of this vowel by bilingual children who have received a relatively limited amount of Russian input. Furthermore, it sheds the light on the connection between

the language experience and sound production and lays the ground for future investigations in these directions.

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