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Learning on the Field: L2 Turkish Vowel Production by L1 American English-Speaking NGOs in Turkey

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Abstract: This study adopts the Speech Learning Model to investigate the first language (L1) influence as well as the effects of the length of residence and second language (L2) exposure on American English-speaking learners of Turkish in their productions of Turkish unrounded–rounded vowel pairs, with a particular focus on the vowel categories "new" to American English speakers (/y/, /œ/, and /ɯ/). L1 (English) and L2 (Turkish) speech samples were collected from 18 non-governmental organisation (NGO) workers. L2 experience was defined by whether the worker lived in an urban or regional environment in Turkey. Participants' audio productions of the word list in L1 and L2 were segmented and annotated for succeeding acoustic analyses. The results show an interesting front–back variability in the realisations of the three vowels, including further back variants of the front vowels (/y/, /œ/) and more forward variants of the /ɯ/ vowel, with a substantial degree of interspeaker variability. While the analysis revealed no significant results for the length of residence, language experience was found to have a significant effect on the production of /y/ (F2) and /ɯ/ (F1/F2). This study forms a first step into the research of adult L2 acquisition in Turkish with a focus on L2 in the naturalistic workplace environment, rather than instructed settings. The findings of this study will contribute to the development of teaching materials for NGO workers learning Turkish as their L2.

Keywords: vowel production; learning context; Turkish; naturalistic immersion; language exposure; interspeaker variation

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1. Introduction

Turkish is the language of a culture that is diverse, rich, and ancient. While Turkey is an increasingly popular destination for travel, manufacturing, and higher education, the Turkish language itself and the L2 acquisition thereof is astonishingly understudied. Turkish hospitality is famous, and given the historically unprecedented levels of irregular migration, the country currently finds itself host to just under four million refugees (UNHCR 2021) who must acquire the language to work and survive—as do the NGO workers and other support staff who rally to respond to this and other crises this nation faces today. This makes a study of L2 adult acquisition of the Turkish language timely and important.

To be effective in understanding the needs of the people they seek to empower and in working with them to create long-term sustainable solutions, NGO workers themselves have a great need to be not only conversant but comprehensible in the local language. For this, the acquisition of speech sounds is critical. No amount of sophisticated grammar mastery will compensate if a worker has not attained clear comprehensibility in the pronunciation of the target language. Not only is this important for job effectiveness, but it has strong implications for a worker's morale and ability to thrive in the local culture. For this reason, the current study was initiated into the acquisition of Turkish rounded and unrounded vowels by American English-speaking advanced learners of Turkish who have resided in Turkey for at least three years. Turkish rounded and unrounded vowel pairs have a high frequency and a high functional load within the language (Radisic 2014) and, as such, are salient and important for comprehensibility (Sewell 2021). The aim of the project was to investigate the nature and extent of the influence of L1 on learners' acquisition of Turkish vowels, as well as the influence of the length of residence and L2 experience. These learner factors have been suggested in the previous literature to influence L2 speech learning (Flege 2007; Flege et al. 2006; Flege and Bohn 2021; Leonard 2015; Yang and Fox 2014).

This paper will engage in a brief survey of the relevant literature on the Speech Learning Model (Flege 1995, 2007) as the theoretical framework, followed by a review of the previous major studies on rounded/unrounded vowel acquisition in various languages, the previous research on Turkish, as well as the effects of the length of residence and exposure on L2 vowel learning, and an introduction to the Turkish and American English vowel spaces. After this, the design of the study will be outlined in detail, followed by a presentation of the results, with a particular focus on vowels novel to L1 American English learners. Any observable effect of the length of residence and language experience on participants' vowel acquisition will also be presented. Following this will be a discussion of the findings with respect to how participants' speech behaviour compares with the existing literature and modelling, and preliminary hypotheses will be put forward to account for the results observed given the immigration context the participants live and work in. Finally, the main findings will be summarised and further research suggested.

1.1. L1 and L2 Phonological Acquisition

To date, a large amount of research has been published on the acquisition of L2 sounds by adult speakers, focusing on learners who acquire a new language for the purpose of functioning in an L2 language environment (Best and Tyler 2007). Several theories for L2 speech learning have been proposed to better explain the relative learner difficulties in acquiring certain non-native segments. These include several models, such as (a) the Speech Learning Model (SLM, Flege 1995), adopted in this study; (b) the Perceptual Assimilation Model (PAM, Best 1994, 1995) and its extension for second language learning, PAM-L2 (Best and Tyler 2007); and (c) the Second Language Linguistic Perception model (Escudero and Boersma 2004). More recently, the investigations have been extended to third language acquisition (3LA) (Westergaard et al. 2017; Archibald 2022), putting forward the idea that the learner engages in the structure-by-structure and property-by property comparisons of the L3 with the L1 and L2, where the L1/L2 properties closest to L3 will likely be transferred to L3 grammar (Archibald 2022).

Much of the current work on L2 speech had been carried out by Flege and his colleagues. According to the SLM (Flege 1995) and the revised model, not empirically tested yet (SLM-r, Flege and Bohn 2021), a learner's L1 and L2 phonetic systems coexist in a common phonological space and naturally influence one another (Flege 1995, 2007). This influence occurs at the level of position-sensitive allophones rather than at the level of phonemes (Flege 1995, 2007; Flege and Bohn 2021; Kohler 1981) and is characterised by a bi-directional interaction, an effect of L1 on L2, and vice versa. The former is of particular relevance to the present paper. As learners acquire an L2, they will draw on their L1 phonetic system to inform and scaffold the formation of their L2 phonetic system. As they do so, the SLM (Flege 1995) proposes the occurrence of two key mechanisms through which the phonetic categories comprising the L1 and L2 phonetic subsystems will interact (Flege 1995, 2007). The first mechanism is assimilation, where an L2 sound is so similar phonetically to an equivalent L1 sound that the learner fails to distinguish them and is likely to employ the already established L1 phonetic category, merging the L1 and L2 sounds into a single category. The degree of the phonetic-acoustic similarity between the L1 and L2 sounds strongly influences the degree an L2 sound assimilates to an L1 sound (Flege 1995; also PAM, Best 1994). The second mechanism is the dissimilation of phonetic categories, where a "new" or unique L2 sound is perceived by the learner as dissimilar from existing categories and is therefore distinguished from the L1 categories (Flege 1995, 2007). This "new" sound will be noticed by the learner as a new phonetic category and produced in a native-like manner. It is important to note that with the establishment of new phonetic categories, the existing L1 categories may shift from their usual positions in the acoustic-phonetic space to allow for a greater distinction between the existing and the new phonetic categories in order to maintain a sufficient contrast between the two sound systems. An assumption is that fewer L1 categories would imply a stronger likelihood for L2 phones to be established as new categories (Flege 1995).

A number of studies have examined L2 speech in migrant settings, with several factors identified as key influences on L2 acquisition—most notably the age of acquisition (Guion et al. 2000; Flege 1999), length of residence (Lu 2015), and level and quality of exposure to the host culture (Allen and Dupuy 2013; Flege and Bohn 2021; Moyer 2009). However, while the age of acquisition (AoA) and length of residence (LOR) are both considered to be fairly reliable predictors of pronunciation acquisition in immigrant children (Lee and Iverson 2009; Yang and Fox 2014, 2017), the influence of the AoA and LOR appears to be far more mixed in studies on adult phonological acquisition and has also received more scrutiny in recent research (see discussion in Flege and Bohn 2021). Flege et al. (1992), in their study of adult L1 Mandarin learners of English, did not observe any significant difference in their production of phonetic segments between two groups averaging an LOR of 0.9 years and 5.5 years, or a group of adult L1 Spanish speakers of English averaging an LOR of 0.4 years and 9 years, a pattern repeated in many subsequent studies of adult learners (see also Flege 1998; Lu 2015; Moyer 1999; Piske et al. 2001). Wayland and Flege (2000) showed an extremely modest improvement in vowel perception with an increased LOR when comparing Spanish immigrants of short LORs (0.2 years of residence), medium LORs (1.2 years of residence), and long LORs (3 years of residence). Similarly, Flege et al. (1997) tested a mixed L1 background of non-native English speakers and observed that learners with an average LOR of 7.3 years produced one of the four target English vowels significantly more accurately than learners with an average LOR of 0.7 years. The long LOR group also performed moderately better than the short LOR group in vowel perception.

Several accounts have been put forward as to why adult acquisition presents this more complex picture, and L2 experience may hold some promise in answering at least part of this complex question. Unlike in school-age children, in adults, such experience can vary greatly in both quantity and quality of the phonetic input in L2 from person to person (Flege and Bohn 2021; Levy and Strange 2008). The influence of target language experience on adult L2 development—particularly in the domain of speaking proficiency—has been extensively researched and reported in the study abroad literature. Study abroad studies often compare learners studying in a country where the target language is spoken versus learners studying in a context where the target language is not predominantly spoken. Results have very much affirmed the importance of target language experience in influencing the outcome of adult L2 acquisition in general (Dewey 2007) and speaking proficiency in particular (Leonard 2015). However, there has nonetheless been a great deal of variation in these speaking gains observed (Hernández 2010). While length of stay, motivation, age, and gender are all variables that have been investigated as playing a part in this variation (Baró and Serrano 2011), several studies have focused on the quantity and quality of informal contact with speakers of the target language as a key differentiator in the L2 speaking achievement among study abroad students (Cadd 2012; Leonard 2015; Moyer 2005). We might often assume that study abroad students—when not in class—live in a perfect state of immersion. In reality, authentic interactions with native speakers outside of the classroom can vary significantly from person to person. Allen and Dupuy (2013) observe that in study abroad, "we count on the extracurricular to be curricular" (p. 473)—and yet this contact depends very much on how the individual participant chooses to engage with the local language and culture (Flege and Bohn 2021).

In light of this, there has been nascent interest in investigating more formally the role of L2 contact beyond the classroom. Freed et al. (2004) developed a Language Contact Profile to investigate items such as language usage frequency, academic hours, and social interaction hours as a survey to observe and document the totality of a student's language learning experience. A subsequent study by Lu (2015), investigating the language learning of Chinese ESL student residents in Arizona in the United States, showed that social interaction with native speakers had a far more consequential impact on L2 speech acquisition than the length of residence alone. While such work on L2 acquisition by students studying abroad provides a useful starting point in demonstrating a positive impact of informal language contact on L2 learners' oral skills, it is tempered by short LORs and a fairly restrictive demographic—almost invariably university students. The target languages typically studied are also limited in variety: a large number of studies focus on L2 speakers of English from diverse L1 backgrounds, with much of the remainder focused on other "prestige" L2 European languages which ambitious students from highly educated middle-class backgrounds often aspire to. The research representative of the average adult learner and adult learner conditions—such as that experienced in migrant communities, typically without the benefit of a university classroom—is sorely needed.

1.2. Turkish and American English Vowel Systems

NGO workers as the target learner population in the current study have a particular need to acquire the local language in order to be effective in their work. Given that a good portion of such workers in Turkey come from the United States, participants were mostly recruited from the "Northern Cities" dialect regions, as defined by Hillenbrand (2003). Turkish and English are typologically distinct languages and show several differences in their vowel systems. For the purpose of this study, we will focus on monophthongal vowels. English boasts a relatively large inventory of twelve monophthongs (Figure 1) (Maddieson 1984; Hillenbrand 2003). The vowel /e/ is a monophthong in this variety of English and corresponds to the vowel in words such as "hay" or "face", while the vowel /ɛ/ corresponds to the vowel in "head".

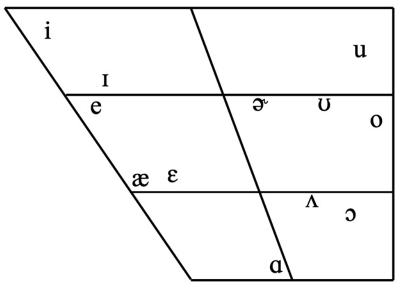


Figure 1. American English vowels in Northern Cities dialect regions according to Hillenbrand (2003).

Turkish includes eight monophthongal vowel phonemes (Figure 2), and the vowels are dichotomously divided into front vs. back, close vs. open, and unrounded vs. rounded, as illustrated in Table 1 (Sabev 2019). The language has a contrastive feature of rounding and involves six out of the eight vowels (/i/–/y/, /e/–/œ/, and /ɯ/–/u/) (Radisic 2014; Sabev 2019), whereby both vowel position and rounding are phonologically contrastive. Turkish and English significantly differ in the rounding feature. Turkish actively employs rounding to distinguish between vowel pairs of the same frontness and height, and it is an important part of vowel harmony. In contrast, the English lip rounding differentiates high and non-high front versus back vowels, but this feature is redundant, whereby the vowel position in the vowel space and its duration play a more important role. This L1–L2 contrast based on the rounding feature may contribute to a challenge for L1 English speakers to acquire Turkish vowels. The vowels /y/, /œ/, and /ɯ/ deserve our special attention as these are "novel" sounds with no near phonetic category in the L1 inventory for American English (AmE) speakers.

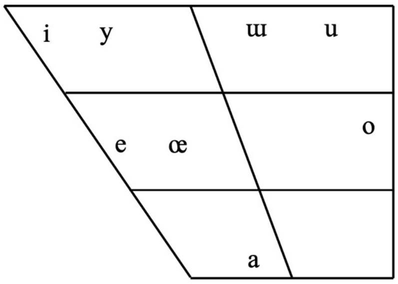


Figure 2. Standard Istanbul Turkish vowels according to Zimmer and Orgun (1992).

Table 1. Turkish vowel contrasts presented according to height, backness, and rounding (adapted from Sabev 2019).

	Front		**Back**	
	Unrounded	**Rounded**	**Unrounded**	**Rounded**
Close (high)	i	y	ɯ	u
Open (non-high)	e[1]	œ	a	o

To add to learners' challenges to acquire Turkish vowels, there has been some controversy in the literature on Turkish over whether the /ɯ/ vowel of the /u/–/ɯ/ pair is indeed a back or a central vowel. Turkish vowel harmony rules consistently treat /ɯ/ as phonologically back (Polgardi 1999). However, some early work on the Turkish language has questioned whether the vowel is back or more central in the vowel space (Ergenç 1989; Selen 1979). Further experimental studies also found somewhat conflicting results in production vs. perception. For example, Kiliç and Öğüt, in their 2004 articulatory, acoustic, and auditory analysis of native Turkish speakers, reported the /ɯ/ vowel to be consistently back in production. However, in their perception test of 220 monosyllabic synthetic stimuli covering 26 different IPA vowels, the same native speaker subjects positively indicated a relatively large range of allophonic candidates for the /ɯ/ vowel—much larger than the range produced by the same subjects. One possible reason for this apparent perception challenge is the vowel's exceptionally short duration. Kiliç et al. (2006) note that /ɯ/ is the shortest vowel in the Turkish language which is at an average of 43 milliseconds. By comparison, the English schwa vowel /ə/ has an average duration of 50 milliseconds (Stevens 1998). Much like the English schwa, Radisic (2008) observed that this short duration has made the Turkish /ɯ/ more prone to the overpowering auditory influence from adjacent consonants. As such, even young native-speaking Turkish children are noted to have some difficulty perceiving this sound (Kiliç et al. 2006).

1.3. Previous Research on Unrounded/Rounded Vowel Pairs

Investigations focusing on languages which include the rounding feature in addition to the features of height and backness are limited, and most of the work has been conducted in perception rather than production. The vast majority have been carried out on the high front vowels in European languages. For example, an early study by Stevens et al. (1969) showed that L1 AmE and L1 Swedish speakers performed overall roughly the same on discrimination tests of the Swedish rounded and unrounded vowel pairs when listening to synthetic vowels produced by a speech synthesiser—with the exception of the /i/–/y/ pair, where AmE participants had difficulty discriminating the /i/–/y/ contrast. Subsequent research has consistently shown the /i/–/y/ contrast presenting L1 AmE participants with greater difficulty (Gottfried 1984; Levy 2009a; Strange 2007; Levy and Strange 2008). An exception to this is Polka's (1995) study of L1 AmE speakers' perception of German vowels, in which the researcher reported a native-like discrimination of the /i/–/y/ vowel contrast. However, her test conditions were criticised as being too easy (no time pressure and low memory load) to yield discernible results (Darcy and Krüger 2012).

Rochet's earlier work (1995) investigated the perception and production of the L2 French high vowels /i/, /y/, and /u/ by L1 speakers of Canadian English and Brazilian Portuguese. The production results, based on an imitation of monosyllables, revealed that both L1 groups reproduced the vowel /y/ about 50% of the time. However, in the instances where they were unsuccessful in producing a high front rounded vowel, Portuguese speakers were highly likely (95%) to repeat French /y/ as [i] or an /i/-like vowel, and rarely as [u] (5%). On the contrary, English speakers frequently (92%) repeated it as [u], with 8% of productions as an /i/-like vowel or somewhere between the phonetic categories [i] and [y]. These patterns were also consistent in the perceptual task, where English speakers heard /y/ as [u] and Portuguese speakers as [i]. Rochet explains these findings in terms of cross-language boundary differences and how the high vowel continuum is divided in different languages, as well as the phonetics of /i/–/u/ variation in English and Portuguese. For English speakers, most tokens of the French /y/ fall within the bound of English /u/ in the acoustic space, while in Portuguese, the French /y/ falls within the bound of the Portuguese /i/.

In her 2009a study, Levy conducted a fine-grained investigation of the various L1 vowels to examine how AmE learners of French perceived the high front vowel pair in Parisian French, depending on language experience (no instruction, formal instruction, and formal-plus-immersion) and consonantal context (bilabial vs. alveolar). She reported that the French vowels were assimilated to the AmE back vowels. No effect of experience was reported for the French /y/ in the alveolar context, but in the bilabial context, an increase in French learning experience resulted in the learners' hearing the target vowel /y/ as /ʲu/, indicative of the poorest discrimination of the contrast /y/–/u/ for the most experienced group. Her findings suggest that "native-language allophonic variation influences context-specific perceptual patterns in second-language learning" (p. 1138).

In comparison to high vowels, the non-high front vowels received less attention in the empirical research, which has also been largely perception-based in scope (i.e., Strange 2007; Levy 2009a, 2009b), also with a lack of experimental work, regarding both perception and production, on Turkish vowels. A study by Levy (2009b) testing the perception of the French vowel pair /ɛ/–/œ/ by L1 AmE speakers, among other vowels, showed results which varied according to their language experience group (defined as "no experience (i.e., naïve listeners), formal instruction, formal-plus-immersion experience"). Errors tended to occur mostly among the no experience and formal instruction only groups. When errors occurred, /œ/ was shown to assimilate to /u/ in bilabial contexts, and /œ/ tended to be perceived as /y/ in coronal contexts. "Formal-plus-immersion experience" group learners were significantly more accurate in distinguishing the vowel categories in French, suggesting the importance of target language immersion experience. Strange's (2007) seminal paper on theoretical and methodological issues in investigating cross-language phonetic similarity focused on the vowels in AmE, French, and German. The results of the perceptual assimilation task, where naïve AmE listeners were presented with French and German rounded vowels, showed that in both citation and sentence materials, AmE listeners overwhelmingly heard the high front vowel token [y] as a back vowel, while the mid front [œ] tokens in the citation context exhibited a greater variability and were perceived as intermediate between the AmE front [ɛ] (55%) and AmE back [ʊ, ɜ] (45%).

There have been even fewer investigations on the high back vowels with a rounding contrast, even though high back unrounded–rounded vowel pairs occur more frequently than front vowel pairs (UPSID, 9.1% vs. 5.8% of the 451 included languages, according to Radisic 2014). In Shport's (2019) study on the perception of Vietnamese rounded–rounded vowel pairs, including /ɯ/–/u/, AmE listeners were presented with the stimuli in Vietnamese and were asked to identify the AmE vowel that they thought was closest to each vowel sound they were played. While the Vietnamese /u/ was perceived as similar to both the English /u/ and /o/, /ɯ/ was left uncategorised by 31% of the listeners. The remaining listeners gave a remarkable spread of answers for /ɯ/, categorised as /ʊ/ by 29%, as /u/ by 20%, and as /ʌ/ by 14% of the listeners. Radisic (2008) made a startlingly similar observation of /ɯ/ in her study of the way Turkish words were incorporated into the Serbian language and suggested that the vowels of the Turkish loan words were all assimilated to the nearest Serbian allophone or nearby adjacent Serbian vowel—with the exception of /ɯ/. Instead, /ɯ/ was assimilated to all five vowels in the Serbian language, again suggesting perceptual difficulty by naïve Serbian listeners in categorising this sound.

1.4. The Present Study

To date, only a handful of instrumental studies have investigated the acquisition of the segmental features in the Turkish language (Albrecht 2017; Darcy and Krüger 2012; Yavaş 2016), either as a study of L1 acquisition or L2 acquisition in young children. The acquisition of L2 Turkish vowels in the adult population remains to our knowledge as yet entirely unexplored. Given Turkey's status as host to the world's largest number of refugees (UNHCR 2021), as well as becoming an increasingly popular destination for tertiary education internationally for second- and third-world countries (Republic of Turkey, Ministry of Higher Education 2021), the acquisition of Turkish as an L2 is a rapidly growing need. The selection of NGO workers as participants is hoped to be somewhat illustrative of the acquisition experience of immigrants learning a language outside of a university classroom environment for a workplace and living setting that is L2-language dependent.

The current study aims to investigate the production of Turkish vowels by adult L1 speakers of American English and focuses on the following vowels: high front rounded /y/, non-high front rounded /œ/, and high back unrounded /ɯ/. To answer the following questions, the scope of the study will be kept deliberately narrow to focus on vowel quality, with vowel duration saved for future investigation. Specifically, the study addresses the following research questions:

1. What are the spectral characteristics of the L2 Turkish vowels /y/, /œ/, and /ɯ/ produced by L1 speakers of American English?
2. What are the effects of target language experience and length of residency (LOR) on the production of the three "novel" Turkish vowels by L1 speakers of American English?

The previous experimental research shows that language experience strongly correlates with a better performance and indicates adults' capability of "continued L2 perceptual learning of vowels in adulthood" (Levy 2009a, p. 1149). Based on the previous work on adult L2 acquisition, we predict that language experience will play a much more important role in the acquisition of L2 vowels as compared to the LOR. The target language experience will be measured by comparing participants resident in cosmopolitan urban settings versus regional/rural settings, which creates a key difference in terms of the immersion experience for the NGOs in Turkey. While all participants in this study have to perform in Turkish language-dependent roles for their work, it is noted that the day-to-day language experience is nonetheless different for residents of major urban centres compared to residents of smaller regional cities or villages. Urban residents were more likely to have access to language schools to learn Turkish during their language learning period and were more likely to encounter English-speaking locals and expats in the course of their day, such as medical professionals, neighbours, and contractors with whom they needed to negotiate for work. When surveyed, urban residents often indicated that English was the common language spoken on their work team. It is recognised that the quality of urban residents' L2 input is thus likely to be susceptible to the individual difference among the participants of this group because the L2 input will likely vary according to the lifestyle and work choices of individual learners (Flege and Bohn 2021). Residents of regional areas, by contrast, were less likely to have had access to language schools for their language learning period and live in areas where English would likely be rarely, if ever, spoken. Living in a regional town or village will typically require social relationships and health-related and commercial negotiations to be performed in the target language.

In the absence of any production studies on L2 Turkish vowels, we will draw on research on the acquisition and perception of L2 French and German (and Vietnamese) unrounded–rounded vowels, which offers the nearest useful corollary for predictive purposes (Flege 1987; Gottfried 1984; Levy 2009a, 2009b; Levy and Strange 2008; Rochet 1995; Shport 2019; Strange 2007). Based on Flege's model (1995, 2007) and the previous findings on the perception of French and German rounded–unrounded vowel contrasts by L1 speakers of English discussed above, we formulate a number of predictions. The high front rounded vowel /y/ will be produced in the speakers' vowel space closer to the high back rounded AmE vowel /u/ by those speakers who have had less experience with the Turkish language (particularly urban residence). Participants with greater language experience (especially those of regional residence) are predicted to be more likely to distinguish the front–back contrast for high rounded vowels and make a better distinction between the vowels /i/–/y/ and /y/–/u/. Similarly, more experienced speakers (with regional residence) will be more likely to produce /œ/ as a phonologically front vowel, while speakers with more limited exposure to L2 (urban residence) are expected to be less consistent in the phonetic realisations of this vowel and are more likely to produce it as a back vowel (possibly mapping it onto the AmE /o/, /ɔ/, and /u/), following the patterns reported in the studies on the perception of French and German vowels by English listeners. Further, some speakers may produce the /œ/ vowel closer to the bounds of the AmE /ɚ/, because of the lower F2 values for the Turkish /œ/ as compared to the Turkish vowel /e/.

Finally, the high back unrounded vowel /ɯ/ will exhibit the most variation in its production. This vowel is phonetically more forward in Turkish (a central vowel), and L1 AmE speakers may produce it with the F1/F2 values closer to the English lax /ɪ/ or possibly closer to the English vowel /ʊ/. The previous research (Shport 2019) clearly shows that L1 English speakers have the most difficulty in categorising this vowel in their L2 by selecting a range of possible L1 phonetic categories and demonstrating a greater inconsistency in their responses to the stimulus. It will be interesting to see how participants in this study map /ɯ/ in their L1–L2 vowel space and which allophones they select in their L1. We predict that the L1 AmE speakers with greater L2 experience will perform relatively better and will also show a more consistent production of this vowel across repetitions.

2. Materials and Methods

2.1. Participants

The 18 participants in this study (male = 8; female = 10) were NGO workers who had been resident in Turkey and were of advanced Turkish-speaking proficiency. All were required to pass an externally administered speaking test equivalent to a B2 level on the Common European Framework of Reference (CEFR) for languages (Council of Europe 2001) in order to qualify for their current work roles. All required advanced speaking proficiency for their day-to-day work.

All participants in this study were either speakers of the "Northern Cities" dialect (n = 13) or the Californian dialect (n = 5) of American English (following Hillenbrand 2003) and had spent their prepubescent and early adult years in these dialect regions prior to their arrival in Turkey. It has been acknowledged in the literature that American English speakers in the "Northern cities" region (Hillenbrand 2003; Hillenbrand et al. 1995) and in California (Ladefoged 1999) show a degree of similarity in their vowel systems, with the exception of category status and phonetic realisation of the open-mid back and the low back vowels (see Hillenbrand 2003). While the Northern Cities dialect is defined largely by the uniformity of the region's vowel production (Labov et al. 2006), some researchers have observed more nuanced variation of given vowels in certain consonantal contexts in certain social groupings within the Northern Cities region (Purnell 2008)—most notably the advanced /æ/-raising before /ɡ/ in Wisconsin, northern Minnesota, and the Upper Peninsula of Michigan (Benson et al. 2011). However, these variations were unlikely to yield a significant impact on the current results given the consonantal contexts used for sampling for this study (i.e., hVD/kVl) and the consonantal contexts generally encountered in Turkish (a language with final-obstruent devoicing, (Kopkalli-Yavuz 1993)). Of note is /æ/-raising before apical consonants, such as /d/ (Labov et al. 2006), also documented in the Northern Cities Shift patterns. This may lead to higher F1 values for the /æ/ vowel produced by the speakers in this study but is unlikely to have a bearing on the analyses and the interpretation of the results. Similarly, past research has uncovered minor vocalic variation between regions indistinguishable to native Californians (D'Onofrio et al. 2016; Villareal 2018), and as participants were relatively homogenous (all university graduates, from similar ethnic and socioeconomic backgrounds) they were unlikely to exhibit significant sociolinguistic diversity (Villareal 2018).

The current participants had no exposure to the Turkish language prior to their residence in Turkey and arrived in Turkey aged typically in their late 20s (mean = 27.5). Length of residence ranged from 3 to 18 years, with a mean of 9.7 years. Notably, participants were evenly divided between those who resided in major urban centres (n = 9), where English speakers are typically more common, versus those residing in smaller regional cities or towns/villages (n = 9), where English speakers are typically rare. Thus, urban vs. regional residence provides a useful distinction in terms of participant's target language exposure. Two participants had residence patterns which slightly deviated from the rest of the group and deserve some qualification: Participant F32 was born in Texas but moved to California a few months later where she remained for the rest of her childhood and early adult years. She displayed a typical Californian dialect and was considered appropriate to include in this study. Participant F34 happened to be resident in Istanbul at the time of the study but, given that she had spent the majority of her residence in Turkey in regional centres and villages up until that point, it seemed more appropriate to categorise her exposure level as characteristic of a regional resident. The participants in the urban and regional groups have comparable mean length of residence: urban (LOR mean = 10.1, SD = 6.0) and regional (LOR mean = 9, SD = 5.5).

2.2. Measurements

The study adopted four production measurements to collect a corpus of data for a larger project, including a Turkish word list reading task, an English word list reading task, a picture description task in Turkish, and a read-aloud passage in Turkish. The dataset analysed and reported in the current paper are based on the Turkish and English word list reading tasks. In Turkish word list reading, participants read aloud eight Turkish words from a word list (Table 2), each for five times, following the common practice in the acoustic-phonetic investigations of vowels. The phonotactic constraints of the Turkish language limit the possibilities of selecting monosyllabic words in a CVC context, where a plosive stop is in the onset and coda positions. Words with two syllables were disregarded due to vowel harmony patterns in Turkish; and nonce words were not considered a valid option, given that the participants' second language pronunciation was being tested in contrast to their first. Further, commonly encountered words were selected so that comprehension could not be considered a factor inhibiting pronunciation. For these reasons, we adopted Zimmer and Orgun's (1992) selection of words illustrating Turkish vowels phonemes. Monosyllabic Turkish words were chosen following the pattern velar plosive–vowel–lateral and delivered in random order in a list. Vowel measurements were extracted at the midpoint of each target vowel. Turkish makes a phonemic distinction between /l/ and /ɫ/ (Zimmer and Orgun 1992), where the non-velarised alveolar lateral approximant /l/ is marked by a higher F2 than the velarised lateral (Börtlü 2020). Four out of eight tokens included a velarised lateral approximant (see Table 1). We acknowledge that a lateral following the target vowel is a limitation of this study. Future work will address the segmental composition of the target words and will extend the examination of the production of L2 Turkish vowels by L1 English speakers to the acquisition of vowel harmony in a range of syllabic contexts and in words with more than one syllable. Several participants missed the tokens with the target vowel /o/, and thus this token was not included in the analysis. We acknowledge that this may pose a limitation to the interpretation of the results but maintain that this is the first investigation of this kind which contributes to research on the acquisition of Turkish as L2.

Table 2. Turkish word list with the corresponding target vowels (after Zimmer and Orgun 1992).

Word (Orthography)	Word (IPA)	Vowel (IPA)
kil	/kil/	/i/
kül	/kyl/	/y/
kel	/kel/	/e/
göl	/ɡœl/	/œ/
kal	/kał/	/a/
kıl	/kɯł/	/ɯ/
kul	/kuł/	/u/
kol	/koł/	/o/

In English word list reading, participants were given a standard list of words (Table 3), following the pattern /hVd/, designed to elicit the common monophthongs in American English (Hillenbrand et al. 1995). This list of words which aimed at eliciting the target English vowels has been widely adopted in many previous investigations on the acoustics of vowels across English dialects, including American English (Hillenbrand et al. 1995; Vonwiller et al. 1995; Cox 2006). Participants were shown a list of words in random order, including six distractor words, on a computer screen. In both languages, participants were asked to read each word five times, starting with the Turkish word list.

Table 3. English word list with the corresponding target vowels (after Hillenbrand 2003).

Word	Vowel (IPA)
heed	/i/
hid	/ɪ/
head	/ɛ/
had	/æ/
hod	/ɔ/
hawed	/o/
hood	/ʊ/
who'd	/u/
hud	/ʌ/
heard	/ɚ/

2.3. Procedure

Data collection was conducted individually with each participant via Zoom due to the COVID-19 pandemic in progress. Participants first completed the ethics procedure and an online language history questionnaire. The elicitation tasks were administered by the first author and a trained research assistant. The task administrator shared with the participant the materials of the elicitation tasks via Zoom screenshare. Participants were instructed to record the data collection session using their own smartphones, then to send the recording to the administrator upon completion.

2.4. Data Analysis

The present data analysis consisted of three steps. The first step was segmentations and annotations. The collected audio recordings were prepared for manipulation on a Microsoft Surface Pro 7. All recordings were automatically segmented using the online platform WebMAUS (Kisler et al. 2017) and were labelled using the "machine readable alphabet" (MRPA), followed by manual correction in Praat for any inconsistencies in the identification of word boundaries and/or pauses (Praat 6.1.16) (Boersma and Weenink 2015). Each token was saved as a separate audio file with the corresponding Praat textgrid. The textgrids included the "Word" tier and the "Vowel" tier. The target vowels were identified on the "Vowel" tier, following standard annotation criteria for acoustic-phonetic segmentation (Peterson and Lehiste 1960). Vowel boundaries generated by WebMAUS were carefully examined and corrected where required. Vowels in each word were determined by clear formant structure in the spectrogram, identified as the onset and offset of regular formant activity associated with the vocal energy.

The second step was acoustic analysis. All measurements were automatically extracted using a Praat script. Mean F1 and F2 frequencies of the target vowels were extracted at midpoint, treated as the "steady-state" point with the least movement of F1 and F2 in the vowel (after Hillenbrand et al. 1995). This approach was employed in order to obtain the highest degree of reliability in the measurement of monophthongal vowels and to allow comparison with previous research. Durational values in milliseconds were also obtained for each vowel target, and while they were not used for the present study, they were preserved for future analyses. The F1 and F2 values for each speaker were inspected and corrected by hand for any errors in formant tracking. Manual corrections of formant data were kept minimal, used only when anomalies with automatic extraction were evident. The data for each speaker was imported into the R statistical package (R Core Team 2013).

The acoustic analysis included a visual inspection of the data by plotting the F1 and F2 formants for both Turkish and English productions for each speaker, using the R Studio package (R Core Team 2013). These plots included a vowel centroid and an ellipse for each target vowel, where the ellipses represented 95% data points for each vowel category. After the examination of patterns in the production of Turkish vowels across the speakers, the F1/F2 values for individual speakers were combined into a single data frame in R for further statistical analyses. Lobanov normalisation (Lobanov 1971) was performed with the help of the phonR package (McCloy 2014) to equalise and align the speakers' vowel spaces and was based on all target vowels for each speaker, including the low vowels. All figures presented in the paper were generated in R Studio with the help of ggplot2 package (Wickham 2016). Inferential statistics analysis was conducted using R, working with the normalised F1 and F2 values. Finally, the Pillai–Bartlett trace statistics (henceforth referred to as the Pillai score) were performed on a number of L2 Turkish vowel pairs and L1 English—L2 Turkish vowel pairs, which exhibited visual overlap in the F1/F2 vowel plane. The Pillai score relies on multivariate analysis of variance (MANOVA) and has been proposed as an alternative and more powerful statistical tool to measuring acoustic distance, such as Euclidean distances (Hall-Lew 2010). More recently, it has been adopted in research on L2 pronunciation (Mairano et al. 2019). This approach allows to examine more than two dependent variables and considers the degree of overlap of the entire distribution (Hall-Lew 2010; Hay et al. 2006; Nycz and Hall-Lew 2013). The Pillai score values range from "0" to "1", with values closer to "1" indicating greater distance (in F1 and/or F2) and a complete separation of the two vowel classes and values closer to "0" indicating more overlap and less distinction. For the present study, the Pillai scores were calculated for each speaker by performing a series of MANOVA tests on vowel pairs that exhibited visual overlap, with each target vowel as an independent variable and F1 and F2 values as dependent variables (see Section 3.3).

3. Results

3.1. Overview of L2 Turkish Vowels

Figure 3 shows the means of the midpoint F1 and F2 values for vowels /i y e œɯu/, combined across all the speakers in the study. The formant frequency values for the L2 Turkish vowels are presented in Hertz (blue colour) to allow, as a point of reference, a direct comparison of the production of these vowels by a female L1 speaker of Standard Istanbul Turkish, recorded by the first author in 2021 (orange colour). The means and standard deviations for the target vowels can be viewed in Table 4 (the results by residence type will be discussed in Section 3.2). As a cohort, the speakers appeared to have produced several Turkish vowels in relative proximity to the vowels of the native speaker in the F1 $\times$ F2 vowel space, suggesting that the L2 speakers make distinctions for some of the unrounded–rounded vowels pairs. The high front vowels /i/ and /y/ show differences in the F2 parameter, and the mean values for the non-high vowels /e/ and /œ/ differ both in F1 and F2 and are higher in the F1 $\times$ F2 vowel space (lower F1 values) for the

AmE speakers in comparison to the native Turkish speaker. The phonologically back high vowels /ɯ/ and /u/ present an interesting pattern. While /u/ is realised with low F2 values by the speakers in the study, consistent with the values for a back vowel, and is likely mapped onto the phonetically close /u/ in AmE, the vowel /ɯ/ produced by the L2 speakers is higher and more back than that of the L1 Turkish speaker. Another more general characteristic of the L2 vowel production is a tighter clustering of the vowels in relation to the centre of the F1 × F2 vowel space and a less peripheral position for /i/, /e/, and /u/ as compared to L1 Turkish.

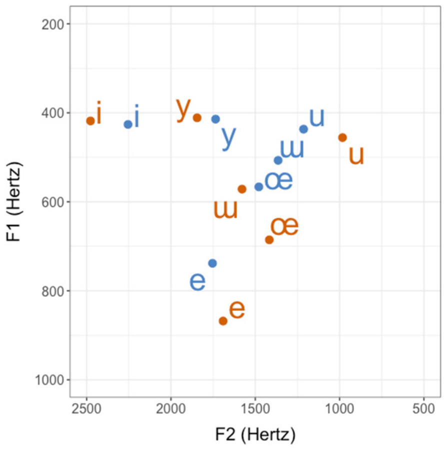


Figure 3. Mean F1 and F2 values for the vowels /i y e œɯu/ produced by L1 AmE speakers (in blue), superimposed over the mean F1 and F2 values for the vowels produced by a native female speaker of Standard Istanbul Turkish (in orange).

Table 4. Descriptive statistics of F1 and F2 values (in Hertz) of target vowels for all participants and by residence group.

Vowel	All Participants		Regional Residence		Urban Residence	
	F1 Mean (SD)	F2 Mean (SD)	F1 Mean (SD)	F2 Mean (SD)	F1 Mean (SD)	F2 Mean (SD)
/e/	738.21 (15.10)	1753.66 (25.51)	745.15 (23.42)	1720.46 (34.17)	730.79 (18.91)	1789.23 (37.75)
/i/	426.16 (13.93)	2254.78 (33.54)	425.18 (18.53)	2322.20 (39.65)	427.18 (21.14)	2184.15 (53.02)
/œ/	566.50 (12.34)	1478.90 (37.20)	570.10 (16.39)	1582.47 (39.90)	562.65 (18.75)	1367.93 (60.03)
/u/	436.77 (12.92)	1213.63 (38.94)	418.33 (17.10)	1231.21 (60.82)	456.53 (19.25)	1194.80 (48.15)
/ɯ/	506.91 (10.95)	1364.44 (34.65)	540.40 (14.91)	1241.14 (28.30)	473.41 (14.54)	1487.73 (58.00)
/y/	414.24 (11.17)	1738.52 (45.79)	394.58 (12.75)	1877.40 (42.68)	434.84 (18.18)	1586.88 (76.46)

Despite the general trends based on the F1 and F2 mean values, a close examination of the data revealed a more complex picture with a large degree of inter- and intraspeaker variation, especially for the second formant. Figure 4 shows the Lobanov-normalised mean F1 and F2 values for the L2 Turkish vowels combined across all speakers. Each ellipse encircles approximately 95% of the samples in each vowel category. The size of the ellipses for the vowels /i/ and /e/ is smaller than the ellipses for the other target vowels, indicating a greater consistency in the production of these vowels in contrast to /y/, /œ/, /ɯ/, and /u/. The productions of /y/ and /ɯ/ exhibit the most amount of variability and a substantial overlap with the other vowel categories in the vowel space, as shown in Figure 4. Some of the speakers produced the target vowel /y/ as a front vowel, while others produced a more central or a back realisation—potentially mapping it onto the English /u/ or /ʊ/. Overall, the speakers who showed the most amount of variation in their L2 vowels frequently "collapsed" their productions of the Turkish high rounded vowels /u/ and /y/ and produced them in the same acoustic space. The Turkish target vowel /ɯ/ has the largest ellipse size, which overlaps with the ellipses for several other vowels. This category seems to be the most challenging for the L1 AmE speakers, with productions ranging from a more front vowel, potentially mapped onto the English tense vowel /i/ or a lax vowel /ɪ/, and a mid-central, mid back or a high back vowel. The vowel /œ/ is realised as a more central vowel and as a back vowel, phonetically more similar to the back mid rounded vowels [o] and [ɔ]. In addition, a small number of speakers produce the target vowel /œ/ as a close back rounded vowel [u]. In addition, the ellipse for the Turkish target vowel /u/ overlaps with the ellipses for the production of /y/, /œ/, and /ɯ/ (Figure 4).

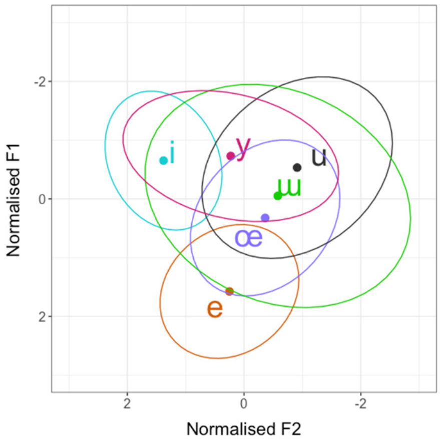


Figure 4. Normalised mean F1 and F2 values for L2 Turkish vowels for all speakers combined. Each ellipse includes approximately 95% of the samples in each vowel category.

3.2. Target Language Experience, LOR, and Vowel Production

To address the second research question, we performed inferential statistics to analyse the effects of the length of residence (LOR) and target language experience on the production of the target Turkish vowels. The variation in the target language experience was operationalised as the distinction between regional residence in Turkey (deeper immersion) and urban residence in Turkey (mixed immersion). The descriptive statistics of the mean F1 and F2 values of the target vowel realisations in the regional and urban residence groups are reported in Table 3. First, a regression analysis indicated that the LOR did not yield significant effects on any vowel production ($p > 0.05$). In contrast, the type of residence produced interesting significant findings which are reported as follows.

First, regarding the normalised F1 values, an ANOVA yielded a significant main effect on vowel ($F = 225.30$, $p < 0.0001$) and a significant interaction between vowel and residence type ($F = 8.76$, $p < 0.0001$). The main effect of the residence type was not statistically significant ($F = 0.11$, $p = 0.74$). The post hoc Tukey-adjusted pairwise comparisons revealed that the following vowel contrasts were all significant: /e/–/œ/ ($p < 0.0001$), /u/–/ɯ/ ($p < 0.0001$), and /y/–/ɯ/ ($p < 0.0001$). The vowel contrasts of /y/–/i/ ($p = 0.94$) and /y/–/u/ ($p = 0.17$) were not significant. Furthermore, the pairwise comparisons of the vowel and residence type interaction suggested a significant difference between regional-residence and urban-residence participants in the production of the /ɯ/ vowel ($p = 0.0000067$) but not the /œ/ ($p = 0.99$) and /y/ ($p = 0.25$) vowels.

Second, regarding the normalised F2 values, an ANOVA also suggested a significant main effect on vowel ($F = 154.826$, $p < 0.0001$) and a significant vowel and residence type interaction ($F = 13.31$, $p < 0.0001$). The main effect of residence type was again not significant ($F = 0.037$, $p = 0.847$). The post hoc Tukey-adjusted pairwise comparisons showed that all vowel contrasts were significant: /e/–/œ/ ($p < 0.0001$), /u/–/ɯ/ ($p = 0.0004$), /y/–/ɯ/ ($p < 0.0001$), /y/–/i/ ($p < 0.0001$), and /y/–/u/ ($p < 0.0001$). The pairwise comparisons of the vowel and residence type interactions revealed a significant regional vs. urban difference in the realisations of the target vowels /ɯ/ ($p = 0.0000037$) and /y/ ($p = 0.00045$), but not in the /œ/ vowel ($p = 0.140$).

Plotting the vowel F1 and F2 values further demonstrates the differences between the groups (Figure 5a,b). In comparison to the regional group, the urban residence group tended to produce the target vowels /y, u, œ, ɯ/ in largely the same regions of the vowel space, with the centroids of the ellipses for the vowels /u, œ, ɯ/ clustered closely together. It needs to be noted that even for the regional group, the ellipses for several vowels are quite large and overlap, indicative of interspeaker variation, which is discussed in detail in Section 3.3.

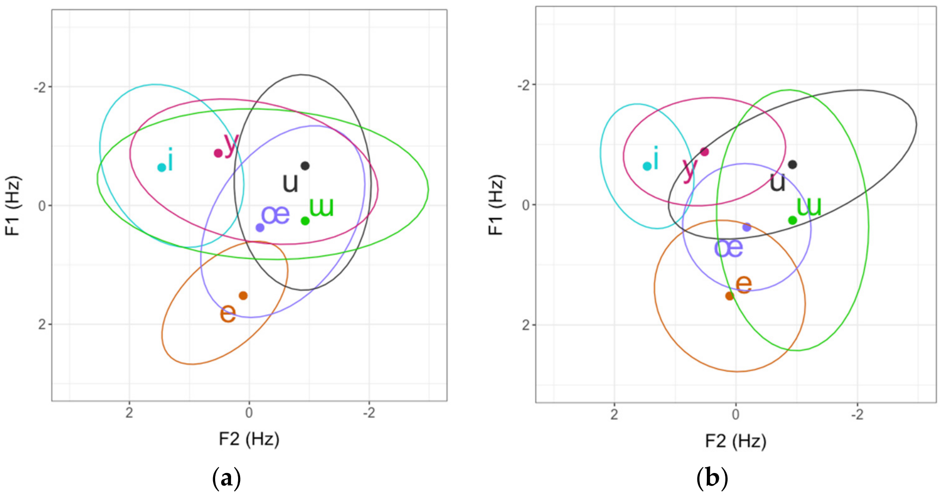


Figure 5. (**a**) Mean F1 and F2 values for L2 Turkish vowels produced by the speakers in the urban group. Each ellipse includes approximately 95% of the samples in each vowel category. (**b**) Mean F1 and F2 values for L2 Turkish vowels produced by the speakers in the regional group. Each ellipse includes approximately 95% of the samples in each vowel category.

To further illustrate the production patterns of the "novel" vowels /y/, /œ/, and /ɯ/ by residence type, each vowel was plotted in the F1/F2 space and presented by group (regional in blue; urban in orange (see Figure 6a–c, respectively). The residence type demonstrates the difference in the production of the Turkish high front vowel /y/ (Figure 6a). The regional group shows a tightly clustered distribution and higher F2 values compared to the urban group. Except for one speaker, the regional group appears to be more consistent at producing a front vowel phonetically closer to the Turkish /y/. By contrast, the tokens representing the urban group are distributed over a wider area, including further back and central realisations in the vowel space. This suggests that the urban group displays less consistency across repetitions in producing this vowel.

As discussed above, experience had no significant effect on the production of the novel vowel /œ/, and there is a substantial overlap for this vowel for both groups (Figure 6b). Some of the speakers in the urban group show a more backed production (lower F2). The regional group, however, has an overall tighter clustered production in both parameters, height and backness, as indicated by the F1 and F2 values, with several speakers producing a more [œ]-like target. Possibly the most interesting result for language experience is shown for the /ɯ/ vowel (Figure 6c). The urban group has a wide-ranging production for /ɯ/, especially for the F2 values. Most of the speakers in this group could be mapping the Turkish /ɯ/ onto several existing L1 sounds, including both front and back vowels. The regional group's production of /ɯ/ appears to be more consistent in terms of backness but shows more variability in the F1 values (vowel height).

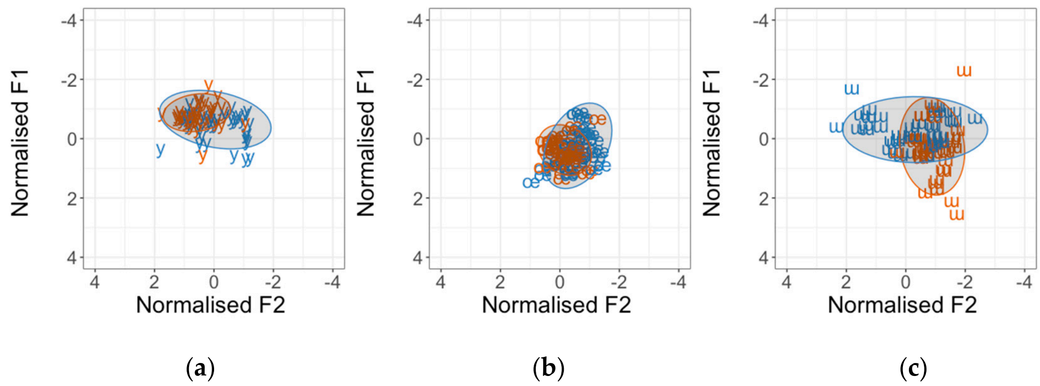


Figure 6. (**a**) Urban (blue) versus regional (orange) groups' productions of the vowel /y/. (**b**) Urban (blue) versus regional (orange) groups' productions of the vowel /œ/. (**c**) Urban (blue) versus regional (orange) groups' productions of the vowel /ɯ/.

3.3. L1 Influence and Interspeaker Variation

The Pillai score analysis allows us to have a much more nuanced picture of the interspeaker variation and L1 influence on the speakers' speech behaviours. Table 5 presents the Pillai scores for the L2 Turkish vowel pairs presented by the speaker and grouped by residency type (urban versus regional). The table includes all possible vowel combinations based on a visual inspection of the F1/F2 vowel plots for each speaker. The shading indicates no spectral overlap for certain vowel pairs. Table 6 shows the Pillai scores for the L2 Turkish–L1 English vowel pairs, also presented by speaker and grouped by residency type. The Pillai scores closer to 1 indicate a separation of the vowels in the acoustic space, while scores closer to 0 are indicative of more overlap and less separation of the two vowels in the acoustic space. The individual Pillai scores are generally interpreted by comparisons across the speakers. In both tables, Pillai scores $\leq$ 0.60 are marked in bold to better illustrate the patterns.

Table 5. Individual Pillai scores for overlapping vowel pairs presented by speaker ID and residence. Shaded cells indicate no visual spectral overlap in the F1/F2 vowel plane.

ID	RS	i–y	i–ɯ	i–œ	y–œ	y–u	y–ɯ	ɯ–u	e–œ	œ–u	e–u	œ–ɯ
F07	Urban	0.97			**0.39**	**0.40**	0.97			**0.57**		
F32	Urban				0.88	**0.47**		0.87	0.89	**0.37**	0.79	
F46	Urban		0.92	0.89	0.74	**0.50**	0.90	**0.60**	0.79	**0.35**	0.68	**0.28**
M02	Urban		0.65			**0.42**			0.82			
M45	Urban	0.90	0.64	0.65	**0.51**	**0.08**	0.89	0.86	**0.37**	**0.12**	0.90	0.80
F06	Urban	0.90						**0.26**	0.94	0.61		
F48	Urban	0.89	0.72	0.88	0.90		0.79	0.67		0.84		0.65
M16	Urban							0.90		0.85		**0.42**
M47	Urban	0.85				0.78	0.67					0.77
M04	Reg	0.82			0.89	**0.60**		**0.51**	0.65	**0.56**	0.72	**0.40**
F34	Reg				0.86	0.62			0.89	0.87		0.83
F56	Reg	0.92				**0.47**				**0.39**		0.92
M38	Reg	0.87			**0.52**	0.68	**0.32**					**0.39**
F14	Reg	0.75							0.75			
F39	Reg	0.85							0.93			
F52	Reg	0.78										
M54	Reg	0.73				0.90				0.91		
M55	Reg	0.75							0.82	0.88		**0.37**

Note: RS = Residence; Reg = Regional.

Table 6. Individual Pillai scores for overlapping L2 Turkish–L1 English vowel pairs, presented by speaker ID and residence. The first vowel in the pair corresponds to L2 Turkish vowel, while the second vowel in the pair corresponds to L1 AmE vowel.

ID	RS	T-L2/i/	T-L2/y/	T-L2/ɯ/	T-L2/u/	T-L2/e/	T-L2/œ/
F07	Urban	/i/-/i/0.77	/y/-/u/0.76	**/ɯ/-/ɚ/0.59** /ɯ/-/ɪ/0.88 /ɯ/-/u/0.98	/u/-/u/0.78		/œ/-/u/0.71 /œ/-/o/0.71
F32	Urban	/i/-/i/0.86	/y/-/ʊ/0.98	/ɯ/-/u/0.93		/e/-/æ/0.72	**/œ/-/ɚ/0.40** /œ/-/o/0.88
F46	Urban	**/i/-/i/0.44** /i/-/ɪ/0.61		/ɯ/-/ɚ/0.90 /ɯ/-/ʊ/0.65		**/e/-/ɛ/0.39**	/œ/-/ɚ/0.94 /œ/-/o/0.95
M02	Urban	/i/-/i/0.91	**/y/-/u/0.45** /y/-/ʊ/0.97	/ɯ/-/ɪ/0.70	/u/-/ʊ/0.89	/e/-/æ/0.63	/œ/-/æ/0.98
M45	Urban	/i/-/i/0.95 /i/-/ɪ/0.71	/y/-/u/0.69	**/ɯ/-/i/0.52**	**/u/-/u/0.57**	/e/-/æ/0.79	**/œ/-/ɚ/0.02** **/œ/-/o/0.48**
F06	Urban	/i/-/i/0.92		/ɯ/-/u/0.95	/u/-/u/0.82	/e/-/ɛ/0.61 /e/-/æ/0.84	/œ/-/ɛ/0.92 /œ/-/ɚ/0.85 /œ/-/o/0.96
F48	Urban	/i/-/i/0.89 /i/-/ɪ/0.75		/ɯ/-/u/0.75 /ɯ/-/ɚ/0.79	/u/-/u/0.91	/e/-/ɛ/0.72	/œ/-/u/0.88
M16	Urban	/i/-/i/0.66		/ɯ/-/ɚ/0.97	/u/-/u/0.73	/e/-/ɛ/0.90	/œ/-/ɚ/0.92
M47	Urban	**/i/-/i/0.60**	/y/-/u/0.86	**/ɯ/-/ɚ/0.35**	**/u/-/u/0.21**	**/e/-/ɛ/0.58**	/œ/-/ɚ/0.91 /œ/-/ɛ/0.84
M04	Reg		/y/-/u/0.86 /y/-/ʊ/0.95	/ɯ/-/ɚ/0.69		**/e/-/ɛ/0.44**	/œ/-/ɛ/0.69
F34	Reg	/i/-/i/0.91	/y/-/u/0.96		**/u/-/u/0.25**	**/e/-/ɛ/0.29**	**/œ/-/ɚ/0.28**
F56	Reg	/i/-/i/0.86		/ɯ/-/ɚ/0.84	/u/-/u/0.96	**/e/-/ɛ/0.23**	/œ/-/o/0.88
M38	Reg	/i/-/i/0.99	/y/-/u/0.82	/ɯ/-/ɚ/0.99	/u/-/u/0.94		/œ/-/o/0.98
F14	Reg	/i/-/i/0.61	/y/-/u/0.98	/ɯ/-/u/0.84			**/œ/-/ɛ/0.58** /œ/-/ɚ/0.87
F39	Reg	/i/-/i/0.81	/y/-/i/0.96	/ɯ/-/ɚ/0.98 /ɯ/-/ʊ/0.97	/u/-/u/0.91		/œ/-/ɛ/0.87
F52	Reg	/i/-/i/0.76		/ɯ/-/ɚ/0.96	/u/-/u/0.95	/e/-/ɛ/0.67	
M54	Reg	**/i/-/i/0.44**	/y/-/ɪ/0.81		**/u/-/u/0.13** /u/-/ʊ/0.78	**/e/-/ɛ/0.55**	
M55	Reg	**/i/-/i/0.01**	/y/-/u/0.91	/ɯ/-/ɚ/0.99	/u/-/u/0.92	/e/-/ɛ/0.90	**/œ/-/ɚ/0.40**

Note: RS = Residence; Reg = Regional.

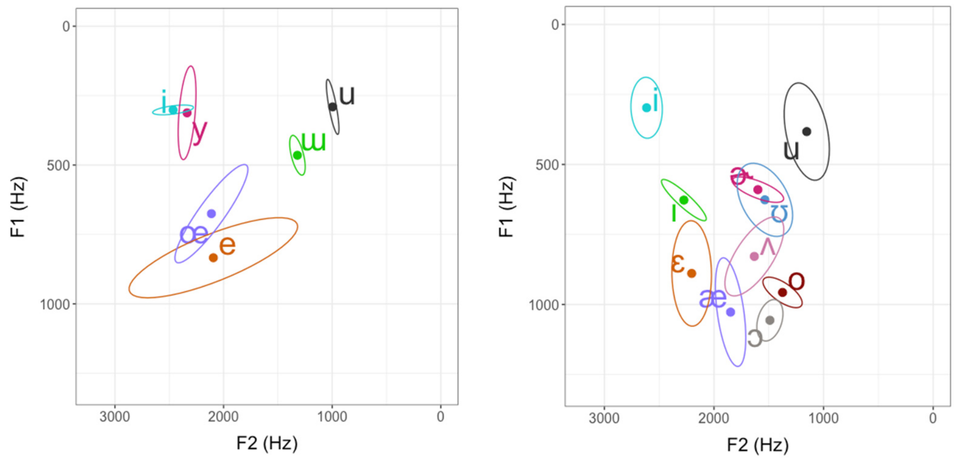
We found that interspeaker variation in our dataset can be defined according to the following key parameters: (a) the number of L2 vowels which show separation in the vowel space, based on the presence and the degree of overlap in F1/F2; (b) the L2 Turkish vowel productions in relation to the phonological properties of Turkish vowels and in relation to L1 English vowel categories; and (c) the consistency in the phonetic realisations or lack thereof in the production of L2 vowels (i.e., variability across repetitions). The Pillai score analysis reinforces the finding that the regional group shows a somewhat stronger profile in the vowel production. The majority of the regional speakers made a better separation among the L2 vowel categories in the acoustic space, characterised by fewer overlapping vowel pairs and, where present, a lesser amount of F1/F2 overlap (as evidenced by the high Pillai values in Table 5). This contrasts with the urban group, whose vowel productions often exhibited a large degree of intraspeaker variation, i.e., different phonetic realisations across repetitions. Further, the L2 vowels for this group often showed evidence of "multiple clustering"—several vowel targets being mapped onto the same vowel space (e.g., speakers F46, F07, and M45). The productions of the vowels /y/ and /u/ by speakers with urban residency show some of the lowest Pillai values and thus indicate a large degree of overlap. The same pattern extends to the phonologically front /œ/, frequently showing overlap with the back vowels /u, ɯ/. However, the Pillai results reveal greater interspeaker variability in the productions of /œ/, regardless of the group.

Recall that among the three novel vowels, residency type had no significant effect on the F1/F2 values of /œ/, and this is reflected in the low Pillai values for the pairs /œ–u/ and /œ–ɯ/ produced by several regional speakers (i.e., M04, F56, and M38). The lack of the tokens for the non-high back rounded Turkish /o/ is a limitation of the current dataset—an examination of the non-high front–back pair /œ–o/ is crucial to better understand the dispersion of the L2 vowels in the vowel space and is part of the future work. Moreover, among the regional group, speakers F14, F34, F39, F52, M52, and M54 showed a "better" performance compared to the other speakers and produced the target vowels /y/, /œ/, and /ɯ/, maintaining height and backness in relation to the phonological Turkish vowel categories. Also, the vowel ellipses for these speakers tended to be clustered tighter in the acoustic space in comparison to other learners, indicating a greater consistency in the phonetic realisations. Further investigation into individual language experiences is needed to determine the factors behind the performance of these participants, most likely linked to the speakers' individual experiences in the phonetic input and use of Turkish.

The results in Table 6 show patterns for the L1–L2 interaction in the production of L2 vowels. Except for F46, M54, and M55, the AmE speakers in this study produced the Turkish /i/ higher and/or more fronted as compared to the English /i/, potentially creating a new phonetic category for the Turkish /i/ to allow for a greater phonetic distinction between the Turkish /i/ and English /i/ (Pillai values ranging from 0.60 to 0.99), carving out space for the high rounded vowel /y/. As shown in the table, all speakers, regardless of their residency type, produced the front Turkish /y/ and the back English /u/ with minimal or no overlap in the acoustic space. This is except for the urban speaker M02 (Pillai for Turkish /y/—English /u/: 0.45). The high back Turkish vowel /u/ exhibited greater interspeaker variation: most speakers produced this vowel with higher F1 and/or lower F2 values compared to their L1 /u/, with the exception of M45 (urban), M47 (urban), F34 (regional), and M54 (regional), whose productions showed a substantial amount of overlap for the L1-L2 high back rounded vowels. The L2 /ɯ/ shows more distinct patterns for the urban versus regional residency groups and further reinforces the findings presented in Section 3.2. While the L1-L2 vowel spaces for the participants from both groups show overlap, at times minimal, between the Turkish /ɯ/ and English /ɚ/ and /u/, several participants with the urban residency type are more likely to produce /ɯ/ towards the front of their vowel space, close to the English vowels /i/ or /ɪ/.

The Turkish /œ/ was produced in the same acoustic space as the English vowels /ɛ/ and /ɚ/ for several speakers, as illustrated by the low Pillai scores for the vowel pairs in the column "T-L2/œ/" (Table 6). Despite a large amount of overlap between the Turkish /œ/ and the English unrounded front and central vowels for the speakers in both groups, only speaker M45 with regional residency produced the rounded front Turkish /œ/ in close proximity to the rounded back English /o/ (Pillai: 0.48). Finally, the Pillai analysis shows that the Turkish /e/ was produced in the same acoustic space as the AmE /ɛ/ for a number of speakers, with Pillai values ranging from 0.23 to 0.55 (see Table 6, column T-L2/e/). However, this is not the case for all the speakers: some were more likely to produce a phonetically distinct vowel, reflected in the table by high Pillai values or by an empty cell. This pattern was more pronounced for participants with regional residency. The following paragraphs discuss examples of speakers' speech behaviours for each residency type and present the F1/F2 vowel plots for the L1 and L2 vowels.

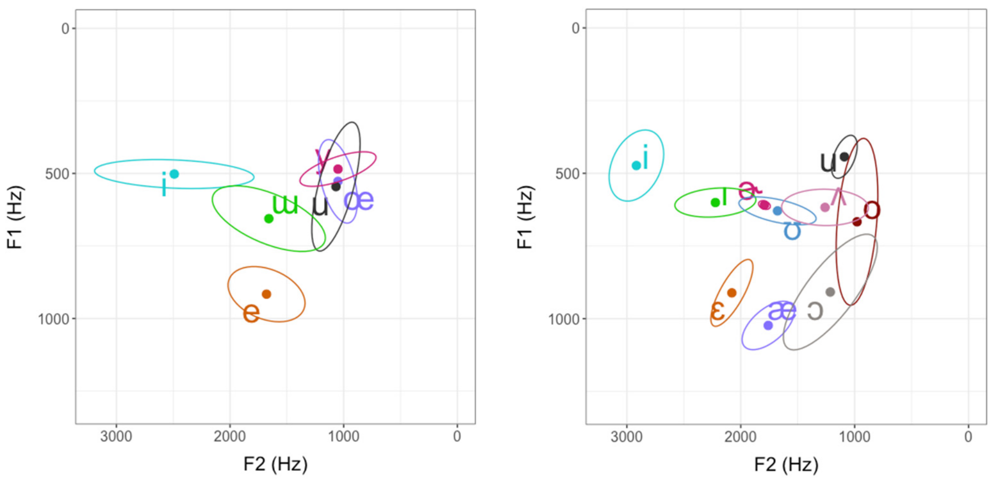
Speaker F39 is an example of a learner from a regional group (Figure 7a,b). She is a 41-year-old woman of 17 years residence. As illustrated in Figure 7a, the three unrounded–rounded vowel pairs (/i/–/y/, /e/–/œ/, and /ɯ/–/u/) are produced with minimal overlap in the F1/F2 vowel space, as shown by the size of the ellipses and the Pillai value (0.85 for /i/–/y/; 0.93 for /e/–/œ/). This speaker produces the L2 Turkish /u/ with lower F1 values compared to the English /u/ (Pillai: 0.91), which possibly helps her make a better distinction between the rounded /u/ and the unrounded /ɯ/ vowel sounds in Turkish. She also produces a non-high front rounded vowel /œ/ with higher F1 values, making a distinction between the two non-high front unrounded and rounded vowels /e/ and /œ/ on the basis of F1.



(**a**) (**b**)

Figure 7. (**a**) Mean F1 and F2 values for L2 Turkish vowels produced by speaker F39. Each ellipse includes approximately 95% of the samples in each vowel category. (**b**) Mean F1 and F2 values for L1 English vowels produced by speaker F39. Each ellipse includes approximately 95% of the samples in each vowel category.

Figure 8a,b illustrate the vowel productions by a learner with urban residency. Speaker F07 is 29 years old and had lived in Istanbul for seven years at the time of the data collection. Figure 8a illustrates that the productions of the unrounded vowels /i/, /e/, and /ɯ/, with a more central realisation of the latter, do not have any substantial overlap with the other vowels. However, the three rounded vowels /y/, /œ/, and /u/ are all produced as high back vowels, as shown by the overlapping ellipses and the centroids proximal to the centroids for the speaker's /y/, /œ/, and /u/ (Pillai scores for /y/–/œ/: 0.39; /y/–/u/: 0.40; and /œ/–/u/: 0.57). Without having any perceptual data, we can speculate that the three rounded Turkish vowels are collapsed into a single category based on the rounding feature and might be possibly viewed as phonetically similar to the L1 high back vowel by this learner.



(**a**) (**b**)

Figure 8. (**a**) Mean F1 and F2 values for L2 Turkish vowels produced by speaker F07. Each ellipse includes approximately 95% of the samples in each vowel category. (**b**) Mean F1 and F2 values for L1 English vowels produced by speaker F07. Each ellipse includes approximately 95% of the samples in each vowel category.

4. Discussion

The aim of this paper was to investigate the production of Turkish vowels by adult L1 speakers of AmE with a particular focus on the "novel" vowels /y/, /œ/, and /ɯ/. We examined the spectral characteristics of the L2 unrounded–rounded vowel pairs /i/–/y/, /ɯ/–/u/, and /e/–/œ/ and the location of these vowels in the F1/F2 acoustic space. We also explored the effects of target language experience, in this case via residency type, and the possible effects of the length of residency. Our empirical findings present an interesting and complex picture, given the standard assumptions posited by the SLM. Here, we discuss in depth the findings with reference to cross-linguistic phonetic similarities, the learning processes of assimilation and dissimilation in the SLM framework, the dynamic interaction between L1 and L2, and the influence of language experience.

4.1. Novel Vowel Characteristics and L1-L2 Interaction

Overall, the production results for the Turkish vowels /y/, /œ/, and /ɯ/ present a rather nuanced picture, which is not surprising considering the importance of the rounding feature in Turkish to make distinctions between high front, high back, and non-high front vowel pairs, and the lack thereof in English. Learners with English as their L1 need to add or remove the [rounded] feature to acquire these Turkish vowel pairs. Given that this is the first study looking at the production of L2 Turkish vowels by adult speakers, a direct comparison with the previous literature on L2 Turkish is not possible. As a result, research on comparable unrounded–rounded vowel pairs in other languages, mostly perception, was instead examined and discussed in relation to the current findings.

As posited by the SLM and maintained in the SLM-r, L2 learners "subconsciously and automatically" relate L2 sounds to L1 phonetic categories (Flege and Bohn 2021, p. 33), and once L2 categories are established, learners tend to dissimilate phonetically similar L1 and L2 sounds in order to better maintain the phonetic contrasts (Flege 1995; Flege and Bohn 2021). The Turkish vowel /y/ was consistently produced as a high vowel but showed greater variation across the speakers in terms of the F2 parameter (front versus back). The previous research reports that L1 AmE speakers have difficulty discriminating the phonetic categories [i] and [y] (e.g., Flege 1987; Gottfried 1984; Levy 2009a; Levy and Strange 2008). For example, Levy (2009a) found that the French /y/ was likely to be perceived as /i/ by less experienced learners or /u/ by learners with more language experience. Our results suggest that AmE speakers make a distinction (in production) between the unrounded /i/ and rounded /y/, based on the evidence of minimal or no overlap in the acoustic space for these two vowels. Furthermore, the Pillai–Barlett trace analysis shows that the majority of the speakers produce the Turkish /i/ as a higher and/or more front vowel as compared to the AmE /i/, thus making the phonetically similar vowels in L1 and L2 more different (dissimilation) and potentially carving out space for the new phonetic category [y] in L2 Turkish. Consistent with the perception studies on the discrimination of the (German and French) [y] and [u] by AmE speakers (i.e., Levy 2009a, 2009b; Rochet 1995; Strange 2007), several participants in our study find this contrast challenging and produce the Turkish /y/ and /u/ in the same acoustic space. Further, unlike the high front /i/, the Turkish /u/ and English /u/ showed substantial overlap in the vowel space for a handful of the speakers. This could be due to (a) the allophonic variation in AmE, whereby the back high vowel /u/ has a more fronted allophone in certain contexts (Hillenbrand et al. 1995) and (b) the English /u/ may acoustically fall within the bounds of the Turkish /y/, similar to the observation made by Rochet (1995) for the French /y/ and English /u/.

The Turkish non-high front rounded vowel /œ/ also showed variation in the F2 parameter. While this target vowel was characterised by higher F2 values, at times in combination with lower F1 values, a number of the participants produced the target vowel between the phonetic bounds of [œ] and [o] in their elicitations, with some producing it in the same acoustic space as their /ɯ/ and /u/ in Turkish. Levy (2009b), in her study of L1 AmE learners of French, found that their perception of the French /œ/ varied depending on learner experience, with the more likely perceptual assimilation to /u/ in the bilabial consonantal context and a higher accuracy for more experienced learners. Our results are more consistent with the findings in Strange (2007), who reported that the rounded mid front vowel in German was perceived as intermediate between the front mid and the back high English vowels for words in a citation context, the context similar to the present study, and as [y] in a sentence context. Moreover, the L1–L2 comparisons revealed that the Turkish /œ/ was produced in the same vowel space as the English back vowels /o/, /u/, and /ʊ/ or the central vowel /ɚ/ for those speakers who did not produce it as a more fronted vowel. The overlap between the AmE /ɚ/ and Turkish /œ/ is of particular relevance if we consider the phonetic characteristics of this phonologically front vowel in Turkish, with the mean F2 values below 1500 Hz, based on our recording of the L1 speaker of Standard Istanbul Turkish (See Figure 3). Without a perceptual study, our tentative thought is that a dissimilation movement is more likely at work for the participants who place the Turkish /œ/ in the front or a relatively central position in the vowel space, and the assimilation of /œ/ to English back rounded vowels is the more likely explanation for those participants whose L1 back vowel(s) show a high degree of overlap with the Turkish /œ/. Further back productions of the Turkish /œ/ could be due to a greater reliance on the feature [rounded] rather than the use of the front–back dimension. The speakers' L1 phonetic inventory includes a number of rounded vowels in the back of the vowel space, possibly accounting for different L2 variants with low F2 values. It is noteworthy to point out that the unrounded non-high front vowel /e/ (represented as /ɛ/ in some of the literature on Turkish) showed overlap in the acoustic space with the English /ɛ/, suggesting a "composite" L1–L2 phonetic category, at least for some of the speakers.

As predicted, the Turkish high back unrounded vowel /ɯ/ presented the most difficulty for the L1 AmE learners. This vowel showed substantial variation in both vowel height (F1) and backness (F2). Unlike the other two novel vowels, the Turkish /ɯ/ exhibited several L2-L1 mappings and was realised as a number of phonetic variants, in the bounds of the acoustic spaces for the phonetic categories [i], [ɪ], [œ], and more frequently—[ɚ]. These findings echo the difficulty Shport's (2019) naïve English listeners exhibited in the discrimination of this vowel, evidenced by a high degree of variation in categorising their response to the Vietnamese /ɯ/. It is interesting to see this phenomenon recur in our production study with highly experienced, advanced language learners. Stevens (1998) observed that /ɯ/ has an exceptionally short duration, and Radisic's hypothesis (2014) that in Turkish /ɯ/ essentially acts much like the shape-shifting schwa in English obscured somewhat by the influence of adjacent consonants, may account for some of the perceptual difficulties with this vowel exhibited by native speakers (Kiliç and Öğüt 2004) and would certainly account for some of productive difficulties observed in this study's learners. It is also important to consider the spectral patterns for the Turkish /ɯ/ in relation to its rounded counterpart, the Turkish /u/. It is possible that /ɯ/ is viewed as a new or distinct phonetic category, leading to the redistribution of the other nearby L1 and L2 phonetic categories, which in turn results in the dissimilation between the Turkish /u/ and English /u/; and the variability in the phonetic realisations of /ɯ/ is due to the unavailable distinction of a Turkish /ɯ/–/u/ contrast in English. The following section will further discuss the findings but in relation to the residency type and LOR.

4.2. Target Language Experience and LOR

The LOR was shown not to have a significant effect in our study, in keeping with the many other previous studies yielding no significant effect of the LOR in adults' phoneme acquisition (Flege et al. 1992; Moyer 1999; Piske et al. 2001, among others). In fact, some of our highest performing participants in this study had some of the shortest LORs (3 or 4 years of residence). It is plausible that unlike for child language acquisition (Flege et al. 2006), the LOR and adult phoneme acquisition do not exhibit a clear, direct linear relationship in our study. In child L2 learning, for school-age children at least, the LOR directly reflects the accumulative amount of time that children are exposed to and immersed in the input environment (Flege et al. 2006) and can be a more reliable measure of children's target language experience. However, for adults, language experience varies greatly from person to person (see Flege and Bohn 2021). The simple time reference of the LOR cannot be used as a reliable measure equivalent to experience (Flege 2007).

The findings in this study support the claim that the type of language experience plays a significant role in the acquisition of L2 sounds. A difference between the regional group of deep language immersion and the urban group of mixed language immersion became evident in the inferential statistics test and upon close examination of their L1-L2 acoustic space. With the exception of /œ/, which showed no statistically significant effect of the group, the more confined ellipses and generally tighter clustered realisations of the regional group compared to the urban group show that the degree of language immersion appeared to be a key factor in the production of Turkish vowels. In the particular situation of adult learners in a regional setting, it is possible that their language experience is constrained to be less dependent on personal choice, and consequently somewhat more predictably homogenous—which may explain the results presented by this group. It is likely that outside of their home, they would speak the target language because they have no other option. Learners of regional residence generally live in smaller cities, towns, or villages and were not likely to have had access to a classroom for their language learning. Many, if not most, would have learned language via a few hours a week of online tutoring, self-study, and with the vast majority of the time spent practicing with native speakers in the local community and workplace. While roles vary highly from person to person, job descriptions typically involve discussing the needs of their clients face-to-face, organising community activities, coordinating supplies, and troubleshooting with vendors in the target language—all of which would give participants ample language exposure, practice, and feedback. This is in keeping with the findings in the study abroad literature (Cadd 2012; Leonard 2015; Moyer 2005) that reported both the quantity and quality of informal contact with speakers of the target language as a key determiner of success in L2 learning during study abroad. However, we also note that even within the regional group, speakers exhibited differences in their speech behaviours, and the findings of this study need to be interpreted carefully, in view of interspeaker variability, which could be attributed to a number of factors, including the comparative quantity and quality of phonetic input, the perceptual link between L1 and L2 sounds, and many more factors (Flege and Bohn 2021). It must be noted that very little work has yet been undertaken on the acquisition of vowels in immersive contexts, particularly in migration contexts. A contribution of this present study is to begin to shed some light on the subject.

4.3. Limitation and Future Research

One of the limitations of the present study is the focus on vowel quality only. Future work is needed to look at both vowel quality (F1 and F2) and vowel duration, taking into account the vowel system in English where the distinctions are based on both spectral characteristics and length. In addition, one of the disadvantages of the present dataset is the absence of the Turkish non-high back rounded vowel /o/; due to a number of missing tokens for several speakers, this vowel was excluded from the analysis. It will be crucial to examine the Turkish non-high back /o/ in relation to the Turkish non-high front /œ/ and English /o/. More importantly, a future follow-up study which employs perceptual discrimination and assimilation tasks is needed to better explain the relative difficulties L2 AmE speakers have in the acquisition of L1 Turkish vowels and to better account for the findings presented in this study. Production data alone do not provide sufficient evidence about the acquisitional processes and how perceptual distinctions between and across phonetic categories are made.

Another limitation of this study was the use of word lists for data elicitation, which has been criticised as potentially less representative of authentic speech than other data collection methodologies (Saito and Plonsky 2019; Thomson and Derwing 2015). The results presented here are part of a larger study, and the choice to start with the analysis of the word lists was motivated primarily due to the understudied nature of the adult L2 acquisition of Turkish vowels. To the best of our knowledge, this is the first study of this kind, and for predictive purposes, the researchers were constrained to rely on comparable (mostly perception) studies on rounded/unrounded vowel pairs performed in other languages. Most of the research on L2 rounded/unrounded vowels cited in the background literature to inform the study's predictions relied on word lists for their data collection (Darcy and Krüger 2012; Gottfried 1984; Levy 2009b; Levy and Strange 2008; Polka 1995; Stevens et al. 1969; Shport 2019). As a result, the choice was made to extract vowels from word lists rather than carrier phrases so that our methods and approaches would resemble those in the previous research carried out thus far and our results could be compared with the current literature. However, we acknowledge that this constitutes a first step only. Following the findings of Strange (2007), who reported different patterns for perceptual assimilation depending on the context (citation words versus words in sentences), further work is recommended beyond this very initial study for the investigation of Turkish vowels, looking at different segmental environments and using a range of materials (based on spontaneous and read speech).

5. Conclusions

The present study investigated the production of L2 Turkish vowel pairs in migrant workers with L1 AmE outside of the classroom, whose learning experience approximates that of the vast majority of adult workers who must learn a language however they can. The evidence presented to us by the current data suggests that there is a process somewhat complex at work. Speakers in the current study used both assimilation and dissimilation processes in their realisations of Turkish vowels, in addition to a substantial degree of interspeaker and at times intraspeaker variation. While some of the study participants produced L2 vowels in relation to their phonological categories and phonetic properties in Turkish, a number of the AmE speakers exhibited an interesting front–back variability in their production of the three novel vowels in Turkish, producing further back variants of the target front vowels (/y/ and /œ/), and more fronted variants in place of the back vowel /ɯ/. Despite the observed variability, the current study has nonetheless shown that language experience plays a significant role in L2 vowel production, particularly in comparison to the length of residence for adults. We emphasise that L2 language experience is defined via the type of residency, urban versus regional, and is closely linked to the amount and type of phonetic input. Following Flege and Bohn (2021), the assumption is made that the L1 and L2 phonetic systems interact and the phonetic input which forms the basis of the L2 categories cannot be identical to the speakers' L1 input.

The study of Turkish as a target language also breaks new ground, given the lack of any work on the production and acquisition of L2 Turkish vowels by adult speakers—all prior studies of Turkish have focused on child acquisition. In addition, vowel acquisition studies in general to date have largely been conducted with university students as participants. This study is novel in that all the participants are highly experienced learners residing in a country where the target language is predominantly spoken. This gives us an unusual opportunity to examine vowel production and the interaction of the L1-L2 phonetic categories occurring in more advanced learners, outside the traditional university or foreign language setting, and in the workplace—where indeed, in today's world, with unprecedented levels of irregular migration, much of adult second language learning must take place.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding authors. The data are not publicly available due to ethics restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

Note

[1] Symbols for this vowel vary in the literature on Turkish, with the phoneme represented as /ɛ/ and /e/ (see Sabev 2019).

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