Phonological acquisition of European Portuguese oral vowels: A forced-choice identification study with Hungarian native speakers

Gabriela Tavares[1], Andrea Deme[2,3], and Susana Correia[1]
[1]Linguistics Research Centre of NOVA University Lisbon
[2]Department of Applied Linguistics and Phonetics of ELTE Eötvös Loránd University Budapest
[3]MTA-ELTE Lingual Articulation Research Group Budapest

Auditory perceptual experiments with Portuguese L2 are scarce, especially within the scope of the European variety (EP). In this study, we aim at observing the assimilation of the EP vowels [ɐ] and [ɨ] by Hungarian native speakers, and their perceptual learning after some contact with Portuguese. A multiple forced-choice identification experiment was run with two groups of Hungarian speakers – a group with and a group without previous contact with EP. The results show that the categorization fell into the closest phonetic categories of the L1. The results also indicate a learning effect for [ɨ], with a recategorization path from [y] to [ø]. As for [ɐ], no major differences were observed between groups. This result is consistent with difficulties observed in the classroom environment, where [ɐ] is particularly challenging to Hungarian learners.

1 Introduction

Second Language (L2) phonological acquisition and teaching is usually focused on production, very often on foreign accent (Edwards and Zampini 2008). However, recent studies on pronunciation instruction have contributed evidence for the role of perception in production and, as a result, the link between perception and production is now becoming "one of general acceptance and strong empirical support" (Isbell 2016: 63). Consequently, auditory perception in L2 acquisition is a field of increasing interest.

When it comes to perceptual studies, a key aspect is the representational nature of auditory perception since perception is filtered by language and problems in speech perception are not necessarily caused by auditory failures. What is at stake is not acoustic reality, but instead the way speakers represent and categorize sounds (Kuhl 2000).

Another important assumption is that perceptual learning is possible in adults and throughout life, although not without constraints (Flege 2003; Best and Tyler 2007; Bundgaard-Nielsen et al. 2011).

Among these constraints, there is a consensus that perceptual accents (Jenkins et al. 1995) are greatly influenced by the L1 of the speaker (Flege 1995; Best 1995; Escudero 2005). A considerable amount of research has been devoted to investigating how native language can act as a constraint in non-native speech perception, with studies on the influence of the nature and size of the L1 phonological inventory in L2 speech perception (Polka 1995; Best et al. 2001; Elvin et al. 2014; Faris et al. 2018). These studies have demonstrated that while listeners are able to discriminate some non-native contrasts, others pose additional difficulties to them, suggesting that this dual behavior "does not depend on the presence or absence of the critical phonetic/acoustic features in native speech" in the L1 (Best et al. 2001: 777), but it is rather due to degree of similarity between the phonological segments of the L1 and L2.

2 The Perceptual Assimilation Model

In terms of how L1 linguistic experience can determine the ability to discriminate non-native speech sounds, different models have been proposed, such as the Speech Learning Model (SLM, Flege 1995), the Perceptual Assimilation Model (PAM, Best 1995), and the Second Language Linguistic Perception model (L2LP, Escudero 2005). While SLM and L2LP base their predictions of L2 sounds' perception and acquisition on acoustic features, assimilation patterns proposed in PAM follow an articulatory basis. Additionally, SLM analyzes the relationship between individual L1 sounds and L2 categories, whereas the PAM and L2LP models focus on the connection between L1 and L2 contrasts. Another important difference between the 3 models is the research focus: Flege's work (hence SLM) has been mainly devoted to study the persistence of foreign accent by more proficient L2 speakers, whereas L2LP focuses on determining and explaining learning scenarios, and analyzing cross-linguistic acquisition of vowel categories. Finally, PAM – a model originally not designed for Second Language Acquisition – has mostly investigated the perception of L2 contrasts by naïve listeners. While it is indisputable that all three models can contribute to a better understanding of L2 auditory perception, for the current study, PAM seems to present the most suitable theoretical framework and empirical examples, considering that our target sample consists of naïve listeners.

According to PAM, the perception of non-native segments is constrained by the phonetic inventory and phonological system of the listener's L1. Following this model's premises, L2 sounds tend to be perceived based on the articulatory similarities of the given segment to the nearest existing native category. In this model, L2 perception is viewed as a similar process as L1 acquisition, when a fine-tuning to meaningful articulatory gestures in the native language occurs.

According to PAM, one of three patterns occurs when a non-native sound is perceived: (i) that sound is *assimilated* to a native category, (ii) the non-native sound can fall between native categories and it is deemed as *uncategorized*, or (iii) the listener fails to perceive it as a speech sound, in which case it is said to be *not assimilated*.

Other than the categorized, uncategorized, and not assimilated patterns, category goodness is also a key concept in PAM, as it refers to the degree of similarity between the L1 and the L2 categories. Category goodness is an important variable to predict discrimination abilities in assimilated non-native sounds which can vary depending on the non-native sound being a good, acceptable, or deviant example of the L1 category.

PAM accounts for three possible scenarios for combining categorized L2 sounds (Figure 1): *Two-category assimilation* (TC), when both L2 segments are categorized as two different native categories, *category-goodness assimilation* (CG), if both non-native segments are categorized as one single native category, but one of them is a significantly better fit than the other, and *single-category assimilation* (SC), when both non-native segments are an equally good or deviant fit to the same native category.

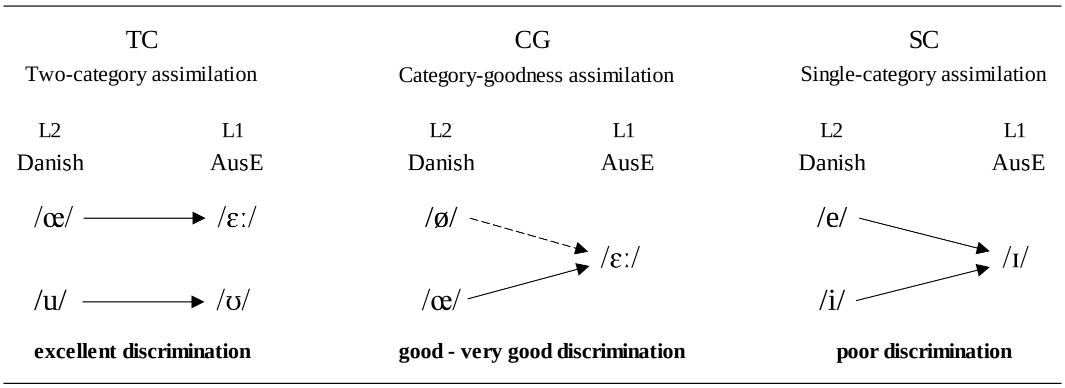

Figure 1. Examples of combinations of categorized non-native contrasts, based on Faris et al. (2018)

In the TC scenario, a contrast in L2 is categorized as a contrast in L1 and, according to PAM, discrimination should be excellent. When both L2 segments are categorized as a single L1 category, discrimination can vary from poor to very good, depending on the goodness-of-fit: if one of the L2 segments is a better fit of the L1 category at hand than its contrasting pair, as in the CG case, then the listener will detect phonetic differences, and discrimination can be good or even very good. On the contrary, if both L2 segments are an equally good or deviant fit to the same native category (SC), then the probability of difficulties in discriminating the sounds is high.

PAM also mentions combinations of non-native contrasting pairs when one or both L2 sounds is/are uncategorized. However, the discrimination predictions in this case are less clear. The *uncategorized-categorized* (UC) situation has a parallel with the CG assimilation type, with a good or very good discrimination scenario. In the case of an *uncategorized-uncategorized* (UU) contrast, discrimination is predicted to vary, depending on the proximity between the two L2 segments and between these and the L1 categories.

As for contrasts not assimilated (NA), the discrimination will depend solely on the psychophysical features of the sound.

3 Hungarian and Portuguese phonetics and phonology

Hungarian is a non-Indo-European language, with a non-configurational syntax and an agglutinative morphology, and with an extensive case system (Siptár and Törkenczy 2000).

The phonemic and phonetic vowel inventory includes 14 elements, /ɒ aː ɛ eː i iː o oː ø øː u uː y yː/. and vowel length is contrastive (e.g., *örül* ['øryl] 'rejoiced' versus *őrül* ['øːryl] 'getting crazy') (Markó 2017).

Hungarian is a syllable-timed language, with fixed stress on the first syllable (Markó 2017) and with no attested stress-induced vowel quality change (Gósy 1997). Studies on the perception of lexical stress in Hungarian are scarce. However, the existing studies demonstrate that Hungarian native speakers reveal stress 'deafness' (Peperkamp et al. 2010; Honbolygó et al. 2019).

Since the present study uses an orthographic identification task, it is worth mentioning that Hungarian orthography is fully transparent, that is, there is a direct grapheme-phoneme relationship (Laczkó 2020).

Portuguese is a Romance language with different national varieties, the two most documented ones being the European and Brazilian varieties.

European Portuguese (EP), the variety the present study is focusing on, has an inventory of 7 phonemic oral monophthongs, /a/, /ɛ, e/, /i/, /o, ɔ/ and /u/, that are respectively realized as [ɐ], [ɨ], [i], [u] and [u] in unstressed position (Figure 2).

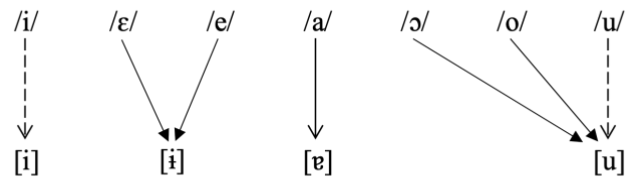

Figure 2. Vowel reduction in EP (Andrade 2020: 3306)
(Dashed lines: realizations without quality changes)

Vowel reduction depends mainly on lexical stress, which in Portuguese is contrastive and variable (*túnel* ['tunɛɫ] 'tunnel' versus *tonel* [tu'nɛɫ] 'barrel'), falling on any of the last 3 syllables, and depending on the morphological structure of the word (Pereira 2020). Vowel reduction is a key feature of EP, as demonstrated in a study on lexical stress perception with Portuguese native speakers which showed that these speakers "show a stress "deafness" effect in the absence of vowel reduction, and this may be due to the fact that vowel reduction is the most relevant cue for stress in their grammar" (Correia et al. 2015: 65).

To be intelligible with Portuguese speakers, Hungarian learners of EP must acquire linguistic features that are absent in their native language: a variable, contrastive lexical stress, vowel reduction, and two novel vowels, [ɐ] and [ɨ]. The present study addresses the last of these issues: the perception and acquisition of the reduced vowels [ɐ] and [ɨ] by Hungarian learners of EP.

4 Questions and Hypotheses

Based on the above, we formulated the following questions:

Q1: How do Hungarian native speakers assimilate the vowels [ɐ] and [ɨ]?
Q2: Is there a different acquisition path for the vowels [ɐ] and [ɨ]?

We expected that the ability of Hungarian native speakers to identify and discriminate contrastive EP vowels will depend on the phonetic – acoustic and articulatory – similarity of those vowels with Hungarian categories.

To formulate our hypotheses, we crossed a map of the perceptual vowel space of Hungarian with the location of the Portuguese [ɐ] and [ɨ] (Figure 3).

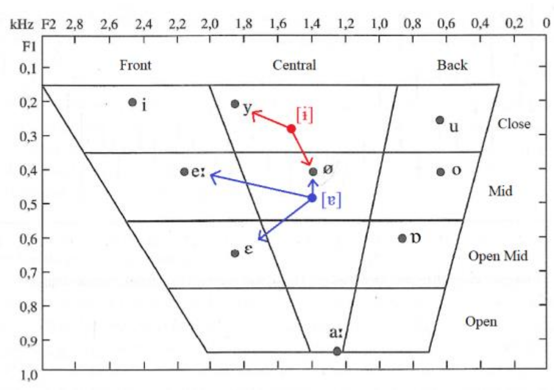

Figure 3. Location of EP [ɐ] and [ɨ] in the Hungarian perceptual vowel space. Perceptual map retrieved from Kiss (1985: 166, as cited by Bolla 1995: 295) and modified according to Markó (2017). Location of [ɐ] and [ɨ] are derived from Andrade (2020: 3253)

We predicted that Hungarian speakers assimilate the Portuguese central vowel [ɨ] into the closest Hungarian central vowels – /y/ or /ø/. Regarding the Portuguese [ɐ], we predicted assimilation into the

Hungarian /ø/, or to /ɛ/ and /eː/, since these two vowels are the closest Hungarian categories that share more articulatory features with [ɐ].[1]

Furthermore, empirical observation by the first author in the classroom indicates an additional difficulty in the acquisition of [ɐ]. Hungarian learners show problems discriminating the EP [ɐ] from [ɛ] in listening tasks. This is observable when learners try to write down EP speech and replace the reduced <*a*> with <*e*> (e.g., *Ene for *Ana* [ˈɐnɐ] 'proper name'). As for [ɨ], learners normally need only a few weeks of instruction to understand that this vowel, although with a phonological and orthographic reality, is very frequently deleted in speech. Following this, we hypothesized that Hungarian learners display a different acquisition path for [ɐ] and [ɨ].

To test these hypotheses, we designed a multiple forced-choice identification test with goodness ratings.

5 Method

In this study, we used a multiple forced-choice identification task to test assimilation patterns. In these tasks, the participants must identify a specific auditory stimulus among a certain number of alternatives. In the current experiment, we presented the participants with nine types of auditory stimuli, corresponding to the nine EP oral vowels. Their task was to identify each of the stimulus with a real word from their L1, presented orthographically in a grid (Figure 4). Although the target of this study is to observe the vowels [ɐ] and [ɨ], it is necessary to test all EP oral vowels to determine overlapping situations.

5.1 Participants

Two experimental groups were formed with Hungarian native speakers: a first group with no knowledge of Portuguese (ExpA), and a second group with Hungarian students of Portuguese as a Foreign Language (ExpB), with approximately two semesters of classes. A Control group with Portuguese native speakers was also included in the study, to serve as baseline condition.

Table 1. Participants' general information

	AGE GROUP					GENDER			ACADEMIC DEGREE			
	18 to 25	26 to 30	31 to 35	36 to 40	40 to 45	female	male	other	secondary	BA	MA	Phd
ExpA	11	4	9	2	6	23	9		10	8	8	6
ExpB	11	2			1	10	4		9	3	1	1
Control	17	6	2	2	3	21	8	1	8	11	10	1

In total, 76 participants aged 18 to 45 completed the experiment (54 females), 32 in the ExpA group, 14 in the ExpB group, and 30 Portuguese native speakers in the Control group.

5.2 Auditory stimuli

Test stimuli consisted of CV structured non-words. Monosyllables were used to prevent the effect of relative prominence of stress in multisyllabic words. Also, CV combinations were structures more likely to appear in the first syllable of real words in both languages, which was relevant for choosing the orthographic stimuli.

[1] Hungarian vowels /ɒ/ and /o/ are approximately at the same distance from [ɐ] as /ɛ/ and /eː/, but while these last two vowels differ from the Portuguese vowel in one feature (front), /ɒ/ and /o/ differ in two features (back and round).

We selected a set of syllables that would have the lowest probability of being words both in EP and in Hungarian: [ga], [gɐ], [gɛ], [ge], [gɨ], [gi], [go], [gɔ] and [gu].[2] The corpus for the training task consisted of [tV] syllables.

To control for intonation, the CV stimuli were inserted in a carrier sentence, and an example of a real word with [gV] or [tV] in the first syllable was given for each case, as exemplified in (1) and (2):

(1)	GUERRA.	[gɛ].	Diga	[gɛ],	por favor:	[gɛ].
	'WAR.	[gɛ].	Say	[gɛ],	please:	[gɛ].'
(2)	TELA.	[tɛ].	Diga	[tɛ],	por favor:	[tɛ].
	'CANVAS.	[tɛ].	Say	[tɛ],	please:	[tɛ].'

Due to lockdown restrictions, it was not possible to record the auditory stimuli in a sound attenuated room. Recordings had to be done individually and at home. The speakers were asked to record the stimuli in the best possible sound conditions, to avoid or reduce background noise, preferably at a late or early hour, in a location where reverberation was the lowest possible.

Portuguese tokens were recorded by seven female native speakers, with a TASCAM DR-05 V2 digital Recorder, and a Beyerdynamic MCE 85 BA condenser microphone. Speakers were instructed to speak at a normal conversational rate. The first of the recordings was made by a trained phonetician, and an example of these recordings was prepared and sent to the other speakers, as a guide. After each recording, the tokens were assessed and, if needed, a new recording was requested from the speakers.

We also recorded Hungarian speech samples for the familiarization task, which were produced by three female native speakers of Hungarian (aged 28 to 45). Since all three Hungarian speakers were trained phoneticians, syllables were recorded in simple citation form and in isolation. The recordings were made in quiet rooms using an external sound card attached to a PC or laptop, and an omnidirectional condenser head-mounted microphone.

Samples from three of the Portuguese speakers (aged 42 to 45) were selected based on duration measurements, and judgments of intonation and of sound quality were made by two trained phoneticians. The tokens of the selected speakers, all from the standard variety, were segmented from the carrier sentence, and, from each speaker, the best tokens were selected, also considering duration, intonation, and sound quality. All selected tokens had a falling intonational contour.

Background noise was cleaned on a manual 'token-by-token' basis with Audacity (Audacity Team 2020). Since Hungarian listeners are sensitive to vowel length, duration of the vowel in the CV syllable was measured and manipulated using Praat (Boersma and Weenink 2020), to guarantee a similar vowel duration across tokens. Intensity was also equalized among tokens and 200 ms of silence were inserted before and after each token, with the same program.

We measured the first and second formants (F_1, F_2), fundamental frequency (f_0), vowel duration, and intensity in the vocalic part of the tested syllables.[3] Formant values were estimated using the Burg algorithm in Praat (Boersma and Weenink 2020). The time step was set to 0.01 ms, the maximum number of formants was 5, the maximum formant frequency was 5.5 kHz, and the window length was 25 ms. F_0 was measured with pitch floor and ceiling set to 75 Hz and 300 Hz, respectively. The final selection of auditory stimuli was based on these measurements and perceptual judgment from a trained Portuguese phonetician.

[2] From these CV possibilities, only [gi] and [ge] have meaning in Portuguese: [gi] is an abbreviation of *Guilherme* 'proper name' and [ge], the name of the letter 'g'.

[3] Segment boundary between consonants and vowels was identified based on the formant structure: we set vowel onset at the first voice bar of a complete formant structure.

Table 2. Duration, f_0, F_1, F_2 and intensity of the [gV] tokens selected for the experiment

	[ga]1	[ga]2	[ga]3	[gɐ]1	[gɐ]2	[gɐ]3	[gɔ]1	[gɔ]2	[gɔ]3	[go]1	[go]2	[go]3	[ge]1	[ge]2	[ge]3	[gɛ]1	[gɛ]2	[gɛ]3	[gɨ]1	[gɨ]2	[gɨ]3	[gi]1	[gi]2	[gi]3	[gu]1	[gu]2	[gu]3
duration (ms)	326	317	269	332	312	249	331	327	268	270	270	282	320	377	293	265	285	265	334	388	256	262	325	285	302	316	277
f0 (Hz)	152	162	211	173	192	213	171	198	206	224	206	195	211	169	210	163	182	218	149	193	242	201	208	240	225	230	207
F1 (Hz)	887	869	891	611	766	620	566	606	598	295	480	382	391	505	404	493	562	524	314	421	394	358	475	370	238	361	399
F2 (Hz)	1650	1480	1522	1994	2042	1897	998	1016	1037	546	834	763	2706	2769	2788	1917	2610	2371	2263	2392	2361	2720	2959	2869	641	808	768
Intensity (db)	83	87	84	86	88	88	87	87	87	88	87	89	88	88	87	87	87	88	90	88	90	91	87	88	90	89	89

	[ga]1	[ga]2	[ga]3	[gɐ]1	[gɐ]2	[gɐ]3	[gɔ]1	[gɔ]2	[gɔ]3
duration (ms)	326	317	269	332	312	249	331	327	268
f0 (Hz)	152	162	211	173	192	213	171	198	206
F1 (Hz)	887	869	891	611	766	620	566	606	598
F2 (Hz)	1650	1480	1522	1994	2042	1897	998	1016	1037
Intensity (db)	83	87	84	86	88	88	87	87	87

	[go]1	[go]2	[go]3	[ge]1	[ge]2	[ge]3	[gɛ]1	[gɛ]2	[gɛ]3
duration (ms)	270	270	282	320	377	293	265	285	265
f0 (Hz)	224	206	195	211	169	210	163	182	218
F1 (Hz)	295	480	382	391	505	404	493	562	524
F2 (Hz)	546	834	763	2706	2769	2788	1917	2610	2371
Intensity (db)	88	87	89	88	88	87	87	87	88

	[gɨ]1	[gɨ]2	[gɨ]3	[gi]1	[gi]2	[gi]3	[gu]1	[gu]2	[gu]3
duration (ms)	334	388	256	262	325	285	302	316	277
f0 (Hz)	149	193	242	201	208	240	225	230	207
F1 (Hz)	314	421	394	358	475	370	238	361	399
F2 (Hz)	2263	2392	2361	2720	2959	2869	641	808	768
Intensity (db)	90	88	90	91	87	88	90	89	89

5.3 Orthographic stimuli

In the experiment, participants had to pair the auditory stimuli with an orthographic word out of a set of nine words, placed in a 3×3 grid, all having CV structured first syllables. Four sets of words were used: two for the test with the Hungarian native speakers and two for the test with the Portuguese control group. The test for each group included real words starting with [gV] in the main test, and real words starting with [tV] in the training task (see Appendix).

We selected disyllabic [g]VCVC structured real Hungarian words for the main test that showed similar word frequency in two Hungarian corpora (Szószablya: Halácsy et al. 2003 and Magyar Nemzeti Szövegtár: Oravecz et al. 2014). We also conducted a familiarity questionnaire with 25 Hungarian native speakers (aged 18–45), to ensure a similar degree of familiarity among the words in Hungarian. Participants were asked to rate the familiarity of different [g]VCVC words on a scale from 1 (not at all familiar) to 4 (very familiar). The nine words we selected for the main test showed similar familiarity ratings (median = 4): *GARÁZS* (['gɒraːʒ] 'garage'), *GÁBOR* (['gaːbor] 'proper name'), *GERELY* (['gɛrɛj] 'javelin'), *GÉPÉSZ* (['geːpeːs] 'machinist'), *GITÁR* (['gitaːr] 'guitar'), *GONOSZ* (['gonos] 'wicked'), *GÖRÉNY* (['gøreːɲ] 'ferret'), *GULYÁS* (['gujaːʃ] 'goulash'), and *GÜGYÖG* (['gyɟøg] 'to babble').[4]

[4] For [gɛ] two words had a median of 4: *GERELY* and *GEBÉK*. However, the mean of the results for the first was 3,68 and for the second 3,08, therefore, *GERELY* was the selected word.

5.4 *Procedure*

The experiment consisted of three blocks: in the first block, we collected informed consent and administered a sociolinguistic questionnaire; the second block consisted of a training task, and the third block contained the main test. In the sociolinguistic questionnaire, participants were asked about their age, gender, academic degree, and second-languages knowledge. After this, they were given the opportunity to adjust the volume and instructed that once the volume was adjusted, they should not readjust it during the test.

In the training task, participants first listened to nine [tV] tokens and had to match them with the first syllable of a [t]VCVC real word presented in the grid. Before the task, participants were informed that they would hear a syllable, and they were asked to pay attention to the first syllable of each word in the grid (highlighted in yellow) and to decide which of the highlighted syllables correspond to the syllable they heard. They were also instructed that they would get an error message if they chose a word that did not match the sound they heard. Hungarian participants were additionally instructed to ignore duration and to focus on vowel quality exclusively.

The second part of the training task differed from the first by providing no feedback to the participants after they completed the identification task. Also, for each trial they had a second task. They heard the same token again, and they were asked to rate how well the syllable fit into the chosen word, on a scale from 1 to 4 (1 = very bad example, 2 = bad example, 3 = good example, 4 = very good example). A four-point Likert scale was used to force participants to express a clearly positive or negative judgment.

The main test started automatically after the end of the training task. The participants were informed that they would have to complete a task similar to the previous one – identification followed by goodness rating with no feedback –, but this time they would listen to a different set of auditory stimuli and see a grid with novel words (Figure 4). The test included three repetitions of each [gV] syllable, in a total of 27 trials per participant (9 EP vowels × 3 repetitions), presented in a random order for each participant.

Figure 4. Screenshot of the grid, retrieved from the experiment conducted with the Hungarian speakers

Two versions of the experiment were created: one for the Hungarian listeners (exp1.1_HU), and one for the Portuguese control group (exp1.1_PT), as shown in Table 3. The two versions were identical in structure and design but differed in three aspects. First, each group received the instructions in its native language (Hungarian or Portuguese). Second, the group with Hungarian speakers was trained with [tV] syllables recorded by Hungarian speakers and [t]VCVC real Hungarian words in the grid, while the Portuguese control group was trained with [tV] syllables recorded by Portuguese speakers and [t]VCVC real Portuguese words. Third, in the main test, the [g]VCVC words presented visually in the grid were real Hungarian words for the Hungarian groups, and real Portuguese words for the Portuguese group.

Table 3. Overview of the experiment

Group	Auditory stimuli	Orthographic stimuli	Task	Experiment version
ExpA	[gV] in EP	[g]VCVC in Hungarian	main test	exp.1.1_HU
ExpA	[tV] in Hungarian	[t]VCVC in Hungarian	training task	exp.1.1_HU
ExpB	[gV] in EP	[g]VCVC in Hungarian	main test	exp.1.1_HU
ExpB	[tV] in Hungarian	[t]VCVC in Hungarian	training task	exp.1.1_HU
Control	[gV] in EP	[g]VCVC in EP	main test	exp.1.1_PT
Control	[tV] in EP	[t]VCVC in EP	training task	exp.1.1_PT

The experiment was built in PsychoPy version 2020.2.3 (Peirce et al. 2019) and hosted by *pavlovia.org*.

Participants were instructed to complete the experiment in a single run and were asked to answer as quickly as possible.

In total, 810 answers were collected from the Control group (30 participants × 9 vowels × 3 repetitions), 864 (32 × 9 × 3) from ExpA and 378 (14 × 9 × 3) from ExpB.

5.5 Statistical analysis

We collected identification data and goodness ratings. Distribution of categories in the identification task was analyzed using $\chi 2$ tests, while goodness ratings were analyzed using a two-way independent samples non-parametric modification of ANOVA, the Scheirer–Ray–Hare test, as suggested by Sokal and Rohlf (1995), and as available in the 'rcompanion' package (Mangiafico 2016) in R (R Core Team 2021).

6 Results and discussion

6.1 Results from the main test

The results of the main test for the Control group (Table 4), ExpA group (Table 5) and ExpB group (Table 6) are shown below. The numbers represent the mean percent of identification across participants, rounded to the nearest whole number. Median of goodness ratings are presented in brackets.

Table 4. Results for the Control Group (Portuguese speakers with no previous contact with Hungarian)

auditory stimuli	Orthographic stimuli* /ga/ GATO	/gɐ/ GAVETA	/gɛ/ GUERRA	/ge/ GUÊ	/gɨ/ GUERREAR	/gi/ GUITO	/gɔ/ GOLA	/go/ GOTA	/gu/ GULA
[ga]	**99% (4)**	1% (2)							
[gɐ]	2 % (3)	**94% (4)**			3% (2)				
[gɛ]			**90% (3)**	9% (3)	1% (2)				
[ge]			3% (3)	**89% (3)**	6% (2)	2% (2)			
[gɨ]			2% (3,5)	6% (2)	**92% (3)**				
[gi]				8% (2)	1% (2)	**91% (3)**			
[gɔ]							**94% (3)**	6% (3)	
[go]					1% (4)		2 % (3)	**50% (3)**	**47% (3)**
[gu]	1% (1)			1% (3)				4% (3)	**93% (3)**

*In capital letters, the Portuguese words presented in the grid; above, the correspondent phonemic notation of the first syllable.
Numbers in boldface represent the stimuli categorized above chance level (11,1%).
The rectangles mark the expected answer.

The results from the Control group show that [gV] syllables were identified with the expected target word, except for [go], which fell between /go/ and /gu/, due to a speaker effect. According to a $\chi2$ test run in all groups pooled, identification of [go] was affected by the identity of the speaker in general ($\chi2= 112.28$, $p < 0.001$), and $\chi2$ tests run on the three groups' data separately revealed that this effect was present in each group of participants (Control: $\chi2= 45.07$, $p < 0.001$, Table 4; ExpA, Table 5: $\chi2= 46.60$, $p < 0.001$; ExpB, Table 6: $\chi2= 21.38$, $p < 0.001$).

Table 5. Results for the ExpA group (Hungarian speakers with no previous contact with Portuguese)

auditory stimuli	Orthographic stimuli* /gaː/ GÁBOR	/gɒ/ GARÁZS	/gɛ/ GERELY	/geː/ GÉPÉSZ	/gi/ GITÁR	/go/ GONOSZ	/gø/ GÖRÉNY	/gu/ GULYÁS	/gy/ GÜGYÖG
[ga]	**95% (4)**	5% (3)							
[gɐ]	2% (1,5)		**65% (3)**				**31% (3)**	1% (2)	1% (4)
[gɛ]			**50% (2)**	**49% (2)**			1% (3)		
[ge]			3% (1)	**79% (4)**	**17% (3)**		1% (2)		
[gɨ]				3% (1)			**22% (3)**		**75% (3)**
[gi]				3% (1)	**97% (3)**				
[gɔ]		**69% (3)**				**31% (2,5)**			
[go]						**51% (3)**	1% (3)	**48% (3)**	
[gu]								**90% (3)**	10% (3)

*In capital letters, the Hungarian words presented in the grid; above, the correspondent phonemic notation of the first syllable.
Numbers in boldface represent the stimuli categorized above chance level (11,1%).
Rectangles in dashes mark the vowels targeted in the hypotheses.

Hungarian listeners with no previous contact with Portuguese (ExpA; Table 5) showed a bigger dispersion of responses in the identification of the target [gV] structure: 15 categories were chosen above chance level. For comparison, in the Control group, ten categories were used above chance level to identify the nine EP vowels.

The percent of identification of the vowel [ɐ] was split between /ɛ/ (65%) and /ø/ (31%), while /eː/ was never chosen. The identification of [ɨ] fell between /y/ (75%) and /ø/ (22%). The identification of [ɛ] was split between /ɛ/ (50%) and /e/ (49%) and the identification of [ɔ] fell between /ɒ/ (69%) and /o/ (31%). As mentioned above, in this group, similarly to what we observed in the Control group, identification of [o] was split between /o/ and /u/. As for [a], [e], [i] and [u], they were identified as /a/, /e/, /i/ and /u/, respectively, in a robust way.

As for goodness ratings, in group ExpA, most of the stimulus vowels had a high median value (3 and 4) reflecting a good fit of the category. There were only two exceptions: [ɛ] when identified as /ɛ/ and /e/, and [ɔ] when identified as /o/. Comparing these ratings with the ones made by the Portuguese native speakers, we observe an identical behavior, with most vowels being perceived as a "good example" of the chosen category.

Table 6. Results for the ExpB group (Hungarian students of Portuguese as a Foreign Language)

	Orthographic stimuli*								
auditory stimuli	/ga:/ GÁBOR	/gɒ/ GARÁZS	/gɛ/ GERELY	/ge:/ GÉPÉSZ	/gi/ GITÁR	/go/ GONOSZ	/gø/ GÖRÉNY	/gu/ GULYÁS	/gy/ GÜGYÖG
[ga]	**98% (4)**	2% (4)							
[gɐ]	2% (3)	2% (2)	**60% (3)**				**36% (3)**		
[gɛ]			**64% (2)**	**36% (2)**					
[ge]				**98% (3)**	2% (2)				
[gɨ]					2% (2)		**40% (2)**		**57% (3)**
[gi]				7% (3)	**93% (3)**				
[gɔ]		**64% (3)**				**36% (4)**			
[go]						**52% (3,5)**	5% (2)	**43% (3)**	
[gu]						**14% (2)**		**86% (4)**	

*In capital letters, the Hungarian words presented in the grid; above, the correspondent phonemic notation of the first syllable.
Numbers in boldface represent the stimuli categorized above chance level (11,1%).
Rectangles in dashes mark the vowels targeted in the hypotheses.

The results for the ExpB group (Table 6) were not very different from the ExpA group results. The identification of the vowel [ɐ] fell between /ɛ/ (60%) and /ø/ (36%), similar to what we have seen in group ExpA, but /eː/ was not picked by any of the participants. The identification of [ɨ] was split between /y/ (57%) and /ø/ (40%). The vowels [ɛ] and [ɔ] received responses for /ɛ/ (64%) and /e/ (36%), and /ɒ/ (64%) and /o/ (36%), respectively. The identification of [o] in ExpB followed the tendencies found in the Control group and in the ExpA group (as mentioned above). As for [a], [e], [i] and [u], they were also identified in a robust way, although the vowel [u] was categorized less consistently than in the ExpA group.

Regarding the goodness of fit evaluations, a tendency for high ratings was found in the ExpB group, with an exception in the perception of [ɛ] and [ɨ] as /ø/, and [u] as /o/.

6.2 Assimilation results

Previous perceptual assimilation studies considered criteria of 50% or 70% as the categorization threshold (Tyler et al. 2014; Faris et al. 2018). This means that to label a stimulus as "categorized", it must be associated with a given sound category at or above that threshold, whereas it is labeled as "uncategorized" if the association ratio falls below that threshold. In the current study, the application of one or the other criteria lead to considerable differences. If we applied a 50% threshold criterion, all the nine L2 vowels were designated as categorized. However, if we applied a 70% criterion, only five and four vowels were categorized by the ExpA and ExpB groups, respectively. Considering that only nine vowel categories were tested, a more stringent criterion – 70% – seemed appropriate for the present analysis. The assimilation patterns considering this criterion are shown in Table 7.

Table 7. Assimilation patterns using a 70% threshold criterion to designate 'categorized' (C) and 'uncategorized' (U) vowels

stimuli	ExpA	ExpB
[a]	C	C
[ɐ]	U	U
[ɛ]	U	U
[e]	C	C
[ɨ]	C	U
[i]	C	C
[ɔ]	U	U
[o]	U	U
[u]	C	C

6.3 Assimilation of [ɐ] and [ɨ]

With respect to [ɨ], the results confirmed our prediction: [ɨ] was assimilated as /y/ (75% and 57%) or /ø/ (22% and 40%), in the ExpA and ExpB groups, respectively, with a high median rating (3). Concerning the assimilation of [ɐ], we predicted that Hungarian listeners would assimilate it as /ɛ/, /ø/ or /eː/. The vowel /ɛ/ was more frequently identified as [ɐ] (60 and 65%, in ExpA and ExpB, respectively), followed by /ø/ (31% and 36%). In both cases, the median of the goodness ratings was 3. However, /eː/ was never chosen.

The first possible explanation for the exclusion of /eː/ in the identification of [ɐ] is that the recorded tokens used in the experiment were deviant from the standard Portuguese [ɐ] vowel. To investigate this possibility, we placed the [ɐ] and [ɨ] vowel tokens used in the experiment, as well as the [ɐ] and [ɨ] measured for Portuguese female speakers from Andrade (2020), in the F1×F2 vowel space as presented in the perception study of Kiss (1985) (Figure 5). For both the recorded [ɐ] tokens and the standard [ɐ], /ɛ/ seems to be the closer L1 category. However, the rejection of /e:/, but not /ø/, as possible candidates in the identification of [ɐ] is still left unexplained.

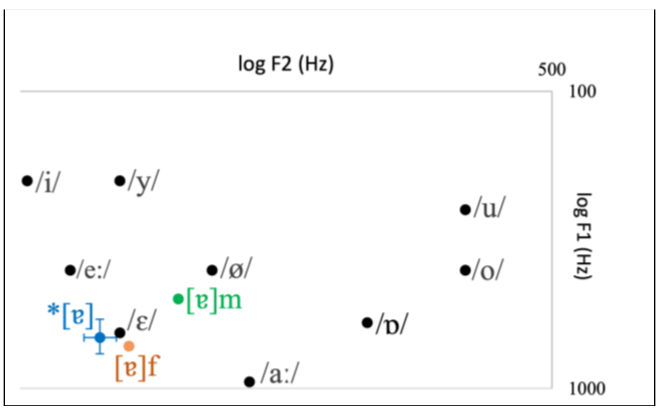

Figure 5. Hungarian perceptual vowel space (based on data retrieved from Kiss 1985; black font, between slashes) with production data of EP [ɐ] (colored fonts; in squared brackets).
*[ɐ]: the recorded tokens mean, with one SD; [ɐ]f: values measured for Portuguese female speakers and [ɐ]m: values measured for Portuguese male speakers, from Andrade (2020: 3251)

The second possible explanation we analyzed lies in the perceptual map we used to establish our hypotheses (Figure 3). Figure 5 shows that the Portuguese [ɐ] token we presented in the experiment is positioned on the bottom leftmost corner of this map, close to both /ɛ/ and /eː/, and that this location is approximately the same as in previous production data for female speakers (Andrade 2020). However, [ɐ] produced by male speakers in the same study is positioned right between the perceptual categories of /ɛ/ and /ø/, and much further from /eː/. On this basis, we may assume that listeners had a reference vowel space that is shifted down and to the left in comparison to the map we considered, in which map [ɐ] would be close to /ɛ/ and /ø/, but relatively far from /eː/. This would mean that the map we considered for our hypotheses is in fact a map for a larger (possibly a male) speaker, but the reference used by our participants was one that is adjusted to a shorter vocal tract, that is, to female production. This suspicion is further supported by the formant dispersion metric, that is, the average distance between each adjacent pair of formants. This is a simple but efficient indicator of body size (Fitch 1997). We calculated this metric in our present data and in the perception data of the study of Kiss (1985) as well, and results confirmed that formant dispersion is higher (1226 Hz) in the present experiment than in the perception data (1017 Hz), which is indicative of a larger (probably male) vocal tract in the perception study.

A complementary explanation lies in the fact that /ɛ/ and /eː/ comprise two competing categories. If this is the case, /ɛ/ can be the 'winning' category, first due to /ɛ/ being far more frequent in Hungarian language than /e/ (~27% against ~7,5% for [e:]; Gósy 2004: 87) and, second, due to the fact that in Hungarian the vowel quality of /e:/ exists as a long vowel exclusively. Since vowel length is contrastive in Hungarian, and thus speakers of Hungarian are sensitive to vowel duration, it is likely that the Portuguese [ɐ] token did not fit the duration criteria for a Hungarian long vowel. Furthermore, Portuguese [ɛ] was also not assimilated as /ɛ/ in a robust way: 50% and 64%, in the groups of ExpA and ExpB, respectively, and the median value for the ratings was only 2 in both groups. In contrast, [e] was assimilated consistently: 79% and 98% in the two groups of Hungarian speaking participants, with 4 and 3 as median values for the ratings. These results suggest that Portuguese [ɛ] was a deviant sound for the Hungarian listeners, which possibly lead them to choose this category for the non-native [ɐ].

6.4 Comparison between experimental groups

In a forced-choice identification task listeners must perform a categorical labeling. In our experiment we presented the labels orthographically to Hungarian listeners with none or with some contact with Portuguese. The orthographic stimuli consisted of words in the L1 of the participants; therefore, the task forced them to pick a native category, even in the case of the EP learners, where changes in the mapping of vowels could have occurred.

Presenting Portuguese words to the EP learners was not an option for two reasons. First, as opposed to Hungarian, Portuguese is not orthographically transparent, and the learners who took part of the experiment had only two semesters of classes, so they were far from mastering Portuguese orthography.[5] Second, a comparison on the exact same conditions between a moment '0' of acquisition (Hungarians without previous contact with Portuguese) and a moment during acquisition allowed us to observe categorization and recategorization of sounds, as we describe below.

When comparing the results of the naïve speakers (ExpA) and learners of Portuguese (ExpB), a difference between the identification of [ɐ] and [ɨ] was observable (Figure 6).

[5] Additionally, difficulties in the L2 orthography have been indicated by different authors as a critical methodological problem (Flege 2003, Elvin et al. 2014).

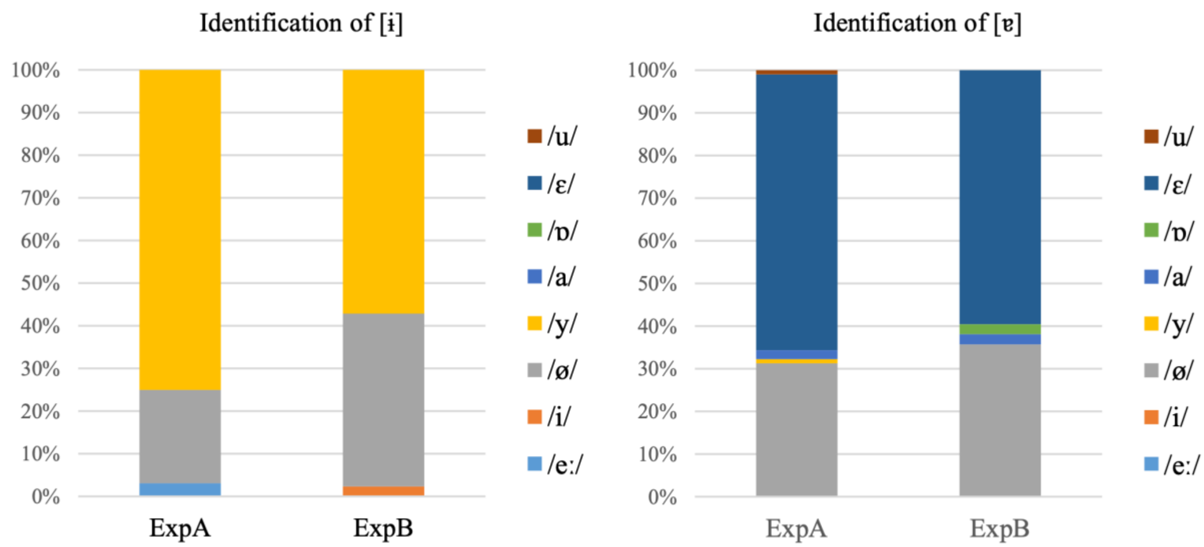

Figure 6. Comparison of identifications of [ɐ] and [ɨ] between ExpA and ExpB groups

Figure 6 shows different distribution of responses (i.e., identification rates) of [ɨ] in the two groups ($\chi2 = 8.61$, $p < 0.05$), but similar distribution of responses for [ɐ] (no significant difference between groups), suggesting a learning effect for [ɨ], but not for [ɐ]. Regarding identification of [ɐ], we observed an assimilation with an existing L1 category, /ɛ/, in both groups, which is probably due to the fact that two semesters of language learning are not enough to tune perception to a non-native vowel category, that is, to discriminate it from an existing native category, /ɛ/, and to create a separate category.

As for [ɨ], however, the differences in the results between naïve speakers and EP learners may indicate a perceptual tuning in Hungarian learners for the non-native [ɨ], as listeners of EP learner group seemed to be more aware of its position between /ø/ and /y/.[6]

6.5 Predictions for discrimination

The results of the forced-identification task allowed us to identify overlapping situations (i.e., cases where two L2 speech sound categories are mapped onto one L1 category), which can possibly cause problems in contrasts' discrimination. Focusing only on the vowels that are of particular interest in our study, and the present results, we can identify three overlapping situations.

In 50% of the cases, Portuguese [ɐ] and [ɛ] were both identified as the Hungarian /ɛ/ (Figure 7), but according to a Scheirer–Ray–Hare test run on the goodness ratings, Portuguese [ɐ] was a better example of Hungarian /ɛ/ (median = 3) than Portuguese [ɛ] (median = 2) in both groups of Hungarian speakers ($H(1, 158) = 7.96$, $p < 0.005$).

In 49% of the answers, Portuguese [ɛ] and [e] were both identified as the Hungarian /eː/, but according to a Scheirer–Ray–Hare test run on the goodness ratings again, [e] was a better example of the Hungarian vowel category at hand (median = 3), than [ɛ] (median = 2), in both groups ($H(1, 175) = 65.44$, $p < 0.001$) (Figure 8).

The last case is the overlap of the Portuguese [ɐ] and [ɨ], where there was a 22% chance of both vowels being identified as the Hungarian /ø/. Here, although we found a generally higher rating for [ɐ] (median = 3) than for [ɨ] (median = 2), statistical analysis of goodness ratings revealed that none of these Portuguese vowels was a better fit for the Hungarian vowel category in either of the listener groups (Figure 9).

[6] A similar perceptual tuning can be noticed with [ɛ]: while in ExpA the results show only a 50% identification as /ɛ/, in ExpB this value rises to 64%.

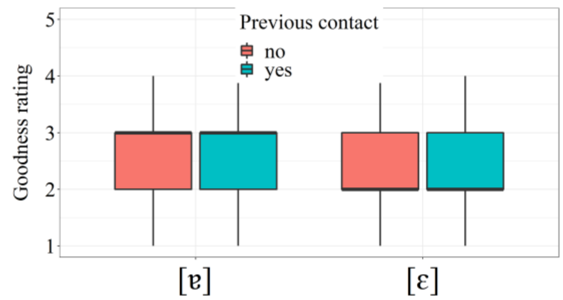

Figure 7. Goodness rating for [ɐ] and [ɛ] identified as the Hungarian /ɛ/ in the two groups of Hungarian listeners

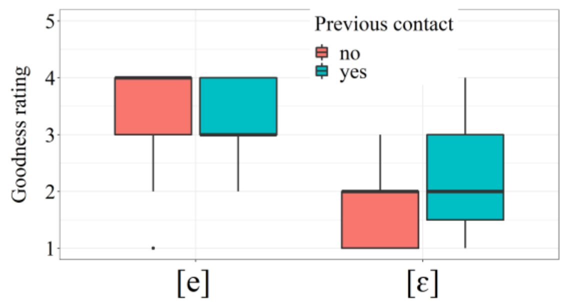

Figure 8. Goodness rating for [e] and [ɛ] identified as the Hungarian /eː/ in the two groups of Hungarian listeners

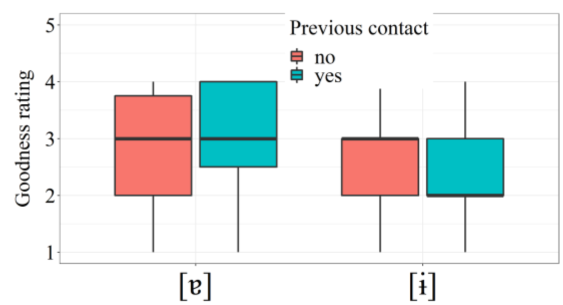

Figure 9. Goodness rating for [ɐ] and [ɨ] identified as the Hungarian /ø/ in the two groups of Hungarian listeners

In contrasts' discrimination scenarios, and based on PAM, we will have different possibilities (Figure 10).[7] In the discrimination contrast between the Portuguese vowels [ɐ] and [ɛ], according to PAM we have an uncategorized-categorized assimilation pattern (UC), which is a parallel situation of a category-goodness pattern, where one of the L2 sounds is a better fit to the L1 category than its contrasting par, and discrimination should be good or very good. In the present case, statistical analysis led to the conclusion that Portuguese [ɐ] was a better example of Hungarian /ɛ/ than Portuguese [ɛ].

A similar UC/CG pattern should occur in the discrimination of the [ɛ]/[e] contrast, since the Scheirer–Ray–Hare determined [e] to be a better example of the Hungarian vowel category at hand than [ɛ].

Finally, in the case of the contrast [ɐ]/[ɨ], results showed that there was only a 22% chance for an overlap between these segments, as [ɐ] was more often identified as /ɛ/ and [ɨ] as /y/. If the later situation occurs, we will have a two-category assimilation situation (TC), with a possibly excellent discrimination of the L2 contrast. However, when the overlap occurs, since the statistical analysis revealed that neither [ɐ]

[7] To test these scenarios, we are currently running an oddity discrimination task with Hungarian native speakers.

nor [ɨ] were a better fit for the Hungarian /ø/, we can expect a single-category assimilation (SC), with a problematic discrimination.

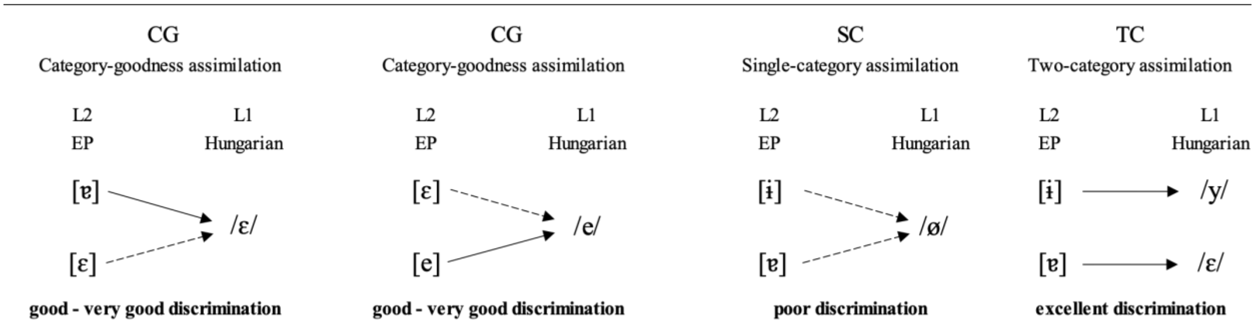

Figure 10. Predictions for contrasts' discrimination, based on PAM

7 Concluding remarks

This study is aimed at observing the assimilation patterns of the reduced EP vowels [ɐ] and [ɨ] by Hungarian native speakers, and some learning effect that may be present after some contact with EP. We predicted that the target vowels are assimilated to the nearest L1 category, namely [ɐ] is assimilated into the Hungarian /ɛ/, /eː/ or /ø/, while [ɨ] is assimilated into the Hungarian /y/ or /ø/ categories. We also predicted that [ɐ] and [ɨ] would show a different acquisition path. To test these hypotheses, we conducted a multiple forced-choice identification task with goodness ratings in two groups of Hungarian native speakers – a group without contact with the EP and a group of EP learners –, and a control group of EP speakers.

Results have partly confirmed our predictions, with [ɐ] assimilated into /ɛ/ or /ø/, but not into /eː/, and [ɨ] assimilated into /y/ or /ø/. The fact that /eː/ was never identified as [ɐ] is presumably due to factors involving vowel duration and the vowel's relative frequency in Hungarian.

As for the differences between the two experimental groups, we found an effect of exposure to Portuguese in the case of [ɨ] exclusively. This result suggests that two semesters of language learning is not enough for Hungarian speaking learners of EP to discriminate [ɐ] from [ɛ]. This difficulty can be related to an overlap between mapping of EP categories onto the listeners' L1 categories since both [ɐ] and [ɛ] tended to be assimilated into the Hungarian /ɛ/ in our experiment. This tendency presumably leads to discrimination problems and, consequently, to difficulties in tuning the perception of [ɐ] and creating a separate category for this vowel in the interlanguage of the Hungarian learners of EP.

With the present study, we hope to contribute to better understand difficulties in speech perception of EP by Hungarian learners and, more generally, also to a better understanding of L2 phonological acquisition. This way, we expect our work to help design theoretically and empirically grounded L2 teaching materials in the future.

Acknowledgments. The authors thank Alexandra Markó, Ana Afeto, Kornélia Juhász, Isabel Pessoa, Joana Silva, Olga Heitor, Susana Martins and Sónia Rebeca for the recordings, LABCC - Communication Sciences Laboratory of FCSH NOVA University of Lisbon, João de Matos, Petra Kovács and the Psychopy forum for the support in building the experiment. This research is supported by the Portuguese National Funding through the FCT – Portuguese Foundation for Science and Technology as part of the project of CLUNL, School of Social Sciences and Humanities, NOVA University Lisbon, 1069-061 Lisboa, Portugal (UIDB/LIN/03213/2020 and UIDP/LIN/03213/2020), a PhD individual grant from FCT (2020.05740.BD), Bolyai János Research Scholarship of the Hungarian Academy of Sciences, the ÚNKP-20-5 and ÚNKP-21-5 New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund, and the National Research, Development and

Innovation Office within the framework of the Thematic Excellence Program: “Community building: family and nation, tradition and innovation”.

References

Andrade, Amália. 2020. Vocalismo. In *Gramática do Português*. *Vol. III*, ed. Eduardo B. P. Raposo, Maria Fernanda. B. do Nascimento, Maria Antónia C. da Mota, Luísa Segura, Amália Mendes, and Amália Andrade, 3241–3330. Lisboa: Fundação Calouste Gulbenkian.

Audacity Team. 2020. Audacity(R): Free Audio Editor and Recorder [Computer application]. Version 2.4.2 retrieved September 2020 from https://audacityteam.org/.

Best, Catherine T. 1995. A direct-realist view of cross-language perception. In *Speech perception and linguistic experience: Issues in cross-language research*, ed. Winifred Strange, 171–204. Baltimore: York Press.

Best, Catherine T., Gerald W. McRoberts, and Elizabeth Goodell. 2001. Discrimination of non-native consonant contrasts varying in perceptual assimilation to the listener’s native phonological system. *Journal of Acoustical Society of America* 109(2): 775–794.

Best, Catherine T., and Michael D. Tyler. 2007. Nonnative and second-language speech perception: Commonalities and complementarities. In *Language experience in second language speech learning: In honor of James Emil Flege*, ed. Murray J. Munro, and Ocke-Schwen Bohn, 13–34. Amsterdam: John Benjamins.

Boersma, Paul, and David Weenink. 2020. Praat: doing phonetics by computer [Computer program]. Version 6.1.16, retrieved September 2020 from http://www.praat.org/

Bolla, Kálmán. 1995. *Magyar fonetikai atlasz. A szegmentális hangszerkezet elemei*. Budapest: Nemzeti Tankönyvkiadó.

Bundgaard-Nielsen, Rikke L., Catherine T. Best, and Michael D. Tyler. 2011. Vocabulary size matters: The assimilation of second-language Australian English vowels to first-language Japanese vowel categories. *Applied Psycholinguistics* 32(1): 51–67.

Correia, Susana, Joseph Butler, Marina Vigário, and Sónia Frota. 2015. A stress “deafness” effect in European Portuguese. *Language and Speech* 58(1): 48–67.

Edwards, Jette G. Hansend, and Mary L. Zampini, eds. 2008. *Phonology and Second Language Acquisition*. Amsterdam: John Benjamins.

Elvin, Jaydene, Paola Escudero, and Polina Vasiliev. 2014. Spanish is better than English for discriminating Portuguese vowels: Acoustic similarity versus vowel inventory. *Frontiers in Psychology* 5, Article 1188.

Escudero, Paola. 2005. *Linguistic perception and second language acquisition: Explaining the attainment of optimal phonological categorization.* Doctoral dissertation, LOT Dissertation Series (113), Utrecht University.

Faris, Mona M., Catherine T. Best, and Michael D. Tyler. 2018. Discrimination of uncategorised non-native vowel contrasts is modulated by perceived overlap with native phonological categories. *Journal of Phonetics* 70: 1–19.

Fitch, W. Tecumseh. 1997. Vocal tract length and formant frequency dispersion correlate with body size in rhesus macaques. *The Journal of the Acoustical Society of America*, 102(2): 1213–1222.

Flege, James Emil. 1995. Second language speech learning: Theory, findings, and problems. In *Speech perception and linguistic experience: Issues in cross-language research*, ed. Winifred Strange, 233–276. Baltimore: York Press.

Flege, James Emil. 2003. Assessing constraints on second-language segmental production and perception. In *Phonetics and Phonology in Language Comprehension and Production: Differences and Similarities*, ed. Niels O. Schiller, and Antje S. Meyer, 319–355. Berlin: Mouton de Gruyter.

Gósy, Mária. 1997. Semleges magánhangzók a magyar beszédben. *Magyar Nyelvőr* 121: 9–19.

Gósy, Mária. 2004. *Fonetika, a beszéd tudománya.* Budapest: Osiris.

Halácsy Péter, András Kornai, László Németh, András Rung, István Szakadát, and Viktor Trón. 2003. A szószablya projekt. In *I. Magyar Számítógépes Nyelvészeti Konferencia előadásai*, ed. Zoltán Alexin, and Dóra Csendes. Szeged: Szegedi Tudományegyetem Informatikai Tanszék.
Honbolygó, Ferenc, Andrea Kóbor, and Valéria Csépe. 2019. Cognitive components of foreign word stress processing difficulty in speakers of a native language with non-contrastive stress. *International Journal of Bilingualism* 23(2): 366–380.
Isbell, Dan. 2016. The perception-production link in L2 phonology. *MSU Working Papers in SLS* 7(1): 57–67.
Jenkins, James J., Winifred Strange, and Linda Polka. 1995. Not everyone can tell a “rock” from a “lock”: Assessing individual differences in speech perception. In *Assessing individual differences in human behavior: New concepts, methods, and findings*, ed. David J. Lubinski, and Rene V. Dawis, 297–325. Palo Alto, CA: Davies-Black Publishing.
Kiss, Gábor. 1985. A magyar magánhangzók első két formánsának meghatározása szintetizált hangmintákat felhasználó percepciós kísérlet segítségével. *Nyelvtudomány Közlemények* (87): 160–172.
Kuhl, Patricia K. 2000. A new view of language acquisition. *Proceedings of the National Academy of Sciences*, 97(22): 11850–11857.
Laczkó, Krisztina. 2020. A helyesírási hibák értékelése. In *Acta Universitatis de Carolo Eszterhazy Nominatae. Sectio Linguistica Hungarica*, ed. Zsófia Ludány, and Gyula Kalcsó, 61–80. Eger: Eszterházy Károly Egyetem.
Mangiafico, S. Salvatore. 2016. Summary and Analysis of Extension Program Evaluation in R, version 1.18.8. rcompanion.org/handbook/
Markó, Alexandra. 2017. Hangtan. In *Nyelvtan*, ed. András Imrényi, Nóra Kugler, Mária Ladányi, Alexandra Markó, Szilárd Tátrai, and Gábor Tolcsvai Nagy, 75–206. Budapest: Osiris Kiadó.
Oravecz, Csaba, Tamás Váradi, and Bálint Sass. 2014. The Hungarian Gigaword Corpus. In *Proceedings of the Ninth International Conference on Language Resources and Evaluation (LREC'14)* 2014: 1719–1723. Reykjavik, Iceland: European Language Resources Association (ELRA).
Peirce, Jonathan, Jeremy R. Gray, Sol Simpson, Michael MacAskill, Richard Höchenberger, Hiroyuki Sogo, Erik Kastman and, Jonas Kristoffer Lindeløv. 2019. PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods* 51(1): 195–203.
Peperkamp, Sharon, Inga Vendelin, and Emmanuel Dupoux. 2010. Perception of predictable stress: A cross-linguistic investigation. *Journal of Phonetics* 38(3): 422–430.
Pereira, Isabel. 2020. Acento de palavra. In *Gramática do Português*. *Vol. III* ed. Eduardo B. P. Raposo, Maria Fernanda. B. do Nascimento, Maria Antónia C. da Mota, Luísa Segura, Amália Mendes, and Amália Andrade, 3399–3425. Lisboa: Fundação Calouste Gulbenkian.
Polka, Linda. 1995. Linguistic influences in adult perception of non-native vowel contrasts. *The Journal of the Acoustical Society of America* 97(2): 1286–1296.
R Core Team. 2021. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/
Siptár, Péter, and Miklós Törkenczy. 2000. *The phonology of Hungarian*. Oxford: Oxford University Press.
Sokal, R. Robert, and F. James Rohlf. 1995. *Biometry: The principles and practice of statistics in biological research.* New York: W.H. Freeman and Co.
Tyler, Michael D., Catherine T. Best, Alice Faber, and Andrea G. Levitt. 2014. Perceptual assimilation and discrimination of non-native vowel contrasts. *Phonetica* 71: 4–21.

Appendix: Words presented in the grids

For the training task, for the Hungarian speakers:
TANÁR ['tɒnaːr] ‘teacher’
TÁBOR ['taːbor] ‘camp’

TEREM ['tɛrɛm] ‘room’
TÉTEL ['teːtɛl] ‘item’
TITOK ['titok] ‘secret’
TOJÁS ['tojaːʃ] ‘egg’
TÖMEG ['tømɛg] ‘mass’
TUDÁS ['tudaːʃ] ‘knowledge’
TÜKÖR ['tykør] ‘mirror’

For the main test, for the Hungarian speakers:
GARÁZS ['gɒraːʒ] ‘garage’
GÁBOR ['gaːbor] ‘proper name’
GERELY ['gɛrɛj] ‘javelin’
GÉPÉSZ ['geːpeːs] ‘machinist’
GITÁR ['gitaːr] ‘guitar’
GONOSZ ['gonos] ‘wicked’
GÖRÉNY ['gøreːɲ] ‘ferret’
GULYÁS ['gujaːʃ] ‘goulash’
GÜGYÖG ['gyɟøg] ‘to babble’

For the training task, for the Portuguese speakers:
TAPA ['tapɐ] ‘cover’
TAREFA [tɐ'ɾɛfɐ] ‘task’
TELA ['tɛlɐ] ‘canvas’
TEMA ['temɐ] ‘theme’
TERROR [tɨ'ʀoɾ] ‘terror’
TINA ['tinɐ] ‘bowl’
TOMA ['tɔmɐ] ‘take’
TODA ['todɐ] ‘every’
TUDO ['tudu] ‘everything’

For the main test, for the Portuguese speakers:
GATO ['gatu] ‘cat’
GAVETA [gɐ'vetɐ] ‘drawer’
GUERRA ['gɛʀɐ] ‘war’
GUÊ ['ge] ‘gee’
GUERREAR [gɨʀi'aɾ] ‘to fight’
GUITO ['gitu] ‘money’
GOLA ['gɔlɐ] ‘collar’
GOTA ['gotɐ] ‘drop’
GULA ['gulɐ] ‘gluttony’