DOI: http://dx.doi.org/10.31513/linguistica.2018.v14n2a17542
Recebido em: 02 de maio de 2018 | Aceito em: 23 de junho de 2018

Perceptual categorization of English vowels by native European Portuguese speakers

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RESUMO

Este estudo reporta os resultados de uma tarefa de assimilação percetiva, usada para avaliar o grau de semelhança inter-linguística entre os inventários vocálicos de português europeu (L1) e de inglês americano (L2), e, assim, prever dificuldades na perceção e produção de sons não nativos. Trinta e quatro falantes nativos de português europeu completaram uma tarefa de assimilação perceptiva, na qual identificaram vogais do inglês (L2) e do português (L1) de acordo com as categorias fonológicas da sua língua nativa, avaliando também a qualidade de representatividade categorial. Os resultados são discutidos partindo de dois modelos de perceção inter-linguística e aprendizagem de fala L2 (SLM, Flege, 1995, & PAM-L2, Best & Tyler, 2007).

Palavras-chave: Categorização percetiva. Semelhança inter-linguística. Vogais do inglês L2. Falantes nativos de português europeu.

ABSTRACT

This study reports the results of a perceptual assimilation task (PAT) used to assess the degree of perceived cross-language (dis)similarity between the vowel inventories of European Portuguese (L1) and American English (L2) and, thus, predict difficulty in the perception and production of non-native vowels. Thirty-four native European Portuguese speakers completed a PAT, in which they mapped both L2 English and L1 Portuguese vowels to native vowel categories and rated them for goodness-of-fit to L1 vowels. The results are discussed in terms of theoretical models of cross-language perception

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and L2 speech learning (SLM, Flege, 1995, & PAM-L2, Best & Tyler, 2007).

Keywords: Perceptual categorization. Cross-linguistic similarity. L2 English vowels. L1 native European Portuguese speakers.

Introduction

Cross-language research on second language (L2) speech learning has revealed that the perception of non-native vowel contrasts is highly challenging for adult L2 learners and "a significant part of the problems many L2 learners have in mastering the L2 phonology" (Strange, 2007, p. 36) mainly due to perceptual biases caused by cross-linguistic influence (CLI), that is, by the degree of perceived perceptual (dis)similarity between the L1 and L2 at both phonemic and phonetic levels. Bohn (2017) describes this relationship between the L1 and L2 speech sounds as "the mapping issue" (p.3), which may cause perceptual and production learning difficulty in the acquisition of the L2 phonological system.

A. Previous studies

Studies on English vowel perceptual categorization by native listeners of Romance languages with small vowel inventories such as Spanish (Aliaga-Garcia, 2010, 2017; Cebrian, 2006; Flege, Bohn, & Jang, 1997; Flege, Munro, Fox, 1994), Italian (Flege, MacKay, & Meador, 1999; Flege, & MacKay, 2004), and Portuguese (Major, 1987, Nobre-Oliveira, 2007; Rato, 2014; Rato, Rauber, Soares, & Lucas, 2013; Rauber, 2010) have shown that perceptual patterns in the identification of English vowels seem to follow, to a great extent, identical patterns across these languages due to their similar vowel inventories. For example, Flege & Mackay (2004) examined the perception of English vowels by 12 native Italian speakers in two experiments, an oddity discrimination task and a mapping task, which included goodness-of-fit ratings. The results of the discrimination task revealed that the group of Italian listeners had difficulty in the discrimination of English vowel contrasts /i/-/ɪ/, /ɛ/-/æ/ and /ɒ/-/ʌ/ and the mapping task showed that both members of the contrasts tended to be identified as instances of a single Italian vowel. English /ɛ/ and /æ/ were mapped to Italian /ɛ/; /ɒ/ and /ʌ/ to Italian /a/; and /i/ and /ɪ/ to Italian /i/. In another study by Flege (1991), 60 native Spanish speakers participated in three experiments, in which they were asked to identify the L2 English vowels /i/, /ɪ/, /ɛ/ and /æ/ as L1 Spanish vowels /i/, /e/, /a/, /o/, /u/ or as "none" if they heard a vowel segment that they thought was not found in Spanish in order to assess cross-language categorization of non-

native vowels. The pattern of mapping of L2 English vowels to Spanish vowels reported was the following: L2 English /ɪ/ was identified as L1 Spanish /i/, English /ɛ/ as Spanish /e/, and English /æ/ as Spanish /a/. In another study on the acquisition of English vowels by speakers with different first-language vowel systems, including L1 Spanish, one of the four experiments conducted by Iverson & Evans (2009) was an L2-to-L1 mapping task, in which participants rated how natural English vowels assimilated into their L1 vowel categories. The results of this task pertaining to native Spanish listeners revealed that L2 English /i/ was identified as L1 Spanish /i/ (100%); English /ɪ/ as Spanish /i/ (85%); English /ɛ/ as Spanish /e/ (96%); English /ʌ/ as Spanish /a/ (81%); English /**əʊ**/ as Spanish /o/ (100%); and English /u/ as Spanish /u/ (100%).

Cebrian, Mora, & Aliaga-Garcia (2010) also conducted a perceptual assimilation task to assess the degree of cross-linguistic similarity between the vowel systems of L1 Catalan and L2 English. The results showed that some of the L2 English vowels were consistently perceived as instances of an L1 category, with varying degrees of goodness-of-fit, namely English /ɪ/, /æ/ and /ɛ/ were identified as Catalan /i/, /a/ and /ɛ/ (> 90%) with goodness ratings between 4.6 and 7 in a continuous 7-point scale ranging from 1 (=same) to 7 (=different), and L2 English /eɪ/, /u/, /əʊ/, /ɔ/, /ʌ/ and **/ɪ/** were identified as Catalan /ei/, /u, /ou/, /o/, /a/ and /i/ (80-90%), respectively, with goodness ratings between 3.5 and 3.8. In L2 identification tasks, in which the L2 English vowels were categorized as English phonological categories, both Nobre-Oliveira (2007) and Rauber (2010) reported native Brazilian Portuguese listeners' difficulty in the identification of English vowels **/ɪ/, /æ/** and /ʊ/ and both authors explain the difficulty in discriminating /i-/**ɪ/, /ɛ/-/æ/** and /ʊ/-/u/ as being caused by bi-directional perceptual confusion in which the L2 vowels **/ɪ/, /æ/** and /ʊ/ were heard as Brazilian Portuguese /i/, /ɛ/ and /u/, respectively. However, these two studies did not conduct any L2-to-L1 mapping task, but rather L2-to-L2 identification tasks. Therefore, their results reveal difficulties with L2 vowel sounds, but do not make predictions regarding ease/difficulty in L2 vowel learning. In studies with native European Portuguese speakers, Rato et al. (2013), Rato (2014), and Rato & Rauber (2015) also reported difficulties in both perception and production of the English vowel contrasts /i-/**ɪ/, /ɛ/-/æ/** and /ʊ/-/u/. English vowels **/ɪ/, /æ/** and /ʊ/ were consistently identified as English /i/, /ɛ/ and /u/, respectively, and, in production, no distinction was made between the segments of each vowel contrast. These studies seem to indicate that participants with an intermediate proficiency level of English L2 were not able to establish phonemic categories for these non-native vowels that, although differing acoustically in terms of spectral quality and duration from corresponding vowels in the L1, are perceptually similar to native sounds. The high degree of perceived similarity between L2 and L1 front vowels seems to have led to the merging of two distinct L2 English vowel categories into one L1

category in production and perception. The findings indicate that the English phonological categories /ɪ/, /æ/ and /ʊ/ tend to be assimilated to the Portuguese vowel sounds /i/, /ɛ/ and /u/, respectively, and no distinction between the two vowels of each pair is made due to their acoustic and articulatory proximity and high degree of perceived cross-linguistic (L1-L2) phonetic similarity. However, these studies did not include any tasks to measure the degree of cross-language (dis)similarity between the English and the European Portuguese vowels and, thus, could not fully explain the reason for the difficulty in the phonological acquisition of these L2 English vowel contrasts.

Therefore, although there are a few studies that investigated the identification of English vowels by native Brazilian Portuguese (BP) and European Portuguese (EP) listeners, there is no research that examines the perceptual mapping of L2 English vowels onto native Portuguese vowels. Moreover, it is important to further investigate the perceptual patterns of native speakers of each language variety, since there might be acoustic and perceptual differences in terms of the vowel systems of each variety. Escudero, Boersma, Rauber, & Bion (2009) conducted a cross-dialect acoustic description of Brazilian (BP) and European Portuguese (EP) vowels and found differences between the two dialects in terms of vowel duration and height (F1). The results of the acoustic analysis revealed that BP has longer stressed vowels than EP, and the lower-mid front vowel approaches its higher-mid counterpart more closely in EP than in BP. Therefore, it is important to examine how native speakers of each variety map non-native vowels to Portuguese phonological categories so that specific perceptual and production difficulties can be predicted accurately.

As described by Bohn (2017), different methods have been used to assess degree of cross-language (dis)similarity in L2 speech research, including the comparative analysis of the phonetic symbols used to represent the phonological categories of the L1 and L2, and acoustic comparisons of the sounds of the L1 and the non-native language. However, both approaches have some limitations (see Bohn, 2017, for an overview). The comparative analysis of the phonetic symbols does not allow for a reliable prediction of learners' difficulties nor does it explain how listeners map the sounds of a non-native language to their native language, since the vowels transcribed with the same phonetic symbol do not always have identical phonetic quality and identical sounds may be transcribed with different symbols. The other method used widely is L1-L2 acoustic comparisons; however, it is difficult to determine which acoustic cues are perceptually relevant for listeners when mapping L2 sounds to L1 phonemic categories and to what extent these acoustic comparisons show the listeners' perception of the relationship between L1 and L2 sounds (Bohn, 2017). This seems to suggest that neither the comparison of L1-L2 phonetic symbols nor the acoustic comparisons of vowels are

reliable indicators of how L2 speakers categorize the sounds of the target language to the native language. Strange (2007) also concludes from her research on cross-language phonetic similarity of vowels that there are "marked discrepancies between acoustic comparisons and direct perceptual comparisons of L1/L2 similarity patterns", which indicates that acoustic comparisons may not predict perceptual assimilation patterns and may not fully account for ease/difficulty in the discrimination of L2 phonological categories. According to Strange (2007), in order to examine how L2 learners perceptually assimilate L2 segments to L1 phonological categories, the most reliable information on L1-L2 perceptual mappings is provided by direct measures of those assimilation patterns (p. 54). Two tasks have been used in research to measure the degree of perceived L2-L1 (dis)similarity, namely a perceptual assimilation task (PAT), in which listeners map the sounds of the L2 to L1 phonological categories and/or a rated discrimination task (RDT), in which perceivers compare L1 and L2 sounds and rate them in terms of degree of similarity (from 'very similar' to 'very dissimilar'). For the present study, a perceptual assimilation task was used because the rated discrimination task would require a very high number of vowel pair combinations (to elicit ratings on a set of six L2 vowels and corresponding L1 vowel set, produced in different phonetic contexts) which would not be sensible to present in one data collection session.

B. Theoretical L2 speech perception models

Strange (1995) uses the term "perceptual accentedness" (p. 22) to describe L2 adult speakers' difficulty in discriminating and categorizing L2 phonological categories due to cross-linguistic influence (CLI), which in turn may lead to inaccuracies in production, commonly termed "foreign accent". There are two existing models – the Speech Learning Model (SLM, Flege, 1995) and the Perceptual Assimilation Model (PAM & PAM-L2, Best, 1995 & Best & Tyler, 2007) - which propose that adult L2 speakers' phonological acquisition depends on their perceptual ability to perceive phonemic and phonetic (dis)similarities between the phonemes of the L1 and the target language (i.e., the perceptual correspondence between L1 and L2 phonemic categories). The models also claim that predictions on relative ease/difficulty in the perception of non-native sounds are based on how an L2 phonemic contrast is assimilated to L1 categories.

The SLM (Flege, 1995) proposes that native-like perception is a pre-requisite for accurate L2 production and learners' difficulty depends on how the non-native sounds are mapped onto L1 categories at the level of position-sensitive allophones (i.e., depends on the position that the L2 sounds occur). According to this model, L2 categories are "new", "similar" or "identical" in comparison to

the closest position-sensitive allophone in the L1: (i) an L2 sound is considered "new" when it has no counterpart in the L1, that is, when it differs from L1 phones; (ii) it is "similar" when it resembles an established L1 category, that is perceptually equivalent to an L1 sound; (iii) and "identical" when it is equivalent to an L1 category. The SLM predicts that the smaller the perceived cross-linguistic difference between L1 and L2 sounds, the higher the chances of perceiving an L2 category as an allophone of an L1 sound, and the less likely a new L2 category is to be established. If a new category is not formed for an L2 sound due to a high degree of perceived similarity to an L1 counterpart, the L1 and L2 categories will assimilate, leading to a merged L1-L2 category. Conversely, the greater the perceived cross-linguistic dissimilarity between an L2 sound and the closest L1 sound, the more likely the phonetic differences are to be perceived, leading to the establishment of a new category for the L2 sound. Nonetheless, according to Flege's model, the perceived relationship between L1 and L2 sounds may change given sufficient L2 experience.

The PAM-L2 (Best & Tyler, 2007), adapted from Best's PAM (1995), was developed to describe the perceptual assimilated patterns of non-native contrasts of experienced L2 speakers. PAM-L2 predicts the following perceptual assimilation patterns: (1) *two-category assimilation* (TC) occurs when two non-native phones are perceived as equally good exemplars of two L1 phonemes and discrimination is predicted to be excellent; (2) conversely, poor discrimination is expected when two non-native sounds are perceived as instances of the same native phoneme (SG – *single category assimilation*); (3) when the two non-native phones of a contrast are perceived as instances of the same L1 phoneme but one as a better exemplar than the other, intermediate discrimination between TC and SG is predicted (CG – *category-goodness assimilation*); in these assimilation cases, a new L2 phonemic category is likely to be established for the deviant L2 phone, while the L2 phone that is perceived as a better exemplar is likely to be perceived as equivalent to the L1 category, and hence no new category is formed for that member of the pair.

If one or both members of an L2 sound pair are very dissimilar from any L1 category, that is, non-existing in the L1, they are uncategorized in the L1 system. The PAM predicts (4) very good discrimination for categorized-uncategorized (UC) contrasts, (5) while discrimination of two uncategorized sounds (UU) depends on the extent to which each phone maps onto a distinct L1 category. Non-native sounds can be also perceived (6) as non-speech sounds if they have articulatory features that do not resemble speech sounds and, thus, are non-assimilable (NA).

In sum, both L2 speech perception models depart from cross-language (dis)similarity to predict

learners' perceptual ease/difficulty in the acquisition of non-native sounds and, therefore, direct measures of cross-language similarity are required to test the predictions of the models.

C. The European Portuguese and American English vowel systems

The American English (AmE) vowel inventory comprises four monophthongs (/i/, /ɪ/, /ɛ/, /æ/) and one diphthongized (/eɪ/) in the front vowel space, whereas the European Portuguese (EP) vowel system consists of three front vowels (/i/, /e/, /ɛ/) that differ in spectral quality and have intrinsic vowel duration differences (Escudero, Boersma, Rauber, & Bion, 2009). In the high back space, EP has one high back vowel (/u/) and AmE has two vowels (/u/ and /ʊ/) that differ both in quality and length. The set of English vowel contrasts, /i /-/ ɪ /; /ɛ/-/æ/; /u/-/ʊ/, which differ both in terms of spectral quality and duration, was selected because they are reported to present production and perception difficulties for adult native EP speakers, (Rato et al. 2013; Rato, 2014; Rato & Rauber, 2015). English /ɪ/, /æ/ and /ʊ/ tend to be identified as vowel sounds /i/, /ɛ/ and /u/, respectively, and no distinction between the two vowels of each pair is made due to their perceived acoustic and articulatory proximity.

Present study

The main objectives of the present study are (1) to assess cross-linguistic perceptual (dis) similarity between the American English (AmE) and European Portuguese (EP) vowel inventories; (2) investigate the assimilation of L2 English vowels /i/, /ɪ/, /ɛ/, /æ/, /ʊ/, /u/ to L1 Portuguese phonemes; (3) examine the extent to which the perceptual patterns observed in the mapping of L2 English vowel by native European Portuguese listeners are similar to those observed with native speakers of other Romance languages, and, with speakers of the Brazilian Portuguese variety; (4) discuss the results in terms of theoretical models of cross-language speech perception so as to make predictions regarding ease/difficulty in L2 English vowel learning by native European Portuguese speakers.

The research hypotheses for this study are the following:

RH1: The degree of perceived similarity between American English and European Portuguese vowels will vary depending on the L2-to-L1 perceptual correspondence, with "identical" vowels /i/, /ɛ/, and /u/ being consistently mapped to the corresponding Portuguese vowels /i/, /ɛ/, and /u/ and the "similar" vowels /ɪ/, /æ/, and /ʊ/ to Portuguese /i/, /a/, and /u/, respectively. It is hypothesized that the former set of English vowels (/i/, /ɛ/, and /u/) will be perceived as good exemplars of L1 phonological

categories, and no difficulty is expected in the perception of these 'identical' segments; conversely, it is predicted that the latter set of L2 vowels /ɪ/, /æ/, and /ʊ/ will be perceived as 'similar' to L1 vowel categories due to the high degree of perceived similarity between the L2 and L1 vowels, leading to L1-L2 merged categories.

RH2: It is hypothesized that the perceptual assimilation patterns will be, to a great extent, similar to those of native speakers of other Romance languages such as Italian, Spanish and Catalan, and to those of Brazilian Portuguese listeners, but differences will be also observed particularly with the low-mid vowel /ɛ/, which is closer to its high-mid counterpart /e/ in EP than in BP.

RH3: The degree of perceived cross-linguistic (dis)similarity will predict relative ease/difficulty in the learning of L2 English vowels, which will be attested by comparing the predictions with two experimental studies on L2 English vowel learning by native EP speakers.

Methodology

Participants

Thirty-four native European Portuguese speakers (17 women and 17 men), whose ages ranged from 17 to 32 years (Mean=19.06 yrs., SD=2.82) participated in this study. All of the participants were first-year university students, majoring in English at a Portuguese university, with a mean onset age of English learning (AOL) of 9 years old (SD=1.77, range=6-15 yrs. old) and a mean length of learning of 8.53 years (SD=2.05, range=9-13). The average level of English proficiency of 29 of the English learners (85.3%) was intermediate level (B1, Common European Framework of Reference for Languages, CEFR) and of the other five participants was upper intermediate (B2, CEFR), as assessed by an English proficiency placement test, which included four linguistic skills (reading, speaking, listening, and writing). No participants had ever lived in an English-speaking country, and no participant reported any speech hearing or speaking impairment.

Tasks

The experiment consisted of a cross-language perceptual assimilation task (PAT), in which participants listened to monosyllabic CVC (C=consonant, V=vowel) words with both the target L2 American English vowels /i/, /ɪ/, /ɛ/, /æ/, /u/, /ʊ/, and a distractor vowel /ʌ/ and the L1 EP vowels

/i/, /e/, /ɛ/, /ɐ/, /a/, /o/, /ɔ/, /u/ and categorized them as one of eight Portuguese oral vowels using a closed-set of eight orthographic response labels[2] <*i, ê, é, â, á, ô, ó, u*> and corresponding keywords <*si, pé, dê, da, dá, pôs, pós, tu*>, representing one of each of the EP vowels, respectively. Immediately after, participants were asked to rate category goodness-of-fit (GoF) of each vowel token in a 7-point Likert scale ranging from 1 (*poor example*) to 7 (*very good example*). The task, which included 246 stimuli, was preceded by a short training phase with 24 stimuli not included in the PAT, to familiarize participants with response buttons and ratings scale. Both English and Portuguese stimuli were included for control purposes. Each of the 34 participants responded to 246 tokens, for a total of 8 364 responses.

Stimuli

The natural stimuli were recorded by three native American English speakers (1 F and 2 M, mean age: 24 years old, SD=7.2) and three native European Portuguese speakers (1 F and 2 M, mean age: 29 years old, SD=10.15). The native AmE speakers were from Iowa, and Chicago, USA, but were living in Braga, Portugal, for less than six months at the time of recording, and the EP speakers were from the Minho region, and lived in the same city.

The stimuli consisted of CVC monosyllables, and the target vowels were presented between voiceless stop consonants: /pVt/, /tVt/, and /tVk/ to facilitate segmentation and minimize vowel duration variability. The 135 tokens (15 vowels x 3 phonemic contexts x 3 speakers) were presented twice in randomized order, totalling 270 stimuli, including the 24 tokens of the familiarization phase.

The words were embedded in the following carrier sentences 'I say (CVC) word again' (English) and 'Digo (CVCɨ) novamente' (Portuguese), which were preceded by a picture illustrating a word whose vowel rhymed with the vowel in the target word so as to elicit accurate productions. Orthographic accents were added to the Portuguese vowels <e> and <o>, for example*, têpe, tépe, tôpe, tópe,* to help native Portuguese speakers distinguish between /e/ and /ɛ/, and /o/ and /ɔ/, respectively. Each talker read the carrier sentences twice, at a normal speed, and volume, and with falling intonation, but only one production of each was included in the stimuli (based on auditory judgments and spectrographic analysis), resulting in 135 tokens (63 AmE tokens and 72 EP tokens). It is worth noting that although the recorded Portuguese words had the following syllabic structure

2 Since the orthographic depth of European Portuguese is, to a great extent, shallow (i.e., the phoneme-grapheme relationship is quite transparent), no anticipated ambiguities in the use of the orthographic labels were predicted.

CVCɨ, in accordance with European Portuguese syllabification, the target vowels were in the stressed syllable and the unstressed syllable with vowel [ɨ] in word-final position was manually truncated using Praat (Boersma & Weenink, 2018), whenever the vowel was phonetically realized so as to have identical EP productions to the AmE CVC stimuli. In order to truncate the unstressed vowel, the boundaries were selected at the first and last zero crossings, where the first positive and the last negative peaks could be seen, marking the onset and offset points of the vowel.

The recordings of both groups of native speakers were done individually in a sound-attenuated booth at the university, with a Roland R-26 digital recorder at a 44 Hz sampling rate, with 16-bit accuracy, and a unidirectional dynamic Sontronics STC-80 microphone. All the recordings were saved as wav sound files and normalized with a 0.99 peak intensity. Each recording session took approximately 10 minutes.

Procedures

The perceptual assimilation task was administered in a quiet computer lab at the university, and run in TP software, version 3.1. (Rauber et al., 2012) simultaneously on several computers. Each participant undertook the test individually and listened to the stimuli over headphones (NGS MSX6 Pro stereo). Instructions for the task were included in the computer experiment, in Portuguese, and available throughout the experiment, in case participants needed to check them. In addition, before starting, oral instructions were delivered to explain the procedures of the session and to give opportunity to participants to raise questions. The PAT took around 20-25 minutes to complete, but the experiment included three breaks (after the presentation of a set of 70 tokens).

After completing the task, participants completed a questionnaire, written in Portuguese, which included 24 questions to collect demographic information and information about their language(s) background.

Results & Discussion

The mean percentage of both L1 European Portuguese and L2 American English vowels' assimilation to L1 phonological categories and mean goodness-of-fit ratings were calculated (see Tables 1 and 2). The categorization and goodness-of-fit data were then combined into a fit index to provide a weighted measure of the L1-to-L2 mapping, following the same procedure as Guion, Flege,

Akahane-Yamada, & Pruitt (2000) (see Table 3).

Table 1. Mean percent identification of L1 European Portuguese vowels to L1 phonemes and goodness-of-fit ratings (in parentheses). Boldfaced values indicate the modal categorization response.

EP vowel stimuli	**Identified EP vowels**							
	/i/	**/e/**	**/ɛ/**	**/a/**	**/ɐ/**	**/ɔ/**	**/o/**	**/u/**
/i/	**100 (6.4)**							
/e/	10 (3.5)	**90 (5.4)**						
/ɛ/		9 (5.5)	**91 (6.1)**					
/a/				**99 (6.5)**	1 (2.8)			
/ɔ/						**97 (5.8)**	3 (3.2)	
/o/						4.2 (3)	**89 (6.2)**	6.8 (3.3)
/u/							8 (2.8)	**92 (6.4)**

The inclusion of the EP stimuli served as control to assess whether participants were consistent in their ratings and if identification responses were reliable. As shown in Table 1, a low degree of variability (i.e., inconsistency) was only found in the identification of the back vowels /o/ and /u/, and the front vowels /e/ and /ɛ/, caused by bi-directional confusion, by which one vowel was heard as its counterpart and vice-versa. Notwithstanding, the results revealed that EP listeners categorized the vowel stimuli accurately, providing baseline data, and that the participants were able to use the orthographic labels correctly.

Table 2. Mean percent assimilation of American English vowels to L1 European Portuguese vowels and goodness-of-fit ratings (in parentheses). Boldfaced values indicate the modal categorization response.

AmE stimuli heard	Assimilation to EP vowels							
	/i/	/e/	/ɛ/	/a/	/ɐ/	/ɔ/	/o/	/u/
/i/	**97 (5.5)**		1 (0.2)	2 (0.5)				
/ɪ/	**52 (4.5)**	43 (3.6)	5 (1.1)					
/ɛ/		8 (1.7)	**79 (5.1)**	13 (2.2)	1 (0.1)			
/æ/			28 (4.2)	**72 (4.7)**	1 (0.2)			
/ʌ/		1 (0.2)			**57 (4.2)**	18 (3.0)	3 (0.6)	23 (2.7)
/ʊ/					15 (2.1)		**54 (4.1)**	30 (3.6)
/u/							7.58 (1.5)	**92 (4.7)**

It can be observed that L2 English /i/ and /u/ were identified as L1 EP /i/ and /u/ consistently (> 90%), L2 English /ɛ/ and /æ/ were identified as EP /ɛ/ and /a/, respectively, with L2 vowel /ɛ/ being slightly more often identified as L1 /ɛ/ (79%) than L2 English /æ/ as L1 Portuguese /a/ (72%); the English distractor vowel /ʌ/ was categorized as EP /ɐ/ (57%); and L2 /ɪ/ and /ʊ/ were identified as L1 /i/ and /o/ much less consistently (52 and 54%). It is worth noting that both /ɪ/ and /ʊ/ were also assimilated to /e/ (43%) and to /u/ (30%), respectively, which are acoustically close sounds in the EP vowel space. The GoF scores show that, unsurprisingly, given the intermediate L2 proficiency level of the participants, EP listeners gave overall lower ratings to L2 American English vowels (4.1-5.5) than to L1 Portuguese phonemes (5.4-6.4), which indicates that participants perceived the L2 English vowel sounds as poorer exemplars of EP phonological categories than L1 vowel sounds. According to both SLM (Flege, 1995) and PAM-L2 (Best & Tyler), the greater the perceived cross-linguistic difference between L1 and L2 phones, the more likely the phonetic differences are to be perceived, leading to the establishment of a new category for the L2 sound. Therefore, a further analysis of both measures will help to rank the relative difficulty of the set of L2 English contrasts. The responses to the English vowel stimuli and the goodness-of-fit were combined into a single metric, the 'fit index'. For the three AmE vowels (/i/, /ɛ/ and /u/) that were consistently mapped onto one Portuguese vowel category (> 75%), the modal response was considered. For the other three AmE vowels (/ɪ/, /æ/,

/ʊ/) that were assimilated to two EP vowels, both were considered. The fit index[3] was calculated by weighting the mean goodness rating and the proportion of classification as a particular Portuguese vowel. For example, the fit index for vowel /i/ was calculated by multiplying the proportion of responses (0.97) receiving the modal categorization by the corresponding mean goodness rating (5.5), which resulted in a fit index of 5.3 for English /i/ to Portuguese /i/. The fix indexes calculated for the six Portuguese vowels are shown in Table 3.

Table 3. Fit indexes of English vowels in terms of Portuguese categories.
Fit indexes: *<2.4 – poor; 2.4-4.6 – fair; >4.6 - good*

English vowel	Most common ID	Proportion of ID	Goodness rating	Fit index	
/i/	/i/	0.97	5.5	5.3	good /i/
/ɪ/	/i/	0.52	4.5	2.3	poor /i/
	/e/	0.43	3.6	1.5	poor /e/
/ɛ/	/ɛ/	0.79	5.1	4.0	fair /ɛ/
/æ/	/a/	0.72	4.7	3.4	fair /a/
	/ɛ/	0.28	4.2	1.2	poor /ɛ/
/ʊ/	/o/	0.54	4.1	2.2	poor /o/
	/u/	0.30	3.6	1.8	poor /u/
/u/	/u/	0.92	4.7	4.3	fair /u/

The fix indexes were divided into three levels: less than 2.4 were considered poor exemplars of L1 categories; between 2.4 and 4.6 were considered to be fair instances of L1 vowel categories; and above 4.6 were good exemplars of native EP vowels. The target vowels with lower fit indexes were perceived to be dissimilar from L1 categories and thus it is more likely that learners will establish L2 categories for these segments. Conversely, the vowels with higher fit indexes were perceived as more similar to L1 phonemes, and thus the less likely a new L2 category will be created.

By analysing each of the L2 vowel contrasts, it is predicted that L2 vowel categories will be established for the *deviant* L2 segments /ɪ/ and /ʊ/, while the L2 segments that are perceived as better exemplars (/i/, and /u/) of L1 categories, are likely to be assimilated as equivalent to L1 categories /i/

3 The fit indexes provide a means to raise the identification scores considered good tokens of the vowel category and to lower the scores of identifications that were selected because they had no good competitors (Guion et al., 2000, p. 2723).

and /u/. The categorization of English contrast /ɛ/-/æ/ shows a slightly different pattern, because each vowel is mapped onto two different L1 phonemes (/ɛ/ and /a/) and both are considered fair instances of EP vowels, so two scenarios might occur: in the first, it is predicted that discrimination between the two phones will be good and, thus, new L2 categories will be formed. However, it is worth noting that /ɛ/ had both a higher frequency of consistent assimilation to EP /ɛ/ and a higher GoF than /æ/, so it is predicted that the establishment of a new L2 category will occur for /æ/ given more L2 English experience but not for /ɛ/.

According to PAM-L2 (Best & Tyler, 2007), the assimilation pattern of the three English contrasts by inexperienced L2 speakers would be cases of single category assimilation (SG), because both sounds would be equivalent to the same L1 phonological categories (/i/ and /u/), that is, /i/-/ɪ/, and /ʊ/-/u/ were expected to be heard as homophones. Therefore, learning to perceive a difference between single-category assimilated phones would depend on whether they were perceived as good or poor exemplars of the Portuguese categories. However, this pattern was not observed in this group of experienced L2 English speakers. Rather, according to the results of the PAT, patterns of category-goodness assimilation (CG) seem more adequate to describe the perceptual mapping of these L2 vowel contrasts, in which one of the members of the pair was heard as an instance of the native phoneme (/**ɪ**/, /ʊ/) but with low category goodness ratings, being thus considered the deviant exemplars of the pair. English /æ/ and /ɛ/ were perceived as fair instances of Portuguese /a/ and /ɛ/, although one of these two L2 sounds had a lower fit index, which suggests that it might have been perceived as a more deviant segment (/æ/) than the other (/ɛ/). Therefore, the prediction is that a new phonemic category is likely to be established for the deviant /æ/ given more L2 experience, while the L2 phone that was perceived as a better exemplar was likely to be perceived as equivalent to the L1 category /ɛ/ and no new category was expected to be formed.

According to these results, it is predicted that new L2 phonological categories for English vowels /ɪ/ and /ʊ/ will be established, more L2 experience will be needed to form L2 phoneme for vowel /æ/, and less likely a new L2 category will be formed for vowels and /i/, /ɛ/, and /u/ because they were perceived as allophones of L1 phonemes. Therefore, the rank of L2 vowel learning difficulty is predicted to be as follow (from easier to more difficult): /**ɪ**/>/ʊ/>/æ/. This order is directly linked with the predictability of establishment of L2 phonological categories, that is, it is predicted that the easiest L2 vowel to be created in the L2 phonological system of native Portuguese speakers is /**ɪ**/ and the most difficult /æ/, due to the degree of perceived cross-linguistic dissimilarity. As previously suggested, 'new' L2 categories will likely be created for /ɪ/, /ʊ/, and /æ/ due to their high degree of perceived

L1-L2 dissimilarity, but not for L2 'identical' vowels /i/, /u/, and /ɛ/ which were perceived as similar (i.e., allophones) to L1 vowel phonemes. However, within this set, predictions can also be made according to the reported fit indexes. Therefore, it is more likely that ease of perceptual discrimination and identification will follow the order (from the easiest to less easy): /i/>/u/>/ɛ/; consequently, due to their high degree of cross-language similarity, it is less likely that, given substantial L2 native input, an L2 category will be created for /i/ than for /ɛ/.

Research on the effects of perceptual training on the perception and production of English vowels by European Portuguese (Rato, 2014; Rato & Rauber, 2015) provides evidence of the 'learnability' of L2 vowels given intensive training (i.e., considerable native English input followed by immediate feedback). After five high variability perceptual training sessions, L2 participants learned to accurately discriminate and identify the English vowels of the three contrasts. Specifically, for vowel /æ/, Rato (2014) hypothesizes that "English /æ/ was perceptually differentiated from /ɛ/ and correctly assimilated as /æ/ because it is spectrally close to Portuguese /a/." However, in terms of production, only the high vowel contrasts (i/-/ɪ/, and /ʊ/-/u/) were produced without any overlap in the acoustic (F1-F2) vowel space after training. Despite perceptual "learnability" of vowels /ɛ/ and /æ/ after training, their production did not show any significant effect of training, with vowel /æ/ showing only a marginal improvement. Therefore, these two studies provide evidence that the measures of the perceptual assimilation task (PAT), which provide indicators of cross-linguistics (dis)similarity between L2 vowels and L1 phonemes, reliably predict relative ease/difficulty in L2 vowel learning.

By comparing the results of this study with the patterns of perceptual assimilation reported by previous studies, as expected, similarities were found, but also some differences.

English vowel **/ɪ/** was identified as the native vowel category /i/, as reported by Flege, (1991), and Iverson & Evans (2009) for Spanish, Flege & MacKay (2004) for Italian, and Nobre-Oliveira (2007), and Rauber (2010) for Brazilian Portuguese. However, it was also categorized as L1 /e/, as observed by Cebrian (2006) for Catalan. English vowel **/æ/** was categorized more often as native /a/ (Flege, 1991; Cebrian et al., 2010), but less as **/ɛ/**, contrary to the results reported by Nobre-Oliveira, (2007) and Rauber (2010) for Brazilian Portuguese. English /ɛ/ was categorized more consistently as native **/ɛ/** (Cebrian, 2006; Cebrian et al., 2010; Flege & MacKay, 2004), but rarely as vowel /e/ (Flege, 1991; Iverson & Evans, 2009), despite the low-mid vowel /ɛ/ being closer to its high-mid counterpart /e/ in EP than in BP. Regarding the back vowels, English vowel /ʊ/ was identified as Portuguese /o/ more often, similarly to the patterns described by Iverson & Evans (2009) and Cebrian et al. (2010)

for Spanish and Catalan, than as vowel /u/ as observed by Nobre-Oliveira (2007) and Rauber (2010) for Brazilian Portuguese.

As hypothesized, the perceptual patterns observed in the categorization of English vowels to native European Portuguese phonemes followed similar L2-to-L1 mappings reported for other L1 Romance languages (Italian, Spanish, Catalan), and for Brazilian Portuguese, but there were also some differences, particularly in the perceptual identification of vowels /ɛ/ and /æ/ by native Brazilian Portuguese speakers. However, it is worth noting that the studies with Brazilian Portuguese listeners only included L2-to-L2 identification tasks.

Conclusion

In order to examine perceived cross-linguistic (dis)similarity between AmE and EP vowels and the perceptual assimilation patterns of L2 vowels contrasts by European Portuguese listeners, and, therefore, predict relative ease/difficulty in L2 vowel learning, 34 Portuguese learners of L2 English completed a perceptual cross-language assimilation task (PAT), in which they were asked to identify the L2 vowel segments in terms of L1 vowel categories and then rate each segment for goodness-of-fit.

As hypothesized, the degree of perceived similarity between L2 American English and L1 European vowels depended on the L2-to-L1 perceptual correspondence, with "identical" AmE vowels /i/ and /u/ being consistently mapped to the corresponding Portuguese vowels /i/, and /u/ (<90%), and L2 vowel /ɛ/ slightly less consistently to EP vowel /ɛ/ (79%). The "similar" vowel /ɪ/, was categorized almost equally as a "poor" exemplar of both Portuguese /i/ and /e/, L2 vowel /ʊ/ was more frequently mapped as a "poor' instance of L1 /o/ (54%) than L1 /u/ (30%). AmE vowel /æ/ was more often assimilated to EP /a/ (72%) and considered a fair exemplar of the native vowel category.

It was predicted that the set of English vowels /i/, /ɛ/, and /u/ would be perceived as good exemplars of L1 phonological categories, which the results of the study confirmed to a great extent. The results indicated that vowels /i/ and /u/ were consistently perceived as instances of L1 vowel categories, with different degrees of goodness-of-fit, and vowel /ɛ/ was less constantly mapped to L1 /ɛ/ than the former vowels. It was also predicted that the set of L2 vowels /ɪ/, /æ/, and /ʊ/ would be perceived as similar to L1 vowel categories /i/, /a/, and /u/; however, the perceptual assimilation patterns of these segments showed some variability as previously described, particularly vowel /ʊ/,

which was more often categorized as EP vowel /o/.

The second hypothesis was confirmed since results of the perceptual assimilation patterns were, to a great extent, similar to those of native speakers of other Romance languages, and to those of Brazilian Portuguese listeners, but differences were also observed particularly in the identification of the front mid low contrast /ɛ/-/æ/. In both studies with Brazilian Portuguese learners, results showed that both vowels were identified as /ɛ/, which indicates a single-category (SC) assimilation pattern; however, the present findings suggest that the two vowels of this pair are assimilated to two different L1 categories revealing instead an intermediate phase between a category-goodness (CG) and a two-category (TC) assimilation pattern.

The third hypothesis proposed that the degree of perceived cross-linguistic (dis)similarity would predict relative ease/difficulty in the learning of L2 English vowels, which could be attested by comparing the predictions with two experimental studies on L2 English vowel learning by EP learners. The comparison of the findings of the present study with two perceptual training studies suggest that measures of direct perceptual assimilation provide reliable indicators of cross-linguistics (dis)similarity between L2 vowels and L1 phonemes, and consequently predict relative ease/difficulty in L2 vowel learning.

However, further research with the full set of English vowels and other measures of L1-L2 comparison are needed to further understand L2 vowel categorization by EP learners and design adequate perceptual tasks to promote L2 phonological learning. Future research should also analyse how the L1-L2 perceptual (dis)similarity patterns change as a function of learners' L2 experience by means of formal phonetic training and/or immersion experience.

REFERENCES

Aliaga-Garcia, C. (2010). Measuring perceptual cue weighting after training: A comparison of auditory vs. articulatory training methods. In K. Dziubalska-Kołaczyk, M. Wrembel, & M. Kul (Eds.), *New Sounds 2010: Proceedings of the Sixth International Symposium on the Acquisition of Second Language Speech* (pp. 2-7).

Aliaga-Garcia (2017). *The effect of auditory and articulatory phonetic training on the perception and production of L2 vowels by Catalan-Spanish learners of English* (Doctoral dissertation). Dept.

Modern Languages and Literatures and English Studies, University of Barcelona.

Best, C. (1995). A Direct Realist View of Cross-Language Speech Perception. In W. Strange (Ed.), *Speech Perception and Linguistic Experience: Issues in Cross Language Research* (pp. 171-204). Timonium, MD: York Press.

Best, C., & Tyler, M. (2007). Nonnative and second-language speech perception: Commonalities and complementarities. In O.-S. Bohn, & M. Munro (Eds.), *Language Experience in Second Language Speech Learning – In honor of James Emil Flege* (pp. 13-34). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Bohn, O-S. (2017). Cross-language and second language speech perception. In E. M. Fernández, & H. S. Cairns (Eds.), *Handbook of Psycholinguistics* (pp. 213-239). West Sussex: Wiley-Blackwell.

Cebrian, J. (2006). Experience and the Use of Duration in the Categorization of L2 Vowels. *Journal of Phonetics*, *34*, 372-387.

Cebrian, J., Mora, J. C., & Aliaga-Garcia, C. (2010). Assessing crosslinguistic similarity by means of rated discrimination and perceptual assimilation tasks. In K. Dziubalska-Kołaczyk, M. Wrembel, & M. Kul (Eds.), *New Sounds 2010: Proceedings of the Sixth International Symposium on the Acquisition of Second Language Speech* (pp. 77-82).

Escudero, P., Boersma, P., Rauber, A., Bion, R. (2009). A cross-dialect acoustic description of vowels: Brazilian and European Portuguese. *Journal of the Acoustical Society of America.* 126(3), 1379-1393.

Flege, J. (1991). The interlingual identification of Spanish and English vowels: Orthographic Evidence. *The Quarterly Journal of Experimental Psychology*, *43A*(3), 701-731.

Flege, J. (1995). Second Language Speech Learning: Theory, Findings and Problems. In W. Strange (Ed.), *Speech Perception and Linguistic Experience: Issues in Cross Language Research* (pp. 233-277). Timonium, MD: York Press.

Flege, J., Bohn, O.-S. & Jang, S. (1997). Effects of experience on non-native speakers' production

and perception of English vowels. *Journal of Phonetics*, *25*, 437-470.

Flege, J., MacKay, I., & Meador, D. (1999). Italian speakers' perception and production of English vowels. *Journal of the Acoustical Society of America*, *106*(5), 2973-4.

Flege, J., & MacKay, I. (2004) Perceiving vowels in a second language. *Studies in Second Language Acquisition*, *26*, 1-34.

Flege, J., Munro, M., & Fox, A. (1994). Auditory and categorical effects on cross-language vowel perception. *Journal of the Acoustical Society of America*, *95*(6), 3623-3641.

Guion, S. G., Flege, J., Akahane-Yamada, R., & Pruitt, J. (2000). An investigation of current models of second language speech perception: The case of Japanese adults' perception of English consonants. *Journal of the Acoustical Society of America*, *107*(5), 2711-2724.

Iverson, P., & Evans, B. G. (2009). Learning English vowels with different first-language vowel systems II: Auditory training for native Spanish and German Speakers. *Journal of the Acoustical Society of America*, *126*(2), 866-877.

Major, R. (1987). Phonological Similarity, Markedness, and Rate of L2 Acquisition. *Studies in Second Language Acquisition*, *9*(1), 63-82.

Nobre-Oliveira, D. (2007). *The Effect of Perceptual Training on the Learning of English Vowels by Brazilian Portuguese Speakers* (Doctoral dissertation).

Rato, A. (2014). Effects of Perceptual Training on the Identification of English Vowels by Native Speakers of European Portuguese, *Proceedings of the International Symposium on the Acquisition of Second Language Speech – Concordia Working Papers in Applied Linguistics,* 5, 529-546.

Rato, A., & Rauber, A. (2015). The Effects of Perceptual Training on the Production of English Vowel Contrasts by Portuguese Learners. *Proceedings of ICPhS 2015*. University of Glasgow, Glasgow, UK. http://www.icphs2015.info/pdfs/proceedings.html

Rato, A., Rauber, A., Soares, L., Lucas, L. (2013). Challenges in the perception and production of

English front vowels by native speakers of European Portuguese. *Diacrítica - série ciências da linguagem,* 28(1), 137-155.

Rauber, A. S. (2010). *Acoustic characteristics of Brazilian English vowels: perception and production results*. Saarbrücken: Lambert Academic Publishing.

Strange, W. (1995). Cross-language studies of speech perception: a historical review. In W. Strange (Ed.), *Speech Perception and Linguistic Experience: Issues in Cross Language Research* (pp. 3-45). Timonium, MD: York Press.

Strange, W. (2007). Cross-language phonetic similarity of vowels: Theoretical and methodological issues. In O.-S. Bohn, & M. Munro (Eds.), *Language Experience in Second Language Speech Learning – In honor of James Emil Flege* (pp. 35-55). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Software

Boersma, P., & Weenink, D. (2016). Praat: doing phonetics by computer (Version 6.0.21) [Software]. Retrieved from http://www.praat.org/

Rauber, A., Rato, A., Kluge, D., & Santos, G. (2012). TP (Version 3.1). [Software]. Brazil: Worken. Retrieved from: http://www.worken.com.br/tp_regfree.php