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A cross-linguistic study of L3 speech perception of voiced and voiceless stops

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Abstract

The study examines the perception of labial stops by English(L1)/Spanish(L2) [Group A] and Spanish(L1)/English(L2) [Group B] learners of French (L3). We investigate Cross-Linguistic Influence (CLI) processes of L3 speech perception by looking at how the previously acquired languages shape L3 perception (progressive CLI) and how an L3 affects the categorization of L2 and L1 sounds (regressive CLI). The possibility that L3 speakers have a single perception system for all languages was also examined. Participants had to identify stimuli from a VOT continuum as either /p/ or /b/, in different languages. Evidence of hybrid L1/L2→L3 progressive cross-linguistic influence was found for Group A and only L1→L3 for Group B. No patterns of regressive CLI were observed. Finally, it is not always the case that trilinguals make use of different perception systems when listening to L1, L2 and L3.

Keywords

third language acquisition; speech perception; cross-linguistic influence; labial stops; VOT

Estudi interlingüístic de la percepció d'oclusives sonores i sordes d'una L3

RESUM

L'estudi examina la percepció de les oclusives labials per part de dos grups d'aprenents de francès com a L3: parlants d'anglès(L1)/espanyol(L2) [Grup A] i parlants d'espanyol(L1)/anglès(L2) [Grup B]. Els processos d'influència interlingüística (CLI) en la percepció d'una L3 s'investiguen segons si les L1/L2 modelen la percepció de la L3 (CLI progressiva) i si l'L3 afecta la categorització dels sons de les L1/L2 (CLI regressiva). També s'examina si els parlants trilingües tenen un únic sistema de percepció per a totes les llengües o diversos. Els participants van identificar estímuls d'un continu de VOT com a /p/ o /b/, en diferents llengües. Es va trobar evidència d'una influència interlingüística progressiva híbrida L1/L2→L3 [Grup A] i L1→L3 [Grup B], i no es van observar patrons de CLI regressiva. Finalment, els trilingües no sempre utilitzen diferents sistemes de percepció per a les diferents llengües.

MOTS CLAU

adquisició d'una tercera llengua; percepció de la parla; influència interlingüística; oclusives labials; VOT

1. Introduction

The phenomenon of multilingualism has only been established as an area being researched systematically in linguistic studies over the last three decades (Wrembel et al., 2019). However, most experimental and theoretical third language (L3) studies have focused on morphosyntax and lexicon, whereas the area of phonetics and phonology has typically gained lesser attention (Gut, 2009; Wrembel et al., 2019). Furthermore, although research into L3 phonetic and phonological acquisition has gained momentum in the past decade (see e.g., Wrembel, 2023, for a review), there remains a significant lack of perceptual studies in this area of multilingual research.

The scope of investigations in L3 phonological studies is fairly broad as it ranges from segmental features including voice onset time (VOT) (e.g., Llama et al., 2010; Wrembel, 2011, 2015b; Wunder, 2011; Sypiańska, 2013; Llama & Lopez-Morelos, 2016; Gabriel et al., 2018; Geiss et al., 2022); vowel quality and quantity (Missaglia, 2010; Sypiańska, 2013, 2016; Kopečková et al., 2016); to suprasegmentals featuring speech rhythm and vowel reduction (Gut, 2009; Gabriel et al., 2015; Cabrelli Amaro, 2013, 2017); as well as global foreign accentedness (Wrembel, 2010, 2012; Lloyd-Smith et al., 2017; Lloyd-Smith, 2023).

L3 acquisition is influenced by a learner's first language (L1) and second language (L2), a phenomenon known as cross-linguistic influence (CLI) (Cenoz et al., 2001; Williams & Hammarberg, 1998). When the target language is simultaneously influenced by two or more languages or when it is influenced sequentially by a language that has already been affected by a prior language, combined CLI occurs (De Angelis, 2007). The combined CLI is a significant research topic in L3 phonological acquisition (Sypiańska, 2016; Wrembel, 2014) and its nature is closely related to the combination of prior languages. For instance, if the two prior languages share certain phonetic features, they will exert a "double interference" in L3 acquisition (Chamot, 1973). Cabrelli Amaro and Wrembel (2016) argue that while current findings in third language acquisition (TLA) research have generally demonstrated complex cross-linguistic influences between native and non-native languages, they do not fully explain the factors that determine or condition CLI in L3 speech. In an attempt to identify the factors involved in TLA, however, most studies on CLI have addressed progressive influence from the L1 and/or L2 to the L3 to the detriment of L3 regressive one (Cabrelli Amaro, 2017; Rothman et al., 2013). The term "regressive/backward" transfer (or influence) is employed in literature to indicate cross-linguistic influence exerted by a later learned on a previously acquired language (i.e., in situations where L3 affects the L2 and/or L1) (Cabrelli Amaro, 2017; Rothman et al., 2013). However, the findings are not always consistent and the reported mixed results can be attributed to various factors, such as the language combinations and their (psycho) typological relationships, the nature of the tasks, the number of participants, their language proficiency levels, the type of language acquisition, the level of education, and the context in which the languages are used.

Moreover, within L3 phonological research, production studies seem to have dominated the field, while a relatively smaller number of studies have dealt with cross-linguistic perception in L3 (e.g., Kopečková, 2015; Liu, 2016; Liu et al., 2019; Liu & Lin, 2021; Luo et al., 2020; Onishi, 2016; Balas et al., 2019; Nelson, 2020; Wrembel et al., 2019). What is more, among L3 speech perception research an even smaller number of studies investigated voice onset time (VOT) (eg. Liu, 2016; Liu et al., 2019; Liu & Lin, 2021). Another source of complexity in L3 research design stems from the distinction between transfer and cross-linguistic influence (CLI). In their keynote article, Schwartz and Sprouse (2021) advocate for greater precision in conceptualization and design of L3 research. They propose using "transfer" specifically to denote the adoption of a prior-language grammar at the initial stage, while "cross-linguistic influence" encompasses any influence from prior languages throughout the course of L3 development, including effects triggered by extra-linguistic factors. The authors suggest refocusing research goals to either examine transfer at the initial stage or explore the process of L3 development. They underscore the effectiveness of adopting a mirror-image L1-L2 research paradigm to provide clearer evidence of which prior languages influence L3 acquisition.

The aim of the study is twofold. First of all, to date, despite the abundance of studies on cross-linguistic research, few studies have centered on comparing Spanish, English and French VOT perception patterns with empirical data. Hence, this study aims at presenting a comparison between the perception of bilabial stops in these three languages. Another main purpose of this study is to examine both progressive influence from L1 and/or L2 on L3 and regressive influence of L3 on L1 and/or L2 in trilinguals' perception systems.

2. Background

2.1. Progressive and regressive L3 influence

The main two kinds of linguistic transfer, progressive or forward transfer (L1 → L2) and regressive or backward transfer (L2 → L1) are used rather conventionally in the Second Language Acquisition (SLA) literature (e.g., Gass et al., 2013). These terms could be applied to the acquisition of third or additional languages, as long as the sequence of acquiring L1, L2, L3, and subsequent languages is clear and significant (Wrembel, 2015a).

In the L3 phonology field, production studies have dominated, while a relatively smaller number of studies have dealt with cross-linguistic perception in L3. These recent investigations indicate that the phonological space of multilinguals seems to be reshaped relatively early in the course of learning the new L3, and that category boundaries can be expanded to accommodate L1, L2, and L3 categories of similar phonetic types, while new L3 categories for novel phonetic types may be formed. When it comes to progressive transfer, research recorded main transfer from the L2 to the L3 (Cal & Sypiańska, 2020, on vowels; Gut, 2009, on production of vowel reduction and speech rhythm; Geiss et al., 2022, on VOT production; Luo et al., 2020, on perception of vowel length); from L1 onto L3 (Zhang & Levis, 2021, on the production of /n/ and /l/ contrast; Sypiańska, 2022, on the production of laterals; Llama & Cardoso, 2018, on VOT production); or L1 and L2 or hybrid L1/L2 transfer both in production (Kopečková, 2014, on rhotic sounds; Liu & Lin, 2021, on stop contrasts; Llama et al., 2010 and Llama & López-Morelos, 2016, on VOT; Patience & Qian, 2022, on the tap/trill contrast; Parrish, 2022, on VOT; Sypiańska, 2016, on vowel articulation; Wrembel, 2010, on foreign accent; Wrembel, 2015a, on VOT) and perception studies (Liu et al., 2019, and Liu & Lin, 2021, on VOT; Onishi, 2016, on both vowels and consonants; Wrembel et al., 2019, on vowels). However, Grünke and Gabriel (2022) found that neither L1 nor L2 transferred onto L3 production in terms of intonational patterns.

Previous studies have also investigated various factors that contribute to cross-linguistic transfer in L3 phonological acquisition. These factors include the L2 status (Llama et al., 2010; Parrish, 2022; Wrembel, 2010), experience with the L2 or L3 (Llama & López-Morelos, 2016; Luo et al., 2020), typological proximity between languages (Liu et al., 2019), and the level of proficiency (Cal & Sypiańska, 2020).

As seen, the majority of L3 phonological studies has mainly focused on the progressive kind of cross-linguistic influence. However, CLI also occurs the other way around, namely from a later learned language onto an earlier one. In fact, several L2 phonology studies conducted in this line of thinking have suggested that the development of a new language system, even in low proficiency instructed learners, will impact the L1 phonology to some degree (Schmid & Hopp, 2014). With three or more languages in the mix, much more complex and diverse patterns of mutual interaction are conceivable for multilingual learners in comparison to those who are only learning their first non-native language. One of the important questions with regard to regressive influence in multilingual learners is what factors condition this form of CLI and which of a learner's languages are more susceptible to it than others. To date, there are few studies that had regressive CLI in L3 phonological acquisition as their focus. A number of them focussed on L3-induced changes to the speakers' L2 only (Aoki & Nishihara, 2013, on VOT production); on L3 as a source of regressive CLI for the other languages, the main question being whether it (rather) influences L1 or L2 (Beckmann, 2012, on VOT production; Cabrelli Amaro, 2017, on vowel reduction in production and perception); or on of all possible kinds of regressive CLI, so including L3 influence onto L1 and L2 as well as L2 onto L1 (Liu, 2016, on VOT perception and production; Nelson, 2020, on VOT production; Sypiańska, 2016, on vowel articulation). In the few L3 studies conducted in this line of inquiry, the effect of language status is discussed frequently. Although their findings are somewhat mixed and exhibit much individual variation, there seems to be a tendency for more L3→L2 than L3→L1 influence. For example, Aoki and Nishihara (2013) found facilitative L3→L2 influence (despite relatively low L3 proficiency), leading to better performance than controls without L3. Liu (2016) reported a similar type of influence in the production tasks while CLI from L2/L3→L1, but no CLI from L3→L2 was found for perception. Moreover, Beckmann (2012) also reported L3→L2 influence in frequent L3 users only while no evidence for L3→L1 was found. An opposite result was obtained by Sypiańska (2016) in which the only direction of CLI that was not observed is from L3 to L2 (while L2→L1 and L2/L3→ L1 effects were observed in the tested groups). Further evidence for L2→L1 transfer was also found by Llama and Cardoso (2018): while it was not authors' intention to focus on regressive transfer, they found evidence of the impact of learning an L2 on the L1 which holds not only for learners immersed in an L2 setting, as could be expected, but also for speakers who live in their L1 environment, although to a lesser extent.

To summarize, findings concerning progressive and regressive CLI in multilingual speakers, show somewhat mixed results while the existing studies differ in the phonological features and language triads under investigation, but also in their research designs, making it difficult to draw generalizations or formulate predictions concerning phonological CLI in trilinguals.

2.2. Target Structure: VOT in Spanish, English and French

One way to approach CLI on L3 phonology in perception is to target specific phonological features rather than phonological contrasts (although one thing does not exclude the other). This is due to the fact that accurate perception of a phonological contrast is always based on the efficient use of a distinctive phonological feature (i.e., a distinct phonetic property that is either present or absent in the sounds making up the contrast). By using such features (e.g., lip rounding, nasalization, voicing, aspiration, etc.) in the languages spoken proficiently, learners become sensitized to them and can effectively use them in perception, so that the features become available for subsequent languages that are learned.

Voice Onset Time (VOT) is considered to be the most salient cue differentiating the language-specific realizations of plosives and it refers to the interval between the release of the stop and the onset of voicing (Lisker & Abramson, 1964). There exist three different types of VOT: 'voicing lead' or 'prevoicing' (voicing starts before the closure release of the stop consonant), 'short voicing lag' (voicing begins with the release or shortly after it, 0-30ms), and 'long voicing lag' (voicing starts after the release: >30ms).

Many of the world's languages distinguish two categories of stops, voiced and voiceless which, depending on the language, are associated with different types of VOT. Even though English, Spanish and French are all languages with two categories, namely a two-way stop contrast, they implement all three voice onset timing explained above: 1) voiced and unaspirated: voicing begins before release, i. e. voice lead VOT; 2) voiceless and unaspirated: voicing starts just after the release, i. e. short lag VOT; 3) voiceless and aspirated: voicing lags behind the release, i. e. long lag VOT (Lisker and Abramson, 1964).

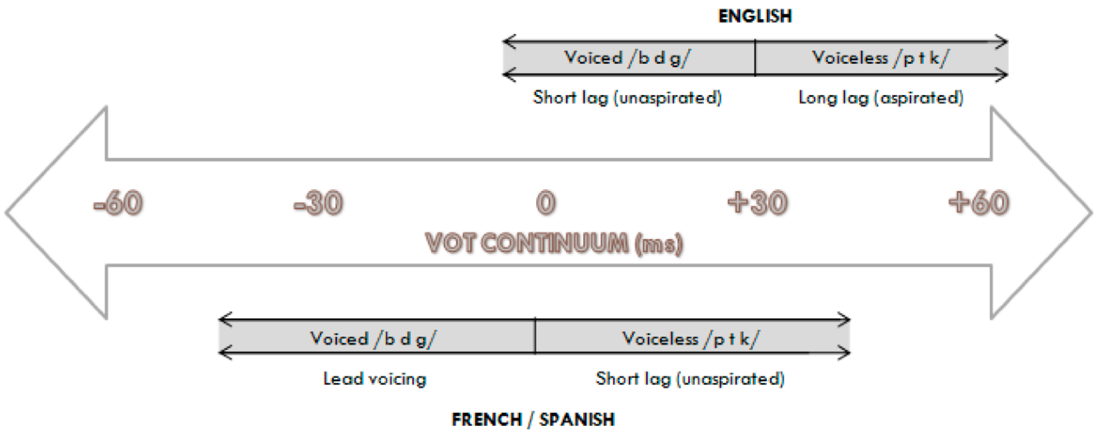

Figure 1. VOT in English, French and Spanish.

In French, as in Spanish, voicing lead characterizes voiced stops /b d g/, and short voicing lag (with VOT values defined as <30ms) characterizes voiceless stops /p t k/. In English, voiceless stops present aspiration in word initial position and thus, have a long lag VOT value. Voiced stops in the same position, however, have short lag VOT value. Ladefoged and Keith (2011) stated that the word-initial /p t k/ in English are voiceless aspirated sounds and that the key difference between /p/ and /b/ is not voicing but aspiration. Figure 1 shows a classification of stops in terms of VOT in these three languages.

2.3. L3 acquisition of stops

Quite a few studies to date have explored patterns in the acquisition of L3 stops (Aoki & Nishihara, 2013; Beckmann, 2012; Geiss et al., 2022; Llama et al., 2010; Llama & López-Morelos (2016); Llama and Cardoso, 2018; Liu, 2016; Liu & Lin, 2021; Liu et al., 2019; Nelson, 2020; Parrish, 2022; Wrembel, 2015a). Although these studies shed some light on the cross-linguistic influence in phonological acquisition through examining the VOT patterns in stops across languages, reported findings are mixed and therefore the breadth and depth of research in this area need to be expanded.

Among the production studies, research carried out by Parrish (2022) and by Llama and colleagues are of particular relevance to the present investigation, given the language combination taken into consideration. Llama et al. (2010) examined the VOT production in onset stressed position of L3 Spanish learners who differed in their L1 and L2, either French or English. All the participants were found to have a higher proficiency in their L2 than L3 by a vocabulary test. The data for L3 production did not show a positive effect of L2 status while the comparison of L2 and L3 production suggested a combined effect of L1 and L2. Llama and López-Morelos (2016) analyzed the characteristics of stop production in L3 French as produced by learners who speak Spanish as a heritage language (HL) along with (Canadian) English. The authors found target-like production in both of their subjects' background languages, but no positive transfer from the HL Spanish to the target language, French, as one might expect against the backdrop of the similar patterns of stop production in the two languages. Instead, participants appeared to have created a hybrid value for /p/, as participants from previous L3 studies have done for all voiceless stops (Wrembel, 2015a). Llama and Cardoso (2018) examined VOT production in the L3 Spanish of L1 English–L2 French and L1 French–L2 English adults. For both groups, prevailing influence from L1 was observed. Moreover, evidence of regressive transfer of L2 on the L1, which holds not only for learners immersed in an L2 setting but also for speakers who live in their L1 environment, was also found.

Parrish (2022) examined the production of L3 French words containing word-initial voiceless plosive consonants by Spanish–English bilinguals and Spanish monolinguals who had no prior knowledge of the L3. The results of generalised mixed-effects models revealed that L3 French productions by the bilingual group fell between L1 and L2 values, and provided evidence that the bilingual group experienced influence from both their L1, Spanish and their L2, English, while the monolingual group produced the French as a Spanish-like short-lag. The findings indicate that there is individual variability in the initial productions of a third language, with speakers simultaneously influenced by both L1 and L2 phonology. However, the extent of language-specific influence varied; some participants exhibited strong L1 influence on their L3 French production, while others produced hybrid values influenced by their L2.

Finally, there are only few perception studies which investigated VOT patterns in trilinguals. Liu (2016) compared 2 groups of L1 Chinese, L2 English speakers (residing in Spain): a group with a high competence of L3 Spanish and another group without any L3 instruction. Results showed regressive CLI from L2/L3→L1 (both groups had different L1 perceptual boundaries than the monolingual control group), but not L3→L2 (no difference between the experimental groups). Liu et al. (2019) explored L1 Chinese students' perception of voiced and voiceless stops in their third language. The participants were Japanese, Russian, or Spanish major university students, who were beginner learners of these languages but who had all learned English as their second language for over 10 years. The main findings highlighted learners' accuracy in perceiving L3 voiceless stops as being closely related to the range and spread of VOT values. Japanese voiceless stops have a relatively large mean VOT and spread, so Chinese learners were able to use the VOT value to help distinguish between voiced and voiceless stops, while Russian and Spanish voiceless stops have a VOT range that is smaller than 30ms and a small spread and therefore cannot be utilized as an effective cue to the voicing feature for Chinese learners. The authors also suggested that in the early stage of L3 phonology acquisition, learners have not yet established the L3 phonemic categories in perception and therefore they are very likely to make use of over-simplified cross-linguistic mapping to perceive the phonemes. When the acoustic parameter representing different phonemes is similar among L1, L2, and L3, learners tend to experience perceptual confusion about phonemes and show poor performance.

Liu & Lin (2021) tested L1 Chinese/ L2 English/ L3 Russian or Spanish university students. Their results demonstrate that the participants were likely to equate voiceless stops in L3 with the L1 voiceless unaspirated stops and L2 voiced stops, causing difficulties in their perception of L3 voiceless stops. Instead, they were better able to perceive the differences in voiced stops between L3 and L1 or L2 since the pre-voicing feature of word-initial stops was basically absent in their L1 and L2 while being present in their L3. Thus, they performed better in perceiving voiced stops than voiceless stops in the L3.

To our knowledge, there are no perception studies investigating VOT patterns within trilingual speakers of Spanish, English and French. Following the issues reviewed in the previous sections, and in order to account for both progressive and regressive types of influence, the general research questions addressed in this study are:

a) To what extent do L3 learners differ from monolinguals in terms of their perception of the stop voicing contrast in their L1/L2/L3?
b) To what extent do English/Spanish/French and Spanish/English/French learners' perception differs when tested in the same previously acquired language?
c) Do trilinguals exhibit different /b/–/p/ contrast perception when tested in L1, L2 and L3?

3. The study

Twenty-five main informants divided into two groups took part in the study. The first group, henceforth Group A (L1 English), was made up of twelve native speakers of British English with a high command of their L2, Spanish who were living in Northern Spain. The second group, henceforth Group B (L1 Spanish), consisted of thirteen native speakers of Peninsular Spanish with an advanced knowledge of their L2, English, living in their L1 Spanish environment. Both groups were intermediate learners of L3 French. Table 1 presents the characteristics of both groups.

Five English monolinguals (Group E), five Spanish monolinguals (Group S) and seven French monolinguals (Group F) served as control groups and participated in the perception test. They had reported little knowledge of other languages and insignificant experience in other foreign countries.

Participants were asked to fill out a Language Background Questionnaire. The answers obtained served two main purposes: they ensured the participants' suitability in terms of number and order of acquisition of the languages they spoke, and provided a first measure of proficiency (self-assessed), since the informants were asked to self-rate their proficiency in their L2 and their L3. The second measure of proficiency in the participants' two non-native languages came from three Vocabulary Size Tests, one for each language. Proficiency in English was tested using *LexTALE* (Lemhöfer & Broersma, 2012). Spanish proficiency was assessed using *Lextale-Esp* (Izura et al., 2014), while proficiency in French was tested using *Lextale_FR* (Brysbaert, 2013).

In order to answer the above research questions, we designed three different identification tasks, one for each language. Our choice of employing three different tasks (with three different sets of stimuli) lies in the need to evaluate the perception of VOT in different languages, which required as natural and language specific stimuli as possible, especially concerning vowels. Therefore, the CVC stimuli consisted of bilabial stops (/b/ or /p/) + vowel (/æ/ for English, /a/ for Spanish and French) + fricative /s/ CVC syllables forming a /bæs/ (/bas/) - /pæs/ (/pas/) VOT continuum, from -60 to +60 ms VOT in 10 ms steps. The endpoint stimuli of each continuum and the 0 VOT stimuli were based on natural productions of the target syllable rather than on synthesized stimuli and were elicited from a trilingual high proficient male speaker of English, Spanish and French. Since we aimed at giving participants equal chances of using their entire speech perception spectrum (in other words, the features that all previously acquired languages present), the English continuum started with negative VOT stimuli (voicing lead) and the Spanish and the French tokens comprised long lag VOT stimuli (aspiration).

The intermediate steps were synthetized using *STRAIGHT* (Kawahara, 2018), a speech analysis, modification, and synthesis system that is widely used in the speech research community. We created two continua, one from aspirated to unaspirated (using the +60ms and 0ms VOT naturally produced stimuli as endpoints) and then from unaspirated to pre-voiced (that ranged from the 0ms to the -60ms VOT tokens). Finally, we merged the two sub-continua into a unique continuum that ranged from -60ms to +60ms in steps of 10ms, for a total of 13 stimuli.

	Group A	**Group B**
Age	23.5 (1.2)	22.0 (1.4)
L2 Learning (years)	13.5 (1.5)	12.3 (1.4)
L3 learning (years)	8.5 (0.9)	8.0 (0.7)
Months in L2 speaking country	14.9 (1.4)	2.9 (0.3)
Months in L3 speaking country	<1 month	<1 month

Table 1. Background information of main participants: M (SD).

The perception experiment involved three identification tasks, one for each language. The software used to design and perform the tasks was PsychoPhy (https://www.psychopy.org/). Each task was a two-alternative forced choice task. Each stimulus (in each task) was set to play eight times randomly and in total there were 104 stimuli for identification in each task. In order to make sure that participants rely on their speech perception only when performing the three tasks, particular attention was given to the layout of the tasks which were delivered in the form of a game in which two characters were presented on a computer screen. The two characters were different for each task and were given the names BAS and PAS. Participants were seated in front of a laptop computer equipped with high-quality headphones and a mouse. They were instructed to first listen to the two characters introducing themselves and successively, when hearing one of the two characters' name, to click on the picture of the character whose name they heard. The names consisted of the tokens we previously described.

4. Data analysis and results

Participants' performance on the forced-choice identification task was assessed by computing an identification function for each VOT continuum that plots the percentage of one of the two alternative responses, namely the /b/ choices, for each of the stimuli making up the 13-step continua involved in each task. The identification curves are presented in Figures 3, 4 and 5.

To better quantify the identification data, each participant's categorization curve was fitted to a logistic function using the Logistic Curve Fit function in SPSS, yielding mean slope coefficients (b1 values between 0 and 1 per stimulus) for each group and continuum as a measure of degree of categoriality of responses, with lower values representing less shallow slopes, meaning more precision, that is, more categorical perception.

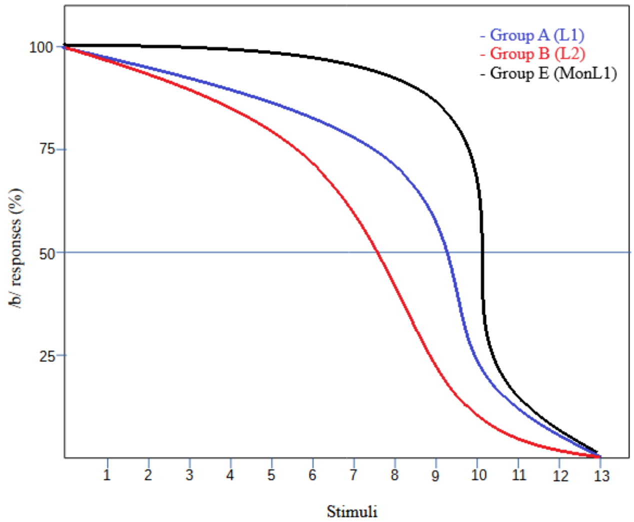

Figure 2. Perception of English /bæs/ (%)

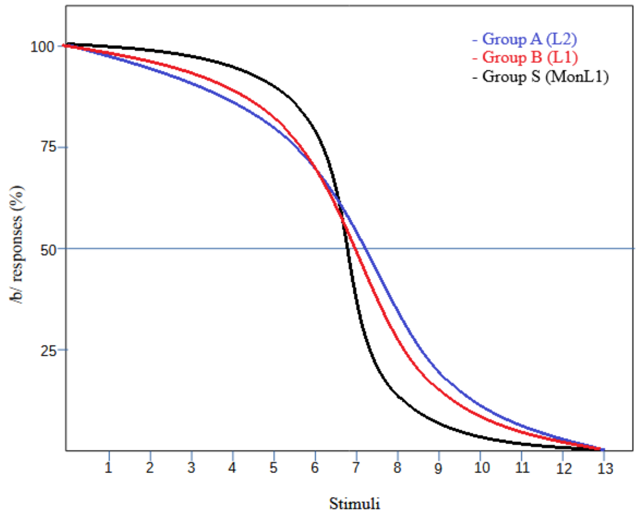

Figure 3. Perception of Spanish /bas/ (%)

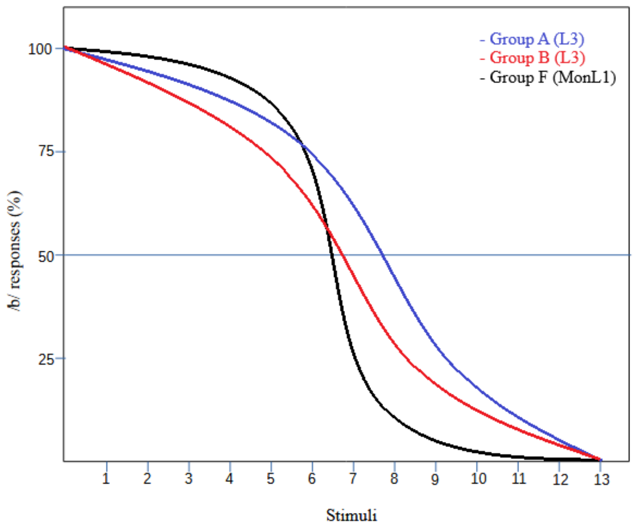

Figure 4. Perception of French /bas/ (%)

Participants' identification was also assessed by means of another measure: mean category boundaries (the 50% crossover points of the fitted labeling curve) were computed for each subject, group and continuum using the formula –Ln(b0)/Ln(b1), where b0 is the constant value of the logistic curve (Keating, 2004).

Table 2 displays data from the two parameters extracted to characterize each identification function: the slope of the fitted curve, taken as an indication of degree of categoriality in identification, and the phonetic category boundary, showing the effect of VOT duration on categorization.

What the data suggest is that for the English continuum, the English monolingual group had the most categorical perception of stops, followed by Group A and Group B, respectively. As for boundary location, the control group exhibited the highest value, between stimuli 10 and 11 (30ms and 40ms VOT), followed by Group A, midway between stimuli 9 and 10 (10-20ms VOT) and Group B, between stimuli 7 and 8 (0-10ms VOT). The slopes for the Spanish continuum show a somewhat inverted behaviour for the experimental groups, with Group B's slope steeper than Group A's one, whereas the monolinguals' perception exhibited a more categorical perception. Boundary location for the Spanish monolingual group was slightly below stimulus 7 (0ms VOT) while for groups A and B were just above the same VOT value. Interestingly enough, while the French monolingual group and the experimental groups exhibited different curve steepness (the monolinguals perceived the /b/–/p/ contrast in a more categorical way than Group A and Group B), the boundary location for Group F was lower (near stimulus 7, at almost 0 VOT) than the boundary for Group B (slightly above stimulus 7, 0ms VOT) and Group A (slightly above stimulus 8, 10ms VOT).

The above differences were then tested for statistical significance. Regarding the English continuum, a Kruskal-Wallis test with the mean slope coefficients as repeated measures and group as independent variable revealed a significant group difference, ($\chi^2(2) = 21.816$, $p < .001$).

Further Man-Whitney U-tests revealed a non-significant difference between Group A and the monolingual group ($U = 37.5$, $p = .442$) and a significant difference between Group B and the controls ($U = 65$, $p < .001$). A second Kruskal-Wallis test with the mean category boundaries as repeated measures and group as independent variable revealed a significant group difference, ($\chi^2(2) = 23.688$, $p < .001$). Further Man-Whitney U-tests revealed a significant difference between Group B and the monolingual group ($U = 55$, $p < .001$) but not between Group A and the controls ($U = 65$, $p = .81$).

Analogous tests were performed for the Spanish continuum. The results showed a significant difference regarding slope coefficients both between Group A and the monolingual group ($U = 55.5$, $p = .004$) and between Group B and the controls ($U = 57$, $p = .014$). A Kruskal-Wallis test with the mean category boundaries as repeated measures and group as independent variable revealed a non-significant group difference, ($\chi^2(2) = 3.411$, $p = .182$).

	English		**Spanish**		**French**	
	Slope	**Boundary**	**Slope**	**Boundary**	**Slope**	**Boundary**
Group A	0.316 (0.16)	9.65 (0.95)	0.421 (0.15)	7.18 (0.96)	0.397 (0.12)	8.10 (0.91)
Group B	0.516 (0.19)	7.28 (0.93)	0.376 (0.07)	7.08 (0.31)	0.481 (0.18)	7.17 (0.59)
Group E	0.283 (0.03)	10.22 (0.38)	—	—	—	—
Group S	—	—	0.214 (0.01)	6.82 (0.01)	—	—
Group F	—	—	—	—	0.275 (0.04)	6.78 (0.02)

Table 2. Identification data: slope coefficients and boundary values: M (SD).

Finally, tests performed on the French slope coefficient values yielded significant results: monolinguals' perception was different than that of Group A (*U* = 46.2, *p* = .018) and Group B (*U* = 57, *p* = .007). As for category boundaries, Man-Whitney U-tests revealed a significant difference between Group A and the monolingual group, *U* = 36.1, *p* < .001 but not between Group B and the controls, (*U* = 76.3, *p* = 1.03).

In order to answer our second research question, to what extent do English/Spanish/French and Spanish/English/French learners' perception differs when tested in the same previously acquired language, we compared the performance of the two experimental groups for each identification task. Regarding the English continuum, the above mentioned Man-Whitney U-tests revealed a significant difference as degree of categoricity (*U* = 156, *p* < .001), which indicates that Group A perceived the stop boundary in a significantly more categorical way than Group B. Comparisons of boundary locations also yielded a significant difference (*U* = 274, *p* < .001). The two tests performed on the Spanish continuum revealed different results: both the degree of categoriality and the boundary locations of the two groups yielded non-significant results, (*U* = 75.5, *p* = .89 and *U* = 69.5, *p* = .65). This indicates that, when tested in Spanish, the two groups exhibited the same categorical perception and the same category boundaries. In order to investigate whether the two groups exhibit a different French perception we compared both mean slope coefficients and mean category boundaries. Regarding the degree of categoriality, the above reported Kruskal-Wallis test yielded a non-significant difference ($\chi^2(2)$ = 1.426, *p* = .49). The French boundary on the other hand revealed significant differences between Group A's boundary and Group B's boundary (*U* = 32.5, *p* = 0.11).

Moving to our last research question, a similar procedure was applied to examine the performance of Groups A and B in the three different languages. Regarding Group A, a non-parametric Friedman test of differences among repeated measures (slope coefficients for the three different continua) was conducted and rendered a Chi-square value of 18.167 which was significant (p < .001). Post-hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at *p* = .002 between the perception of the English and the Spanish stimuli (*Z* = -3.059) and at *p* = .018 between the English and the French stimuli (*Z* = -2.895). There was no significant difference between the Spanish and the French stimuli (*Z* = 0, *p* = 1). The above results indicate that English/Spanish/French multilinguals exhibit the same degree of categoriality when tested in Spanish and French but not when tested on English stimuli. A second non-parametric Friedman test on mean category boundaries rendered a Chi-square value of 17.431 which was significant (*p* < .001), confirming this way that Group A places the boundaries in English, Spanish and French /b/–/p/ distinction in a different way. Results from post-hoc analyses showed a significance level set at *p* = .013 between the perception of the English and the Spanish stimuli (*Z* = -4.42) and at *p* = .021 between the English and the French stimuli (*Z* = -4.129). There was no significant difference between the French and the Spanish stimuli (*Z* = -.706, *p* = .480). This indicates that English/Spanish/French multilinguals exhibit the same category boundary when tested in Spanish and French but not when tested on English stimuli.

Moving to Group B's performance, a similar test of differences among repeated measures (slope coefficients for the three different continua) was conducted and rendered a Chi-square value of 16.582 which was significant (p < .001). Post-hoc analysis with Wilcoxon signed-rank tests resulted in significance levels set at *p* = .029 between the perception of the English and the Spanish stimuli (*Z* = -4.037), at *p* = .038 between the English and the French stimuli (*Z* = -2.304) and at *p* = .008 between the Spanish and the French stimuli (*Z* = -3.814). This results indicate that English/Spanish/French multilinguals exhibit different degrees of categoricity when tested in previously learned languages. A second non-parametric Friedman test on mean category boundaries for the three different continua was conducted and rendered a Chi-square value of 0 which was not significant (*p* = .834), confirming this way that Group

B places the boundaries in English, Spanish and French /b/–/p/ distinction in the same way.

5. Discussion and conclusions

The purpose of the present study was to gain a better understanding of the complex mechanisms of L3 speech perception by investigating the extent to which two groups of bilinguals, namely English/Spanish and Spanish/English, learners of French as an L3, adapt the features they have already been sensitized to through previously acquired languages in order to accommodate the new ones and how these already present features shape the perception of the new ones.

Our results showed that L1-English trilinguals perceive the native /b/–/p/ contrast in a monolingual fashion, either as categoriality and boundary location (nearly at 30ms VOT) and that when tested in L2 Spanish, although their perception curve is shallower, they place the category boundary as monolinguals do (between 0 and 10ms VOT). However, their L3 French perception is less categorical and their boundary is significantly more towards the right side of the continuum (just above 10ms VOT) than those of monolinguals. This would seem to indicate that altogether there was no progressive L1→L2 nor regressive L2/L3→L1 influence but L1 or L1/L2 influences the L3 perception (in line with previous studies carried out on trilingual VOT production such as Llama et al., 2010; Llama & López-Morelos, 2016; Liu & Lin, 2021; Parrish, 2022; and on VOT perception such as Liu et al., 2019; Liu & Lin, 2021).

The second group, namely the L1-Spanish trilinguals, don't perceive their native stop contrast as categorically as monolinguals but they do exhibit the same category boundary (at 0ms VOT). On the other hand, their perception of the /b/–/p/ contrast in English as a second language moves away from the monolingual speakers' pattern as both categoriality (less evident) and boundary location (more towards the left side of the continuum, again around 0ms VOT). Interestingly enough, when tested in their L3, they again exhibited the same behavior as monolinguals (boundary placed around 0ms VOT). This brings evidence for L1→L3 influence (similar to Llama & Cardoso, 2018, on VOT production) and again no L1→L2 nor regressive L2/L3→L1 as far as boundary location is concerned. Multilingualism seems to also have influenced Spanish/English/French categoriality of stop perception (perception in Spanish is more categorical than in French and English respectively).

The above results are up to a certain extent in line with findings from Parrish (2022) in which a subset of participants also experienced heavy L1 Spanish influence on their L3 production. On the other hand, the remaining participants showed a lower, but considerable, degree of L2 English influence on L3 productions. Although both studies highlight the complex interplay of L1 and L2 influences on L3, they focus on different aspects (production vs. perception) and involve different language proficiency groups (first exposure to a third language vs. intermediate language proficiency).

When comparing the two groups of trilinguals we observed that they exhibited the same Spanish perception — which let us recall, was equal to monolinguals — but not the same English perception. Therefore, being tested in Spanish as an L1 or an L2 does not make any difference in terms of stops perception whereas being tested in English as an L1 brings advantages over being tested in the same language as an L2. On the one hand, this cannot be explained by proficiency levels, since both groups are advanced learners who studied their L2 for a comparable amount of years. Let us recall though that L1-English speakers were living abroad, in Northern Spain, and therefore were immersed in an L2 environment at the time of data collection. On the contrary, L1-Spanish speakers were living immersed in their native environment and spent far less time in an L2 environment. In our opinion, the length of residence in an L2 environment greatly contributed to accurate L2 speech perception.

From a phonetic point of view, it can be said that it was easier for L1-English speakers to get acquainted with the voice contrast and to correctly perceive voicing lead and short-lag in their second language than for L1-Spanish speakers to get sensitized to aspiration in their L2. A possible explanation for this comes from the SLA domain: in their study on L1 English (aspirated language) and French (voiced language) learners of Thai (voiced and aspirated language), Curtin and colleagues (1998) brought interesting evidence of voice contrasts being learned before aspiration due to the presence of aspiration in surface, but not in form of lexical representations in their L1s. More precisely, L2 learners initially constructed lexical representations that make use of only those features that are present lexically in the L1, even though they may be able to discriminate other L2 contrasts on the basis of surface features, and may eventually lexicalize these surface features (Curtin et al., 1998). As it could be expected, L1-English trilinguals resort to their L2 Spanish perception in L3 French, although their L3 category boundary is placed somewhere between the English and Spanish ones, pointing towards a mixed L1/L2→L3 cross-linguistic influence. When tested in French, the L1-Spanish monolinguals performed the same way as in their L1 Spanish, although their categoriality was less defined in their L3 than in their L1. Interestingly enough, since they seemed to rely on their L1 perception even in L2 English, only the L1→L3 CLI pattern can be observed.

As already discussed, in Llama et al. (2010), the data for L3 production did not show a positive effect of L2 status while the comparison of L2 and L3 production patterns suggested a combined effect of L1 and L2 which is up to a certain extent in line with Group A's L3 perception. In Llama & Cardoso (2018) L2 plays a less determinant role, especially in the case of Francophone Group. The main reason behind such behavioral difference lies in the increase in L3 proficiency and their findings appear to provide support to the claim that there is an L2 effect that weakens when the L3 is acquired and/or fades in favor of the L1 as proficiency increases. Nevertheless, in our study, the primary source of influence on L3 perception appears to originate from Spanish, whether it is an L1 or L2, and to some extent from Spanish and English together. Although VOT is a continuum, it is well established that human beings' categorical perception constrains it (Liberman et al., 1957). Learners are significantly better at distinguishing between stop consonant categories than vague acoustic features. When learners can detect and categorize the phonetic differences between an L3 sound and an L1 or L2 sound, they can more easily establish a new phonetic category in the L3. Conversely, if learners struggle to distinguish a target language sound from a similar sound in their L1 or L2, they are less likely to verify and reproduce the phonetic differences, leading to difficulties in perception (Kingston, 2003). The most notable difference in the voiced stop system between the L3 and L1 or L2 lies in the feature of pre-voicing. When learners recognize the presence or absence of pre-voicing, they can more easily distinguish between voiced and voiceless stops.

Our data did not allow us to identify any regressive pattern of CLI, neither from the second (contrary to Liu, 2016) nor from the third language on the previously acquired ones (in line with Liu, 2016). For Group A this can be explained by speakers' ability to attend to the voice contrast in their L2 and to aspiration in their L1. Being advanced speakers of their L2 Spanish which raised their metalinguistic awareness, their L3 perception falls somewhere in the middle, although they tend to place the French boundary more towards the left side of the VOT continuum (or better, towards the voice/voiceless feature). As far as Group B is concerned, in spite of an advanced knowledge of their second language, they seem to not have acquired aspiration in English and to rely on the voice contrast in both non-native languages. Let us recall that they mainly learned English as a foreign language in their native environments and that they spent little time in English speaking countries. Therefore, it could be the case that the type of English they have been exposed to already lacked (or made little use of) the aspiration feature.

This study has some limitations. First of all, the sample size was small and more participants, especially in the L1-Spanish group, might have yielded different results. More attention needs to be addressed on L3 acquisition, especially on phonetics. Future studies could be longitudinal and test the same participants before and after having learned an L3, or participants with the same (high) L2/L3 proficiency. As we have seen, language experience might also influence results, so greater attention needs to be placed on research design and participant selection. A further study could also examine stops at other places of articulation.

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