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Destabilizing effects of L2 explicit pronunciation instruction on L1 speech: Voice Onset Time production by Brazilian intermediate users of English

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Abstract

Anchored in a Complex Dynamic perspective on language development, this study explores the effects of L2 explicit pronunciation instruction on L2 English and L1 Brazilian Portuguese VOT production. To this end, 16 Brazilian intermediate users of L2 English were investigated. Volunteers were divided into control and experimental groups. The latter received explicit pronunciation instruction on the production of the English voiceless stops. The study included three data collections, a pre-test, an immediate post-test and a delayed post-test. An acoustic analysis of VOT duration is reported. The results revealed that the control group did not produce the expected VOT pattern for L2 English at any time of the study. No alterations in the L1 were reported. On the other hand, after the instruction, the experimental group produced higher L2 English VOT values. First language attrition was reported since the L1 BP VOT durations also increased after instruction. In addition to highlighting the effects of explicit instruction on L2 development and L1 attrition, this study confirms that language development is constant, and that even L1 adult grammars are not rigid, with potential to change due to the perception and processing of novel nonnative phonetic-phonological categories.

Keywords: explicit pronunciation instruction; VOT; second language development; first language attrition.

Resumo

Ancorado em uma perspectiva Dinâmico Complexa para o desenvolvimento linguístico, este estudo explora os efeitos da instrução explícita de pronúncia de L2 na produção do VOT do inglês (L2) e do português brasileiro (L1). Para tanto, 16 brasileiros usuários intermediários de inglês (L2) foram investigados. Os voluntários foram divididos em grupos controle e experimental. Esse último recebeu instrução explícita de pronúncia sobre a produção das oclusivas não vozeadas da língua inglesa. O estudo incluiu três coletas de dados, um pré-teste, um pós-teste imediato e um pós-teste postergado. A análise acústica da duração do VOT foi relatada. Os resultados revelaram que o grupo controle não produziu o padrão de VOT esperado para o inglês (L2) em nenhum momento do estudo. Nenhuma alteração na L1 foi relatada. Por outro lado, o grupo experimental, após a instrução, produziu valores de VOT em inglês (L2) mais elevados. O atrito de L1 foi relatado, uma vez que as durações do VOT do PB (L1) também aumentaram após a instrução. Além de destacar os efeitos da instrução explícita no desenvolvimento de L2 e no atrito de L1, este estudo confirma que o desenvolvimento linguístico é constante, e que mesmo gramáticas adultas de línguas maternas não são rígidas, com potencial de mudança devido à percepção e ao processamento de novas categorias fonético-fonológicas não nativas.

Palavras-chave: instrução explícita de pronúncia; VOT; desenvolvimento de segunda língua; atrito de língua materna.

Introduction

In a Complex Dynamic approach to bilingual development,[1] both first (L1) and second languages[2] (L2) are interconnected subsystems. Therefore, since the languages of bilingualsare represented in a single neural architecture,[3] and the sound systems of these individuals cohabit the same phonetic-phonological space in the brain,[4] in L2 development, the L1 is expected to influence how novel nonnative phonetic-phonological categories are processed, represented and applied.[5] A vast body of research, however, has pointed out that both first and second languages dynamically interact with each other, regardless of bilinguals' proficiency level,[6] and even when nonnative languages are developed in early childhood.[7] In other words, the L2 also influences the L1.

The premise that bilinguals behave in each of their languages differently from monolinguals has been corroborated by a growing number of studies on all linguistic levels, from phonetics to pragmatics. Several investigations have claimed that, in becoming bilingual, the L1 of any individual will suffer an amount of change and/or adaptation.[8] In some cases, bilinguals are not even perceived to be native speakers of their L1.[9] The fact that the L1 will inevitably show signs of alteration in bilinguals is thus a viewpoint that cannot be ignored in Linguistics.[10] In this work, changes in the L1 triggered by L2 development represent cases of first language attrition (FLA), defined as a non-age-related alteration in a previously developed (or "stable") language or language ability in a healthy speaker.[11]

When an L2 becomes more frequent and more dominant in the brain of a bilingual, it consequently exerts more influence on the L1. L2 influence on L1 speech perception and/or production is therefore commonly evidenced in bilinguals who reach a high level of L2 proficiency and who, as a consequence, present greater variability in the way L1 properties are applied[12] compared to monolinguals. For that reason, FLA is more robustly documented in studies investigating L1 speech during L2 immersion. For instance, bilinguals in L2-dominant contexts are consistently found to be less "native-like" when compared to monolingual compatriots.[13]

Nonetheless, research in the area has been indicating that FLA is not, as initially understood, something rare and present only in the speech of a small group of bilinguals, generally first-generation immigrants with long lengths of residence in L2 communities and little or no L1 use.[14] There is no denying that changes in the L1 are more evident in the speech of those individuals, but recent studies have also demonstrated that bilinguals reveal attrited L1 data after short periods of time in an L2-dominant environment.[15] Additionally, FLA has also been documented in the L1 speech of

[1] de Bot, "Complexity Theory and Dynamic Systems Theory": same or different? (2017).

[2] This article does not make any distinction between the terms "second language" and "nonnative language".

[3] MacWhinney, "Language emergence" (2002).

[4] Best and Tyler, "Nonnative and second-language speech perception": Commonalities and complementarities (2007); Flege, "Second language speech learning": Theory, findings and problems (1995); Flege and Bohn, "The revised Speech Learning Model (SLM-r)" (2021).

[5] Kupske and Alves, "Orchestrating chaos": teaching foreign language pronunciation in the complexity paradigm (2017).

[6] van Hell and Dijkstra, "Foreign language knowledge can influence native language performance in exclusively native contexts" (2002).

[7] Werker and Byers-Heinlein, "Bilingualism in infancy": first steps in perception and comprehension (2008).

[8] Köpke, "Language attrition at the crossroads of brain, mind, and society" (2007); Schmid and Köpke, "Introduction" (2019).

[9] Karayayla, "Turkish as an immigrant and heritage language in the UK": Effects of exposure and age at onset of bilingualism on grammatical and lexical development of the first language (2018).

[10] Kupske, "Atrito linguístico" (2021).

[11] Kupske, "Atrito linguístico" (2021).

[12] Schmid, *Language Attrition* (2011).

[13] de Leeuw et al., "The effects of contact on native language pronunciation in an L2 migrant setting" (2010).

[14] Schmid and Köpke, "Introduction" (2019).

[15] Chang, "First Language Phonetic Drift During Second Language Acquisition" (2010).

bilinguals who have never left their home countries.[16]

Laboratory phonology has been consistently reporting that proficient L2 learners in L1 settings might also yield attrited L1 data. For example, many experimental studies have revealed that native speakers of short-lag Voice Onset Time[17] (VOT) languages who are advanced users of a long-lag VOT L2, even when immersed in an L1 context, produce L1 voiceless stops with significantly longer durations compared to monolinguals.[18] Other studies have brought to light that FLA is also evidenced in bilinguals with different L2 proficiency levels, including intermediate[19] and basic users of the L2, encapsulating emerging bilinguals and instructed language learners.[20] However, FLA in L1-dominant contexts is still very under-researched, and there are few studies investigating the role of L2 instruction on L1 alterations in those settings. In view of the foregoing, considering language as a Complex Dynamic System,[21] this work aims at investigating the impact of a single session of L2 English explicit pronunciation instruction on L2 English (long-lag) and L1 Brazilian Portuguese (short-lag) VOT production by Brazilian intermediate users of English.

Although there are no absolute VOT values for each voiceless stop, in BP, the durations vary around 12 ms for /p/, 18 ms for /t/, and 38 ms for /k/.[22] In English, on the other hand, typical values are around 55 ms for /p/, 70 ms for /t/, and 80 ms for /k/.[23] Such being the case, the hypothesis in this study is that, prior to the explicit instruction, independent L2 English speakers (levels B1 and B2) will not produce long-lag VOT durations for L2 English, transferring and adopting the BP short-lag pattern. After the instruction, it is expected that participants will yield longer VOT values for the L2 and, as a consequence, long VOT values for the L1, since the L1 and L2 subsystems interact and will both suffer from the destabilization brought about by the pronunciation instruction.[24]

To test this hypothesis, 16 volunteers were recruited, and their production of initial voiceless stops (/p, t, k/) both in L2 English and L1 BP was recorded and acoustically analyzed. Speech data were collected in three moments:

(1) a pre-test, with a data collection prior to the instruction;

(2) an immediate post-test, right after the instruction; and

(3) a delayed post-test, collected three months after the immediate post-test.

Participants were divided into two groups: an experimental group (EG) that received explicit instruction on the production of English stops based on a communicative framework for pronunciation teaching;[25] and a control group (CG), composed by participants who did not receive instruction during the investigation.

This work is divided into three sections apart from this Introduction. In the first section, the methodology supporting this study

[16] Schereschewsky et al., "First language attrition": the effects of English (L2) on Brazilian Portuguese VOT patterns in an L1-dominant environment (2017); Schereschewsky et al., "Atrito linguístico em plosivas em início de palavra": dados de bilíngues e trilíngues (2019).

[17] VOT can be defined as the time interval between the release of a stop and the onset of voicing.

[18] Alves et al., "L2 development and L1 attrition in an L1-dominant environment": analysing Voice Onset Time in L1 Spanish and L2 English (2019).

[19] Schereschewsky et al., "First language attrition": the effects of English (L2) on Brazilian Portuguese VOT patterns in an L1-dominant environment (2017); Schereschewsky et al., "Atrito linguístico em plosivas em início de palavra": dados de bilíngues e trilíngues (2019).

[20] Dmitrieva et al., "The effect of instructed second language learning on the acoustic properties of first language speech" (2020); Osborne and Simonet, "Foreign-language phonetic development leads to first-language phonetic drift": plosive consonants in native Portuguese speakers learning English as a foreign language in Brazil (2021).

[21] Beckner et al., "Language is a Complex Adaptive System" (2009).

[22] Istre, "Um estudo do VOT em monolíngües brasileiros" (1980).

[23] Toribio et al., "Perseverative phonetic effects inbilingual code-switching" (2005).

[24] Schereschewsky, "Desenvolvimento de Voice Onset Time em sistemas multilíngues (português - L1, inglês - L2 e francês - L3)": discussões dinâmicas a partir de diferentes metodologias de análise de processo (2021); Alves and Schereschewsky, *"One for all, all for one"*: On process-oriented approaches to multilingual phonetic-phonological development (2021).

[25] Celce-Murcia et al., *Teaching pronunciation*: a reference for teachers of English to speakers of other languages (1996); Celce-Murcia et al., *Teaching pronunciation*: a course book and reference guide (2010).

will be shown. The second section is dedicated to results and to a general discussion. A section of Final Remarks will close this work.

Methodology

Participants

For this study, 16 volunteers, native speakers of Brazilian Portuguese were recruited, and reported no speech, hearing or language difficulties. Participants were all undergraduate students pursuing a degree in English in the city of Salvador, Brazil, all born and raised in the same city. At the recruitment, participants were aged between 19 and 25 years (mean = 22.9 years, SD = 3.8 years), and were divided into two groups: experimental (N = 8) and control (N = 8). Only intermediate users of English, classified as B1 and B2 with a *C-test*,[26] were considered.

Participants completed a basic questionnaire, and were invited to fill out and sign an Informed Consent Form. They had the right to stop taking part in the investigation at any time. Volunteers' identities were kept confidential.

[26] Keijzer, "Last in first out?": an investigation of the regression hypothesis in Dutch emigrants in Anglophone Canada (2007).

Target words

The literature on VOT points out that, in addition to the number of syllables and the speech rate, the height of the following vowel affects the production of stops.[27] Based on previous studies,[28] this work takes into account 36 targets with word-initial stops preceding high and low back vowels as presented in table 1.

[27] Schwartzhaupt, *Factors influencing Voice Onset Time*: analyzing Brazilian Portuguese, English and interlanguage data (2012).

[28] Kupske, "Imigração, atrito e complexidade": a produção das oclusivas surdas iniciais do Inglês e do Português por sul-brasileiros residentes em Londres (2016).

Table 1: Target words.

Stop	Vowel	English	Portuguese
/p/	high back	Poodle	*Puma*
		Poof	*Puro*
		Pool	*Pulo*
	low back	Pop	*Poça*
		Posh	*Posso*
		Pot	*Pote*
/t/	high back	Tool	*Tudo*
		Toot	*Tufo*
		Tooth	*Tusso*
	low back	Tod	*Toca*
		Top	*Toque*
		Toss	*Tosa*
/k/	high back	Cool	*Cujo*
		Coop	*Cume*
		Coot	*Cura*
	low back	Cob	*Cola*
		Cod	*Copa*
		Cop	*Copo*

Apart from the targets in table 1, 16 distractor items were included. These items were not considered in the analysis.

Procedures and Explicit Instruction

All data collections were conducted in the language being tested with all instruments and written and oral instructions in the same language. Therefore, L1 BP and L2 English targets were collected on different days to minimize any possible bias of language mode/shift effects. Participants were individually recorded in soundproof booths. A professional Rode NT1 microphone was used. The recording was carried out with AUDACITY,[29] with a sampling rate of 44.1 kHz, 16-bit resolution, on an iMac, 3,6 GHz Intel Core i5 Quad-Core, with 16 GB of RAM. The data was recorded in stereo and later converted to mono, so that no recording channels were lost.

[29] URL: https://www.audacityteam.org/download/

In the data collection sessions, in view of previous studies,[30] participants should read the two following carrier-sentences: "I would say (target word)" and "*Eu diria* (target word)" for English and BP, respectively. Participants individually recorded all items from table 1 twice. Targets were randomized to ensure that any participant was provided with the same order of items to mitigate any bias related to order effects. In addition, participants could repeat any target when necessary. In cases of repetition, the last production was used for the analysis. The carrier-sentences with the targets were presented on a computer screen.

[30] KUPSKE, "Imigração, atrito e complexidade": a produção das oclusivas surdas iniciais do Inglês e do Português por sul-brasileiros residentes em Londres (2016).

After the data collection for the pre-test, the EG members were invited to participate in a short course about English pronunciation based in a communicative framework.[31] The single session lasted 120 minutes and started from a more analytical treatment of the English stops, evolving to teaching stages in which the volunteers would use those English sounds in an organic way and with authentic communicative purposes. The instruction included five steps:

[31] CELCE-MURCIA et al., *Teaching pronunciation*: a course book and reference guide (2010).

(i) *description and analysis*, in which explicit information about the pronunciation of English voiceless stops was provided;

(ii) *listening discrimination*, in which perceptual discrimination tasks about the targets were applied;

(iii) *controlled practice and feedback*, which included the repetition of some preset targets in a more controlled manner;

(iv) *guided practice and feedback*, in which participants had more autonomy to use the English stops in a less controlled and mechanistic way; and finally

(v) *communicative practice and feedback*, which took place when learners were able to produce the target forms freely in authentic interactions.[32]

[32] KUPSKE and ALVES, "Orchestrating chaos": teaching foreign language pronunciation in the complexity paradigm (2017).

It is valid to point out that the targets containing voiceless stops in English considered in the study were not used in the material presented during the pronunciation teaching session. It is noteworthy that participants in the CG, for ethical reasons, received the same 120-minute instruction after the delayed post-test.

Succeeding the instruction, in the immediate post-test, both the EG, which received instruction on the production of English stops, and the CG recorded new data. Three months after the second data collection, a delayed post-test was conducted. The same methodology applied in the pre-test was adopted for both post-tests.

A total of 3.456 target items, 1.728 for each group (36 words x 8 participants x 3 tests x 2 repetitions), was considered in the analysis. VOT duration was measured from the stop burst to the onset of voicing. In case of multiple bursts, the last one was considered. Acoustic measurements were made with PRAAT.[33]

[33] https://www.fon.hum.uva.nl/praat/.

Results and general discussion

In general terms, EG (N = 8) and CG (N = 8) yielded VOT values both for L1 BP and L2 English that are similar to the 12 ms for /p/, 18 ms for /t/, and 38 ms for /k/ expected for BP.[34] The mean VOT values and standard deviations (SD) for the groups are shown in table 2.

[34] ISTRE, "Um estudo do VOT em monolíngües brasileiros" (1980).

Table 2: Mean VOT values and standard deviations for the pre-test in ms.

Language	**Stop**	**CG** ($N = 8$)		**EG** ($N = 8$)	
		Mean	SD	Mean	SD
Brazilian Portuguese (L1)	/p/	21.49	5.84	21.12	5.9
	/t/	22.02	7.3	22.20	1.8
	/k/	48.44	5.3	52.32	3.4
English (L2)	/p/	22.50	10.6	21.60	7.8
	/t/	33.09	16.6	32.89	14.3
	/k/	46.70	12.2	54.75	13.6

Table 2 reveals that the VOT values for L1 BP and L2 English for the CG and EG, in the pre-test, are similar. As expected for L2 learners, both groups present high standard deviations in the durations of English stops, indicating a great variability in L2 speech production. Detailing the L1 data, fig. 1 shows the central tendencies for BP.

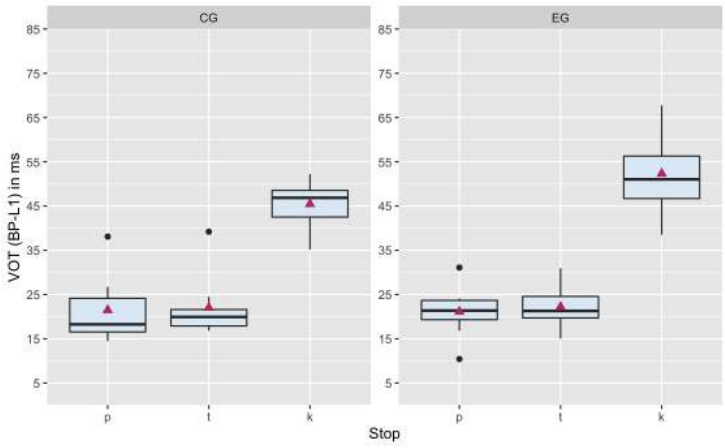

Figure 1: Boxplots of VOT for L1 BP. Left: Boxplots of VOT durations for the CG in the pre-test; Right: Boxplots of VOT durations for the EG in the pre-test (VOT in ms; boxes represent quartiles and median; whiskers represent values within 1.5 times interquartile range below the 25th percentile and above the 75th percentile; pink triangles represent mean values).

As can be seen, CG and EG present very similar data in descriptive terms. Being the data normally distributed after a log transformation ($\log_{10}$), a *t test* for independent samples was carried out. The test revealed that there are no statistically significant differences between the groups for the BP VOT production:

- $t(14) = 0.106$, $\rho < .05$, for /p/
- $t(14) = -0.055$, $\rho < .05$, for /t/
- $t(14) = -1.752$, $\rho < .05$, for /k/

Fig. 2 presents the central tendencies for L2 English in the pre-test. For English, CG and EG also present similar mean values for all three stops, and similar central tendencies for /p/ and /k/. However, the CG presents more variability in the central tendency for the alveolar stop compared to the EG.

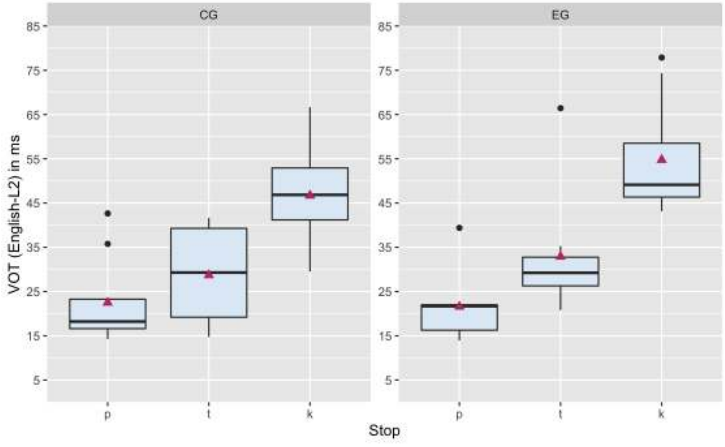

Figure 2: Boxplots of VOT for L2 English. Left: Boxplots of VOT durations for the CG in the pre-test; Right: Boxplots of VOT durations for the EG in the pre-test (VOT in ms; boxes represent quartiles and median; whiskers represent values within 1.5 times interquartile range below the 25th percentile and above the 75th percentile; pink triangles represent mean values).

A *t test* for independent samples confirmed that, in the pre-test, CG and EG produced similar VOT durations for L2 English:

- $t(14) = 0.194$, $\rho < .05$, for /p/
- $t(14) = -0.0647$, $\rho < .05$, for /t/
- $t(14) = -1.249$, $\rho < .05$, for /k/

Thus, before the instruction about the production of L2 English stops, both groups presented statistically similar VOT values for BP and English. The pre-test data indicate that the groups transfer the short-lag L1 VOT pattern to the L2.

Oppositions between segments can vary depending on the different acoustic cues speakers of a given language perceive as central.[35] VOT, for instance, is known to be an important acoustic cue in English for establishing the contrast between voiced and voiceless initial stops, but not in Brazilian Portuguese.[36] Therefore, VOT is not expected to assume a fundamental status in the production of stops by Brazilian speakers, as revealed by the pre-test data for both groups.[37] As mentioned in the introduction of this study, since both sound systems of bilinguals are represented in a single neural architecture,[38] it is expected that the L1 will transfer to the L2. Even though transfer is a mechanism that underlies any type of learning through the application of already established knowledge to new situations, as in L2 development, L1 transfer makes bilinguals less efficient in speech perception and production of nonnative sounds that are very similar or that do not exist in the L1. For this reason, the BP short-lag VOT category affects how the L2 English VOT category is perceived, represented and produced, as the latter (a long-lag pattern) is categorized through the pre-existing short-lag BP VOT pattern.[39]

Following the pre-test, the EG participated in a 120-minute session of explicit pronunciation instruction about English stops as reported in the methodology section. Right after the instruction (immediate post-test) and three months later (delayed post-test), data from both groups were collected. The mean VOT values and standard deviations for the groups are shown in table 3.

35 Holt and Lotto, "Cue weighting in auditory categorization": implications for first and second language acquisition (2006).

36 Alves and Zimmer, "Percepção e produção dos padrões de VOT do inglês por aprendizes brasileiros": o papel de múltiplas pistas acústicas sob uma perspectiva dinâmica (2015).

37 Alves and Kampff, "Efeitos de longo prazo do treinamento perceptual na percepção e produção das plosivas iniciais surdas do inglês por estudantes brasileiros": implicações para o ensino de pronúncia (2019).

38 MacWhinney, "Language emergence" (2002).

39 Kupske and de Oliveira, "O desenvolvimento do padrão de Voice Onset Time das oclusivas surdas iniciais do inglês por aprendizes soteropolitanos": efeitos da instrução explícita (2020).

Language	Stop	CG ($N = 8$)					
		Pre-test		Immediate post-test		Delayed post-test	
		Mean	SD	Mean	SD	Mean	SD
English (L2)	/p/	22.50	10.6	20.03	5.2	21.78	4.8
	/t/	33.09	16.6	32.85	9.73	30.73	6.7
	/k/	46.70	12.2	54.85	5.0	55.60	3.1
BP (L1)	/p/	21.49	5.84	23.06	6.0	22.81	7.2
	/t/	22.02	7.3	21.31	3.9	21.76	4.0
	/k/	48.44	5.3	47.80	4.6	47.50	4.1

Language	Stop	EG ($N = 8$)					
		Pre-test		Immediate post-test		Delayed post-test	
		Mean	SD	Mean	SD	Mean	SD
English (L2)	/p/	21.60	7.8	93.14	31.3	43.64	14.8
	/t/	32.89	14.3	108.80	32.3	54.09	15.1
	/k/	54.75	13.6	127.36	27.9	81.21	11.4
BP (L1)	/p/	21.12	5.9	31.63	7.5	24.93	5.4
	/t/	22.20	1.8	34.94	2.3	38.87	3.5
	/k/	52.32	3.4	50.65	4.0	61.11	4.3

Table 3: Mean VOT values and standard deviations for the pre-test and post-tests in ms.

Regarding the production of L2 English VOT, as table 3 shows, the mean durations for the CG are very similar across the three tests and seem to be anchored in the short-lag VOT standard. The EG, on the other hand, shows extremely high values, even for the long-lag VOT pattern described for English in the literature, in the immediate post-test. Although the mean values are reduced in the delayed post-test, they are still higher compared to the pre-test. It is worth noting that the standard deviations for the EG after the instruction are high. Bilinguals' language systems usually present a great degree of variability, but higher SD, in this case, might be representing a great perturbation of bilinguals' language systems triggered by the explicit instruction.

For pedagogical reasons, the data produced by the CG will be analyzed separately from the EG data. Figure 3 shows the production of L2 English stops by the former group for the three tests.

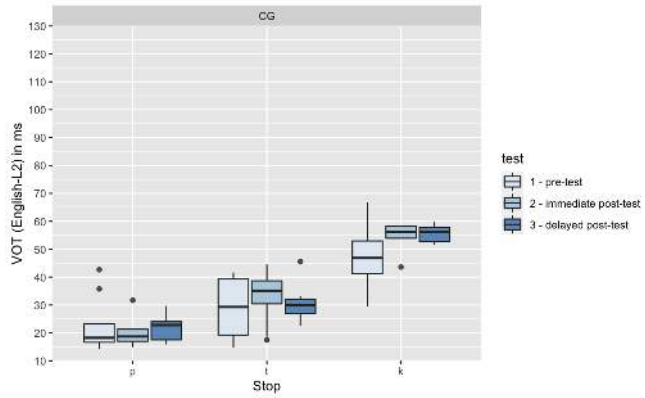

Figure 3: Boxplot of VOT durations (L2 English) for the CG sorted by test type (VOT in ms; boxes represent quartiles and median; whiskers represent values within 1.5 times interquartile range below the 25th percentile and above the 75th percentile).

As figure 3 shows, the productions for the three tests are descriptively similar for the CG. Peculiarly, the durations for L2 English seem to present less variability in the two post-tests than in the pre-test. Figure 4 shows the production of L1 BP stops for the same group for the three tests.

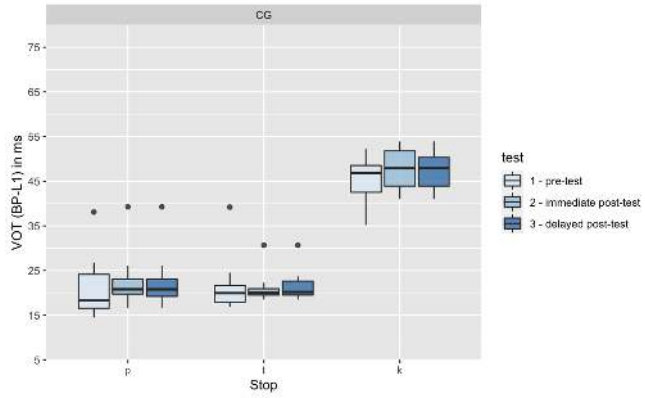

Figure 4: Boxplot of VOT durations (L1 BP) for the CG sorted by test type (VOT in ms; boxes represent quartiles and median; whiskers represent values within 1.5 times interquartile range below the 25th percentile and above the 75th percentile).

As revealed in the L2 data, the productions for L1 BP are similar in the three tests. Therefore, at least in descriptive terms, the CG produces VOT for the L1 and the L2 with no significant differences throughout the whole investigation. As shown in table 4, Repeated Measures ANOVAs confirm that there are not statistically significant differences in the production of L2 English and L1 BP VOT across different tests for the CG.

		Voice Onset Times (in milliseconds) ($N = 8$)						$F(2, 14)$
		Pre-test		Immediate post-test		Delayed post-test		($\rho > .05$)
		Mean	SD	Mean	SD	Mean	SD	
English (L2)	/p/	22.50	10.6	20.03	5.2	21.78	4.8	0.528
	/t/	28.70	11.4	32.85	9.73	30.73	6.7	0.453
	/k/	46.69	12.2	54.85	5.0	55.60	3.1	0.61
BP (L1)	/p/	21.49	5.84	23.06	6.0	22.81	7.2	0.864
	/t/	22.02	7.3	21.31	3.9	21.76	4.0	0.152
	/k/	45.44	5.3	47.80	4.6	47.50	4.1	1.098

Table 4: Summary of Repeated Measures ANOVAs (control group). In all ANOVAs, $\rho > .05$ (not significant).

Turning the attention to the EG data, figure 5 reveals a different scenario for L2 English VOT production.

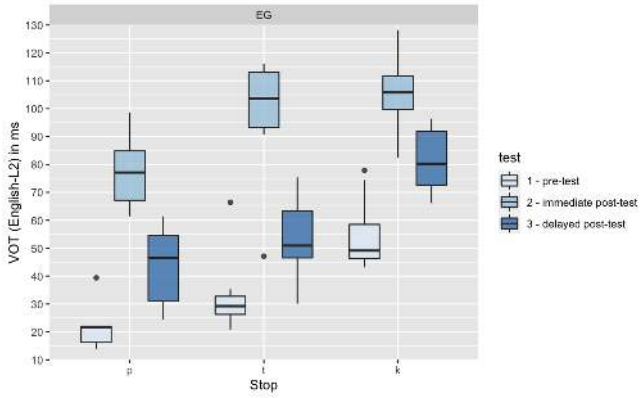

Figure 5: Boxplot of VOT durations (L2 English) for the EG sorted by test type (VOT in ms; boxes represent quartiles and median; whiskers represent values within 1.5 times interquartile range below the 25th percentile and above the 75th percentile).

While the CG presents a quite "stable" production in three months, the EG yields extremely high values and variability for the immediate post-test. Even though the EG participants produce more mitigated values in the delayed post-test, the great variability persists. Figure 6 introduces de BP data for the EG.

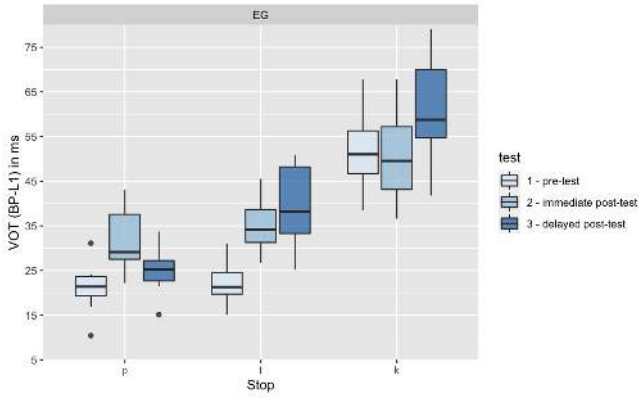

Figure 6: Boxplot of VOT durations (L1 BP) for the EG sorted by test type (VOT in ms; boxes represent quartiles and median; whiskers represent values within 1.5 times interquartile range below the 25th percentile and above the 75th percentile).

For the L1 BP VOT production, the EG displays a different pattern compared to the CG. EG produces longer VOT values and more variability after the instruction. Repeated Measures ANOVAs confirm a contrasting production pattern for the EG, revealing that there are statistically significant differences across the tests for L2 English and L1 BP by Brazilians who have received explicit pronunciation instruction (table 5).

		Voice Onset Times (in milliseconds) ($N = 8$)						$F(2, 14)$
		Pre-test		Immediate post-test		Delayed post-test		($\rho < .001$)
		Mean	SD	Mean	SD	Mean	SD	
English (L2)	/p/	21.59	7.9	93.14	31.3	43.64	14.8	23.309
	/t/	32.89	14.3	108.80	32.3	54.09	15.1	24.238
	/k/	54.75	13.6	127.36	27.9	81.21	11.4	30.568
BP (L1)	/p/	21.12	5.9	31.63	7.5	24.93	5.4	21.715
	/t/	22.20	1.8	34.94	2.3	38.87	3.5	10.849
	/k/	52.32	3.4	50.65	4.0	61.11	4.3	9.802

Table 5: Summary of Repeated Measures ANOVAs (experimental group). In all ANOVAs, $\rho < .001$.

Table 6 complements the analysis and presents Pairwise Comparisons made with Bonferroni's Method.

		Pre-test *vs.* Immediate post-test	**Pre-test *vs.* Delayed post-test**	**Immediate post-test *vs.* Delayed post-test**
English (L2)	/p/	$\rho < .05$	$\rho < .05$	$\rho < .05$
	/t/	$\rho < .001$	(not significant)	$\rho < .05$
	/k/	$\rho < .001$	$\rho < .05$	$\rho < .05$
BP (L1)	/p/	$\rho < .001$	(not significant)	$\rho < .001$
	/t/	$\rho < .05$	$\rho < .05$	(not significant)
	/k/	(not significant)	$\rho < .001$	$\rho < .05$

Table 6: Summary of Pairwise Comparisons.

For the L2 English bilabial, *post hoc* comparisons demonstrate that the VOT durations in the immediate post-test (mean = 93.14 ms) and in the delayed post-test (mean = 43.64 ms) are different from the pre-test values (mean = 21.59 ms). In addition, the two post-tests are also statistically different from each other, being the values for the immediate post-test the highest. Therefore, after the instruction, participants produce very long durations for the L2 bilabial stop. Three months later, there is a decrease in VOT values, but they are still statistically different from those obtained in the pre-test.

Regarding the L2 alveolar stop, comparisons reveal that the VOT production in the pre-test (mean = 32.89 ms) is statistically different from the production for the immediate post-test (mean = 108.80 ms), but is similar to one presented in the delayed post-test (mean = 54.09 ms). The values for the alveolar stop in the immediate post-test are statistically different from those revealed in the pre-test and in the delayed post-test. For /t/, after the instruction, participants demonstrate increased VOT durations. However, in three months, there is a reduction in VOT values compared to the immediate post-test, and the new pattern is statistically similar to the pre-test one.

Finally, with reference to the L2 English velar stop, comparisons revealed that there are statistically significant differences between all possible comparisons. The mean VOT value moves from 54.75 ms, in the pre-test, to 127.36 ms after the instruction. In the delayed post-test, the mean duration for /k/ is reduced to 81.21 ms, but the final VOT values are still different from those revealed in the beginning of the study.

Since this article draws on and defends Complex Dynamic systems applied to language development,[40] language destabilization, attrition and relearning are considered to be integral parts of bilingualism.[41] This point of view compulsorily implies, as already mentioned, that both L1 and L2 are interconnected complex subsystems of a greater bilingual system and dynamically adapt as a result of mutual crosslinguistic influence and according to the environment. On this note, research has shown that context and

[40] DE BOT, "Complexity Theory and Dynamic Systems Theory": same or different? (2017).

[41] OPITZ, "Language destabilization and (re-)learning from a Complexity Theory perspective": timescales and patterns across four studies (2017).

language frequency and recency of use are paramount in language development. Furthermore, individuals' agency and their will to learn and/or maintain languages is pivotal in the process.[42] Bilinguals are active agents in language development by shaping and building language use contexts.[43] Therefore, language systems are largely experience-based and adaptive.

At this point, however, it is important to remember that language transfer results from the consolidation of memory and quantity and quality of input received,[44] and that the L1 influence on the L2 might create a context of use that constraints L2 speech development. Even though the environment is capable of providing a vast source of information, it is only processed if perceived from the perspective of individuals' previous experiences.[45] With this in mind, context, use and agency are limited by what bilinguals are able to perceive and process from the L2 with their L1 entrenched systems. It is important to mention that the fact that bilinguals are not always able to operate on the information to which they have access does not imply that external stimuli are inadequate or poor. It only designates that the human cognitive ability to process and interpret such information is based on the ecology of individuals' experiences.[46] For this reason, explicit pronunciation teaching is important, as it can guide learners to perceive, represent and use novel nonnative categories.[47] In this light, studies on explicit pronunciation instruction based on communicative models have shown positive effects in improving perception and/or production of L2 sounds,[48] such as in the case of the L2 data above.

Although participants produce extreme values for L2 English VOT in the immediate post-test, after the system's destabilization, for the delayed post-test, the values revealed are around 44 ms, 54 ms and 81 ms for /p/, /t/, and /k/, respectively. Those values are not exaggerated and are closer to the 55 ms, 70 ms, and 80 ms described in the literature for English. This finding suggests that, after the system is perturbed and due to the increase in L2 phonological awareness, L2 English VOT production shows signs of self-organization, a clear dynamic characteristic.

In a complex dynamic perspective, all languages of an individual interact. Therefore, a perturbation in one language/subsystem might have an impact in other languages/subsystems of the greater bilingual system, and that is precisely what the data for L1 BP VOT production by the EG exposes. Regarding the BP bilabial stop, the VOT values produced in the immediate post-test (mean = 31.63 ms) are statistically different from those found prior to the instruction (mean = 21.12 ms) and in the delayed post-test (mean = 24.93 ms). When pre-test and delayed post-test are compared, no differences are found. In other words, after the instruction, the L1 VOT values for /p/ become higher, but, three months later, they decrease and present a similar central tendency compared

42 Kupske, "O impacto do desgaste da língua no ensino de línguas: a dinâmica da retenção e manutenção de conhecimentos linguísticos no multilinguismo" (2019).

43 Opitz, "Language destabilization and (re-)learning from a Complexity Theory perspective": timescales and patterns across four studies (2017).

44 MacWhinney, "Emergentism—use often and with care" (2006).

45 Perozzo and Kupske, "Speech perception and production as constructs of action": Implications for models of L2 development (2021).

46 Perozzo and Kupske, "Speech perception and production as constructs of action": Implications for models of L2 development (2021).

47 Kupske and Alves, "Orchestrating chaos": teaching foreign language pronunciation in the complexity paradigm (2017); Alves and Kampff, "Efeitos de longo prazo do treinamento perceptual na percepção e produção das plosivas iniciais surdas do inglês por estudantes brasileiros": implicações para o ensino de pronúncia (2019).

48 Kupske and de Oliveira, "O desenvolvimento do padrão de Voice Onset Time das oclusivas surdas iniciais do inglês por aprendizes soteropolitanos": efeitos da instrução explícita (2020).

to the pre-test. In a nutshell, the destabilization created by the L2 English pronunciation instruction affected how the L1 BP /p/ was produced in the immediate post-test.

For BP /t/, on the other hand, Pairwise Comparisons show that the VOT values obtained in the immediate post-test (mean = 34.94 ms) are statistically different from those in the pre-test (mean = 22.20 ms), but are not different from the ones found for the delayed post-test (mean = 38.87 ms). When immediate and delayed post-tests are analyzed, no differences are observed. This suggests that the VOT values for L1 BP still drift away from the initial short-lag pattern three months after the L2 explicit instruction. It is worth noting that, in the delayed post-test, the values and the variability for the alveolar stop are higher, suggesting that participants who have received the L2 pronunciation instruction present a greater variability in the way L1 properties are applied, a characteristic of FLA.[49]

[49] Schmid, *Language Attrition* (2011).

Finally, the BP velar stop shows a unique emergent trajectory. Pairwise Comparisons demonstrate that VOT values found for /k/ in the immediate post-test (mean = 50.65 ms) are not statistically different from those in the pre-test (mean = 52.32 ms), but are different from those observed in the delayed post-test (mean = 61.11 ms). When immediate and delayed post-tests are analyzed, no significant differences are reported. As revealed for the BP /t/, in the delayed post-test, the values and the variability for /k/ are higher. These findings strongly suggest that the L2 instruction did not immediately affect the production of L1 BP /k/, which showed higher (attrited) values only three months later. In other words, it is evidence that the L1 continues to adapt months after the L2 explicit perturbation.

Although, under certain contexts and conditions, languages might "settle" into more persistent states,[50] bilingual systems are never stable, and the learning of a new language will destabilize the previous language subsystems of any individual. However, as already mentioned, the impact of the L2 depends on what bilinguals are able to perceive and process from this language, and explicit instruction may trigger perception leading to new destabilization both in the L2 and the L1.

[50] Opitz, "Language destabilization and (re-)learning from a Complexity Theory perspective": timescales and patterns across four studies (2017).

While parts of the bilingual system tend to show relative stability, such as the L1 knowledge, the data described in this work supports a strong multidirectional influence between L1 and L2, at least as far as VOT is concerned. Taken together, the findings of this article support not only the claims of Complex Dynamic systems applied to language development, but also the premise that FLA is an integral and expected part of bilingual development. Data like this help going against the colonial conventional idea that treats phonological grammar as an unshakable group of rules or constraints.

By drawing on the idea that language is purely a mental phe-

nomenon, only indirectly connected to use and the environment, the possibility that grammar is also built from the outside ends up being completely ignored.[51] However, this study reveals that speech production is adaptive, and that the phonological grammar is only relatively stable. The L1 and the L2 dynamically interact and self-adapt with one another and with the context, bringing to light new VOT variants supported by the L1 and the L2 that also produce meaning. Bilingualism is thus compulsorily hybrid and adaptive, and FLA must be seen as a natural part of bilingual development, emerging from the dynamic interactions of speakers and the ecological "perceived pressures" of the environment. Bilingualism is not only gain-oriented and is nonlinear, meaning that "the act of playing the game has a way of changing the rules".[52]

[51] Albano, *O gesto audível*: fonologia como pragmática (2020).

[52] Gleick, *Chaos*: Making a New Science (2008).

Final remarks

This article sought to analyze the effects of explicit pronunciation instruction on L2 English development and L1 BP attrition regarding the production of word-initial voiceless stops by Brazilian intermediate users of English. It was assumed that, prior to the instruction, independent English speakers would not produce the expected VOT pattern for L2 English, thus adopting the BP standard. After the instruction, however, the hypothesis was that the L2 values would increase towards the long-lag pattern, and that this destabilization in the L2 subsystem would also translate into changes in the L1. The hypothesis was confirmed, and the VOT for both languages showed a significant increase in duration after the explicit pronunciation instruction. With this being said, in addition to highlighting the effect of explicit instruction for L2 development and L1 attrition, this study confirms that language development is constant,[53] and that even L1 "adult" grammars are adaptive, with potential and plasticity to change due to the perception and processing of novel nonnative phonetic-phonological categories or by induced destabilization of the language system, as the one brought about by explicit language teaching.

[53] Kupske, "A complex approach on integrated late bilinguals' English VOT production": a study on south Brazilian immigrants in London (2017).

In addition, the findings reported here validate that the mechanisms for language development operate similarly in the L1 and the L2 and remain active during the lifespan.[54] The alterations in VOT values for the EG in the delayed post-test, for example, evidence that phonetic-phonological categories evolve over time, indicating that language and language development are Complex Dynamic systems, as they are constantly changing anchored in individuals' experiences and on the environment.

[54] Best and Tyler, "Nonnative and second-language speech perception": Commonalities and complementarities (2007); Flege, "Second language speech learning": Theory, findings and problems (1995); Flege and Bohn, "The revised Speech Learning Model (SLM-r)" (2021).

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