The Functional Origin of Foreign Accent: Evidence from the Syllable Frequency Effect in Bilingual Speakers

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Individuals that speak more than one language often have a foreign accent. Previous investigations have focused on the acoustic phonetic properties of speech, showing how language learning history shapes the occurrence of accent. By contrast, little is known about the phonological and phonetic representations that allow the production of each language within one speaker. We investigated this issue via the syllable frequency effect, thought to index the retrieval of syllable sized representations during speech production. We tested French-Spanish early and late bilinguals in a task in which the materials' syllabic frequency in both languages was manipulated. The frequency of syllables in the non-spoken language affected performance only with late bilinguals. This is interpreted as evidence that syllabic representations are shared across languages in late bilinguals, but are separate in early bilinguals. One of the functional origins of foreign accent in late bilinguals may be the retrieval of syllabic representations shared across languages.

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There are well-known limitations in humans' ability to learn a second language (e.g. Pallier, Bosch, & Sebastián-Gallés, 1997). Without an optimal environment (e.g. frequent verbal interaction during early childhood), speakers often produce their second language with a pronunciation largely influenced by their mother tongue, *i.e.* with a foreign accent. Most of the research into this phenomenon has focussed upon the acoustic properties of spoken material, highlighting language learning parameters that modulate the strength (or possible absence) of foreign accent (Piske, MacKay, & Flege, 2001). By contrast, the cognitive mechanisms that occur prior to spoken production have been much less studied. Here we report an investigation of these processes where we used a marker effect – the syllable frequency effect previously reported with monolingual speakers – to test the structure of syllabic representations in early and late bilinguals. Our results clarify the structure of bilinguals' spoken production system, and suggest a plausible hypothesis for the functional origin of foreign accent.

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As noted above, phonetic aspects of foreign accent have been investigated by quantifying acoustic properties of bilinguals' speech either objectively (with phonetic measures) or subjectively (with off-line ratings). Early bilinguals tend to produce the same phoneme with distinct acoustic properties across languages. Caramazza, Yeni-Komshian, Zurif, and Carbone (1973) observed cross-linguistic differences in the voice-onset times of stop-consonants produced by French-English bilinguals (see also Fowler, Sramkoc, Ostry, Rowland, & Hallé, 2008; for vowels, see Flege, Schirru, & MacKay, 2003). These observations depend to some extent on the language history of the speakers. Many features of early bilinguals' native language appear to be similar to those of monolinguals (Mack, 1989), whereas within-speaker cross-linguistic differences tend to be weaker in late bilinguals (Flege, 1981).

Experimental investigations of the phonological representations recruited during bilingual speech production are scarcer. Roelofs (2003) reviewed arguments in favor and against shared phonological systems. His own experiments showed that repeated use of a phoneme decreased naming latencies within as well as across languages, suggesting shared phoneme representations across languages. Costa, Caramazza, and Sebastián-Gallés (2000) observed faster picture naming for cognate than non-cognate nouns. They hypothesized cascaded activation from the lexicon to a shared phonological system, where cognate nouns produce conver-

gent, stronger activation levels (see also Costa, Roelstraete, & Hartsuiker, 2006). In both studies, fairly proficient bilinguals were tested.

In summary, for proficent bilinguals, a shared phonological system would lead to the production of cross-linguistically distinct acoustic features. The contrast between a "common phonological space" and distinct phonetic realizations is acknowledged in theoretical models (e.g. Flege, 2002), yet the locus of the processing divergence between languages is still unknown. For late or less proficient bilinguals, the presence of foreign accent in L2 suggests some degree of interaction between the representations or processes involved in the production of the two languages. The details of this interaction remain to be clarified.

To address these issues, we focused on the processes that lie between phonological encoding and articulation, where a "syllabary" has been posited to hold pre-stored syllable size representations that command syllable articulation (Crompton, 1981; Levelt & Wheeldon, 1994). Evidence supporting this framework includes facilitatory syllable frequency effects modulating monolingual naming latencies in different experimental paradigms (Levelt & Wheeldon, 1994; Cholin, Levelt, & Schiller, 2006). Considering the case of bilingual speakers, we asked whether such syllable representations are language-specific (hypothesis a) or shared across the two languages (hypothesis b).

Language-specific syllabic representations could allow distinct phonetic realizations accross languages. By contrast, shared representations could promote an asymmetric cross-linguistic influence (i.e. foreign accent) if the phonetic representation of syllables set during the early acquisition of L1 were to remain inflexible, and then put to use articulating L2 (as suggested above, given the weak cross-linguistic differences in late bilinguals' speech; Flege, 1981). We defined which syllables are good candidates to be shared across languages on the basis of their descriptive phonological properties. The contrast between the two representational hypotheses was then operationalized by testing whether syllable frequency in the language not being spoken affects bilinguals' performance[1].

To test this hypotheses, the production of spoken syllables had to be tested in a task suited to inform us about speech production processes. We used timed pseudo-word reading (Laganaro & Alario, 2006). Pseudo-word materials allow an efficient manipulation of syllable frequency. Crucially, the interpretation of the syllable frequency effect in terms of output processing applies to speech elicited by printed words or pseudo-words, even if recognition effects may dominate in other tasks such as lexical decision (Conrad, Stenneken, & Jacobs, 2006; Perea & Carreiras, 1998; see also Dijkstra, Grainger, & van Heuven, 1999).

Experiment

Participants

Fifteen early bilinguals (who learned Spanish and French before they were 5) and sixteen late bilinguals (who learned French after 12) participated in our study. All participants are immersed in a French environment; all but two use French at work or school. They reported using Spanish with family, friends or when reading or listening to the media. Late bilinguals are fluent French speakers, but have a foreign accent in French, not quantified beyond subjective assessment.

Materials

The experimental materials were composed of French and Spanish syllables whose properties were manipulated. A combined French-Spanish syllabary was constructed from the syllabification of the French database LEXIQUE (New, Pallier, Brysbaert, & Ferrand, 2004) and the Spanish database LEXESP (Sebastián-Gallés, Martí-Antonín, Carreiras, & Cuetos, 2000) using the procedures described by Laporte (1993), and empirically evaluated in Goslin and Frauenfelder (2001). Syllable frequencies were recalibrated to arrive at the frequency of occurence per million produced syllables for each language. This allowed a more accurate relative measure of language-specific frequency of common syllables (removing differences in average syllabic word length across languages, for example).

We used strict criteria to define syllables common to both languages, looking for good candidates rather than trying to determine all possibly shared syllables. This classification was made according to the International Phonetic Alphabet transcriptions of the phonemes in the two languages. Although the same phoneme may be produced differently by native speakers of two languages (Delattre, 1964), the studies reviewed in the Introduction suggest that in bilinguals such phonemes may be subserved by a single representation. This led to three categories: phonemes that clearly map to one another across languages (e.g. /k/), phonemes that are clearly language specific (e.g. /õ/ in French, /χ/ in Spanish), and phonemes for which there may be uncertainty as to their similarity (e.g. consonants with variable allophonic realizations: /ʁ/ and /r/, /b/, /β/, and /v/). Only the first category was used to construct the experimental items.

The vowels retained as "common" were /i/, /a/ and /u/, whilst "common" consonants and glides were /p/, /t/, /d/, /k/, /g/, /f/, /s/, /ɲ/, /m/, /n/, /l/, /w/, and /j/. These criteria yielded 506 common syllables, with 5452 syllables specific to French, and 5965 specific to Spanish. Although common syllables only represent a small minority of all syllable types (4.2%) they are some of the most frequent syllables of both languages, accounting for 27.3% of the total syllable token count over both languages

The experimental items were 200 pseudo-words to be produced in both languages. Each was composed of two shared syllables (experimental and pivot syllables, respectively). The 100 experimental syllables are those whose frequency effect is tested (e.g. /pal/). They were drawn from a large independent range of frequencies in the two languages

[1] This is a strong test; it is indeed possible that the bulk of foreign accent comes from non-shared syllables approximated by different native syllables (e.g. /ð/ produced as /z/ by French speakers).

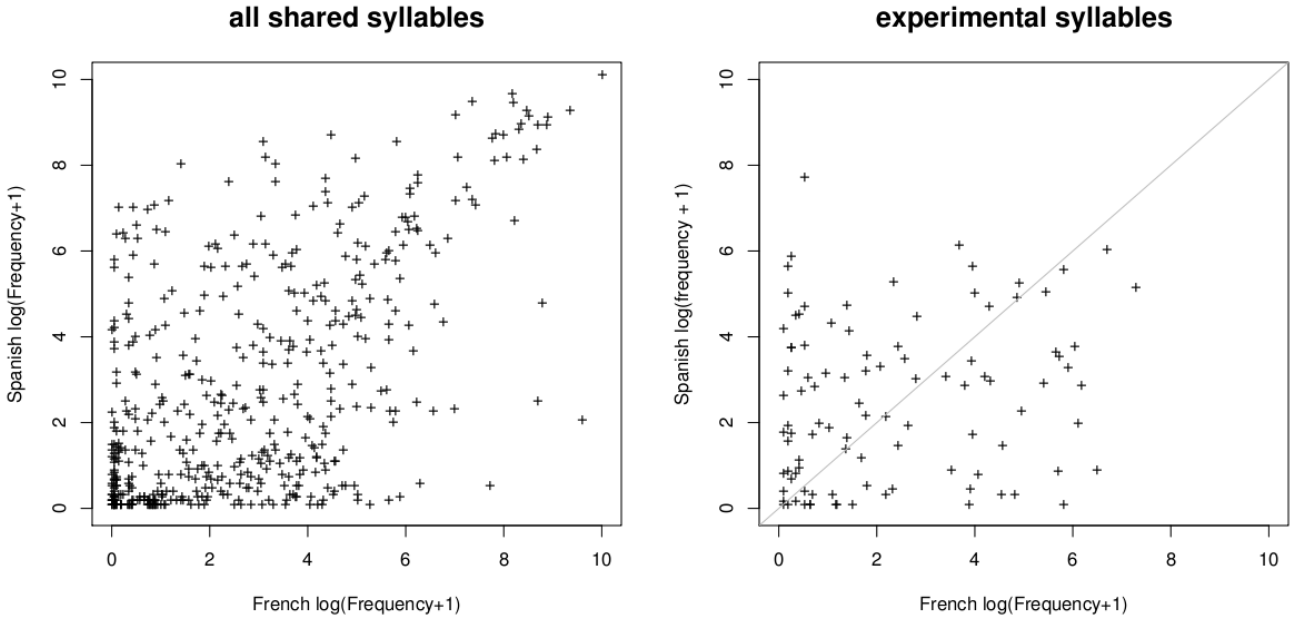

Figure 1. Properties of shared syllables (defined in the main text) in French and Spanish. *Left*: frequencies of individual syllables across languages; each point is a syllable. *Right*: similar graph restricted to the experimental materials; syllables lying in the lower quadrant (*i.e.* below the grey line) are more frequent in French than in Spanish (and *vice-versa*).

(Kendall $\tau = .14$, $z = 2.04$, $p = .04$; Figure 1). The 20 pivot syllables had consonant + vowel structure (e.g. /ku/), and high frequency in both languages. The 200 pseudo-words were created by pairing each pivot syllable with five distinct experimental syllables, in initial and final positions (e.g. /kupal/ and /palku/). Orthographic transcriptions of these items maximizing language idiosyncrasies were chosen (e.g. French *coupal* vs. Spanish *cupal*). In addition, there were 100 disyllabic filler pseudo-words in each language (e.g. /tiʃõ/ for French, /piχal/for Spanish), constructed with the same pivot syllables paired with language specific syllables.

Procedure

Participants were tested in two language-specific blocks with counterbalanced orders across participants. Each block started with two warm-up tasks in the block's target language: a standard conversation with the experimenter, and reading a short text aloud. Participants then named the 300 pseudo-words in a quasi-random order, such that filler items were homogeneously spread throughout the block. In each trial a fixation point appeared in the middle of the screen for 500 ms, immediately followed by the pseudo-word for 800 ms. Participants were asked to name the item aloud as fast as possible. The following trial started 2000 ms later, with short breaks every 100 trials.

Analysis

The naming latency data, with errors excluded, were log-transformed to reduce skewness and approximate a normal distribution. They were fitted with linear regression models including random and fixed effects (Baayen, Davidson, & Bates, 2008). To exclude possible confounds, the models included fixed effects for phoneme frequency, phonological and orthographic neighborhood sizes whenever they had significant contributions. Note that these dimensions were not manipulated expicitely; their range of variation across items may not be large enough to produce significant effects.

The theoretical focus was on shared syllables, and their frequency effect. Under the hypothesis that these syllables have a common representation their frequency should be the accumulated frequency from counts in the two languages, modulated by the extent to which speakers have used each of the two languages. One difficulty for specifying this hypothesis is that both the accumulation function across languages, and each participant's precise share of language use are unknown. A plausible function could be chosen (e.g. $log(p \cdot Freq_1 + (1 - p) \cdot Freq_2)$, where p is the estimated share of L_1 use, and $Freq_i$ is syllable frequency in L_i). However, if such cumulative frequency does not affect performance, it is not straightforward to decide whether the shared hypothesis, or the particular cumulative function should be rejected.

A theoretically more neutral operationalization of the hypothesis was adopted. We defined L-syllables as those that have a lower frequency in the non-target than in the target language (Figure 1). H-syllables were those with a higher frequency in the non-target language. Under the shared representation hypothesis, the available *monolingual* frequency count used to test syllable frequency in the tar-

Table 1
Performance averaged by items with syllable frequency broken down in four quartiles (noted 1st to 4th). Notice that these figures are not corrected for possible effects of variables not presented here (see model description for details).

		Early bilinguals			Late bilinguals		
Relative syl-freq	Syl-freq quantile	M	SD	Err	M	SD	Err
Higher in the other language	1^{st}	678	75	10.3	715	76	11.7
	2^{nd}	662	69	10	672	59	12.4
	3^{rd}	657	102	7.7	670	74	7.4
	4^{th}	626	41	2.4	659	42	0.9
Lower in the other language	1^{st}	650	49	6.7	703	61	9.4
	2^{nd}	671	83	9.6	702	73	13.2
	3^{rd}	646	72	5.7	677	59	9.3
	4^{th}	637	53	2.9	670	65	5.2

[a] Syl-freq = syllable frequency; M = mean; SD = standrad deviation; Err = % error rate

get language is *overestimated* for L-syllables, and *underestimated* for H-syllables. Therefore, over and above the target language syllable-frequency effect, L-syllables should be named slower than H-syllables. Of course, in the alternative hypothesis of independent syllable representations there should be no effect of Relative Frequency.

Interestingly, the definition of Relative Frequency does not require explicit assumptions about the cumulative function, and syllable groupings do not depend of the speakers' share of language use. Also, a proficiency asymmetry between L1 and L2 is not expected to modulate the relative frequency effect, even if foreign accent typically affects L2 and not L1. This is because speakers using a shared syllable will access the *same* representation when speaking either language. In contrast, the magnitude of the relative frequency effect would be expected to vary accross languages and speakers, depending on their (variable and unknown) proportion of L1 and L2 use. This latter prediction was not tested.

Results

There were 12400 experimental trials. Among them, 1062 trials resulted in errors (8.6% error rate) and 9 were considered to be outliers (naming latencies below 200 ms and above 2000 ms); both categories were excluded from the analysis. Late bilinguals had an average naming latency of 684 ms (mean standard deviation across participants: 144 ms), whilst for early bilinguals it was 652 ms (mean standard deviation: 130 ms) (see Table 1 for further details).

The left side of Table 2 indicates that early bilinguals show a facilitatory syllable frequency effect in the target language, but no effect of relative syllable frequency. Late bilinguals (right side of Table 2) also show an effect in the target language. Crucially, they show an effect of the relative syllable frequency: responses were slower for syllables with lower (rather than higher) non-target language frequency. These results are substantiated by a joint analysis of Early and Late bilinguals' performance, in which there were significant interactions between population groups and syllable frequency in the target language ($t[11319] = 2.01$, $p < .05$), as well as between population groups and relative frequency ($t[11319] = 2.86$, $p < .01$). These analysis indicate (a) that the syllable frequency effect was smaller in mangnitude for late than early bilinguals and (b) that the relative frequency effect was present for late bilinguals only.

General Discussion

Our results show that both early and late bilinguals show the facilitory effect of increased syllable frequency previously reported with monolinguals. More importantly, late bilinguals were sensitive to non-target language syllable frequency, while no evidence for such sensitivity was found in early bilinguals. We consider two interpretations for this finding.

According to the first interpretation, the critical difference between early and late bilinguals may lie in their ability to restrict the application of ortho-phonological conversion rules to only one language. Consider the joint hypothesis that a) early and late bilinguals both have distinct syllable representations for each language, and b) early bilinguals reading pseudo-words selectively activate the syllable representation of the target language whereas late bilinguals activate syllable representations of both languages. Under some further specifications of this hypothesis (concerning activation and selection), late bilinguals are expected to be influenced by syllable frequencies of both languages, while early bilinguals should not be affected by the frequency in the (non-activated) non-target language. Such interpretation seems unlikely, however, because non-target phonological activation is only observed under specific circumstances, unlikely to be met in our study (Jared & Kroll, 2001; Jared & Szucs, 2002; Schwartz, Kroll, & Diaz, 2007). In particular, language use was primed before the beginning of the blocks, which were 300 trials long and involved largely language specific orthographic stimuli.

An alternative interpretation, which we favor, is that early and late bilinguals differ in terms of the syllable representations they retrieve for speaking. According to this view, early bilinguals have independent syllable representations even for

Table 2
Syllable frequency effects in early and late bilinguals' pseudo-word naming latencies

	Early bilinguals			Late bilinguals		
	β	t	p	β	t	p
syl-freq in target language	$-8.40e-03$	5.07	$< .01$	$-6.24e-03$	3.64	$< .01$
relative syl-freq	n.s.	.42	.75	$1.58e-02$	2.46	$< .02$

[a] syl-freq = syllable frequency; n.s. = non significant
[b] p values validated with Markov-chain Monte-Carlo simulations

syllables shared across languages. This would provide an explanation to why thy are able to approach monolingual phonetic patterns in each language. By contrast, late bilinguals use the same representation when sepaking either language. As this would originate from their earlier L1 it experience, would be appropriate for L1 but only a reasonable approximation for L2. As a consequence, late bilinguals would produce non-native L1-like patterns in their L2. Altoghether, this interpretation favors the hypothesis that one of the functional origins of foreign accent lies in syllable representations.

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