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PRESENTATION/POSTER

WHO FOLLOWS THE RULES? DIFFERENTIAL ROBUSTNESS OF PHONOLOGICAL PRINCIPLES

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This study investigates sensitivity to violations of two phonological rules by 14 native speakers of German and 23 L2 learners (L1 American English). Participants completed a phoneme detection task, listening for [t] in pseudowords, including sequences that conformed to the German rule of Dorsal Fricative Assimilation (e.g., [b**ax**t]/[b**ɛç**t]) or violated it (e.g., *[b**aç**t]/*[b**ɛx**t]). Additional stimuli included [h] in initial position (e.g., [**h**amt]), where it is legal in English and German, and in syllable codas (e.g., *[ba**h**t]/*[bɛ**h**t]), where it is banned in both. Systematic reaction time effects in response to phonotactic violations are analyzed as evidence that the principle is psychologically real in the phonological grammar. Learners exhibited reaction time effects for both types of violations. In contrast to previous findings, Germans showed no effect for violation of Dorsal Fricative Assimilation; they also showed a slowdown trend for [h] in coda position. These findings suggest important differences between phonological knowledge types and between native and L2 learner exposure to phonological principles.

INTRODUCTION

Second language (L2) phonology (i.e., systems of sounds and their abstract relationships) is necessarily intermingled with phonetics (physical properties of speech sounds). Phones are the lowest common denominator between first language (L1) and L2 in perception and production, and thus a necessary element in L2 phonology studies. Therefore, L2 phonology research must include both phonetic sensitivity and phonological knowledge at different stages of development. Focusing on German native speakers (NS) and early L2 learners (L1 American English), this study investigates the psychological reality of two phonological rules—namely, the German alternation of the palatal fricative [ç] with the velar fricative [x] (Dorsal Fricative Assimilation: DFA) and the restriction in both English and German that bans [h] from occurring at the end of syllables.

LITERATURE REVIEW

Dorsal fricative assimilation

Palatal [ç] and velar [x] fricatives are novel for L1 American English speakers. In German, they are called *ich-Laut* (‘I-sound’ after the pronoun *ich* ‘I’) and *ach-Laut* (‘oh-sound’ after the interjection *ach* ‘oh’). In the phonological literature, they famously alternate in word-internal post-vocalic position, depending on whether they follow a front vowel or a back vowel (e.g., *Buch*, [buːx] ‘book, SG.’ vs. *Bücher*, [ˈbyː.çɐ], ‘book, PL.’) or certain consonants (e.g., *Mönch*, [mœnç], ‘monk’). In general terms, *ach*-Laut surfaces as velar [x] after non-low back tense vowels, as uvular [χ] after low vowels, and as either [χ] or [x] after non-high back lax vowels [ʊ/ɔ] (Wiese, 1996, pp. 209–210). Some exceptions exist, especially with the invariant diminutive suffix (e.g., *Kuh*, ‘cow,’ [kuː] vs. *Kuhchen*, ‘cow, DIM.,’ [ˈkuː-çən]). I treat DFA as an active allophonic alternation in German, whereby, at least in monosyllables, [x]/[χ] surfaces after back vowels and [ç] surfaces elsewhere. For convenience, sequences that conform to DFA are termed “Good;” violations of DFA are “Bad.”

Distribution of /h/

The feature [+spread glottis] aligns [h] with voiceless aspirated stops (e.g., [p^h]; Halle & Stevens, 1971). This natural class makes the prediction that, in some language(s), some phonological rule or constraint applies to or is triggered by both types of segments. American English bears this out: aspirated stops and /h/ pattern together. For a thorough treatment of the distribution of /h/ and aspirated stops with respect to the prosodic foot in English, see Davis and Cho (2003). Jessen (1998, pp. 152–153) notes the same alignment of /h/ and aspirated stops for German, using [tense] as the operative feature. Here, the fact that [h] may not appear in the right syllable margin is called the *Coda-[h] ban. To unify terminology between conditions, items in [h]-conditions that have [h] in the left syllable margin are called “Good;” items with [h] in the right margin, violating the *Coda-[h] ban, are “Bad.”

Phoneme detection

Figure 1 presents a summary of phoneme detection studies that have investigated phonological knowledge of place assimilations. Otake, Yoneyama, Cutler, and Van der Lugt (1996) investigated Japanese regressive (right-to-left) nasal assimilation to the place of a following consonant, where place assimilation is obligatory, and Weber (2001a, 2001b) replicated this. Weber (2001a, 2001b, 2002) also investigated sensitivity to violations of progressive (left-to-right) DFA in German. Otake et al. (1996) and Weber (2001a, 2001b) found consistent and strong reaction time (RT) slowdown (inhibition) when nasals and following stops clashed in place of articulation (“Bad”). Weber instructed participants to listen for dorsal fricative allophones—velar [x] or palatal [ç]--and press a button when they were heard. Native German speakers responded slightly faster (facilitation) for front+[x] “Bad” sequences, but not for back+[ç] (also “Bad”). Weber argues that this is because this type of sequence occurs in German (e.g., *Kuh-chen*). Thus, the alternation of [ç] and [x], governed by the place of the preceding segment, seems to have psychological reality for German NSs. Lindsey’s (2013) replication included L2 German learners (L1 American English), finding strong and consistent RT inhibition in both German NSs and advanced L2 learners for violations of DFA (all “Bad” sequences). These results suggest that learners can acquire sensitivity to novel L2 alternations. It is unclear whether and under what conditions “Bad” sequences inhibit or facilitate phonological processing. In contrast to the studies cited here, this study replicates and expands on Weber’s and Lindsey’s studies to include the *Coda-[h] ban, but avoids cross-language labels by using the familiar listening target [t].

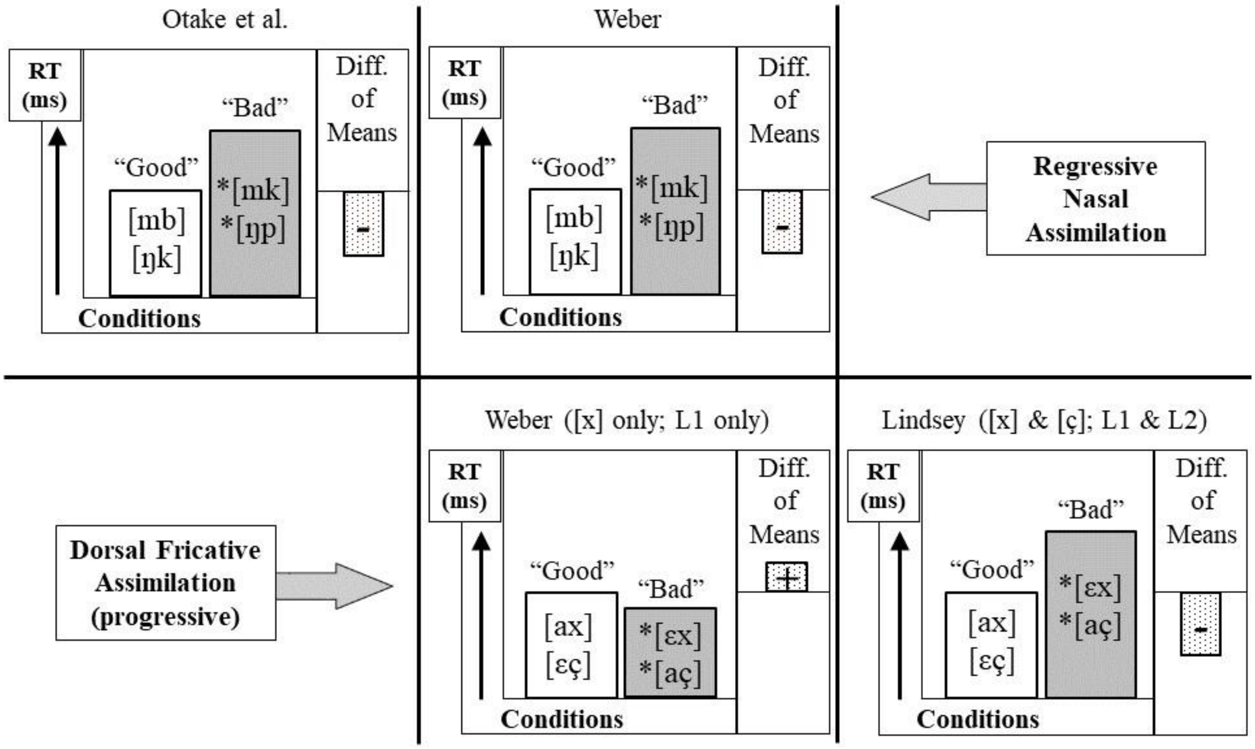

Figure 1. Summary of phoneme detection studies investigating place assimilations. Diagrams show examples for reported patterns in these conditions, not actual data. Difference of means represents mean RT of "Bad" conditions subtracted from "Good."

Research questions

The current investigation pursues the following research questions:

1. What RT effects arise from violation of progressive (left-to-right) assimilation expectations?
2. What RT effects arise from violation of syllable constraints on phoneme distribution?
3. How robust (consistent and strong) are these phonological principles compared to other (obligatory) assimilation rules?

If DFA is acquired as phonological knowledge, then "Bad" sequences *[aç/ɛx] that violate DFA should trigger a RT effect compared to expected sequences [ax/ɛç] (RQ 1). The restricted distribution of [h] in English and German represents a different type of phonological knowledge from rules of assimilation. When [h] appears illegally in the right syllable margin, NSs and L2 learners should exhibit consistent and strong inhibition (RQ 2). The *Coda-[h] ban in the right syllable margin (e.g., *[ba**h**t]) is without exception in English and German. Similarly, if allophonic alternation from DFA is acquired as an obligatory phonological rule, then violation of DFA should yield a similarly strong and consistent effect (RQ 3).

METHOD

Participants

Participants included 14 German NSs (2 male, 12 female; 20–29 years old, mean age = 22.9) in Stuttgart, Germany [i] and 23 NSs of American English (12 male, 11 female; 18–23 years old; mean age = 19.6) enrolled in second-semester German at a large Midwestern university. At the time of data collection, German L2 learners reported 1–11 previous semesters of secondary or post-secondary instruction in German; 12 reported just one previous semester and seven reported six or more previous semesters. Participants 2002 and 2039, respectively, reported initial German exposure at age 3 or "very young," but no use of German until the late teens. (Results of both contribute to the group majority trends reported here.) Data collection with L2 learners was conducted at two time points during the same spring semester. Six participants completed the task at both time points; only their data from the later time point were analyzed.

Materials

The experiment included 384 nonword trials with [t] as the listening target. Critical trials (*n* = 48) were balanced for "Good" and "Bad" in three pairs of conditions (*n* = 8 trials / condition), shown in Table 1. "Good" conditions included back Match (e.g., [gl**ax**t]), front Match (e.g., [gl**ɛç**t]), and Onset-[h] (e.g., [**h**amt], [**h**ɛlkt]); their "Bad" counterparts were back-front Mismatch (e.g., *[gl**aç**t]), front-back Mismatch (e.g., *[gl**ɛx**t]), and Coda-[h] (e.g., *[gla**h**t], *[klɛ**h**t]). There were 144 trials containing [t] in other (nonfinal) positions, and all 192 [t]-trials were balanced by 192 fillers without [t].

Table 1

Onset and duration of pre-targets and listening targets (means and standard deviations)

		Fricative				Listening Target [t]			
		Onset (ms)		Duration (ms)		Onset (ms)		Duration (ms)	
Condition	*n*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Licit position									
Match [ax]	8	258	61	162	19	420	53	184	14
Match [ɛç]	8	275	67	160	20	435	76	180	18
Onset [h]	8	5	1	114	20	393	55	176	28
Illicit position									
Mismatch *[aç]	8	281	69	199	20	480	53	149	13
Mismatch *[ɛx]	8	300	60	153	17	454	51	180	20
Coda Cluster *[h]	8	236	65	316	39	552	73	200	24
Filler with [t]	144	-	-	-	-	102	109	81	44

Note. For [x]- and [ç]-conditions, fricatives immediately precede the listening target [t]. For [h]-conditions, "Bad" [h] immediately preceding the listening target in coda clusters is longer than the other fricatives, including "Good" [h] in onsets.

For each item, at least three tokens were recorded in a sound-attenuated booth at a sampling rate of 44100 Hz by a phonetically trained female NS of German from Saxony. The researcher selected tokens on the basis of recording quality. In addition to tokens recorded for experimental trials, six nonword training trials were used: *Tiesel, gamisch, frettig, Skirm, Prasen,* and *Schloft.* In the training phase, these were presented as one block in the order shown. Practice trials alternated with training scripts highlighting that [t] occured in various positions.

Procedure

Data collection sessions (90–120 minutes) included a language background questionnaire in participants' native language and two other experiments not reported here. Participants received instructions in their native language verbally and on screen. Stimuli were presented via headphones with volume control. Participants were instructed to listen for the target sound [t] and respond as fast as possible with the space bar when they heard it. As /t/ is phonemic in both English and German, it was readily available to both groups for labeling the listening target. All "Good" conditions ([ɛç]-Match, [ax]-Match, Onset-[h]), "Bad" conditions (*[aç]-Mismatch, *[ɛx]-Mismatch, *Coda-[h]), and fillers were randomized in a single block with self-paced breaks after every 32 trials.

Native speakers. German NSs completed the experiment in Stuttgart, Germany. All units ran Windows 7 Professional (Service Pack 1, 64-bit). The experiment was run in OpenSesame (Version 2.9). Participants received €15 cash.

L2 learners. Data were collected from the L2 group at the middle and end of the same semester of their second-semester university German course. Testing was administered by desktop computer running Windows 7 Service Pack 1 (64-bit). Additional specifications varied by computer in the laboratory. The experiment was run in OpenSesame (Version 2.8). Participants received US$10 cash for the first session and 1% bonus German course credit for the second. Returning participants at the second session were entered in a drawing for a $50 cash prize (one per 10 returning participants).

RESULTS

Data preparation

Dependent variables. Trials had a "go" versus "no-go" response format; therefore, only hits (i.e., accurate identification of the listening target present in the stimulus) and false alarms (i.e., inaccurate indication of the listening target's presence in a stimulus that did not contain it) resulted in recorded responses. Only hits were analyzed. Slower RT, a measure of variation in speech processing, is attributed to greater processing load (Weber, 2001b, p. 12). The dependent variable for analysis was derived from the recorded RT.

Derivation of augmented RT. Reaction time measurements logged by OpenSesame were augmented by duration (ms) from the onset of the [t] listening target to the end of the audio file, measured with Praat (Version 6.0.19). Augmented RT was used for analysis. The onsets and durations for critical condition stimuli shown in Table 1 (see Materials) only reflect occurrences of [t] in final position, whereas measurements of [t] presented for fillers collapse instances of [t] in all nonfinal positions. Descriptive statistics in Table 1 are for overview only; the precise onset time for each stimulus was used to calculate the adjusted RT for analysis.

Exclusion criteria. To mitigate the impact of nonparticipation on the analysis, participants with fewer than five hit responses in any of the four conditions were excluded. This criterion excluded nine of the L2 group and five of the NS group from subsequent analyses, retaining data from 14 learners and nine NSs. Table 2 summarizes the data retained for analysis.

Table 2

Data set totals after participant exclusion

	Dorsal Fricatives		Glottal Fricative		
	"Good"	"Bad"	"Good"	"Bad"	
Group	[axt]$_{\sigma}$ / [εçt]$_{\sigma}$	*[açt]$_{\sigma}$ / *[εxt]$_{\sigma}$	[hVCt]$_{\sigma}$	*[…Vht]$_{\sigma}$	Totals
L2 (n = 14)	194	195	100	97	586
NS (n = 9)	135	123	60	56	374
Totals	329	318	160	153	N = 960

Note. Fillers are excluded from the table and analysis. All critical trials were monosyllables with the listening target [t] in syllable-final position, indicated by]$_{\sigma}$. For "Good" glottal fricative trials, the penultimate consonant was always licit in that position in both English and German.

Group means

Each participant's mean RT was computed across items for each fricative condition (Dorsal, Glottal) in combination with the factor Context ("Good," "Bad"). Table 3 displays the mean RT for each group by condition. For dorsal fricatives [ç/x], RT in the "Good" condition is equivalent, establishing baseline performance for both groups. The groups differ in their performance with "Bad" dorsal fricatives: NSs' RT is equivalent to the "Good" condition, whereas L2 learners respond more quickly to "Bad" than to "Good." For the glottal fricative [h], NSs are slower than L2 learners in both "Good" and "Bad" conditions. Both groups are slower with "Bad" *Coda-[h] than "Good" Onset-[h], but this is more pronounced for learners.

Table 3

Mean RT (ms) and standard deviation (SD) for each group and each condition

	Native Speakers (*N* = 9)		L2 Learners (*N* = 14)	
Condition	RT	*SD*	RT	*SD*
Dorsal Fricatives [ç x]				
“Good” [axt]/[ɛçt]$_σ$	554	83.6	548	75.2
“Bad” *[açt]/[ɛxt]$_σ$	551	80.0	521	62.0
Glottal Fricative [h]				
“Good” $_σ$[hVCt]	622	77.5	545	63.9
“Bad” *[…Vht]$_σ$	669	102.9	632	57.2

Analysis of variance

For comparability with earlier phoneme detection studies, a one-way repeated measures analysis of variance (ANOVA) was conducted in SPSS 25 on the RT means for each group and each fricative type, declaring the factor Context (two levels).

Native speakers. There was no main effect of Context on RT in dorsal fricatives [ç/x], $F(1, 8) = 0.038$, $p = .851$, $\eta_p^2 = .005$. This result is unsurprising given the difference of means in this condition was only 3 ms. There was also no main effect of Context found on RT in glottal [h], but there was a trend for slower RT with “Bad” *Coda-[h] (669 ms) than with “Good” Onset-[h] (622 ms) in this group, $F(1, 8) = 2.866$, $p = .129$, $\eta_p^2 = .264$; the partial eta-squared measure of effect size indicates a “would-be” large effect, so this result may have resulted from limited statistical power due to sample size.

L2 learners. The ANOVA showed a main effect of Context on RT in dorsal fricatives [ç/x], $F(1, 13) = 6.874$, $p = .021$, $\eta_p^2 = .346$. This means that “Bad” dorsal fricatives *[aç/ɛx] have a reliably faster RT (facilitation) than “Good” dorsal fricatives [ax/ɛç] for this group, and that is a large effect despite the apparently small difference of means (26 ms). This particular effect may not be as robust as the ANOVA suggests. Scott (2019) treats the same data with a mixed effects model, finding only a marginal trend. A main effect of Context on RT was also found in glottal [h], $F(1, 13) = 27.858$, $p < .001$, $\eta_p^2 = .682$, which means that “Bad” *Coda-[h] reliably had considerably slower RT (inhibition) than “Good” Onset-[h], with a large effect size.

Summary of ANOVA. Surprisingly, German NSs do not manifest expected RT shifts for violations of DFA, and they exhibit only a trend for slower RT (inhibition) with “Bad” *Coda-[h] compared to “Good” Onset-[h]. In contrast, L2 learners exhibit RT facilitation with “Bad” dorsal fricatives and marked RT inhibition with “Bad” *Coda-[h], as opposed to “Good” Onset-[h] (RQ 1). Learners react strongly to violation of the *Coda-[h] ban; the NS group shows a similar nonsignificant trend (RQ 2). Thus, L2 learners exhibit more reliable RT effects for both types of violations than NSs do.

Effect consistency and strength

This section investigates observed RT effects within groups by individual differences of means between “Good” and “Bad” conditions for each fricative type.

Subtracting the “Bad” mean RT from “Good” for each NS participant yields categorically negative differences of means for the [h]-conditions (Figure 2). Every L2 learner exhibits a slower mean RT for the “Bad” *Coda-[h] condition. This indicates a consistent and strong inhibition by L2 learners in response to violation of the ban. This is not surprising, as this ban holds for English—it is not new phonological knowledge.

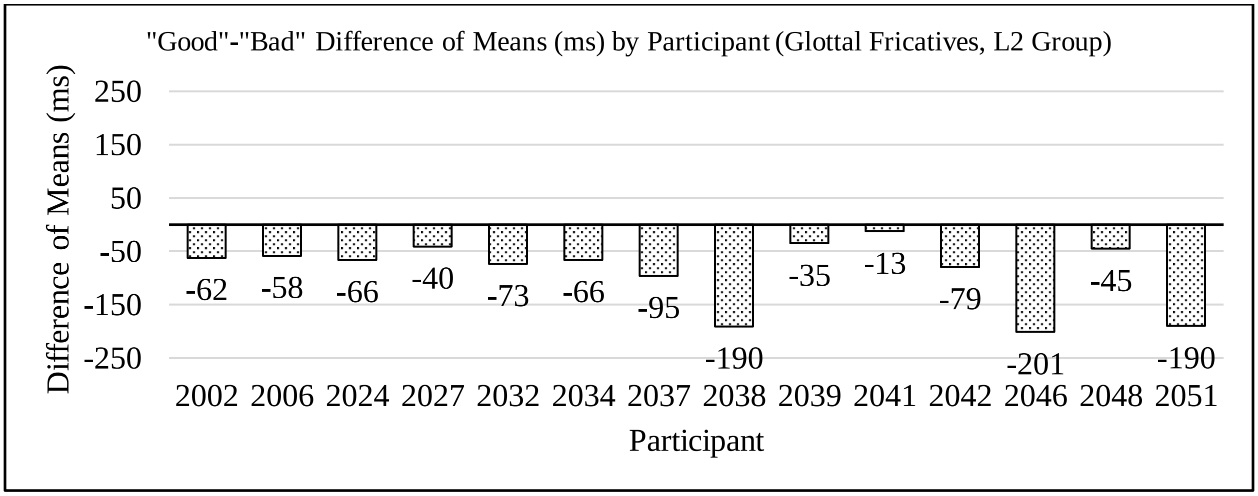

Figure 2. Individual difference of mean RT by participant for [h]-conditions.

Differences of means for the dorsal fricative conditions (Figure 3) are mainly positive, indicating that mean RT for “Bad” dorsal fricatives *[aç/ɛx] tended to be faster than for the “Good” dorsal fricatives [ax/ɛç]. However, several L2 learners exhibit no RT effect, and variation is high. Although some L2 learners exhibit strong facilitation in response to violation of DFA, this is not a consistent group effect.

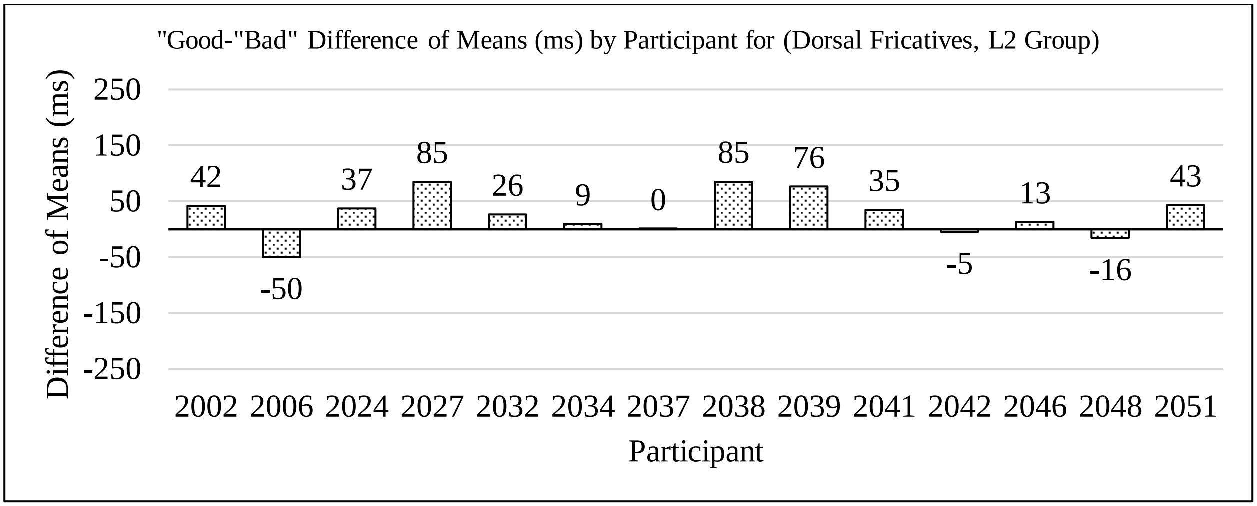

Figure 3. Individual differences of mean RT by participant for dorsal fricative conditions.

Figure 4 displays differences of means between [h]-conditions for NSs. Several NSs show strong inhibition with "Bad" *Coda-[h], several show only minor differences, and variation is high. Two-thirds of these NSs exhibit strong RT shifts, but no single effect is consistent for the group. This suggests that individual Germans differ as to whether the *Coda-[h] ban is psychologically real in their phonological grammars and how it is represented; however, this may be the result of interaction with the preceding vowel (see Discussion).

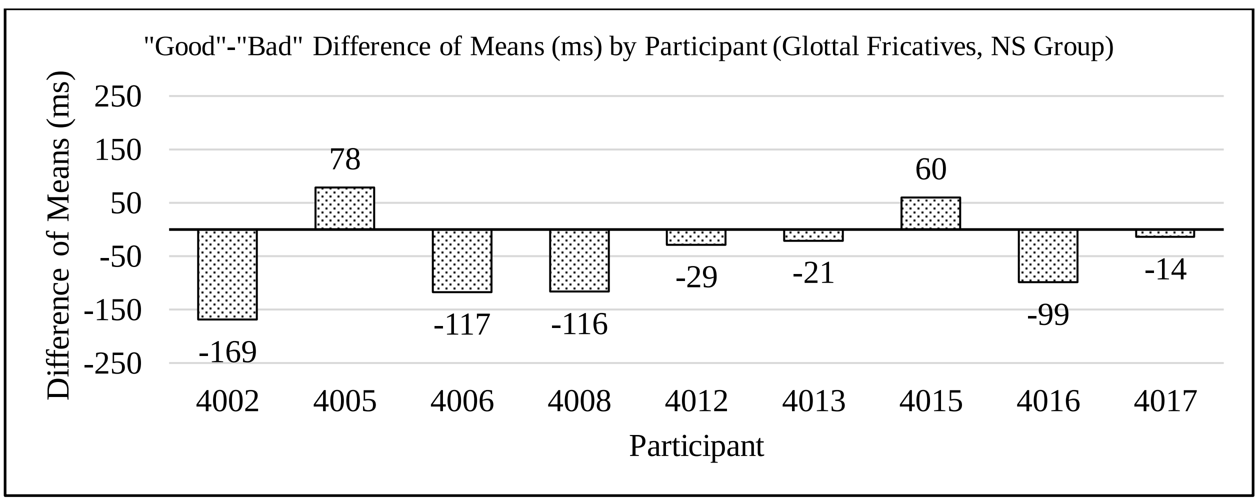

Figure 4. Individual differences of mean RT by participant for [h]-conditions.

Finally, no effect of "Good" versus "Bad" sequence on RT was found in differences of means for NSs in the dorsal fricative conditions (Figure 5). Each participant exhibits weak RT shifts, if any, and differences are not consistently positive or negative. This suggests that individual Germans differ in terms of how (and whether) DFA is represented in their phonological grammars (see Discussion).

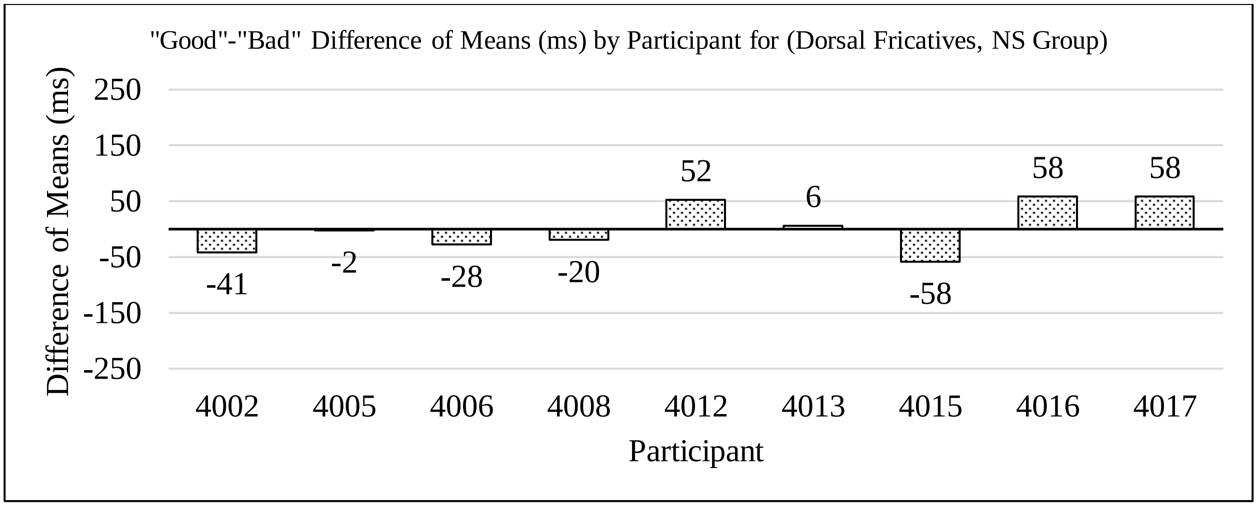

Figure 5. Individual differences of mean RT by participant for dorsal fricative conditions.

General summary

These results support the following conclusions with regard to the Research Questions:

1. Early L2 learners respond faster to violations of German DFA than to place-assimilated sequences. Surprisingly, German NSs manifest no corresponding RT effect.
2. Early L2 learners react more slowly to violations of *Coda-[h] than to trials with licit Onset-[h]. Although predicted to react similarly due to the same ban in German, NSs show only a nonsignificant trend.
3. Learners' slower response to "Bad" *Coda-[h] is robust (strong and consistent). German NSs exhibit high variation in RT in response to these violations—that is, the group is not consistent. Some L2 learners respond faster to "Bad" *[aç/ɛx], but the group is not consistent. Surprisingly, German NSs exhibit no clear RT shifts in response to DFA violations.

DISCUSSION

This study investigated the psychological reality of DFA, which governs the alternation of allophones [ç] and [x] in German, and the ban of [h] in syllable codas in English and German. It adopts the assumption that violation of a phonological rule or constraint increases processing load, which manifests as measurable RT shift. The results suggest that early L2 German learners attend to violation of both phonological rules more than NSs, despite the understanding that both are active in German.

Models of L2 phonological acquisition generally agree that L2 learners are more attentive to subphonemic (phonetic) detail than NSs are. Thus, German NSs may attend less to the wrong allophone appearing in a given DFA context if the allophones themselves are not the listening target. An alternative explanation for Germans' less consistent reactions to DFA violations may lie in the difference between the highly variable linguistic/dialectal exposure of NSs and the low-variability exposure afforded L2 learners in FLA instructed settings (Barriuso & Hayes-Harb, 2018). Phonetic realization of the German dorsal fricative varies widely across German dialects (Hall, 2014); thus, German NSs encounter high variability in the allophones of the dorsal fricative and numerous talkers. In contrast, L2 learners of German as a foreign language rely primarily on instructors for phonological input. As (some) students learn to attend to DFA in perception and production, less variable input may lead to RT effects with "Bad" *[aç/εx].

The difference between learner and NS reactions with the *Coda-[h] ban requires a different explanation. German NSs showed a RT slowdown trend in response to "Bad" *Coda-[h]. Exploratory *t*-tests suggest that this trend interacts with the preceding vowel (Scott, 2019). The "Bad" *[εh] subcondition shows a significant slowdown compared to its "Good" [εç] counterpart, but the "Bad" [ah] does not result in significantly slower mean RT than the "Good" [ax]. This may find explanation in the acoustic similarity of glottal [h] to velar [x], which is legal in that position. Segui, Frauenfelder, and Hallé (2001) describe three types of *phonotactic assimilation*, by which listeners may perceptually ignore a phonotactically illegal phone, or substitute it perceptually with a phone that is legal in that position. German NSs have [x] in their inventory, so may reinterpret acoustic [h] after back vowels (e.g., [a]) as [x] early in processing, then parse it as phonotactically legal [x], triggering no RT effect. However, if L2 learners have not fully acquired (automatized) a fricative that is legal in this position, this mechanism would not be available (cf. Selective Perception Routines; Strange 2011). This experiment included eight "Bad" *Coda-[h] trials: four included [a] and [ε], respectively. Of those, some data were missing due to lack of response, leaving less than four data points for each vowel subcondition. The present data set is too small to test this asymmetry without relying on multiple *t*-tests, increasing likelihood of Type I error.

The present study is limited by power and high variation. Although variation among students of foreign language is ecologically valid, to investigate the relationship between length of exposure and phonological perception, previous instruction should be treated as a variable. To investigate the interaction of [h] with preceding vowels in NSs, more items per vowel and more vowels should be included. More research is required to ascertain to what degree DFA is psychologically real for Germans, and whether RT effects differ between cases in which the listening target is involved in the assimilation rather than adjacent to (but independent of) segments involved in the assimilation.

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[i] German NSs self-reported dialects including Swabian, Westphalian, Palatine, Bavarian, (Thuringian-)Franconian, “Hessisch-Platt,” Standard German, or none, and all reported knowledge of English. Additional language exposure in this group included French, Spanish, Latin, Swedish, Russian, Italian, Dutch, Hindi, Marathi, Malayalam, and Turkish. I agree with an anonymous reviewer that individuals’ different exposure to other L2s may be an important factor for variation. Practical constraints on field work did not allow recruitment of a more uniform German NS group, and individual case studies are beyond the scope of this study.