

The Trouble with /h/: Evidence from ERPs

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1. Introduction

Recent work on second language (L2) phonological acquisition has argued that the relative ease and difficulty that adult L2 learners encounter with particular novel segments can be attributed to the underlying inventory of phonological features required to represent contrasts in the learner's first language (L1): segments which present difficulty in acquisition are precisely those whose representations require features that are not supplied by the L1 (Brown, 1997, 2000). Brown proposes that this inability to construct target-like representations for the new segments results in an inability to perceive contrast. In Brown's view, the difficulty that native Japanese speakers encounter with the novel English /l/ vs. /r/ contrast (Yamada, 1995) is due to the absence of the feature [coronal] from underspecified inputs in the Japanese grammar; [coronal] is required for the representation of /l/ in English (Brown, 1997, 2000). Native Chinese speakers, on the other hand, show improvement with increasing proficiency on this novel contrast as the Chinese grammar does supply all the necessary features for the representation of /l/: crucially, the Chinese phonemic inventory contains sub-coronal contrasts, thereby implicating the presence of [coronal] in the grammar (Brown, 1997, 2000).

Under this approach, new segments whose representations require a subset of available L1 features are predicted to be acquirable. This seems to be at odds, however, with the observation that native French speakers encounter a great deal of difficulty with the phoneme /h/ in acquiring English: evidence from production shows that it may be either omitted or inserted, as in (1) (Janda & Auger, 1992). The presence of both types of errors for any given speaker suggests that a perceptual problem is at fault; we will return to this in section 2.1 below.

- (1) ...[h]after the 'olidays...
...who (= [u]) [h]are well-informed people...
... 'ead[h]ache...
...[h]ass'ole...

This observation, together with Brown's findings, suggests that there is some feature required for English /h/ that French lacks. Yet current work in theoretical phonology shows that /h/ is frequently found cross-linguistically as a default segment (Lombardi, 2002), suggesting an unmarked status and underspecified representation that could not require a feature that is absent from French. It would seem, then, that francophones' difficulty with /h/ is either a counterexample to Brown's analysis of L2 segmental phonology, or a counterexample to current views on the representation of /h/.

The present paper aims to resolve this paradox by investigating the underlying cause of francophones' difficulty with /h/ through recordings of event-related potentials (ERPs). The paper is organized as follows: section 2 reviews the details of the /h/ paradox; section 3 presents the alternate solution being evaluated here; section 4 describes the methodology of the study that was carried out; section 5 presents the results, and section 6 provides a concluding discussion.

2. The /h/ Paradox

Cross-linguistic evidence strongly suggests that laryngeals /h, ʔ/ lack place feature specifications, and a place node altogether, thus yielding a representation for place like that given in (4) below (Steriade, 1987).

(4) Place-less laryngeals

/h, ʔ/

Root

We review four types of evidence for a representation like (4) as follows. Epenthetic segments have been hypothesized to be insertions of minimal amounts of segmental structure (Howe & Pulleyblank, 2001), and /ʔ/ is frequently found as an epenthetic consonant¹, as in Malay in (5) (Lombardi, 2002).

(5) Epenthetic /ʔ/ (data from Lombardi, 2002, after Durand, 1986 and Onn, 1980)

(a) No /ʔ/ epenthesis

/di-pukul/	[dipukol]	‘to beat (PASS)’
/di-daki/	[didaki]	‘to climb (PASS)’

(b) /ʔ/ epenthesis

/di-ikat/	[diʔikat]	‘to tie (PASS)’
/di-ukir/	[diʔuke]	‘to carve (PASS)’

In addition, debuccalisation or loss of Place structure in certain positions (McCarthy, 1988) produces laryngeals, as shown in (6), where stops become /ʔ/ while fricatives become /h/.

(6) Debuccalisation produces laryngeals

Standard Malay	Kelantan Malay	(data from Rose, 1996, after Trigo, 1991)
ʔasap	ʔasaʔ	‘smoke’
kilat	kilaʔ	‘lightning’
balas	balah	‘finish’
negatef	negatʰh	‘negative’

Further, coda constraints on Place also favour laryngeals, as illustrated in (7a) from Macushi. The only other segments permitted in coda in this language are Place-linked consonants, such as the homorganic nasals shown in (7b), and /ŋ/, which has been argued to be Placeless (Trigo, 1988).

(7) Coda constraints on Place favour laryngeals in Macushi (data from Rose, 1996, after Abbott, 1991)

(a)	ahbu	‘my foot’	(b)	šumba	‘tray’
	moh	‘worm’		unda	‘my mouth’

Finally, laryngeals and only laryngeals allow complete identity between the vowels that immediately precede and follow, so-called translaryngeal harmony, as shown in (8).

¹ Though /h/ itself is not typically found as an epenthetic consonant, /h/ and /ʔ/ form a natural class in languages: the class of laryngeals (Ladefoged, 2001).

(8) Translaryngeal harmony in Arbore (data from Rose, 1996, after Steriade, 1987)

/ma beʔ-i/	[ma biʔi]	‘he did not go out’
/ma beh-o/	[ma boho]	‘he is not going out’

In sum, these facts lend compelling support to the hypothesis that laryngeals lack Place.

Under Brown’s hypothesis, /h/ should be universally acquirable due to its impoverished representation, as it will always involve acquiring a subset representation with respect to the representations of existing L1 phonemes. In other words, the L1 grammar will always supply the necessary features required for constructing an appropriate representation for /h/. This, however, stands in sharp contrast to the production difficulties observed by Janda and Auger (1992), given in (1) above. Further, LaCharité and Prévost (1999) found evidence from perception supporting Janda and Auger’s observation from production. Fifteen phonetically trained francophones who were very advanced speakers of English² completed an AX discrimination task, in which participants were presented with auditory pairs of words, and were asked to indicate on a response sheet whether the words in a given pair were the same word, or different words. The results showed that the francophones’ performance on /h/ is significantly worse than that of native speakers.

It would seem, then, that there are two possible accounts for francophones’ difficulties with /h/: either that Brown’s hypothesis is incorrect, and L2 phonology is not constrained by L1 features in the way that she proposes, or the representation of /h/ is not impoverished in the way suggested, and there is some feature required that is not available to francophones. Indeed, the latter option is that adopted by LaCharité and Prévost, who assume that /h/ is specified as pharyngeal.

3. Another Possibility: Acoustic Properties of /h/

Thus far, the discussion has shown that the observed difficulties that francophones encounter with English /h/ are at odds with the structure typically assumed for this segment: the theory tells us that this segment should be easy to acquire, yet it seems to be notoriously difficult.

There is, however, another possibility that can be appealed to in accounting for the observed patterns. It may be the case that the acoustic qualities of /h/ are such that this segment is not reliably detected in the speech stream, and thus no representation for it can be built by the L2 learner. /h/ is a voiceless, non-sibilant, low intensity fricative, produced with no inherent constriction in the vocal tract (Ladefoged, 2001). Put simply, English /h/ is a very quiet speech sound. Furthermore, since /h/ manifests itself acoustically as the voiceless counterpart of the following vowel³, it is not as distinct from the corresponding voiced vowel as are other consonants. On this view, francophones’ difficulties with /h/ stem from the hypothesis that, on a very basic acoustic level, they do not hear it.

One of the goals of the present paper is to evaluate whether this possibility can be maintained. To test this, we compare learners’ perceptual abilities with respect to the segment /h/ in both linguistic and non-linguistic conditions, following Werker and Tees (1985). In their study, Werker and Tees demonstrated that adults are better able to discriminate segmental contrasts not found in their L1 when these were presented in such a way that they would not be identified as linguistic data. Native speakers of English performed poorly in discriminating the Thompson Salish uvular /q/ vs. ejective uvular /q’/ contrast when these were presented in simple CV syllables, but these same speakers performed well when the syllables were truncated to remove the vowel portion, leaving only the noise burst of the stop release, which resembled click-like sounds more than they did language. This same difference in ability to perceive non-native contrasts was also found with respect to the Hindi dental /t/ vs. retroflex

² Along with L2 native speaker controls.

³ Given that /h/ is manifested acoustically as the voiceless counterpart of the following vowel, its articulation is strongly influenced by the tongue position required to articulate the vowel, and is thus produced with tongue fronting before front vowels and backing before back vowels. In extreme cases, e.g., before high front vowels, /h/ tends to be realized as a palatal [ç] (Ladefoged, 2001). This behaviour is not restricted to English: in Japanese, high vowels /i/ and /u/ completely superimpose their articulations over /h/, resulting in [ç] before /i/ and [ϕ] before /u/ (e.g., Rogers, 1991).

/t/ contrast. Thus, it seems that the L1 segmental inventory influences perception only so long as the auditory stimuli are perceived as being language.

Here, we present /h/ in both linguistic and non-linguistic conditions to francophones (as well as to a group of native English speaker controls) while recording event-related potentials (ERPs). In particular, the ERP we seek to examine is the mismatch negativity (MMN), a response manifested by a negative-going component occurring approximately 200 milliseconds after stimulus presentation that indicates automatic detection of physical deviance in a stream of acoustic stimuli (Coles & Rugg, 1995; Näätänen, 1999; Phillips, Pellathy, Marantz, Yellin, Wexler, Poeppel & McGinnis, 2001). There is evidence that the MMN is elicited by changes which cross a phonemic category boundary (Phillips et al., 2000). If francophones' difficulties with /h/ are due to difficulties at the level of phonological representations, then they should be able to perceive this segment when it is presented non-linguistically (as Werker & Tees found English speakers could do with Thompson Salish uvulars); this should be reflected by a robust MMN response in the non-linguistic condition paired with a lack of MMN response in the linguistic condition. If, however, their difficulties with /h/ are due to its physical acoustic non-salience, then no MMN should be obtained in either condition.

4. Methodology

4.1 Stimuli

For the linguistic condition, the syllables /ʌm/ 'um' and /hʌm/ 'hum' were used. The vowel /ʌ/ was selected in order to avoid potential coarticulation effects on /h/: given that /h/ is manifested acoustically as a voiceless vowel, /ʌ/ was selected because among stressed vowels in English, its articulation most closely approximates a positionally-neutral vocal tract. Three instances of each item were recorded by a female native speaker of English, each with a falling intonation, and all tokens were used in the task in an adapted oddball paradigm as described in section 4.3 below (Phillips et al., 2000).

For the non-linguistic condition, the recordings of /hʌm/ and an additional syllable /fʌn/ were used to create fricative noise bursts corresponding to /f/ and /hf/. /f/ was used as it is another low-intensity fricative; it is also present in both English and French. Two tokens of each fricative noise burst sequence were created, and both tokens were used in the task.

4.2 Participants

Nine subjects participated in this experiment as native speaker controls: all were right-handed native speakers of North American dialects of English who were undergraduate students at McGill University.

Seven subjects participated as L2 English speakers: all were right-handed native French speakers who were enrolled in Elementary level English language classes at the Université du Québec à Montréal, where students must complete a placement test before being allowed to register for any English class. This ensures that all students within a class are of equal proficiency: the only way to register for an Elementary class is to either be placed there following a placement test, or to have completed the level that is the prerequisite (in this case, Beginner). Two participants were French (on exchange from France), while the remaining five were Canadian.

4.3 Procedure

Participants were fitted with an ElectroCap silver-silver chloride electrode cap that recorded activity from eleven scalp electrodes (Fz, Cz, Pz, FP1, FP2, F3, F4, C3, C4, F7, F8) with a forehead ground and linked earlobes reference. EOG channels (both horizontal and vertical) were also recorded to monitor eye movement, and an electrode was also attached to the nose. Participants were then seated comfortably in an electrically-shielded acoustically controlled booth for the duration of the experiment, during which they watched a silent video with subtitles. Auditory stimuli, which participants were instructed to ignore, were presented by insert earphones to both ears. The

experimental phase itself took approximately an hour and a half, and participants were each compensated \$30 for their time.

The test syllables were presented using EEvoke software in an adapted oddball paradigm (Phillips et al., 2000): at the acoustic level, since multiple tokens of each test syllable were used, no single token occurs with sufficient frequency to be considered a standard. At the representational level, however, a clear pattern of standard (or frequent) and deviant (or infrequent) tokens emerges. This paradigm was chosen in order to ensure that any effect observed in the data reflects consultation of stored representations. Four blocks of stimuli were presented: a linguistic condition block with /hΛm/ items as deviants, a linguistic condition block with /hΛm/ items as standards, a non-linguistic condition block with /hf/ items as deviants, and a non-linguistic condition block with /hf/ items as standards. All participants were presented alternating blocks of linguistic and non-linguistic stimuli, and the order of presentation of blocks was counterbalanced to create four versions of the experiment. For each block of testing, the standard type occurred with 80% frequency, while each of the two deviant types occurred with 10% frequency. Stimulus onset asynchrony (SOA) was set to vary between 700 ms and 850 ms; a variable SOA was used to prevent participants from using a perceived delay in stimulus presentation (due to non-perception of /h/) as a reliable identifying cue for /h/-initial items. EEG data were recorded continuously using a NeuroScan SynAmps 2 amplifier and Scan 4.3's Acquire data acquisition software using an A/D rate of 500 Hz; data were analyzed offline using EEProbe software. Trials contaminated by eyeblink or movement artifact were rejected offline.

5. Results

5.1 Non-linguistic condition

Figure 1A below shows the responses of the native English speaker control group to /hf/ items, comparing /hf/ as a standard and /hf/ as a deviant, as recorded at Fz and Pz.

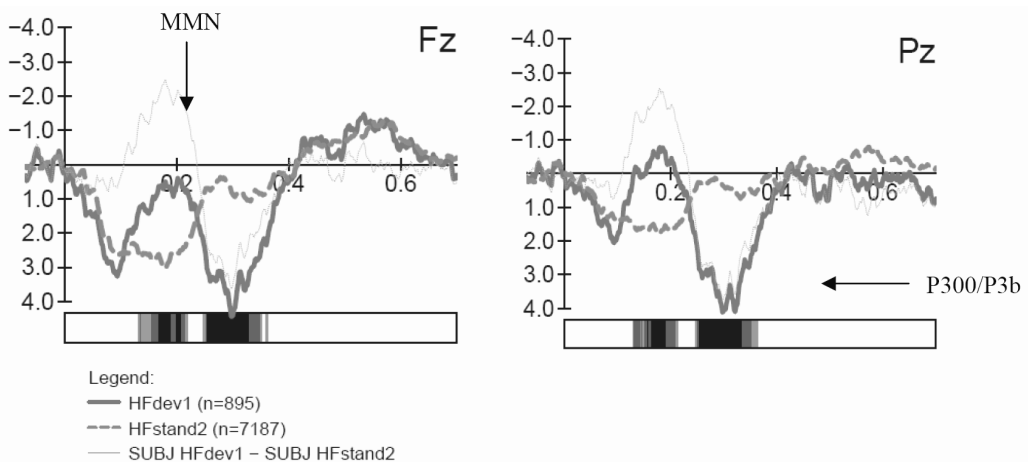


Figure 1A. Native English speaker responses to /hf/ items, both standards and deviants⁴

Figure 1B shows the responses of the francophone group to /hf/ items, comparing /hf/ as a standard and /hf/ as a deviant, as recorded at Fz and Pz.

⁴ Negativity is plotted upwards; areas where the responses to /hf/ as a standard differ significantly (as revealed through t-tests) from those to /hf/ as a deviant are indicated by shading in the bar below the waveform. Data recorded at Fz reveal a significant MMN, while data recorded at Pz reveal a significant P300/P3b component.

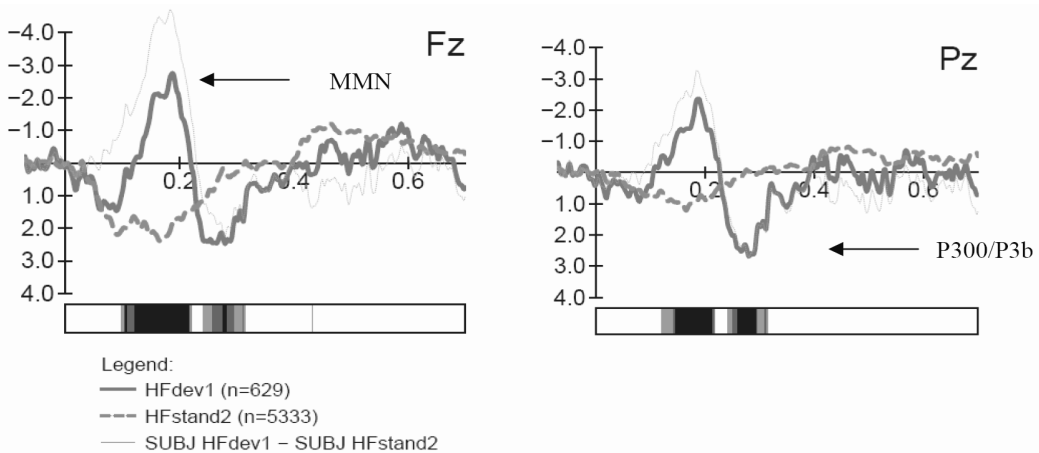


Figure 1B. Francophone responses to /hf/ items, both standards and deviants⁵

Much like the native English control group, /hf/ as a deviant also elicited a large significant MMN for the francophones. This suggests that the francophones were also able to detect the presence of /h/ in /hf/. Again like the native English speaker controls, the francophones also show a large significant P300/P3b component at Pz.

5.2 Linguistic condition

Figure 2A below shows the native English control group's responses to /hΛm/ items both as standards and as deviants, as recorded at Fz and Pz.

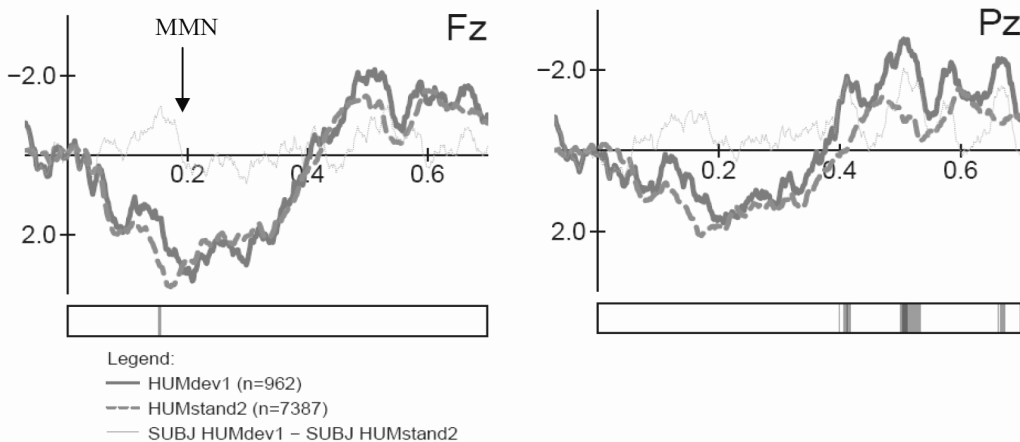


Figure 2A. Native English speaker responses to /hΛm/ items, both standards and deviants⁶

The responses obtained here differ from those obtained in the non-linguistic condition: though we do find a significant MMN, inspection of Pz reveals the absence of a P300/P3b component. The presence of the MMN suggests that these participants were able to detect the /h/ in deviant /hΛm/ items where /Λm/ served as the standard.

⁵ See f.n. 4.

⁶ Negativity is plotted upwards; areas where the responses to /hΛm/ as a standard differ significantly (as revealed through t-tests) from those to /hΛm/ as a deviant are indicated by shading in the bar below the waveform. Data recorded at Fz reveal a significant MMN; no P300/P3b component is observed at Pz.

Figure 2B shows the francophones' responses to /hΛm/ items as standards and as deviants, as recorded at Fz and Pz.

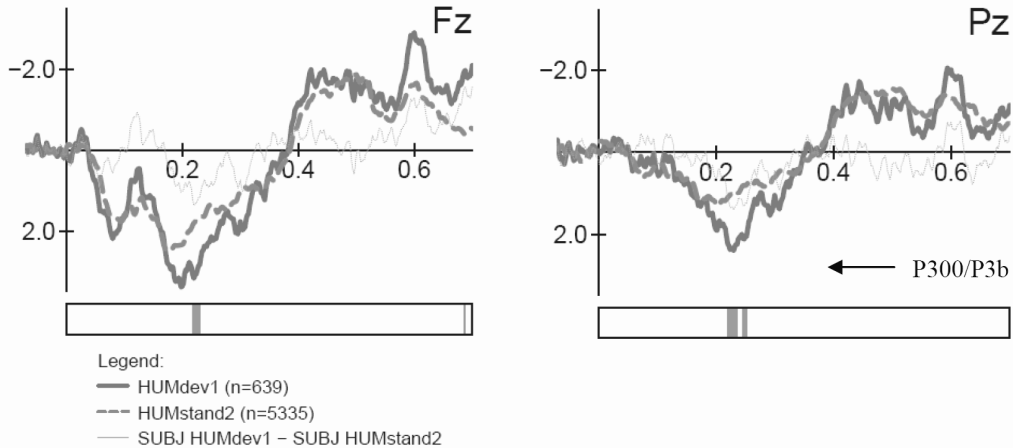


Figure 2B. Francophone responses to /hΛm/ items, both standards and deviants⁷

Unlike the native English control group, the francophones do not show a significant MMN response, suggesting that they do not detect the presence of /h/ on these items as deviants among /Λm/ standards. They do, however, show an early P300/P3b component at Pz.

6. Discussion

The results of this study indicate clearly that francophones' difficulties with English /h/ are not due to this segment's acoustic properties: in the non-linguistic condition, they performed like native English speakers, in that a deviant /hf/ item elicited both a large significant MMN as well as a large significant P300/P3b. This finding supports the hypothesis that francophones' difficulties with /h/ are due to problems with the linguistic representation.

It is not, however, clear from these results that the trouble with /h/ is in its phonological representation, as in both the linguistic and non-linguistic conditions, any elicited MMN occurred early following stimulus presentation, which is suggestive of more automatic levels of processing. That is, our results may reflect acoustic or phonetic processing and representations, rather than phonological processing and representations. In light of this, we are preparing a follow-up study that will seek to elicit the N400 component through lexical priming. Sentences such as "They wanted to heat/*eat the room because it was cold" would be presented; we would predict these to elicit an N400 response among native speakers on the word room where *eat* is presented due to semantic mismatch. Such a study will enable us to address the question of whether francophones can build lexical (stored) representations that include /h/: if they cannot, then they are expected to exhibit an N400 in this condition in a reading study, but not in an auditory study.

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⁷ See f.n. 6.

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