Cue Switching in the Perception of Approximants: Evidence from two English Dialects

Christina Villafaña Dalcher[*],
Rachael-Anne Knight[‡], and Mark J. Jones[§]

1 Introduction

A surprising dissimilarity is found in the perception of approximant sounds by speakers of American English (AE) dialects and Standard Southern British English (SSBE). Thirty-three subjects (8 AE and 25 SSBE speakers) performed a forced-choice identification task in which they judged whether stimuli were more like /r/ or /w/[1]. The stimuli comprised five sounds copy-synthesised from a source /r/, where formant values were manually adjusted.

The only significant difference between the two dialect groups' performance occurred with a stimulus in which F3 was typical for /r/ and F2 typical for /w/. AE speakers identified this stimulus as /r/ 93% of the time and SSBE speakers only 69% of the time. Such a disparity is unexpected given that alveolar approximant [ɹ] in both dialects is generally characterised acoustically by a low F3 (Delattre & Freeman 1968; Nolan 1983; Alwan et al. 1997; Stevens 1998; Espy-Wilson et al. 2000). Why then the significantly different results between the two groups when Stimulus D involves the canonical /r/ cue of a lowered F3?

A possible solution lies in the well-documented existence of a non-standard realisation of /r/ in Southeast England, an increasingly common sociolinguistic variable in adult speech. This 'labiodental' /r/ (realised as [ʋ]) (Foulkes & Docherty 2001; Trudgill 1988) does not have the low F3 normally associated with English /r/ (Docherty & Foulkes 2001).

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[1] Throughout this paper square brackets will be used in references to the phonetic realisations of apical [ɹ], labiodental [ʋ], and [w]. Slanted brackets will be used in general references to /r/ and /w/ sounds.

2 Background

Because this study examines the acoustic cues of two different approximants, /r/ and /w/, a brief description of these sounds in terms of their acoustic characteristics, acquisition, and variation patterns is appropriate.

2.1 Phonetic Qualities of /r/ and /w/

The standard description of /r/ in British and American English is a voiced postalveolar approximant, where the tongue tip is in wide approximation to the region of the palate behind the alveolar ridge. While studies of AE apical [ɹ] show that speakers employ different articulatory strategies (Westbury et al. 1998), there are two stable acoustic traits of these [ɹ]s in both dialects. One trait is a low third formant (F3) (Delattre & Freeman 1968; Nolan 1983; Alwan et al. 1997; Stevens 1998; Espy-Wilson et al. 2000). Another is the proximity of the second and third formants (F2 and F3) (e.g., Guenther et al. 1999). The labial-velar approximant [w], in contrast, is characterised by a high F3 and low F2, resulting in a wide gap between these formants.

2.2 The Acquisition of Approximants

Examining /r/ from an acquisitional point of view, research suggests that adult-like apical [ɹ] does not emerge until around the age of 4;5 (after most other sounds) and remains highly variable before being mastered (e.g., Vihman 1996: 219–239). Many studies that have addressed children's acquisition of /r/ commonly class mispronunciations as [w]-like, and while some children may in fact substitute [w] for /r/, it is also likely that such a classification is a result of adult misperceptions of the developing sound.

Rather than a straight substitution, it appears to be the case that children at the developmental stage may be making a covert contrast in their articulations of the two approximants. Instrumental studies (Klein 1971; Dalston 1972; Hoffman et al. 1983) indicate that some children produce an /r/ with an atypically high third formant and a high, non-[w]-like F2 (that is, a second formant more typical for apical [ɹ]).

2.3 Sociophonetic Variation of /r/

It has recently become apparent that many younger speakers in England use a variant of /r/ that differs from the canonical form described above. This

variant, [ʋ], has acoustic qualities similar to developmental high-F3 realisations of /r/, and has been described as a labial or, more commonly, labiodental approximant. The details of this articulation are unknown, and we use the term 'labiodental' broadly here. Per Foulkes and Docherty (2001), earlier descriptions class this variant as a speech defect (Gimson 1980), or as a feature of either immature speech (Gimson 1980) or upper-class speech (Wells 1982). More recently, however, the labiodental realisation is becoming increasingly common in English dialects. Trudgill's (1974) work in Norwich, for example, shows very few instances of [ʋ] in 1974, but Trudgill (1988) reports that by 1983, 33% of speakers born between 1959 and 1973 used [ʋ].

In the United States, however, [ʋ] is not regularly found outside of Brooklyn, New York (Wells 1982:508). While studies of AE [ʋ] are absent from the literature, the assumption that speakers outside metropolitan New York are not exposed to a labiodental variant is central to the current study.

2.4 A Comparison of Approximants

Figure 1 compares formant values of three relevant approximants, apical [ɹ], labiodental [ʋ], and [w]. These adult speech samples illustrate common acoustic qualities the labiodental variant shares with both [ɹ] and [w]: the labiodental's F2 is similar to the mid-range formant frequency of [ɹ], while its F3 is similar to the high F3 of [w].

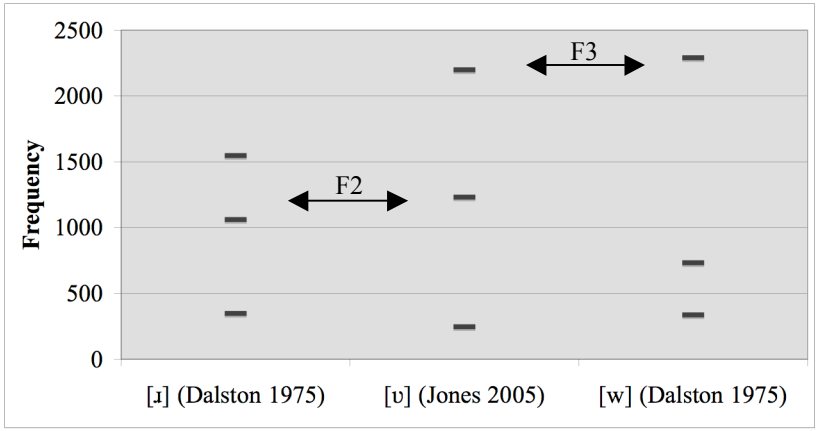

Figure 1: Formant frequencies of three approximants

Assuming a new /r/ variant present in SSBE, we may ask whether there are implications of the existence of labiodental [ʋ] for the way in which

speakers handle the /r/-/w/ contrast, specifically with respect to the way in which acoustic cues such as F2 and F3 frequency are utilised.

3 A Perceptual Study of /r/ Variants

3.1 Overview

This study collected perception data from two speaker groups who are expected to differ in their exposure to the adult labiodental variant of /r/, and tested for significant differences in perceptual cues between the groups.

The subjects comprised eight native speakers of American English from Washington, DC and 25 native speakers of British English from Southeast England. As the AE data was collected remotely, these subjects were not recorded, but all were judged to use apical [ɹ] based on auditory analysis. The BE speakers were recorded and found to use either apical [ɹ] or labiodental [ʋ], although some varied their articulations contextually. Based on sociolinguistic studies of /r/ variants in AE and BE, it was assumed that none of the AE speakers are exposed to adult labiodental [ʋ], while the BE speakers, regardless of their production, are regularly exposed to the variant.

3.2 Methodology

The perception experiment, built in PsyScope (Cohen et al. 1993), contained a forced choice identification task and a discrimination task. In the former, subjects were asked to judge whether stimuli in "a _ing" context were more like /r/ or more like /w/. In the latter, subjects decided whether pairs of stimuli in the same "a _ing" context were identical. The stimuli for both tasks comprised five copy synthesised sounds from a source apical [ɹ] uttered by an adult male native speaker of SSBE, where the frequencies of F2 and F3 were manually adjusted. Table 1 shows the actual frequencies of the stimuli formants and Figure 2 presents a schematic illustration of the five tokens.

Stimulus	F1	F2	F3	Description
A	355	1201	1682	/r/-like formants
B	355	963	1682	F2 at midpoint of /r/ and /w/, F3 /r/-like
C	355	1201	2541	F2 /r/-like, F3 /w/-like
D	355	725	1682	F2 /w/-like, F3 /r/-like
E	355	725	2541	/w/-like formants

Table 1: Input formant frequencies of copy-synthesised stimuli

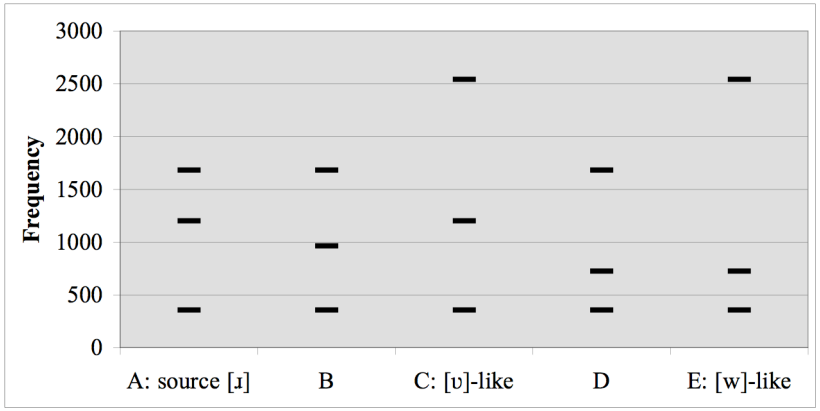

Figure 2: Input formant frequencies (Hz) of copy-synthesised stimuli

For the identification task, the total number of tokens equalled 50, with ten randomised repetitions of each stimulus. The discrimination task, used to assess subjects' perceptual sensitivity, comprised 105 tokens: five repetitions of each ordered pair of stimuli, with five instances of identical pairs used as controls.

Assuming low F3 as the primary acoustic cue for /r/ identification, subjects' behaviour was predicted as follows: stimuli with a low, /r/-like third formant (Stimuli A, B, and D) would be heard as /r/, while stimuli with a high third formant (Stimuli C and E) would be heard as /w/.

3.3 Results

The outcome of the identification task was that most subjects in each of the dialect groups identified Stimuli A, B, C, and D (that is, all stimuli except for the token with [w]-like formants) as /r/ a majority of the time. Table 2 summarises the responses in terms of the percentage of /r/ responses to each of the stimuli, by dialect group.

	Stim A	Stim B	Stim C	Stim D	Stim E
AE	100	100	93	93	5
BE	99	97	88	69	2

Table 2: Percentage of /r/ responses to identification stimuli

The shaded cells in Table 2 highlight the response patterns that do not fit with the predictions. Stimulus C, with a high, [w]-like F3, was identified as

/r/ most of the time by both the AE and BE subjects, with no significant behavioural difference between the groups. Stimulus D, with a low F3, was judged as /r/ in a majority of instances, but heard as /w/ 31% of the time by the BE dialect group.

Before addressing dialectal differences in subjects' perception of Stimulus D, it is appropriate to discuss the unexpected results in Stimulus C identification as well as the general level of subjects' perceptual sensitivity.

3.3.1 Identification of High F3 Stimulus as /r/

With respect to Stimulus C, which we predicted would be perceived as /w/ due to its high, non-[ɹ]-like third formant, there are two possible explanations for the unexpected behaviour.

First, this stimulus was copy-synthesised with a formant structure close to that of the labiodental variant of /r/ found in SSBE. Given the spreading occurrence of this variant in England, the fact that the BE subject group identified the token as an /r/ is not altogether surprising.

The real problem lies in the response of the AE group to this stimulus. We might expect speakers not regularly exposed to labiodental [ʋ] in their linguistic community to perceive such a sound as non-/r/-like. In fact, many treatments of the variant in academic literature, popular culture, and literary sources claim or imply that the labiodental [ʋ] is identical to [w]. Non-standard realisations of /r/ have been described as [w] substitutions, or at least [w]-like substitutions by Jesperson (1909, per Foulkes & Docherty 2000 and 2001) and by Wright (1981) in his comments on East London speech where "some East Enders…pronounce instead a *w*." In popular films such as *Monty Python's Life of Brian*, Michael Palin exploits the [w] substitution for comic effect, as does Peter Cooke in his role of the archbishop in *The Princess Bride*. In literary sources, Dickens uses an orthographic *w* to reflect Lord Mutanhed's unconventional /r/ in *The Pickwick Papers* (1836-37); Orwell's *Keep the Aspidistra Flying* (1936) marks a character as effeminate by substituting *w* for *r* in words like 'really' [*w*]*eally*, 'browse' *b*[*w*]*owse*, and 'terrible' *te*[*ww*]*ible*. Despite the implications of this regular substitution, however, the AE group identified the labiodental [ʋ] stimulus as /w/ only seven percent of the time.

Several possible explanations for this outcome exist. First, the high number of /r/ responses to Stimulus C might be a result of the proximity of F2 and F3 in this token. In other words, notwithstanding a low, non-[ɹ]-like F3 in absolute terms, the closeness of the two formants may itself be a sufficient cue for /r/. It is also reasonable that the high, [ɹ]-like F2 in this stimu-

lus could have outweighed low F3 and as acoustic cue – in other words, if F2 isn't sufficiently high, then a sound will be perceived as /w/ regardless of the absolute frequency of F3. A third reason for Stimulus C being judged as /r/ lies in the nature of the stimulus itself, not the subjects' response. Although the copy-synthesised sound was intended to have the acoustic qualities of a labiodental [ʋ], in fact it sounds much more like a lateral approximant than a labiodental approximant[2]. The identification of Stimulus C may have been influenced by the choices available more than by the acoustic signature per se: because the identification task was forced-choice, subjects did not have a "none of the above" option.

Another potential factor contributing to unexpected results is the general level of accuracy in subjects' judgments. To investigate whether subjects' sensitivity to differences among the stimuli was low (and therefore any perception testing results might be questionable), d-prime (d') analysis was run on the discrimination responses (Macmillan & Creelman 1991). For the AX discrimination test in this study, the mean d-prime for all subjects of 2.66, indicates that subjects were generally sensitive to differences among the stimuli. Of the 33 subjects, only nine had d-prime scores below 2.0, the typical value. Based on these results, we assume that subjects were sufficiently sensitive to the stimuli and not performing in a random manner.

With the unexpected results for Stimulus C discussed and an overall level of accuracy on the part of the subjects confirmed, the focus now turns to the judgments returned for Stimulus D.

3.3.2 Identification of Low F3 Stimulus as /w/

The surprising outcome of this study was the judgment of Stimulus D, a token with a typically low, [ɹ]-like third formant, as /w/ with significantly more frequency than predicted, at least by some subjects. This stimulus was identified as /r/ three times as often as it was identified as /w/, averaging over all subjects. However, when we split the subjects by dialect type, we find a robust difference in behaviour: the AE subjects judged the stimulus as /r/ 93% of the time; the BE subjects judged it as /r/ only 69% of the time. In fact, the only significant difference between the two dialect groups' identification of the five stimuli was found in the reaction to Stimulus D, based on independent sample T-tests (t=3.146, p<.005). No other statistically signifi-

[2] In a post-hoc survey of 11 native speakers of AE where the choice was expanded to /r/, /w/, and /l/, eight speakers identified Stimulus C as /l/, two speakers as /r/, and one speaker as either /r/ or /l/.

cant patterns between the AE and BE speakers were found with respect to identification of stimuli or reaction times.

4 Discussion

4.1 Cue-switching in the Perception of Approximants

If alveolar approximant [ɹ] in both American and British English is generally characterised acoustically by a low third formant, the results of this study pose the question of why such a robust difference was found between speakers of the two dialects in identification of a low-F3 stimulus. We suggest that a possible solution lies in a switching of acoustic cues on the part of the BE speakers, arising from the presence of an alternate form of /r/ in England and a continued pressure to differentiate /r/ and /w/.

As shown in Figure 1 above, the labiodental variant on the rise in SSBE is acoustically characterised by a third formant quite similar to that of [w]. Yet speakers (and listeners) who are routinely exposed to this variant have an ongoing need to distinguish /r/ from /w/ — a need normally satisfied by referring to differences in F3. When the acoustic cue necessary for contrasting the two sounds is removed, a new differentiation strategy must be adopted. Looking only at formant frequencies, it becomes clear that the distinguishing characteristic remaining between labiodental [ʋ] and [w] is the positioning of the second formant. Figure 3 illustrates this alteration in contrastive features.

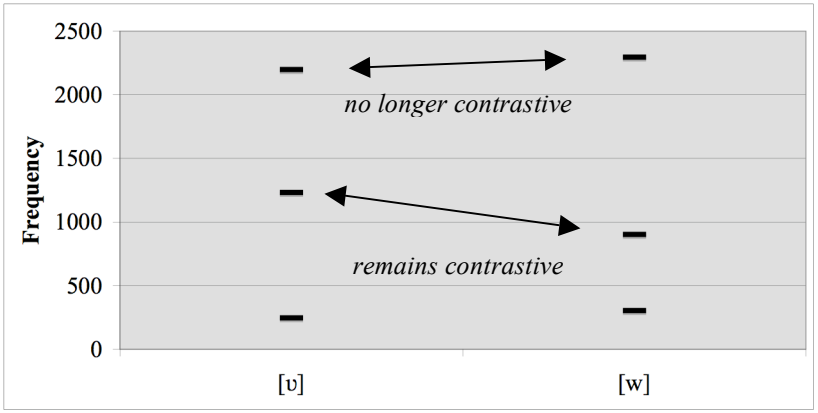

Figure 3: Formant contrasts: [ʋ] and [w] (Jones 2005)

The AE subjects, assumed to lack exposure to an adult high-F3 [ɹ] variant, experience no pressure to alter their acoustic cues in perception of the /r/-/w/ contrast.

We can now look at the stimuli used in the identification task in a more quantitative way, bearing in mind that the dialect groups in this study may reasonably adopt different strategies when presented with certain stimuli. Instead of examining the absolute formant frequencies of labiodental [ʋ] and [w], we measured the slopes of the differences between these sounds' second and third formants. With the schematic spectrograms from Figure 3 serving as a plot, slope measurements may be calculated by subtracting the horizontal distance between the formants' centre points from the vertical distance. Note that the resulting slopes and their ratios are simply a way of quantifying formant differences, but are not indications of temporal relationships or correlation coefficients.

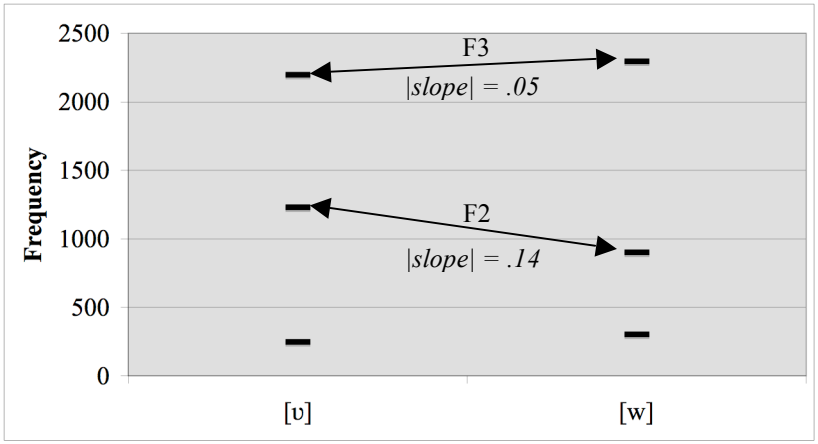

Figure 4: F2 and F3 slopes of [ʋ] and [w] (Jones 2005)

As Figure 4 illustrates, the absolute value of the F2 slope between labiodental [ʋ] and [w] is nearly three times the value of the F3 slope (absolute values are used due to the irrelevance of directionality for this data). These measurements serve to confirm intuitions about the relative weight of contrasts: labiodental [ʋ] and [w] will likely be distinguished by the height of F2, not of F3.

Given the contrastive cue for [ʋ] and [w], judgments of a slightly different stimulus – where F3 is [ɹ]-like and F2 is [w]-like – is predictable from the assumed exposure to labiodental [ʋ] in a subject's linguistic environment.

For speakers with this exposure, and therefore relying more on F2 as the salient contrast between /r/ and /w/, Stimulus D will be perceived as a /w/, as Figure 5 indicates. Note that the slope of F2 when comparing [ɹ] and Stimulus D is ten times F2's slope comparing Stimulus D to [w].

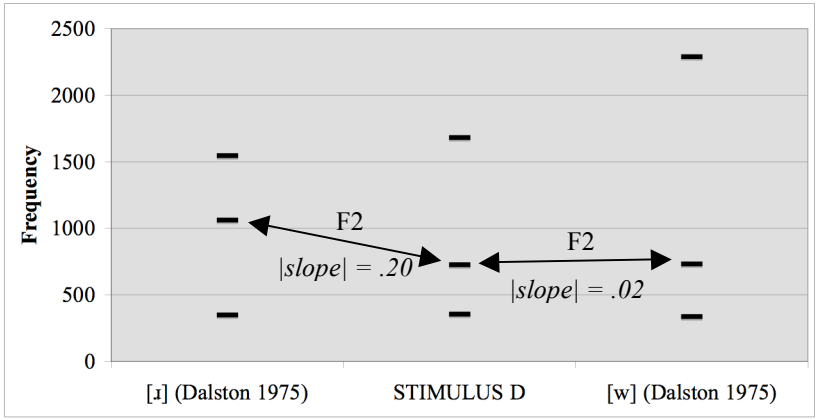

Figure 5: Comparison of F2 slopes
Stimulus D (present study), [ɹ] and [w] (Dalston 1975)

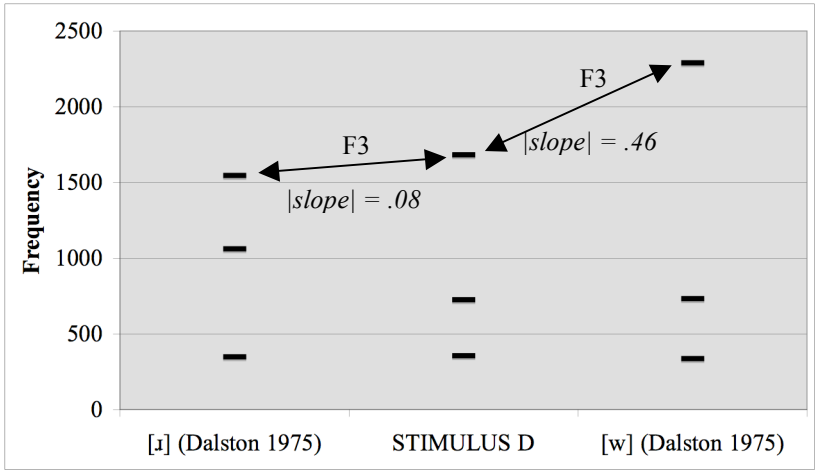

Figure 6: Comparison of F3 slopes
Stimulus D (present study), [ɹ], and [w] (Dalston 1975)

Subjects without any exposure to high-F3 labiodental [ʋ], on the other hand, are assumed to rely on F3 as a contrastive cue and will therefore perceive Stimulus D as /r/ due to the robust difference between this stimulus's F3 and that of [w], despite the fact that the F2s of Stimulus D and [w] are identical. Figure 6 illustrates this.

The striking difference, then, in the AE and BE subjects' choices with respect to Stimulus D seems entirely predictable from the known characteristics of the two groups' linguistic environments: SSBE speakers must tolerate a wider diversity of /r/-types, including /r/s without a canonically low F3. As a consequence, the /r/ category in SSBE may be becoming increasingly defined by F2, rather than by F3. If this is the case, SSBE speakers will weight F2 more than F3 in their perceptual categorisation, and the F2 boundary between /w/ and /r/ will become sharper in SSBE relative to AE. AE speakers, who likely encounter adult labiodental [ʋ] less frequently, continue to attend more to F3 than F2. For them, the [ɹ]-like low F3 in Stimulus D leads them to a definite /r/ categorisation. For the SSBE speakers, however, the [w]-like F2 cue interferes with the low F3 cue to cause greater perceptual uncertainty – precisely the pattern we see in the data, where SSBE speakers categorise Stimulus D as /r/ in 69% of the cases, but as /w/ 31% of the time.

4.2 Cue-switching as an Effect and Cause of Sound Change

Up to this point, we have shown that a shifting in acoustic cues may be a direct result of the presence of a sociolinguistic variant in a listener's environment. The increase in /r/ variability, specifically with respect to its third formant, serves to catalyse a cue-shift from F3 to F2 in the perception of the /r/-/w/ contrast. However, this shift can subsequently have an effect on articulation: listeners for whom the frequency of F3 is perceptually less prominent may be less concerned to reconstruct the low-F3 [ɹ], resulting in an increase in /r/ variability. As we have proposed that such an increase in the frequency with which a variant occurs serves as a trigger to acoustic cue-shifting, the relationship among presence of a variant, shifting in perceptual cues, and alterations in production is necessarily cyclic. Thus a gradual erosion of low F3 instances of [ɹ], and a concomitant increase in labiodental [ʋ] may be predicted across SSBE.

5 Conclusions and Future Research

This study has presented /r/-variant perception data from two distinct dialect groups differing in the types of rhotics existent in their linguistic environ-

ments. Examining formant frequencies of [ɹ], [w], and three variants, we have attempted to explain why speakers of Standard Southern British English exhibit a different pattern in their categorisation of certain acoustic signals than speakers of American English. This dialect-dependent variation in perception has been shown to be a logical consequence of the presence or absence of variant forms in a speaker's linguistic environment, where such forms are sufficiently similar in acoustic characteristics to necessitate a shift in perceptual strategy. Furthermore, the shift in reliance on one acoustic cue to another has potential ramifications for speech production.

Rather than a purely descriptive account of /r/ variants in a linguistic community, the present study supplies us with a way to address sound change propagation from a phonetic point of view. While the inception of the labiodental variant in SSBE remains in question, Janda and Joseph (2003) argue that, for sound change generally, it is possible to examine the reasons for spread independently of the reasons for innovation.

Plans for future research include an expansion of the current perception experiment to include well-defined subject groups using a variety of /r/ types. These experiments will also incorporate cue weighting in the stimuli. Because no articulatory data exists for either apical or labiodental /r/ in SSBE, a further research priority is the collection and analysis of ultrasound data on both types of British English /r/. Finally, the robust differences in perception of /r/ variants between BE and AE dialect groups have stimulated an interest in labiodental (or at least heavily labialised) variants in American English, and plans are underway to carry out acoustic analysis of speech from the non-rhotic dialects of the Northeastern United States. Phonetic analysis of the /r/ sounds in such dialects will fill a gap in the linguistic literature and at the same time allow for the design of richer perception experiments along the lines of the study discussed herein.

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Christina Villafaña Dalcher
Department of Language and Communication Science
City University London
Northampton Square
London ECV 0HB United Kingdom
cvdalcher@mac.com

Rachael-Anne Knight
Department of Language and Communication Science
City University London
Northampton Square
London ECV 0HB United Kingdom
r.knight.1@city.ac.uk

Mark J. Jones
Department of Linguistics
University of Cambridge
Sidgwick Avenue
Cambridge CB3 9DA United Kingdom
mjj13@cam.ac.uk