An EPG Study of Repetition and Lexical Frequency Effects in Alveolar to Velar Assimilation

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ABSTRACT

The relationship between assimilation, lexical frequency and repetition was investigated in compound words containing a potential assimilation site (alveolar + velar consonant clusters). Responses were elicited from speakers using a sentence completion task; acoustic and EPG data were recorded. Lexical frequency was found to influence speakers on a range of acoustic and EPG measures. The effect of repeating speech stimuli, on the likelihood of assimilation, was also investigated and it was found that productions were strengthened across repetitions.

1. INTRODUCTION

This study aims to investigate the influence of lexical frequency and repetition on the process of assimilation. Assimilation is the variation in speech sounds due to surrounding phonemes. For example *goodbye* is often produced more like [gəbai].

Recent research on assimilation has focused on the extent to which it is discrete or gradient [1]. Although assimilation has been modeled as categorical in some phonological theories [2], articulatory experiments have shown assimilation occurs along a continuum between no assimilation through to complete assimilation. For example, alveolar articulations may vary between these two extremes, producing instances of partial assimilation where tongue movement towards the alveolar ridge remains even if the articulation is not complete [3].

Lexical frequency has been found to influence reaction times and naming latencies such that high frequency words are responded to faster than low frequency words [4]. An explanation for this finding is that higher frequency words are more frequently accessed and so are retrieved from the lexicon faster. Frequency has been reported to influence the rate of *t/d* deletion. Words with a final *t/d* consonant are more likely to show a reduction in the alveolar place of articulation if the word is of high frequency [5]. Also, reduction is more likely to occur if the *t/d* is followed by a consonant rather than a vowel.

One of the main motivations for this study was to investigate whether these frequency effects are related to the likelihood of assimilation. In terms of Lindbom's [6] hyper- and hypoarticulation model of speech production, for example, reductions are less likely at points of low frequency in the speech stream so that meaning is not compromised for the listener. Compatibly, Wright [7] has shown that high frequency words are produced with less peripheral, i.e. phonetically less distinct vowels.

It is hypothesized that these hyper- and hypoarticulation effects may carry over to assimilation: if a low frequency compound is formed that includes a potential assimilation site at the boundary between its constituents, assimilation, either gradient or total, may be less likely than in a high frequency compound (i.e., one in which the co-occurrence of its two constituents is more likely). If assimilation acts as a form of reduction, high frequency compounds may show more instances of assimilation than low frequency compounds.

Another aim in this study was to investigate whether repetition influences assimilation. Previous research has shown reduction is more likely in repeated sequences: for example, Fowler and Housum [8] provide evidence that repeated words are more likely to be undershot and reduced. This is in part predicted by Lindblom's [6] model which suggests information that is more predictable for the listener is likely to be produced with less clarity. It may be the case therefore that repeated items are more likely to be subject to consonant cluster assimilation.

2. METHOD

2.1 Stimuli: Two-constituent noun-phrase compounds were selected from CELEX [9] such that they contained a consonant cluster with an assimilation site at the boundary between the constituents. The selected compounds were of high frequency with a parallel low frequency compound. Fourteen high and 14 low frequency compounds were constructed for alveolar + velar consonant clusters.

Sentences were then constructed which contained both the constituent words of the compound. The speakers' task was to complete the sentence with a compound word. For example, for the high frequency 'night-cap' the speaker heard *"A cap worn at night is a …",* as a prompt to be completed with 'night-cap'. A parallel low frequency compound was constructed for each high-frequency

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compound: in the present example, the parallel low frequency compound was derived from 'flight-cap' which the speaker completed in response to hearing *'A cap worn on a flight is a ....'* .

Each speaker produced 168 tokens (6 repetitions of each of the 28 compound words). This paper will examine only the first and last (6^{th}) repetition (56 tokens per speaker) to investigate the effect of repetition and lexical frequency.

2.2 Data recording: Electropalatographic (Reading EPG3 system), and acoustic data were simultaneously recorded from three speakers of Australian English. Sp1 and Sp2 were both female trained phoneticians and Sp3 was male with no training in phonetics. None of the speakers had knowledge of the aims of the experiment or any known speech or hearing disorders. All three speakers had participated previously in electropalatography (EPG) experiments.

Speakers were instructed that they should complete the sentence they heard with a compound word as quickly and accurately as possible. Speakers completed 20 practice items with different compound words to ensure they were familiar with the task. Experimental sentences were presented in 6 blocks with a randomized order of the sentences in each block.

2.3 Data analysis: Data was segmented and labeled from the EPG palatograms and acoustic waveform. The labels included the reaction time from the acoustic offset of the auditorily presented sentence to the acoustic onset of the speaker's response.

From EPG data, alveolar and velar stops in the clusters were labeled according to the following criteria. An alveolar stop closure was marked as 'closed' when there was a complete row of contacts in any of the first three rows of the palate. The alveolar was labeled as 'incomplete' (i.e. lenited) if there was not a full row of contact and the alveolar contact was made in the central four columns of the artificial palate. If there was no contact in the central four columns and evidence of velar closure, the alveolar was labeled as 'assimilated'. A velar stop closure required a complete row of contacts in either of the two back rows of the palate. A velar was labeled as 'incomplete' if there was contact at the back of the palate and if but no row showed complete closure. Examination of the data took into account both EPG and acoustic data for velar segments as closure may occur behind the EPG palate.

The main EPG parameter was a centre-of-gravity (COG) measure [10] which provides a numerical indication of the average position between the front and back of the palate at which place of articulation occurred; higher COG values therefore represent more anterior contact and lower values more posterior contact.

All statistical analyses were applied separately to each speaker (except reaction time data for which speakers were pooled as no significant speaker differences were found) using a mixed model ANOVA, with a 2 level repeated measure variable 'repetition' (first/last) and a fixed factor 'frequency' (high/low).

3. RESULTS

3.1 Reaction Time: The reaction times (RT) for each speaker are given in Figure 1. Across all speakers, significant main effects were observed for frequency (p=.002) and repetition (p=.003). High frequency and final productions words were responded to faster. However, there was a significant interaction between repetition and frequency (p=.008). Post-hoc Bonferroni t-tests suggest the difference in reaction time between high and low frequency words was significant only at the first production (p<.001) and was significantly reduced after multiple repetitions (p=.56).

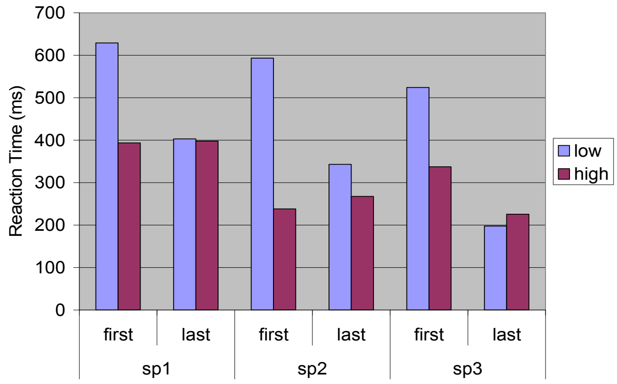

Figure 1: Reaction Times by speaker, frequency (high/low) and repetition (first/last).

3.2 Distribution of assimilation patterns: Patterns of assimilation displayed by the speakers were divided into the three labeled categories of closed, incomplete and assimilated. Figure 2 shows patterns of assimilation from the speakers (averaged over repetition for Sp1 and Sp3 as they showed no difference across repetitions).

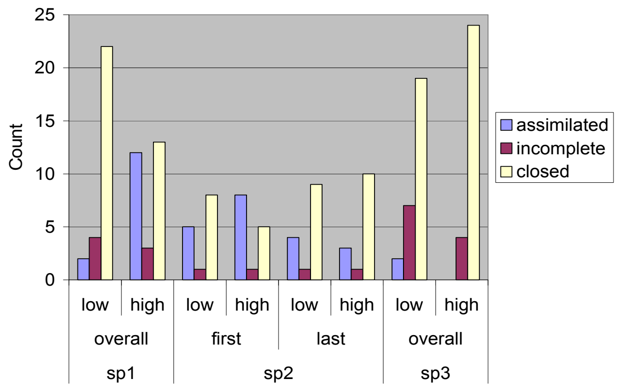

Figure 2: Distribution of assimilated, incomplete and closed productions across repetitions by speaker (Sp1 & Sp3 averaged across repetitions).

For Sp1, the number of complete assimilation assimilations in the high frequency condition (12) was much greater than those in the low frequency condition (2). Sp2 changed assimilation patterns over repetitions, in the first repetition more high than low frequency compounds were assimilated but in the final repetition this difference is removed. Sp1 and Sp2, in general, produced far more assimilations than the phonetically naïve speaker, Sp3.

3.3 Acoustic consonant cluster durations: Figure 3 shows the acoustic duration of the consonant cluster by speaker across repetition and frequency (Sp1 collapsed across repetition as no significant differences were found). A trend was seen in Sp3 (p=.10) for shorter consonant cluster duration for high frequency than low frequency tokens. Both Sp1 and Sp2 showed the same non significant pattern.

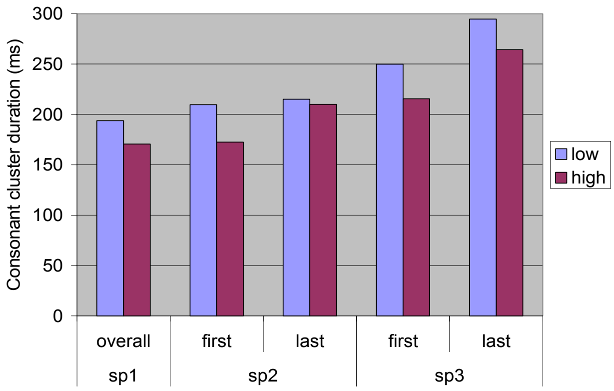

Figure 3: Consonant cluster durations across frequency (high/low) by speaker (Sp1 averaged over repetitions).

Significant repetition effects on consonant cluster duration were found for Sp3 (p<.001), where consonant cluster duration was longer at the final repetition. A similar trend was also seen for Sp2 (p=.10)

3.4 EPG consonant cluster durations: Cluster duration from the EPG data, defined as closure of the first consonant and release of the second consonant, showed a similar pattern to the acoustic data. However, there were no statistically significant differences seen for any of the three speakers.

3.5 Duration of initial consonant complete closure from EPG trace: Using EPG data, duration of the complete closure within the first consonant of the consonant cluster was examined (see Figure 4).

Sp3 (a phonetically naive speaker) showed a significant effect of frequency on closure duration (p=.04), whereby high frequency tokens were produced with shorter consonant closure durations than low frequency tokens. In contrast, the two phonetically trained speakers produced greater closure duration in high frequency compounds, a trend was observed for Sp2 (p=.07) and a non-significant pattern for Sp1 (p=.30).

Although for all speakers there was a tendency for the complete closure duration to be longer in the final than the initial production, this effect was not significant.

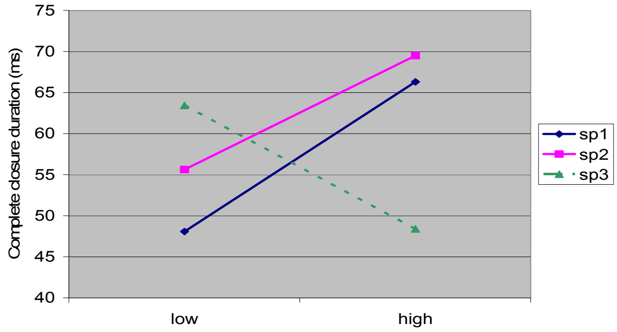

Figure 4: Consonant closure durations across frequency (high/low) by speaker.

3.6 Centre of Gravity (COG): The COG was calculated at the point of maximum contact within each consonant cluster. Figure 5 shows the effect of frequency on the COG measure for each speaker.

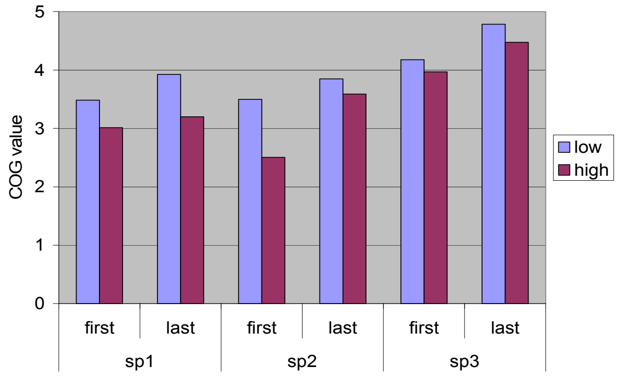

Figure 5: COG values across frequency (high/low) by speaker.

For Sp1, COG was significantly lower for high than low frequency tokens (p=.02), suggesting high frequency compounds were produced with less alveolar contact than low frequency compounds. There was a similar, but non-significant relationship between lexical frequency and COG for Sp2 (p=.13) and Sp3 (p=.54). The effect of repetition was significant for all three speakers, Sp1 (p=.03), Sp2 (p=.04) and Sp3 (p=.02). COG values for productions in the last repetition were significantly higher, indicating more alveolar contact, than in the first production.

4. DISCUSSION

Reaction time data showed that high frequency words were responded to faster than low frequency words. However, the frequency effect disappeared with later repetitions. This suggests the frequency effect found in reaction time data is modulated by recent access to particular words. Therefore, low frequency words that have recently been frequently accessed are more likely to show RT priming, that is, a reduction in the time taken to initiate speech.

This study showed that alveolars in high frequency compounds were produced with greater assimilation than

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those in low frequency compounds This is consistent with Lindblom's [6] H&H model of articulation as well as Wright's [7] analysis of vowel reduction: it suggests that listeners can nevertheless recover the linguistic code from less careful articulations in a more frequently occurring and hence more predictable context.

The influence of frequency was seen in the acoustic duration of the consonant clusters. All three speakers produced shorter cluster duration for high frequency tokens in comparison to the low frequency tokens. A frequency effect was also found for Sp3 who produced high frequency tokens with shorter EPG measured closure duration. In contrast, Sp1 and Sp2 showed the opposite pattern, with high frequency complete closure duration being longer in than low frequency tokens.

Frequency was an important factor for the COG measure of linguo-palatal contact. For all three speakers, the alveolar in low frequency compounds was associated with higher COG values and therefore a more anterior production. This result demonstrates that alveolars are less likely to assimilate to velars in low frequency compounds.

Different speakers therefore appear to be showing frequency effects in different measures. One distinction was the difference between phonetically trained and untrained speakers. Trained speakers showed an effect of frequency on place of articulation, whereas the untrained speaker showed the effect on duration. Further, in line with [1] it seems that some speakers are consistent with assimilation patterns (Sp1 & Sp3), while others are more variable (Sp2).

This study also investigated the effect of repetition on assimilation. Repetition effects were seen in all speakers for the place of articulation measure. However, contrary to previous findings [8] repeated compounds did not show more assimilation than compounds produced as the first item in the experiment. The memory demands required by this task, due to the number of different sentences used, may have resulted in careful speech. Also, speakers are not interacting with an ordinary listener in this task; rather they are speaking to be recorded and so may not show reduction over repetition. Sp3, the naïve speaker, was more consistent in showing the strengthening effect; perhaps this speaker was particularly influenced by experimental conditions.

5. CONCLUSIONS

This study has found evidence that the process of assimilation is influenced by frequency and repetition. This provides further support for assimilation as a gradient function and not a categorical process. High frequency compounds were more likely to show instances of complete assimilation. Also, the effects of frequency were seen for some speakers on durational measures and for others on place of articulation measures. Further, repetition was also found to influence the process of assimilation, repeated compounds showed articulatory strengthening. Significant differences were found in the pattern of assimilations and the effect of frequency on assimilation between phonetically trained and untrained speakers.

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REFERENCES

[1] L. Ellis and W.J. Hardcastle, “Categorical and gradient properties of assimilation in alveolar to velar sequences: evidence from EPG and EMA”, *Journal of Phonetics,* **30**, pp.373-396, 2002.

[2] A. Spencer, *Phonology: Theories and Description,* Oxford, Blackwell, 1996.

[3] W.J. Hardcaslte, “Assimilations of alveolar stops and nasals in connected speech”, in *Studies in General and English Phonetics in honour of Professor J.D. O’Connor*, J.W. Lewis, Ed., pp.49-67. London, Routledge, 1994.

[4] K.I Forster and S.M. Chambers, “Lexical access and naming time”, *Journal of Verbal Learning & Verbal Behavior*, **12(6)**, pp.627-635, 1973.

[5] J. Bybee, “The phonology of the lexicon: Evidence from lexical diffusion”, in *Usage-based models of language*, M. Barlow & S. Kemmer, Eds., pp.65-85. Stanford: CSLI, 2000.

[6] B. Lindblom “Explaining phonetic variation: A sketch of H & H theory”, in *Speech Production and Speech Modelling*, W.J. Hardcastle & A. Marchal, Eds., pp. 403-439. Dordrecht: Kluwer, 1990.

[7] R. Wright, “Lexical competition and reduction in speech: A preliminary report”, *Research on Spoken Language Processing*, **21**, pp.471-485, 1997

[8] C.A. Fowler, and J. Housum, “Talkers’ signaling of “new” and “old” words in speech and listeners’ perception and use of the distinction”, *Journal of Memory & Language*, **26(5)**, pp.489-504, 1987.

[9] R. Baayen, R. Piepenbrock and H. van Rijn, *The CELEX lexical database* (CD-ROM), Linguistic Data Consortium, University of Pennsylvania, 1993.

[10] W.J. Hardcastle, F. Gibbon, and K. Nicolaidis, “EPG data reduction methods and their implications for studies of lingual coarticulation”, *Journal of Phonetics*, **19**, pp.251-266, 1991.