PERCEPTION OF ANTICIPATORY VCV-COARTICULATION: EFFECTS OF VOWEL CONTEXT AND ACCENT DISTRIBUTION

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ABSTRACT

This paper examines the perceptual effects of first and second order anticipatory coarticulation in V1CV2-sequences in meaningful Dutch phrases, where the CV2-portion was deleted from the stimulus. V1 was /a,i,u/ or schwa and C was /p,t,k/. Either V1 was accented and V2 was not, or vice versa. Effects are generally stronger when V1 is unaccented. Identification of V2 but not for C is better from schwa than for other types of V1. The effects of accent distribution and vowel type are additive.

1. INTRODUCTION

By first order coarticulation we mean the mutual influence of adjacent phones. When a segment contains influences from a non-adjacent phone we are dealing with higher order coarticulation. Generally, first order coarticulation is quite strong, and more easily demonstrated than higher order effects. Nevertheless, it has been shown that coarticulation effects can manifest themselves across several segment boundaries. Öhman [2] showed that part of the behaviour of the formant transition movements in V1 toward C in V1CV2 sequences depends on the formant frequencies of V2 (and vice versa). Lip rounding in anticipation of a vowel can begin as many as four segments ahead (for a literature survey pertaining to these and subsequent claims cf. [1]). Additional evidence for the relatively large number of segments across which anticipatory coarticulation can extend is provided by investigations into anticipation of nasality.

Perceptual effects of coarticulation typically involve the use of stimuli of which parts have been deleted. The subjects' ability to identify the deleted sounds is considered a reliable measure of the perceptual usefulness of coarticulation. Stops turn out to be identified well above chance level on the basis of the transitions from, or into, the neighbouring vowel. Similarly, it was demonstrated that consonants may contain perceptually useful cues for the identification of adjacent vowels. However, so far, no one has been able to show the perceptual relevance of higher order coarticulation effects using the truncation method. We claim that in none of the available studies assessing higher order coarticulation effects did the investigators include an optimal type of context for assessment of such effects. In the present experiment we set out to examine the perceptual effects of first and second order anticipatory coarticulation in V1CV2 sequences under optimal conditions.

Vowels located in the central area of the traditional two-dimensional vowel diagram should be more prone to adjustment under the influence of context than vowels situated along the edges of such a diagram. Whereas the latter are accompanied by extreme tongue positions, the

former are produced with the tongue in a more or less neutral position, from which it can move in any direction. We assume, therefore, that the central vowel schwa carries cues that are perceptually more useful than those carried by other vowels. We have tested perceptual effects of coarticulation in both schwa and the three point vowels. We predict higher identification scores for segments deleted after schwa than after /i,a,u/ (hypothesis 1).

We predict further that effects of coarticulation depend on the distribution of stress over the coarticulatory domain. Stressed vowels may cause their features to spread further forward into following, and back into preceding segments than unstressed vowels. One therefore expects weak syllables to reflect coarticulatory influences from neighbouring stressed syllables more strongly than vice versa. We have used stimuli prepared from fragments in which either V1 was accented and V2 unaccented, or V1 was unaccented and V2 was accented. Perceptual effects of anticipatory coarticulation will be stronger when V1 is weak and V2 strong, rather than vice versa (hypothesis 2).

Assuming additive effects of vowel quality and stress distribution, we further predict particularly strong perceptual effects when V1 is both central and unaccented, and V2 is an accented point vowel (hypothesis 3).

2. METHOD

Targets were nine Dutch disyllabic words beginning with a CV1 syllable in which C was one of the three voiceless stops /p,t,k/ and V1 was one of the three phonologically long vowels /i,a,u/. The targets, such as tafel 'table' or koepel 'dome', were monomorphemic words with lexical stress on their first syllable. Each target was embedded in a fixed set of carrier sentences, after one of four common, monosyllabic words. Since stress (to be realised as a pitch accent) was required either on the vowel of the monosyllabic word (V1) or the vowel of the target-initial syllable (V2), a total of 72 sentences (9 targets x 4 types of V1 x 2 stress patterns) was made.

The set of 72 sentences was read by a male native speaker of standard Dutch. The final portions of the utterances were cut off in the silent interval of the voiceless plosive at the beginning of the target word. The resulting 72 sentences were copied on a test tape in nine series of eight sentences. In each series the order of the stimulus sentences was randomized. The interstimulus interval was fixed at 7 s (onset to onset).

Stimuli were presented through headphones to 62 native Dutch listeners. They were instructed to indicate which word they thought had been deleted after V1, with forced choice from nine preprinted response alternatives.

3. RESULTS

The experiment yielded a total of 62 (subjects) x 72 (stimuli) = 4,464 CV2 responses. The way in which consonant and V2 prediction is affected by the type of preceding vowel (V1) and the accent pattern over V1/V2 is shown in table I.

Table I: Percent correctly identified C and V2 broken down by type of V1 and accent condition.

	RESPONSES FOR	
	C	V2
V1 accented		
V1= /i/	65	32
/u/	62	38
/a/	85	38
schwa	80	41
V1 unaccented		
V1= /i/	80	38
/u/	64	32
/a/	87	44
schwa	82	50
Overall	76	39

C-identification

The overall correct identification score for C was 76%, which is way above chance (=33%). Obviously, the type of V1 played an important role in the identification of C. The deleted consonants were, on the whole, identified best from preceding /a/. The overall effect of V1 on consonant identification was strongly significant [X^2 (3) = 185.5, $p < .001$]. While subjects identified C significantly better from schwa (81% correct) than from /i/ (73% correct) or /u/ (63% correct), the difference in scores between /a/ (86% correct) and schwa contexts was likewise found to be significant [X^2 (1) = 10.2, $p < .01$]. Our first prediction, viz. that stops are better identified in the environment of preceding schwa than after point vowels, was therefore not quite confirmed by the overall results of VC-coarticulation.

When we next examine the effect of accent pattern over V1/V2 it turns out that the results support our second prediction: with the accent on V2 rather than on V1 an overall score of 78% was found; when the stress distribution is reversed the overall score is 73% [X^2 (1) = 15.5, $p < .001$].

V2-identification

The vowels /a/ and especially /u/ were identified well above chance while identification of /i/ was not. The total correct identification score is 39%, which is significantly different from chance [z = 12.3, $p < .001$; binomial test]. Clearly, anticipatory coarticulation in word-final vowels (V1) can be usefully employed in the perception of non-adjacent vowels (V2).

The overall effect of V1 on the identification of V2 is substantial [X^2 (3) = 32.8, $p < .001$]. Identification is significantly better when V1 is schwa (45% correct) than when V1 is /i,a,u/ (between 35% and 41% correct). This finding provides evidence that hypothesis (1), which predicts larger perceptual effects of anticipatory information in tokens of schwa than in tokens of point vowels, is essentially correct for vowel-onto-vowel coarticulation.

Examining effects of stress distribution on the identification of V2 we observe that scores were generally higher for stimuli in which V1 was unaccented and V2 was accented (41% correct) than for stimuli in which the distribution of stress was reversed (37% correct) [X^2 (1) = 5.9, $p < .05$]. We conclude that hypothesis 2, whereby unaccented vowel tokens were expected to carry perceptually more relevant cues for the perception of V2 than were accented vowel tokens, is confirmed.

Crucially, a large difference (41% versus 50% correct) between the two accentuation conditions can be observed in contexts where V1 was schwa [X^2 (1) = 8.3, $p < .01$]. The value of 50% correct identification for V2, measured in unaccented schwa contexts, exceeds all other values. This result shows that, as far as identification of V2 is concerned, hypothesis (3), which predicts that facilitation of vowel identification should be maximal in the context of an unaccented schwa followed by an accented target-initial syllable, stands.

4. CONCLUSIONS AND DISCUSSION

We predicted larger percentages of correctly identified segments from tokens of the central vowel schwa than from tokens of point vowels. The prediction was confirmed as regards identification of the deleted transconsonantal vowel; it could not be fully confirmed for the identification of the deleted consonant. Indeed, we found that percent correct scores were of equal magnitude in the environment of preceding /schwa, a/, which were both significantly better than the environments /i/ and /u/.

As concerns the role of V1 with respect to the identification of V2, our results clearly demonstrate the expected effect: of the four vowels /i,a,u,schwa/ the central schwa most strongly facilitated the restoration of V2. Correct responses were generally more frequent in contexts where the vowel containing the anticipatory cues was unaccented and the target vowel was accented than in contexts where the accent distribution was reversed. This pattern of results was consistently found for both first order (C) and second order (V2) coarticulation effects. Our experiment therefore provides substantial evidence that prediction (2) as stated in the introduction is essentially correct.

Moreover, our results indicate that the effects of stress distribution and V1 vowel type are largely additive. Crucially, vowel restoration was optimal when the target V2 was accented and when V1 was unaccented and schwa. Consequently, our hypothesis 3, predicting additivity of stress distribution and vowel type, stands.

Our experiment is the first to show convincingly that perceptual effects of anticipatory coarticulation from-vowel-onto-vowel are not necessarily restricted to immediately adjacent segments. When conditions are carefully chosen, the perceptual effect of the second order vowel-onto-vowel effect can be substantial. Clearly, the reason why other researchers have by and large failed to uncover convincing perceptual effects of vowel-onto-vowel coarticulation ([1,3,4,5,6]), lies in their infelicitous choice of stimulus material. Notice, in this context, that our optimal condition (predicting an accented V2 from a preceding unstressed schwa across an intervening word-initial stop consonant) is by far the most frequent triphone type in Dutch (and probably in English as well). This means that such coarticulation effects have ample opportunity to be used outside the laboratory in everyday speech perception.

NOTE

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