A REPRESENTATIONAL ACCOUNT FOR APRAXIA OF SPEECH

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ABSTRACT

The present study proposes a new interpretation of the underlying distortion in apraxia of speech. Based on the experimental investigation of coarticulation it is argued that apraxia of speech has to be seen as a defective implementation of phonological representations at the phonology-phonetics interface. The characteristic production deficits of apraxic patients are explained in terms of overspecification of phonetic representations.

INTRODUCTION

Most of the explanatory approaches in recent research refer to some higher cognitive functions within the motor system to describe the underlying pathomechanisms in apraxia of speech [1], [2]. But since pure apraxia of speech affects only verbal performance (cf. [1], [2]) and since patients suffering from apraxia of speech produce not only phonetic errors (eg. distortions) but phonemic errors as well (eg. substitutions), it is reasonable to think about a more linguistically based interpretation of this disturbance.

The aim of this paper is to propose a view on apraxia of speech which is founded on linguistic theory – in particular on nonlinear phonology and feature geometry – and which is supported by experimental evidence.

An important point of modern phonological theories is the principle of underspecification [3]. Underspecification is crucial for the description of many common processes such as vowel harmony, vowel-consonant asymmetries, reduction to unmarked sounds etc. Moreover, it has been shown that classes of sounds can easily be defined on the basis of underspecified, nonredundant representations and that the degree of underspecification can serve (a) as the structural representation of the degree of markedness within classes of sounds and (b) as a structural explanation for the sonority hierarchy [4].

Keating [5] proposes that parts of the phonologically underspecified gestures remain unspecified even in phonetic representations with the corresponding articulators resting in a neutral position or moving from one target to another without affecting the actually produced sound(s).

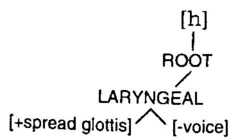
Now, our hypothesis is that apraxia of speech can be descibed as the loss of the ability of constructing underspecified phonetic representations.

COARTICULATION IN APRAXIA OF SPEECH

To illustrate and to support the overspecification hypothesis we will report some findings of experiments regarding the coarticulatory performance of patients with apraxia of speech.

VhV-sequences

The laryngeal fricative [h] is an element of the class of sounds which are maximally underspecified in phonological representation – the laryngeals (cf. [4]). For laryngeals it is only necessary to specify the features on the laryngeal tier, all features dominated by the supralaryngeal tier are underspecified:



So, assuming that the supralaryngeal underspecification is preserved in phonetic representation, [h] is expected to receive its supralaryngeal features from its phonetic context. Regarding formant structure this supralaryngeal transparency means, that the place features (which are primarily reponsible for the formant structure) of the surrounding vowels determine the position of the noise formant of [h].

Figure 1 shows a wide-band spectrogram of the first two syllables of the nonsense word *gehobe*. It is a part of the utterance *Ich habe* **gehobe** *gehört (I have heard gehobe)* by a male control speaker (data taken from [6]).

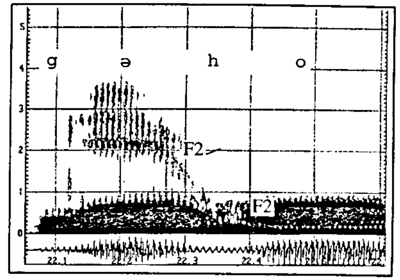


Figure 1. Wide-band spectrogram and signal display of **gehobe**, *male control speaker. Y-axis: frequency in kHz, x-axis: time in sec.*

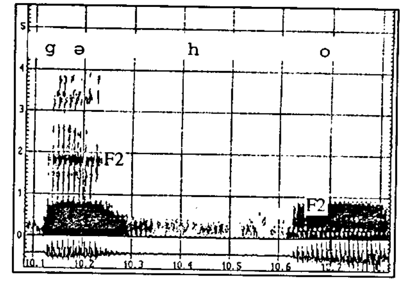


Figure 2. Wide-band spectrogram and signal display of **gehobe**, *male apraxic speaker. Y-axis: frequency in kHz, x-axis: time in sec.*

The noise formant of [h] has no target of itself. It moves, starting at the end of F2 of schwa, to the beginning of F2 of [o]. In other words, the source quality of [h] is well defined (laryngeal friction) but the characteristic of the oral filtering depends completely on the phonetic context.

In figure 2, the same part of speech is shown, uttered by a male subject suffering from severe apraxia of speech. He sustained a left-sided cerebrovascular infarct 2 years prior to testing.

There is no indication for any interaction between the vowels and the [h]. The vowels and the fricative are completely seperated. In terms of the overspecification hypothesis this can be interpreted as a full specification of each sound for all features and, as a result, in the case of [h] as the loss of the supralaryngeal transparency.

Figure 3 illustrates the two representational qualities with a underspecified representation on the left side and a maximally specified (i.e. overspecified) representation on the right side. In the non-redundant representation all segments are more or less underspecified. As mentioned above [h] is most underspecified, followed by the vowels, which are only specified for the place features (the schwa – due to its neutrality – lacks any further specification below the place node). The obstruent [g] needs the greatest amount of specification (cf. [4]).

As the dotted line indicates, formant interpolation can take place, due to the lack of any supralaryngeal specification

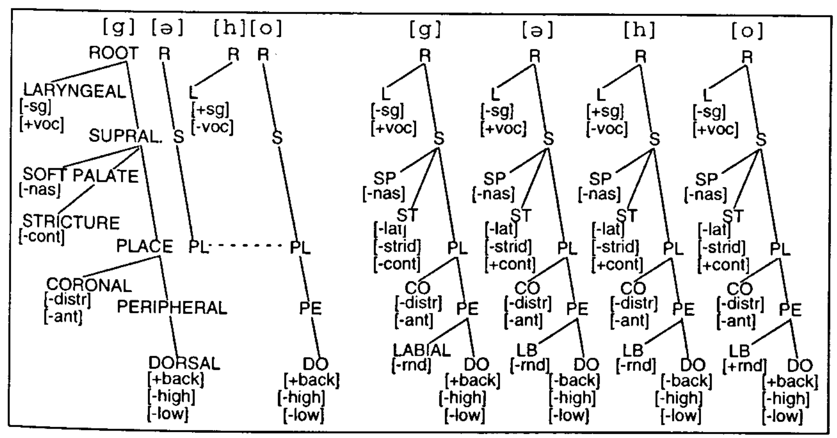


Figure 3. Underspecified, non-redundant representation (left) and overspecified representation (right) of **gehobe**. *The dotted line indicates the ability of formant interpolation.*

of the segment [h]. Regarding the overspecified representation, which is hypothesized to be the starting point of apraxic speech production, it is obvious that the propensity of features to spread is completely blocked. It is impossible for adjacent segments to interact because their (potential) transparency is eliminated.

Long-distance anticipatory coarticulation

In the second experiment (cf. [7]) anticipatory labial coarticulation at a distance has been examined. The material consists of the two test items *Spieligel* and *Spielübung* embeded in the carrier phrase *Ich sagte __ zweimal (I said __ twice)*. The syllable structure and the morhological structure of both items are identical (# indicates a strong morheme boundary):

ˈʃpiːlˌiɡəl ˈʃpiːlˌybʊŋ

[CCVC]$_\sigma$ # [V]$_\sigma$ [CVC]$_\sigma$

However, they differ in segmental structure: in the first item the unrounded vowel [i] serves as the nucleus of the second syllable, whereas in the second item it is the rounded vowel [y]. It is expected that these different vowel qualities in the second syllable have a different influence on the vowel in the first syllable (in both cases [i]). To check whether there is any anticipatory coarticulation we measured F2 and F3 of the [i] in the first syllable of both items. If coarticulation takes place F2 and F3 of [i] in the second item should be lowered – due to anticipated lip rounding – compared to F2 and F3 of [i] in the first item. As figure 4 illustrates this coarticulatory effect is fairly strong for control speakers (norm1 and norm2): F2 of [i] in the second item is by 30/65.5 Hz lower, F3 is lower even by 42.25/186.75

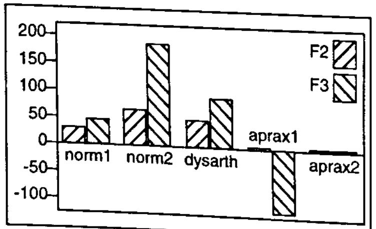


Figure 4. [i] *in the first syllable of item 1 vs.* [i] *in the first syllable of item 2: Mean differences of formant frequencies. Y-axis: difference in Hz.*

Hz (these are mean values of 4 utterances of each item). The same effect can be seen in a dysarthric speaker (dysarth) with a lowering by 49.25 Hz (F2) and 89.75 Hz (F3).

In comparison with this the apraxic subjects (aprax1 and aprax2) do not show any lowering of formants. Aprax1 is the same subject as in the first experiment, aprax2 is a 69 year old male with mild apraxia of speech as a result of a large left-sided cerebrovascular infarct 5 month prior to testing.

The lack of formant frequency lowering means that each [i] is realized identically independent of the phonetic context. The negative value for the difference of F3 in the case of aprax1 is due to a raise of the third formant in the context with the rounded vowel following. This might be interpreted as an instance of dissimilation – to get a better contrast between the target [i] and the [y] in the next syllable the formants of [i] are raised.

DISCUSSION

Both experiments have shown that apraxic speakers do not coarticulate, at least as far as macro coarticulation is concerned. Regarding micro coarticulation we have found differences between subjects dependend on the severity of the disturbance. In the speech production of aprax1, who suffers from severe apraxia, micro coarticulation is also absent. Spectrograms of his speech look like sequences of segmented steady states, with short intervalls of low energy across the whole spectrum between adjacent sounds. Transitions are missing. In comparison the milder distorted aprax2 does have transitions, at the edges of sounds his ability to coarticulate seems to be preserved.

In figures 5 to 7 the phonetic representation of the sequence [ily] is shown, which was the critical sequence in the second experiment. The representations are reduced to crucial gestures. We also abstained from indicating the hierarchical ordering to make the illustrations clearer. The most important difference to phonological representations (cf. figure 3) is that features are represented as boxes with extensions in the time domain.

The normal, partially underspecified representation is shown in figure 5. Since [i] and [l] are not specified for roundness (assuming non-roundness as neutral

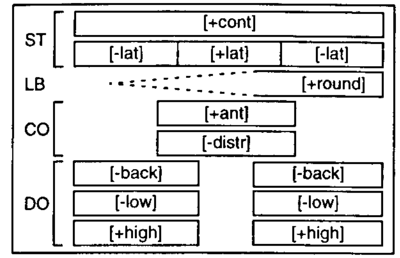


Figure 5. Reduced phonetic representation of [ily]. *Underspecification allows for the feature [+round] to spread forward.*

position for the lips) the feature [+round] in the domain of [y] is able to spread forward into the domains of the sounds ahead. This spreading process is indicated with a dotted line because the lips are supposed to achieve full rounding slowly somewhere before the [y]-domain – the [i] is still perceived as a plain [i], the correlation for anticipated lip rounding is only found with the help of acoustic analysis.

Overspecified representations as supposed for apraxic speakers are illustrated in figures 6 and 7. The representation in figure 6, however, differs from that in figure 7 in that it is additionally 'overspecified in the time domain'. All features of each segment are completely time aligned within the domain of the relevant segment. The lack of feature overlap represents the described loss of transitional phases between adjacent sounds in severe apraxia of speech. On the other side, figure 7 illustrates that preserved micro coarticulation is not a contradiction to the

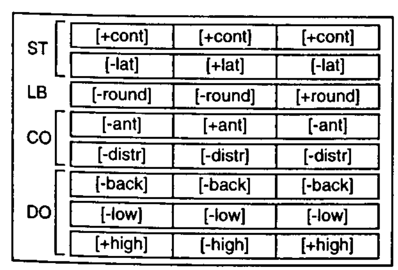


Figure 6. Reduced phonetic representation of [ily]. *Overspecification blocks spreading processes. Complete time alignment represents the loss of micro coarticulation.*

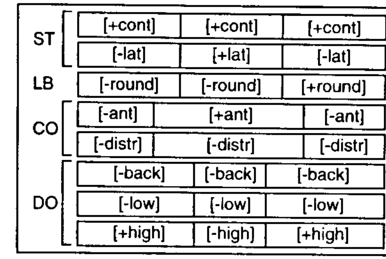


Figure 7. Reduced phonetic representation of [ily]. *Overspecification blocks spreading processes, but micro coarticulation (feature overlap) is intact.*

overspecification approach. Feature spreading at a distance is still blocked due to overspecification but the possibility of features to overlap locally is not affected.

CONCLUSION

We have explained one of the main characteristic of apraxic speech production – loss of coarticulation – in terms of overspecification of phonetic representations. Furthermore, we think that also other production deficits which are claimed to be typical in apraxia are interpretable within this framework, though we can not yet provide experimental evidence.

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