PERCEPTUAL, ACOUSTIC AND ELECTROPALATOGRAPHIC EVALUATION OF COARTICULATION EFFECTS IN APRAXIC SPEECH

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ABSTRACT: The relationship between perceptual and instrumental assessments of coarticulation effects in apraxic and normal speech are investigated.

INTRODUCTION

The nature of speeech apraxia and its differentiation from the dysarthrias on the one hand, and phonological disorders in aphasia on the other, has been a long standing problem in clinical speech research. If speech apraxia can be differentiated from phonological disorder in aphasia, then it would seem likely to be done so on the basis that it represents a motor control disorder of quite a specific kind, distinct also from the dysarthrias.

In recent years, the problem of speech motor disorder in apraxia that has been pursued through the study of coarticulation effects. Ziegler and von Cramon (1985, 1986) found perceptual and acoustic evidence of a lack of coarticulatory cohesion in the speech of a patient suffering from verbal apraxia, explainable by 'a consistent delay in the initiation of anticipatory vowel gestures'. Katz (1988) confirmed the finding of diminished perceptual signs of coarticulation effects in speech apraxia. However acoustic studies have yielded mixed findings, with some finding acoustic signs of normal anticipatory coarticulation effects (Tuller and Story, 1987). Behavioural physiological observations would seem to be required, to settle questions of the magnitude and direction of coarticulation effects in apraxia. Electropalatography (EPG) provides a useful means of observing linguo-palatal coarticulation effects and fine details of tongue movement control.

A comparative study of normal and apraxic speakers' coarticulation effects is reported, using perceptual evaluations of coarticulation effects in conjunction with EPG measurements of tongue contact patterns and spectrographic analysis of the speech signal. The combination of perceptual, acoustic, and articulatory behavioural indices is important, because it makes it possible to assess the perceptual consequences of any altered articulatory behaviours, and to relate any perceptual anomalies to the gestures that produced them.

The aims of the study were to:

1. Investigate the magnitude and direction of coarticulation effects in dyspraxic speech, which might be accompanied by disorders in the phasing or co-ordinating of component speech motor gestures.

2. Investigate the relationship between perceptual and instrumental (acoustic and electropalatographic) assessments of coarticulation effects and the implications for the detection and characterization of speech motor disorders.

SUBJECTS

The apraxic subject Mr M., aged 53, suffered a stroke in 1985. A right hemiplegia was observed at the time and a CT scan revealed a left cerebral infarct. Initially, his speech was characterized by a severe verbal apraxia. He was unable to initiate phonation or articulation, communicating through fragmented writing, in which some spelling and syntactic errors were noted. Speech improved and one month post-onset a Boston Aphasia Examination indicated moderate comprehension and naming difficulties, and frequent paraphasias, in addition to groping, effortful speech. Speech continued to improve and stabalized after 12 months to a level 'characterized by some dyspraxic and dysarthric features' (speech therapy notes). The two control speakers are JI a 44 year old Australian male and FG, a British female, approximatly 30 years of age and of similar dialect background to the apraxic speaker.

METHOD

In connection with another study, simultaneous EPG and audio recordings of six bisyllabic words (mainly compounds) involving a medial consonant cluster, had been obtained from the apraxic speaker:

tickling	bookshop	bikeshop
weekday	cocktail	kitkat.

Apart from their interest as examples of apraxic speech production, these items were chosen for more detailed study because they showed auditory/perceptual anomalies, which it seemed, on impressionistic assessment, were not reflected in any straightforward way in their corresponding EPG patterns. At the same time, certain anomalies in their EPG patterns did not appear to impact upon auditory perception of the items. For example, the medial stop in one rendition of the item 'bookshop' gave the auditory impression of an alveolar or palatal point of articulation, yet its EPG trace clearly indicated a velar point of closure and release.

It was decided to subject these items to a systematic acoustic and perceptual analysis, focusing on coarticulation effects and the transitional consonantal gestures across the syllable boundary, which are known to be difficult for apraxic speakers. Acoustic and EPG recordings were also obtained for two control speakers, using the same set of items. A parallel perceptual rating experiment was conducted to provide a baseline for evaluating perceived coarticulation effects in the apraxic speech.

To assess coarticulation effects, individual syllables were digitally spliced at the point of cleanest division between the

two consonants in the medial cluster. This splicing was less problematic than might be expected for the apraxic speaker because of his singular, discretely syllabified, speaking style. The mono-syllabic stimuli created by the splicing procedure were employed in a perceptual identification task.

In the perceptual experiment, listeners judgements were directed to the final consonant of initial syllables and to the initial consonant of second syllables. If co-articulation affects a given sound, then its perceived place of articulation might be expected to shift in the direction of the sound which is providing the 'coarticulation pressure'. An example of the judgement task is given below. Listeners were required to indicate where the taget sound (the final stop in this case) fell on a phonetic continuum between [k] and [t] (velar-alveolar). The stimulus was /kIt/, spliced from 'kitkat'. If the /t/ shows anticipatory coarticulation effects, then its perceived place of articulation will presumably shift somewhat in the direction of /k/. However, it cannot be assumed that the perceptual effect on the target sound will simply represent a shift in place of articulation towards the co-articulating sound. Hence the 'outside range' option was offered in recording listeners responses:

Example of perceptual task

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      WITHIN RANGE OF TARGETS                    OUTSIDE RANGE
  [kick]                          [kit]            [boo?]
    (__)   (__)    (__)   (__)     (__)              (__)
  clearly          half-way       clearly        sounds like:
 this sound        between       this sound          [  ]
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Ten listeners were used in the perceptual experiment with the items from the apraxic speaker and 8 for the items from the two controls. All raters had experience in phonetic transcription, but were of varying expertise.

RESULTS

Perceptual ratings

The distribution of listeners' perceptual responses to the ataxic items is given in Table 1 (space precludes presentation of the controls). There is a striking discrepency between the perceptual response distributions for the two tokens of syllable final /k/ in 'bookshop', which was not found in the case of the two control speakers. From the perceptual data alone, it might be debated whether the impression of alveolar articulation in 'bookshop1' is caused by an exaggerated anticipatory coarticulation effect to the following alveopalatal, or whether it simply represents inaccurate spatial targeting of tongue movement. However, such a 'debate' is rendered irrelevant by examination of EPG traces, which indicate similar velar contact and release gestures for medial /k/ in both utterances.

ANTICIPATORY EFFECTS:

	clearly 'k'		half-way between		clearly 't'	outside range
bookshop1	(0)	(0)	(1)	(2)	(17)	(0)
bookshop2	(4)	(5)	(1)	(6)	(1)	(3)
bikeshop	(1)	(0)	(0)	(2)	(17)	(0)
cocktail	(18)	(1)	(0)	(0)	(1)	(0)
weekday	(7)	(0)	(0)	(4)	(9)	(0)
tickling	(1)	(3)	(5)	(3)	(1)	(9)
	't'				'k'	
kitcat	(5)	(3)	(0)	(4)	(1)	(7)

CARRY-OVER EFFECTS:

	't'				'k'	
cocktail	(11)	(8)	(1)	(0)	(0)	(0)
	'k'				't'	
kitkat1	(9)	(5)	(1)	(1)	(3)	(1)
	'd'				'g'	
weekday	(6)	(9)	(4)	(0)	(0)	(1)
	'sh'				'ch'	
bookshop1	(2)	(3)	(4)	(10)	(1)	(0)
bookshop2	(0)	(0)	(5)	(5)	(10)	(0)
	'l'				'r'	
tickling	(6)	(2)	(9)	(0)	(0)	(3)

Table 1: Perceptual response distributions, apraxic speaker

More generally, comparison of the apraxic and control perceptual response distributions showed, (a) greater consistency in listeners' perceived coarticulation effects for the two controls and greater similarity of the response distributions to the controls than to the apraxic speaker; (b) stronger perceived anticipatory coarticulation effects than carry-over effects in the response distributions to the two controls. In the case of the apraxic speaker, any general tendency towards dominance of anticipatory over carry-over effects was masked by item variation.

	'k'	<-	->		't'	outside range
bookshop1	(0)	(4)	(4)	(0)	(0)	(12)
bookshop2*	(0)	(2)	(3)	(1)	(0)	(12)
bikeshop	(0)	(0)	(7)	(1)	(1)	(11)
cocktail	(1)	(2)	(6)	(1)	(0)	(10)
weekday	(0)	(2)	(7)	(2)	(0)	(9)

*=missing data

Table 2: Perceptual response distribution, final /k/, without acoustic release, apraxic speaker.

Unlike the controls, the apraxic speaker heavily released all final stops. It was possible in his case to investigate the perceptual contribution of the acoustic energy in the release to the perception of place of articulation, by gating the syllable final consonant just before the release burst, and

presenting these stimuli to listeners as unreleased final stops. As can be seen from Table 2, this effectivly removed the variation in the perceptual response distributions. Listeners consistently heard these stops as glottalized. Glottalization of stops in a pre-obstruent environment seems to be a feature of Mr M.'s dialect and that of MG, the female control, also, judging from listeners' responses.

EPG patterns

Consistent with the perceptual findings, the EPG patterns of the two controls showed pervasive coarticulation effects that varied somewhat with item and speaker. In addition to anticipatory movements towards an upcoming target during the closure gesture for a stop, these coarticualtion effects, apparent in the EPG traces, also took the form of co-productions of temporally overlapping, independent gestures. A typical example of the co-production of independent gestures can be seen in the simultaneous velar-alveolar closures used by both control subjects during the consonant cluster of items such as 'weekday'.

By contrast, the apraxic speaker appeared to avoid temporal overlap of consonantal gestures. There were abnormally long latencies (up to 270 msec.) between the release of a velar stop closure and movement of the tongue body towards the following alveolar or alveopalatal constriction.

Cases of double velar-alveolar contact were observed in the apraxic speaker, such as the abnormal constriction pattern observed on the initial /t/ of 'tickling' (which was, incidently, perceived as a normal 'alveolar' stop by listeners). But the time course of the gestures involved and the phonological environment in which they occurred strongly suggested that they were not cases of co-production of independent gestures, but simply poorly controled constriction gestures.

Acoustic analysis

It was clear from analysis of the perceptual response distributions that perceived coarticulation variation of the syllable final /k/'s for the apraxic speaker was attributable to acoustic properties of the release burst. This was also confirmed simply by listening to the bursts in isolation. A spectral analysis of the release bursts for 'bookshop1' (perceived as alveolar/palatal), 'bikeshop' (alveolar/palatal), and cocktail (velar) was undertaken, using a 512 point FFT and a sampling rate of 20kHz. The results are presented as a waterfall plot in Figure 1. The spectral energy distributions appear to be more similar than auditory impressions suggest. The perceived velar burst is distinguished by a greater concentration of acoustic energy in the 1kHz region.

CONCLUSIONS

Results of this experiment have bearing on the topical controversy over the use of acoustic vs behavioural-

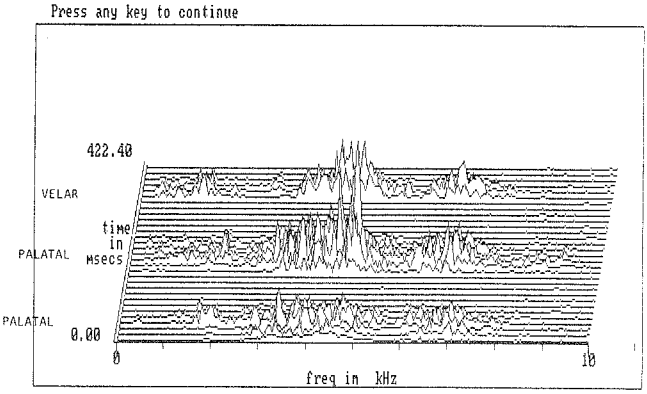

Figure 1. Spectral analysis of release bursts
512 point FFT 20kHz sampling rate

physiological indices of co-articulation effects (Sussman et al., 1988; Katz, 1988; Ziegler, 1989), and instrumental observations in relation to perceptual assessments of speech disorder. Although EPG traces are direct behavioural indices, whereas acoustic measures are indirectly related to articulatory gestures, the EPG trace gives only partial information about the relevant articulatory events. Consideration needs to be given also to the aerodynamics of speech production, and in the present case, the spectral energy distribution of the noise burst seemed to carry more information as to the articulatory target attained by the tongue blade. On the other hand, it should also be noted that EPG traces may reveal abnormal patterns of lingual-palatal contact which, because they have no acoustic consequences, do not register in perceptual assessments. The 'double articulation' of the initial /t/ in 'tickling' is a case in point. Only the release portion of the gesture had audible consequences, and hence the gesture sounded normal, despite the grossly abnormal initiation of the closure. Also, the EPG traces revealed details of complex co-productions of independent articualatory gestures in the normal speakers that were not found in the case of the apraxic speaker.

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