EPG Providing New Insights Into Complex Speech Disorders

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The last two decades have seen great advances in the development of instrumental tools for use by both clinicians and speech scientists. The limitations of assessments based entirely on auditory-perceptual judgments are well recognized, and non-invasive methods, such as EPG and ultrasound, are now providing a new precision in diagnosis based on dynamic records of specific articulatory organs, such as the tongue during speech. Many established views of the nature of speech abnormalities are being revised in the light of new data from these techniques.

We address three phenomena from recent EPG studies which have both clinical and theoretical implications:

1. *'misdirected articulatory gestures' in aphasic adults suggesting how articulatory target gestures might be selected during neurolinguistic programming.*
2. *'undifferentiated lingual gestures' in children with articulation/phonological speech problems as evidence of possible motor speech control limitations in these children.*
3. *labial-lingual double articulations in cleft palate, throwing light on the ways in which speakers can compensate for orofacial abnormalities.*

Introduction

The last two decades have seen important advances in the development of instrumental tools for use by both clinicians and speech scientists in the quantitative analysis of normal and pathological speech. One such technique is Electropalatography (EPG) which is now well established in many laboratories and clinics throughout the world. EPG is a non-invasive technique designed to record spatio-temporal details of tongue contact with the palate during continuous speech (for a bibliography of work carried out with EPG see our website http://sls.qmuc.ac.uk). Although the technique records only one aspect of lingual dynamics, this contact information is particularly relevant because the different patterns of contact revealed by EPG are frequently not detected auditorily, yet they may have significant implications for therapy. This paper illustrates how EPG can supplement auditorily-based assessments of complex speech disorders in contributing to a greater understanding of the underlying nature of the deficit itself. We address three phenomena from recent EPG studies carried out in the speech laboratory at QMUC which have important clinical and theoretical implications and have encouraged us to review established views of the nature of some speech abnormalities. The three phenomena are: *'misdirected articulatory gestures'; 'undifferentiated lingual gestures'; and 'labial-velar double articulations'*.

Misdirected articulatory gestures (MAGs)

The term misdirected articulatory gesture (MAG) describes one of a number of abnormal EPG contact patterns observed in adults with neurogenic disorders (see review in Wood & Hardcastle, 2000). First observed in the speech of adults with apraxia of speech (Hardcastle et al., 1985; Hardcastle & Edwards, 1992; Sugishita et al., 1987) the phenomenon has been noted more recently in a number of post-CVA aphasic adults (Wood & Hardcastle, 2000). The MAG pattern can be illustrated by an EPG printout of the word "deer" spoken by an apraxic adult as compared to a normal speaker's production (Figure 1). As the printout shows, the aphasic speaker produces a clearly defined velar contact pattern at the onset of the word. This is presumably detected as a placement error by the speaker who then corrects it to the required alveolar stop pattern for the target [d]. There is a brief period of overlap involving both velar and alveolar gestures. The interesting point about this pattern is that the listener does not hear the 'intrusive' or 'misdirected' velar gesture because the velar closure is 'masked' by the alveolar and it is the alveolar release that provides the perceptual cues to its identity. Hardcastle et al.'s study (1985) found that the misdirected velar closure pattern, when considered as a separately identifiable pattern, is similar spatially and temporally to this speaker's patterns elsewhere in the corpus for target velar stops.

Figure 1 about here

More recent studies (Wood, 1997; Wood & Hardcastle, 2000) have identified alveolar as well as velar MAGs. Figure 2 shows EPG records of a speaker with conduction aphasia producing the word "key" heard as "tea". As the record shows, the speaker begins with a velar stop pattern normal for this word but towards the latter part of the closure phase for the stop, an intrusive alveolar stop pattern occurs which results in a brief period of simultaneous alveolar-velar contact followed by an alveolar release at frame 67. The alveolar pattern in the MAG was characteristic of this speaker's normal production for alveolar stop targets. An analysis based on auditory judgments alone would not detect the velar gesture in Figure 2 and would characterize the error as a phoneme substitution (/t/ for /k/). However, the EPG pattern shows this is far from a straightforward substitution. Similarly the abnormal velar MAG in Figure 1 means that the [d] target in this case is not a normal production although it may be heard as such.

Figure 2 about here

MAGs are also found accompanying bilabial stop targets and may involve either alveolar or velar contact or both. We suspect that these MAGs occur relatively frequently in aphasic speech and they provide us with additional insights into the nature of the deficits traditionally described by labels such as distortions, substitutions, omissions, etc.

Errors such as these MAGs are not only important diagnostically however. They may also reveal some insights into the neural processes involved in speech production. Their presence suggests, for example, that competing places of articulation for stops (alveolar, velar and bilabial) interact with each other during a neurolinguistic planning stage in the generation of an utterance and in the case of certain types of neural damage the wrong selection for the target may not always be inhibited.

Undifferentiated lingual gestures

A particular EPG error pattern involving a relatively higher amount of lingual-palatal contact than normal has been identified from EPG records of school-aged children with articulation/ phonological disorders (Gibbon, 1999). Gibbon refers to this underlying articulation in these patterns as involving undifferentiated lingual gestures with reference to a hypothesized lack of coordinated control between different parts of the tongue.

Hardcastle (1976) refers to separately controllable functional parts of the tongue, the tip/ blade system, tongue body system and lateral margins, and suggests that techniques such as EPG can show evidence of co-ordination between these systems (e.g. double velar / alveolar contacts in words like "tractor" and precise sequencing of velar and alveolar contacts in the initial cluster in "clock"). An example of an undifferentiated gesture is in Figure 3 showing a large amount of tongue contact across the palate symptomatic of the main bulk of the tongue being brought up to the palate as an 'undifferentiated' whole. Standard perceptually-based analysis does not typically identify such abnormal gestures which could be variously transcribed as distortions, substitutions or even correct targets.

Figure 3 about here

The undifferentiated gesture may be interpreted as reflecting a speech motor deficit involving either delayed or deviant control of the tongue. These patterns may be more widespread than was previously thought (in an analysis of the EPG literature, Gibbon (1999) found 12 out of 17 children showing evidence of undifferentiated gestures) and could go some way towards explaining the wide variability noted by previous investigators in identifying place of articulation for lingual obstruents. For example, transcribers frequently disagree on place of articulation for stops (velars heard as alveolar and vice versa). It may well be that they are hearing stops produced with undifferentiated gestures together with the accompanying ambiguous acoustic cues.

Double labial-velar articulatory patterns

Double articulations have frequently been noted in the speech of cleft palate children (Trost-Cardamon, 1990, for example describes glottal or pharyngeal articulation occurring simultaneously with alveolar or bilabial stops). EPG analysis has revealed another type of double articulation that may occur in these children, a simultaneous labial-velar pattern such as that illustrated in Figure 4. The figure shows an EPG printout of the phrase "a pig" and an acoustic waveform with annotation marks to indicate different phases of the velar stop production which occurs simultaneously with the bilateral closure for the [p]. Other bilabial target articulations showed similar overlapping velar contact for example initial [f] (Dent et al. 1992). The velar closure in these words was not detected by the listener who noted the words produced in isolation to be highly intelligible. The child's connected speech, however, was not so intelligible and the transcribers did note some secondary velarization.

The production of velar contact accompanying alveolar closures is compatible with a general backing tendency noted as being characteristic of cleft palate speech. This backing in some cases may be compensating for the presence of an anterior fistula and is a mechanism for producing the build-up in oral pressure necessary for obstruent sounds. The backing is normally manifested as a more retracted place of stops and fricatives such as [t] and [s]. A strong backing pattern has been found to occur at an early age in many children later found to have the labial / velar double articulation pattern (Gibbon & Crampin, 2002).

Labial-velar double articulations may be regarded by some as minor speech errors as they tend to be judged by the listener as correct bilabials particularly in isolated words. But as mentioned above, the situation may be different in connected speech where the prevalence of the 'backing' velar pattern simultaneous with more anterior alveolar target obstruents may lead to more serious problems with intelligibility. A therapy goal for the children showing these abnormal patterns is to eliminate the unwanted velar contact. The visual feedback facility in EPG has been found to be particularly successful in reducing abnormal posterior tongue movements for a range of anterior targets (see Gibbon & Hardcastle, 1989).

Conclusion

These three examples of abnormal articulatory patterns revealed by EPG illustrate how the technique can provide insights into speech production which would not normally have been detected in an auditory-based analysis. We have indicated how analysis such as this may have important implications for both diagnosis and treatment of these complex disorders.

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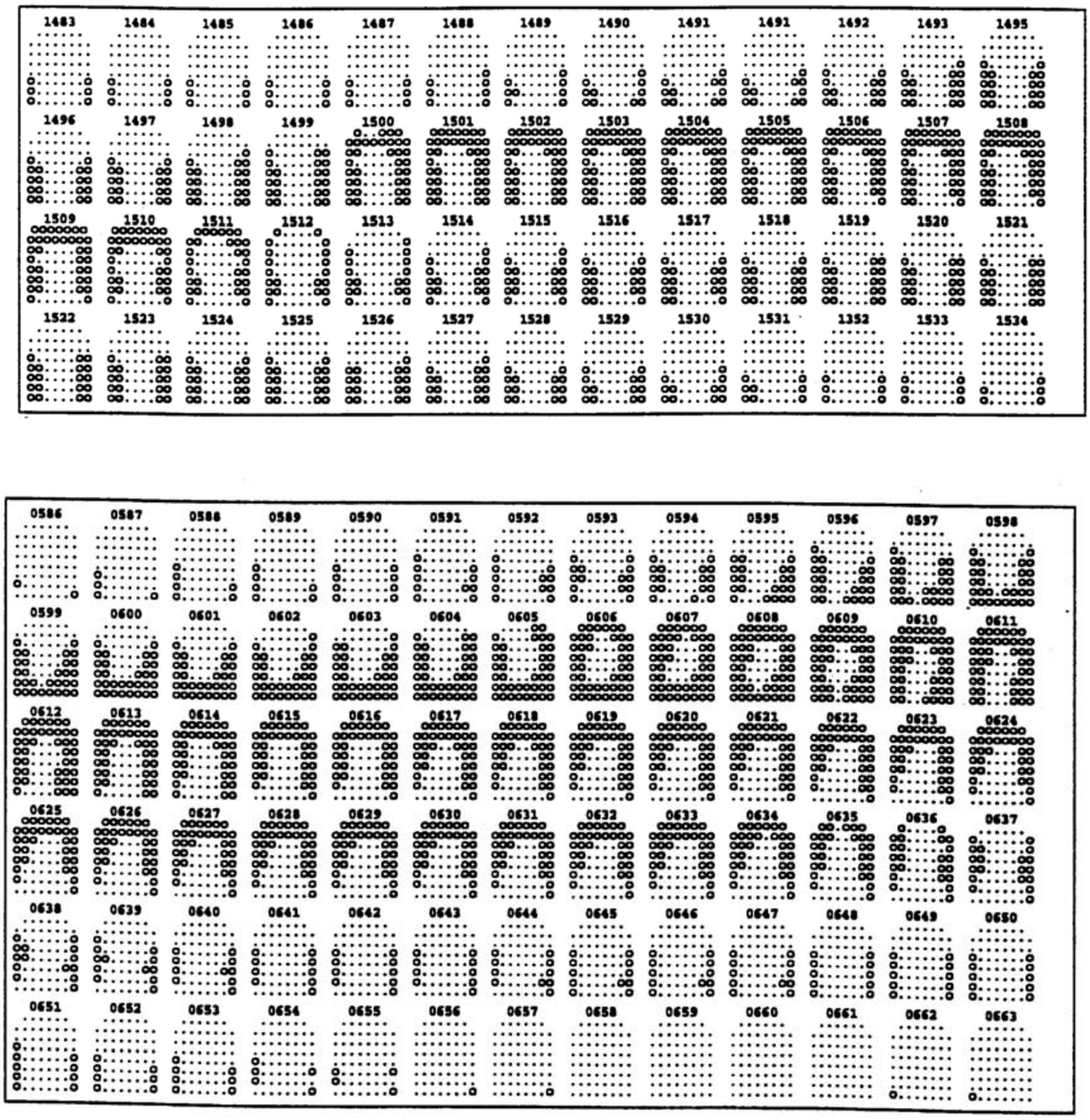

figure 1: EPG printout of the initial stop consonant in the word "deer" spoken by a normal speaker (above) and an apraxic speaker. Sampling interval is 10ms and, in each palate diagram, the alveolar region is at the top (from Hardcastle et al., 1985)

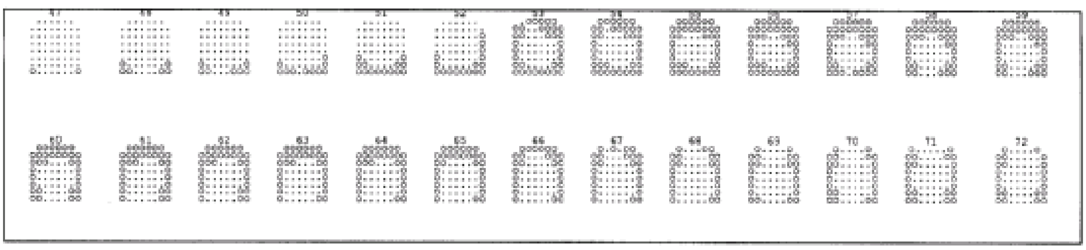

figure 2: EPG printout for the word "key" spoken by a speaker with conduction aphasia (from Wood, 1997)

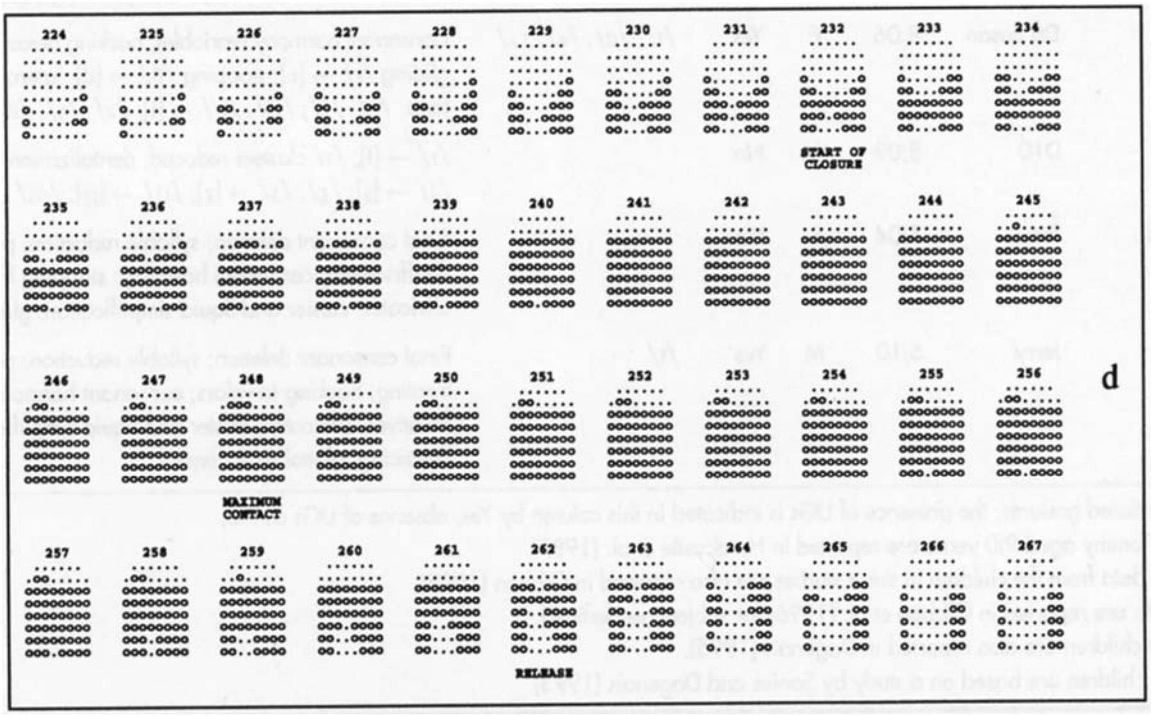

figure 3: EPG printout showing 'undifferentiated gesture' for word-final [d] in "shed" produced by a child with articulatory / phonological disorder judged by listeners as a correct [d] (from Gibbon, 1999)

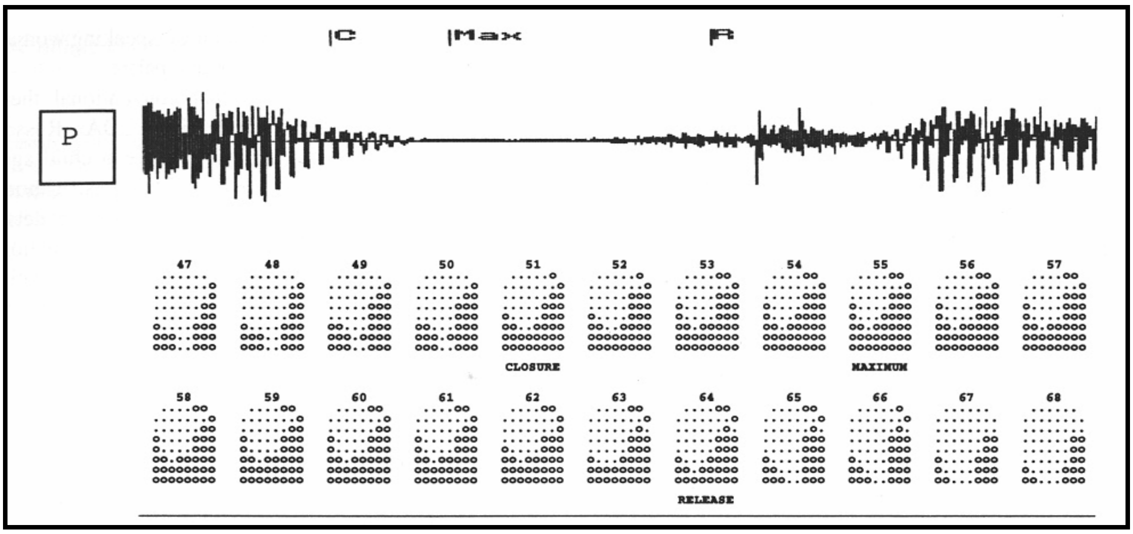

figure 4: EPG printout and acoustic waveform for the phrase "a pig" spoken by a cleft palate child (from Dent et al., 1992 and Gibbon & Crampin, 2002)