EFFICACY OF SPEECH INTERVENTION USING ELECTROPALATOGRAPHY WITH A COCHLEAR IMPLANT USER

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Abstract

Electropalatography (EPG) has become relatively well established as a safe and convenient technique for use in the assessment, diagnosis and treatment of children and adults with articulation disorders (Gibbon, Dent & Hardcastle 1993; Gibbon, Hardcastle & Dent 1995; Gibbon, Hardcastle, Crampin, Reynolds, Razzell & Wilson 2001). EPG's wide applicability is reflected in the range of different cases that has been researched in recent years. Some research has been carried out using EPG therapy for deaf[1] individuals who use hearing aids (Crawford 1995; Parsloe 1998), however there are no similar studies for cochlear implant users. The purpose of this single case study is to explore the technique of EPG as a therapeutic intervention to treat voiceless velar stop consonant sound production in a deaf child cochlear implant user. EPG therapy was offered as a last resort when traditional therapy failed to achieve specific changes.

During therapy, a list of familiar words was practised, using the visual feedback provided by EPG. The client's articulation was assessed using objective (EPG printouts) and subjective (listener ratings) measures at four assessment points. Changes were found to be statistically significant. Generalisation of the newly-acquired skills to untaught words containing voiceless velars was also observed. The results are discussed in the broader context of implications of this type of therapy with deaf clients.

Keywords: cochlear implant users, EPG, voiceless velar stops

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[1] 'Deaf' is used here to refer to individuals with any degree of hearing impairment

Introduction

Cochlear implants provide auditory feedback which can significantly assist the acquisition of spoken language in deaf children (Tobey 1993; Osberger, Robbins, Todd, Riley & Miyamoto 1994). Many studies have demonstrated significant improvements in speech perception skills following implantation (Geers & Moog 1991; Busby, Tong & Clark 1993), whereas the effects of a cochlear implant on speech production are less well documented (Robinshaw 1996). The question therefore arises whether speech perception gains resulting from improved pure tone thresholds lead to corresponding gains in speech production.

Rehabilitation following cochlear implantation is routinely implemented, however the merits of different types of therapy approaches seeking to effect change have generally not been documented. Therapy typically comprises traditional auditory and production based approaches. In addition, a range of visual feedback devices is available to clinicians, however there has been relatively little research on the benefit conveyed by their use. One potentially valuable adjunct to therapy involves providing visual feedback of articulatory behaviour using the technique of electropalatography (EPG).

EPG is a computerised–based system. It records details of the location and timing of tongue contacts with the hard palate during speech (Hardcastle & Gibbon 1997). EPG has the facility to provide real time visual feedback of tongue-palate contacts, which can be used to monitor and physically practise new articulatory gestures as part of a speech therapy program. It can record alveolar, post-alveolar, palatal and velar placements, and register specific characteristic patterns for a wide range of consonants. The general strategy in using this system is to compare the patterns of tongue contact for a pathological speaker with those of a normal speaker and to interpret the differences in terms of linguapalatal patterns. By imitating the prescribed patterns of contact on the EPG display screen, a child who is deaf may be encouraged to use tactile and proprioceptive sensory feedback information as associative learning stimuli, substituting for the auditory speech stimuli used by hearing children.

EPG has been used successfully to treat disorders ranging from dyspraxia (Hardcastle & Edwards 1992), dysarthria (Wood & Hardcastle 1999), cleft palate (Gibbon *et al* 2001; Whitehill, Stokes & Man, 1996), glossectomy (Fletcher 1988) and dysfluency (Wood 1993;

1995) to speech problems related to deafness (Fletcher & Hasegawa 1983; Dagenais & Critz-Crosby 1991; Fletcher, Dagenais, & Critz-Crozby 1991a; Dagenais, Critz-Crozby, Fletcher & McCutcheon 1994; Crawford 1995; Parsloe 1998). However, no research to date has been based on children who have cochlear implants. Despite this lack of research, various factors suggest that EPG might have a positive effect in this case. First, EPG utilizes a client's visual information processing skills, which are often strong in deaf children. Second, studies on deaf children with hearing aids have proven successful. Third, EPG can display the exact place of articulation, which is highly significant for a velar closure, as the tongue's location within the mouth for this sound is not visually accessible.

Methodology

Subject

The subject was F, a girl aged 8;9 at the beginning of the research. F was referred to the Department of Language & Communication Science at City University, London, by her speech and language therapist for remediation of her velar stop consonant production using EPG. F has a profound bilateral sensori-neural hearing loss, present from birth. She received a cochlear implant three years previously, which she wears consistently at school and at home. F takes responsibility for her implant and reliably monitors the quality of sound she receives through it.

F's average pure tone audiogram is 40 dB (500Hz-4KHz). Perceptually, F is able to discriminate differences in stress, voicing, syllable number, all vowel contrasts and some specific consonant contrasts. Regarding velars, F is able to discriminate auditorily both the voiced /g/ and the voiceless /k/.

F communicates primarily using speech alongside signing when communicating with hearing people. Her speech is unintelligible out of context to inexperienced listeners, although good use of lip patterns are an aid to speech intelligibility. F has received regular intervention targeting her speech intelligibility and despite having made progress in many areas, was unable to modify her production of velar stop consonants. This was in spite of having good auditory access to the acoustic cues for velars using her cochlear implant and receiving blocks of therapy targeting velar consonants over the previous eighteen months. Production of velar nasals was appropriate.

Procedure

A single case study design was used to investigate the efficacy of EPG intervention. The subject was assessed four times on her production of 30 single words containing voiced and voiceless velar stop consonants. The first assessment (pre-assessment 1) took place at the beginning of the study, prior to a short course of traditional auditory and production based therapy. Assessment data were audio recorded, but no EPG recordings were made at this assessment point. The subject was reassessed (pre-assessment 2) a second time after this therapy period, prior to commencing EPG therapy. At this and each subsequent assessment point, audio and EPG recordings were taken. The third assessment (post-assessment 1) was carried out after EPG therapy (12 training sessions). The final assessment (post-assessment 2) took place one month later after a period of no therapy in order to gain some measure of generalisation.

The assessment data was analysed using the EPG printouts from pre-assessment 2, post-assessment 1 and post-assessment 2. In addition, audio tapes were rated by 10 untrained listeners from all four assessment points. No control subjects were used in this study, but the subject had undergone therapy aimed at improving velar production before the research commenced.

Materials

The target stimuli consisted of thirty familiar words, twenty of them including /k/ and ten of them including /g/, presented to the subject in picture and written form and recorded on a tape recorder and on the EPG3 computer programme. The target words were chosen because they are all simple monosyllabic words containing velar sounds in either initial or final position and in singleton or consonant cluster contexts (see Table 1). No difference was apparent in F’s production of these consonants in relation to their syllable position or singleton/consonant cluster context before EPG therapy commenced.

Table 1: List of Target Words

Taught /k/ words	**Untaught /k/ words**	**Untaught /g/ words**
Cow	Book	Grass
Duck	Coin	Glue
Queen	Brick	Egg
Comb	Cut	Dog
Cat	Coat	Girl
Sock	Kite	Pig
Bike	Kick	Goat
Cake	Cry	Frog
Key	Cup	Gate
Car	Talk	Bag

The Electropalatograph (EPG)

In this study, the British Reading EPG3 system was used as described by Hardcastle, Gibbon & Jones (1991). The primary component of EPG3 is an artificial palate. This is custom made to fit against the individual's hard palate, and is embedded with 62 electrodes which are exposed to the lingual surface. Wires connect the artificial palate to the multiplexer, which the subjects wears around the neck. The multiplexer interfaces directly with the EPG3 program on the computer.

When the tongue touches any of the electrodes, a signal is conducted to a processing unit. The tongue position is displayed on the computer screen in real time. Flashing lights indicate the electrodes which the tongue touched. EPG does not record the part of the tongue which makes contact with the palate, however it is possible to make inferences about contact points.

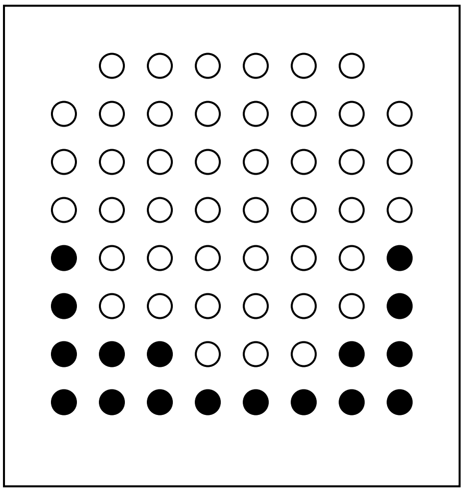
Therapy

Twice weekly treatment sessions each lasting 45 minutes were carried out. Therapy aimed at increasing the subject's ability to monitor and change her tongue movements, particularly in the velar region. The general aim was to use the EPG to help her achieve the correct articulation by visual feedback initially and eventually by tactile and proprioceptive feedback. Usually half of each session was devoted to the establishment of correct tongue positions using the EPG. The rest was used to ensure that these positions could be maintained without the artificial palate or visual feedback.

Results

Following intervention with EPG, an analysis of pre- and post-assessment data was made using objective data (linguapalatal contact patterns) and subjective data (listener identifications). In order to analyse the former, the frame of maximum contact from F's lingual palatal contact patterns was measured using percentage-correct scores for each word. In other words, the score was determined by counting the number of correctly activated electrodes along the palate (17 correct electrodes) according to EPG /k/ and /g/ prototypes derived from the therapist's production (see Figure 1).

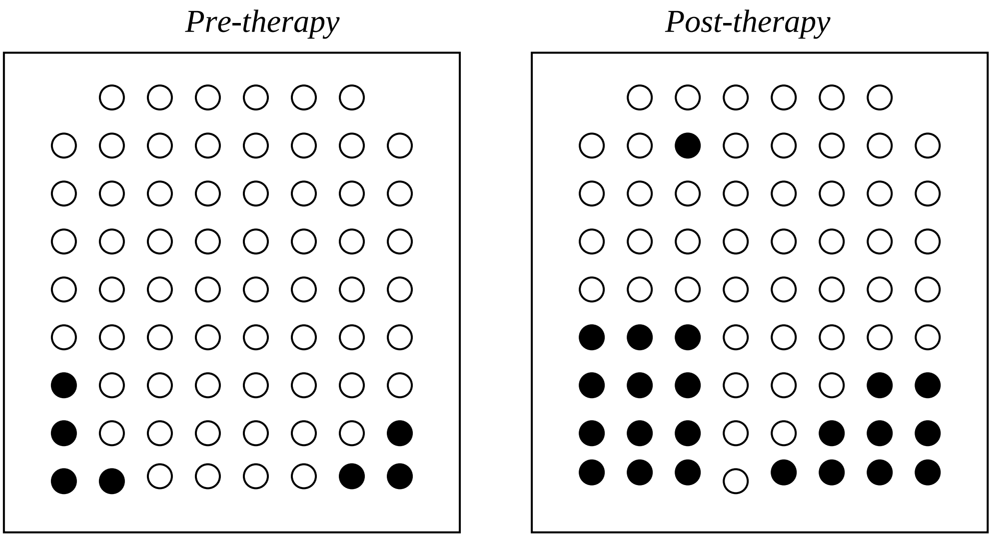
Figure 1: EPG prototype for k/g



The number of incorrectly activated electrodes was deducted from the number of the correct ones to produce a final score for each word and the total for each word list was then calculated. Afterwards, the three scores (pre-1 post 1 and post 2) for each word were compared.

Analysis of data from the pre-therapy assessment 1 showed consistently minimal contact for all /k/ targets, the results varying between 1-4/17. For the /g/ target, scores were higher and varied between 10-12/17; however, despite better placement for some /g/ targets, many were produced as pharyngeal implosives. Post therapy data (post 2 and post 3) revealed a significant improvement. The EPG patterns showed that, in all of F's productions, she had contacted a high proportion of the correct electrodes, activating 12-15/17 electrodes for the voiceless velar sound /k/ (see Figure 2) and similar numbers of correct electrodes for voiced velar /g/.

Figure 2: Pre and post therapy EPG displays showing maximum contact for /k/ in 'car'

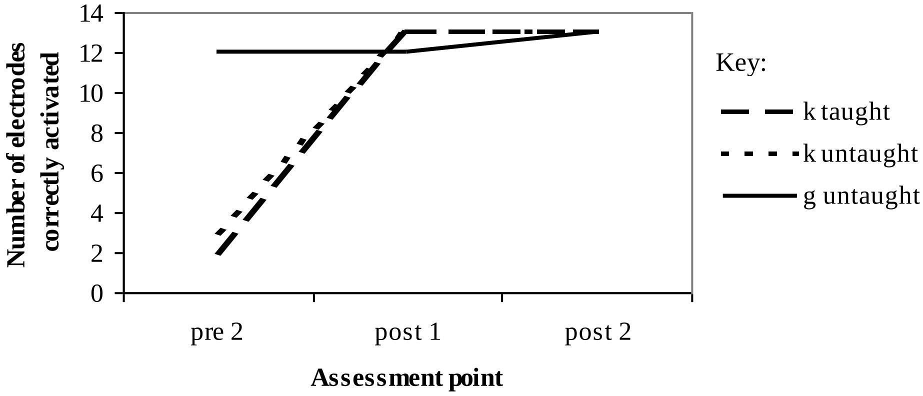


A 2-Factor Mixed Anova was conducted: the between factor was "words" with 3 levels (k taught, k untaught and g untaught) and the within factor was "time" with 3 levels (pre 1, post 1, post 2). Both main effects were significant, for Words $F(2,27)=105.59$, $p<.0001$, for Time $F(2,54) = 472.67$, $p<.0001$. A significant interaction was also found, for words x time $F(4,54)=104.54$, $p<.000$. Figure 3 illustrates the differences observed between pre and post therapy data.

Additionally, an analysis of simple main effects showed that there were significant changes in the scores of the taught and untaught /k/ words (taught $F(2, 54) = 396.13$, $p < 0.0001$, untaught $F(2, 54) = 306.05$, $p < 0.0001$) following treatment, but not in the untaught /g/

words. Furthermore, the three sounds did not differ significantly from each other after treatment but did before ($F(2, 81) = 312.66$, $p < 0.0001$).

Figure 3: Difference in pre and post EPG therapy data (objective measures)

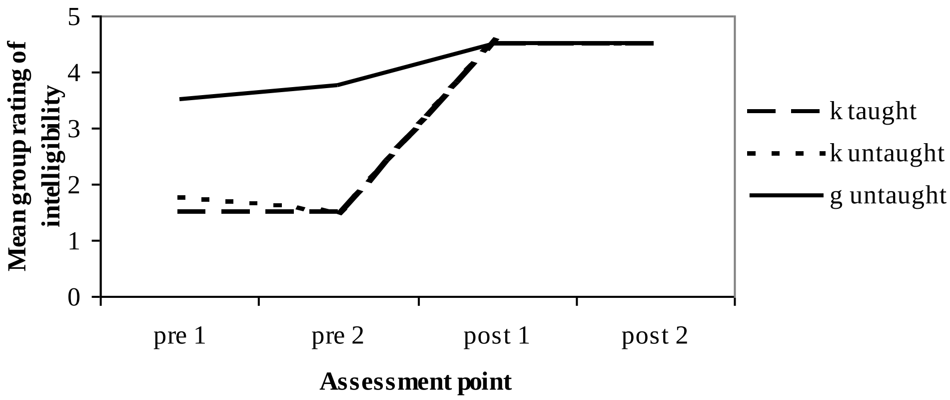


In order to measure changes in perceived intelligibility post intervention, 10 untrained listeners were asked to rate from 1-5 the words produced by the client at each assessment point (1 = unintelligible, 5 = intelligible). The scores in the first and second pre-EPG assessments ranged from 1-1.3/5 for the /k/ words, indicating low intelligibility. The scores for the /g/ words ranged from 2.1-3/ 5, indicating nearly acceptable intelligibility. Pre EPG therapy, F often produced an idiosyncratic /g/, a combination of pharyngeal and implosive /g/, which can be auditorily interpreted as a near normal /g/ when produced within a word, even though the manner and place of articulation are not correct.

The results indicated post EPG therapy ratings to be higher, suggesting improved intelligibility of all velar sounds (see Figure 4). For the voiceless velar /k/ target, the scores varied from 3-3.8/ 5; for the voiced target /g/ the scores varied from 2.6-3.6/5. The latter indicates an improvement in intelligibility of /g/ targets, nonetheless a smaller one compared to the improvement of the /k/ targets. Statistical analysis was conducted using a 2 Factor Mixed Anova procedure. The between factor is "types of words" with 3 levels (k taught, k untaught, g untaught) and the within factor is "time" with 4 levels (pre 1, pre 2, post 1, post 2). Both main effects are significant, for Words $F(2,27)=28.29$, $p<.0001$ for Time $F(3,81)=740.91$, $p<.0001$. A significant interaction was observed, for words x time $F(6,81)=96,79$, $p<.0001$.

The analysis of simple main effects explains the interaction. There are significant changes in intelligibility for all three sounds (/k/ taught $F(3, 81) = 471.77$ $p < 0.0001$, /k/ untaught $F(3, 81) = 471.36$ $p < 0.0001$ and /g/ untaught $F(3, 81) = 21.36$ $p < 0.0001$). The fact that the/g/ targets have improved suggests that listener ratings may be a more sensitive measure of real change than the EPG, even though their improvement is much less than the /k/ targets. This is also supported in the simple main effects where the pre therapy measure show significant

Figure 4: Intelligibility ratings pre and post EPG therapy by untrained listeners (n=10)



differences favouring the /g/ targets (pre 1: $F(2, 108) = 108.27$ $p < 0.0001$, pre 2: $F(2, 108) = 126.42$ $p < 0.0001$) but the post therapy measures show significant differences favouring the /k/ targets (post 1: $F(2, 108) = 13.87$ $p < 0.0001$, post 2: $F(2, 108) = 11.90$, $p < 0.0001$). This demonstrates that the trained sounds were more intelligible than the untrained ones, even though /g/ production was reasonably intelligible before treatment.

Discussion

This study has investigated the use of EPG as a therapeutic tool for the treatment of velar plosives in a young cochlear implant user. The results can be summarized as follows:

- A significant improvement was observed in production of voiced and voiceless velar plosives immediately post EPG therapy, in both taught and untaught words, measured by objective analysis of EPG printouts and listener ratings.
- A significant improvement in production of voiced and voiceless velars was maintained 5 weeks after EPG therapy was complete, indicating generalisation of skills.

The findings of this case study raise a number of issues relating to the subject's intelligibility post EPG treatment, the subject's response to EPG treatment, and the generalisation of newly acquired skills.

Speech intelligibility post therapy

Responses from the listener judges indicated good intelligibility for all words post EPG therapy, in comparison with conventional speech and language therapy. The post EPG therapy productions were consistently rated with higher scores than the pre therapy ones. The statistical tests performed show the overall mean of both post therapy assessment results for taught and untaught words to be higher than the pre therapy results. Since the utterances were all read rather than spoken spontaneously, no inferences can be made as to the intelligibility of the subject's spontaneous speech.

The listener ratings were also compared informally with the EPG printouts for certain words. This analysis indicated that when productions were judged as accurate auditorily, the EPG patterns reflected the same results. Conversely, when productions were identified perceptually as distorted, the source of distortion was evident in the tongue contact patterns. This finding indicates that improved consonant intelligibility had a strong correspondence with the new linguapalatal contact patterns learned, which increases the validity of the subjective results.

Response to EPG treatment

EPG successfully resolved F's velar placement problem at a single word level. According to statistical analysis, pre EPG therapy printouts showed that there was hardly any contact across the palate in the velar region; velar consonants were perceived auditorily as uvular fricatives [h]. Post EPG therapy perceptual analysis revealed near normal production for velar plosives.

It is interesting to speculate on the reasons for F's positive response to EPG therapy, where traditional auditory and production based approaches failed. Two different explanations are possible: the first has to do with the nature of the EPG technique and the second involves the subject's role in the therapeutic process.

Regarding the former, therapy using EPG shares some features of a conventional approach, such as explanations, use of subject's metalinguistic skills and use of supplementary sensory channels. For deaf clients, auditory feedback is an important supplementary channel, however conventional hearing aids rarely provide full auditory access to speech. Cochlear implants can improve access to the full range of speech sounds, yet even then, F illustrates that improved auditory access does not automatically lead to modified speech patterns. Therapy using EPG can offer significant benefits in such cases. It provides a visual display which enables the clinician to acquire more detailed information on the client's tongue/palate contact than is normally available. The therapist can break down tasks, like the establishment of a new articulatory placement into smaller component steps. At the same time, it offers the client important visual feedback for instantaneous monitoring of tongue contacts. EPG encourages an active role in the discovery of the relationship between tongue movements and the resulting sound heard and appears to be inherently motivating for subjects. This enables the articulatory patterns to become more accessible to the subject, resulting in modifications of tongue placement patterns.

An additional factor to consider relating to success in therapy is the subject. F was a bright and motivated child with good family support. EPG gave F the opportunity to be active in the therapeutic process. The fact that F was able to explore her mouth morphology was important in enabling her to place her tongue more accurately.

Generalisation of Skills

Newly acquired speech skills can be described as learned only when they are used in naturally occurring, connected speech. In F's case, she did show a great improvement in her /k/ production in single words, to the extent that she increased her ability to produce target sounds correctly both with and without looking at the visual prompts provided by the EPG. During the period of EPG therapy, as F learned the articulatory pattern being modelled for the voiceless velar /k/, improved intelligibility was reported to be evident at home as well.

However, it would be inaccurate to describe F's skills as automatic or fully established immediately following this short course of EPG therapy. Conventional auditory based therapy is required to facilitate and ensure generalisation of new skills beyond single word production and to contexts outside of the therapy setting.

<u>Conclusion</u>

This single case study has shown that EPG has a role to play in teaching velar sounds to a cochlear implant user. Some generalization of these skills were also shown through the subject's production of untaught words including these sounds.

However, there are certain limitations. Firstly, these findings are based on a single case study, so it is not possible to generalise findings to the population of deaf children. It is likely that various factors, such as parental support or the subject's increased awareness and motivation, might have positively influenced the outcome of this study. Similar studies with more subjects are required to confirm the generalisability of these findings. Secondly, the study took place over a 3-month period, hence, no longer-term effects of therapy could be measured. Thirdly, as mentioned before, spontaneous speech was not recorded.

Despite these limitations, this study does go some way towards supporting the use of visual feedback therapy with EPG with cochlear implant users. We need to keep in mind that targets for production work are unlikely to be fully generalised by deaf speakers unless further therapy is provided which encourages the move from visual to auditory monitoring of speech targets. Future studies should also investigate the longer term maintenance of skills and the impact on the intelligibility of spontaneous speech.

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