AN EPG THERAPY PROTOCOL FOR REMEDIATION AND ASSESSMENT OF ARTICULATION DISORDERS

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ABSTRACT

This paper describes technical and methodological advances in the development of a procedure for measuring changes in accuracy and stability of linguopalatal (tongue-palate) contact patterns during a course of visual feedback therapy using electropalatography (EPG). The procedure is exemplified by a case in which therapy was aimed at resolving a pattern of velar fronting whereby phonetic targets /k, g, ɣ/ had abnormal alveolar placement [t, d, n]. The EPG remediation and assessment procedure can be implemented using recording, feedback and analysis software designed for the purpose.

1. INTRODUCTION

One potentially valuable diagnostic and therapy procedure for articulation disorders is electropalatography (EPG). EPG records details of the location and timing of tongue contacts with the hard palate during speech [1]. The instrument records alveolar, post-alveolar, palatal, and velar placement, and registers characteristic patterns for many consonants and vowels that occur in English, making it a useful technique for investigating a wide range of targets. EPG also has a facility to provide real-time visual feedback of tongue-palate contacts, which can be used to monitor articulation as part of a speech therapy programme. The latest EPG system additionally provides means for automating the analysis described in this paper.

EPG is now relatively well-established as a clinical tool, and has been used successfully for articulation disorders such as those associated with developmental and acquired conditions such as dyspraxia, dysarthria, cleft palate, and hearing impairment [2][3][4].

The technique requires the speaker to wear a custom made artificial palate that fits against a speaker's hard palate. The artificial palate contains 62 silver contacts exposed to the lingual surface. The contacts are arranged in 8 horizontal rows, with the spacing between the back four rows being double that of the front four rows. Phonetic regions are correlated to zones on the EPG palate, making it possible to classify articulations according to the location (i.e. place) of articulation within the oral cavity at which major articulation events occur. Where EPG contact occurs in the anterior zone (i.e. the first four rows) placement is alveolar or post-alveolar regions. Where contact is in the posterior zone (i.e. the back four rows), placement is palatal or velar.

2. EPG THERAPY PROTOCOL

2.1. Preparation

An EPG palate is manufactured for the client. Currently this requires a visit to the dentist to have a cast made of the client’s upper dentition and hard palate. The cast is then sent off to a specialist who manufactures the EPG palate. Once fitted, the client should become accustomed to wearing the EPG palate and it should be worn up to an hour before each session depending on how easily the client adapts to its presence.

2.2. Recording Protocol

We illustrate the recording protocol by describing a procedure that we adopted for a group of children with articulation disorders that involved velar fronting. We analysed data from this group by recording 16 repetitions of /t/ and /k/ in word-initial position in minimal pair phrases ‘a top’, ‘a cop’, ‘a tap’ and ‘a cap’. Each prompt consisted of two minimal pair target phrases preceded and followed by distracter phrases. For example: “a sugar, a top, a cap, a chicken” (Figure 1)

![Figure 1: “Recording” display with pictorial as well as textual prompt](image-url)

The prompts were randomly generated but with the following constraints:

- The 16 prompts include 8 occurrences of each of the four target phrases.
• The two target phrases in each prompt must differ by more than the initial consonant. If ‘top’ and ‘cop’ or ‘tap’ and ‘cap’ appear next to each other then there is a possibility that the client will realise that the words look different but sound the same and alter their standard production to realise a difference. This behaviour would confuse the assessment results.

The client’s speech is recorded on three occasions:
1. Before EPG therapy commences
2. Soon after initial indication of differentiation in the client’s articulation of the target minimal pairs
3. At completion of the therapy program

2.3. EPG Therapy Protocol

A client’s EPG therapy involves weekly clinic-based sessions. The sessions are conducted by a speech-language pathologist and last approximately ¾ hour. During the clinic-based sessions, the client uses visual feedback of tongue-palate contact patterns to establish velar and alveolar placement for phonetic targets /k/ and /t/ respectively. The computer-based system also provides a facility for rewarding young clients for good effort. The reward is controlled by the speech-language pathologist and takes the form of short animated cartoons.

The speech and language pathologist has the option of wearing a palate themselves to demonstrate the target articulation or a target pattern may be recalled from a library stored on the computer as shown in Figure 2.

![Figure 2: “EPG Feedback” display with reward screen at the top, the live client palate display on the left and the target display on the right.](image)

In addition to the clinic-based sessions, the client uses a portable training unit [5] at home after the 3rd or 4th clinic visit once they are accustomed to using it. Portable units are small and lightweight and have a real time display consisting of light emitting diodes for visual feedback of tongue palate contact. The client uses the portable unit in between the weekly clinic sessions, with instructions from the speech-language pathologist or, in the case of a young client, instructions are given to the client’s parent or carer who will supervise the practice sessions at home.

3. ASSESSMENT PROTOCOL

3.1. Annotation of data

The annotation procedure is semi-automatic and involves the following stages:
• Manual isolation of the target phrases from within each utterance.
• Automatic classification of the frame of maximum contact within the stop closure in each of the 32 target phrases.
• Manual check and correction of the results of the automatic procedure.
• Automatic calculation of “Centre of gravity” and “Variability” measures

3.2. Classification of Closure

The automatic EPG classification scheme identifies place of articulation for /t/ and /k/ targets. The EPG frames at maximum contact are classified according to contact in the midsagittal four rows of the palate, and whether the contact is in the alveolar region (first 4 rows) or velar region (last 2 rows). For every frame, a 45% threshold on the total of active contacts in these two regions is used to identify timespans of closure and, within each timespan, the frame of maximum total palatal contact is annotated as kmax or tmax. This also allows for the possibility that the client could produce double alveolar-velar articulations, as noted in some types of articulation disorder [6]. In such cases the stop closure or part of the closure will be annotated as both a /k/ and a /t/, as shown in Figure 3.

![Figure 3: “a top a cap” Automatically labelled /k/ and /t/ closure regions based on 45% thresholds on the anterior and velar contact totals evaluated for each frame displayed at the bottom of the display. Spectrogram and EPG frames are also displayed.](image)
3.3. Centre of gravity (COG)
Centre of gravity (COG) values determine whether the client is producing a statistically significant difference between /t/ and /k/ target phonemes. The COG index is a well-established measure of placement on the hard palate and is reported in previous studies [7]. Centre of gravity gives a single numerical value representing the position of the greatest concentration of activated contacts across the palate in the front/back dimension. A high value represents a forward, i.e. anterior, place of articulation, whereas a low value reflects a posterior place of articulation.

COG values are automatically calculated for each annotation and can be arranged by session and target. They can then easily be exported into a statistical analysis package for further analysis.

3.4. Variability Index
The Variability Index provides a value for the stability/variability of articulatory gestures [8]. To calculate the index, the percent frequency of activation of each contact across repetitions is measured. For each contact, 100% and 0% activation frequency represent invariance and are assigned a variance index of 0. The variability index increases as contact frequency approaches 50% which is assigned a maximum index of 50. The overall variability index is calculated by summing the index values for all contacts and dividing by 62. An index value of 0 represents invariance, the higher the variability index the more unstable the EPG patterns (maximum index value is 50).

4. CASE STUDY

4.1. Client Background
The following case study, already described in previous papers [9][10], illustrates how the new analysis procedures outlined above can be used to quantify changes in EPG patterns that occurred during a course of visual feedback therapy for velar fronting. The client was P, a girl with Down’s syndrome aged 10;07 years, her speech-language pathologist referred P for EPG therapy. P’s EPG therapy involved 12 weekly clinic-based sessions over a 14-week period. P practiced at home using a portable training unit from week 4.

4.2. Segment Classification
The results in Table 1 show that before EPG therapy both /t/ and /k/ targets had 100% alveolar placement, with no instances of velar placement or alveolar-velar double articulations. In other words, at this stage, alveolar targets were 100% correct, while velars were 0% correct. At transition, accuracy of /t/ targets decreased from 100% to 62% correct. At the same time, accuracy of /k/ targets dramatically increased from 0% to 87% correct. At this stage, P produced 25% of /t/ and 13% of /k/ targets as alveolar-velar double articulations. At the end of the therapy regime, accuracy of /t/ and /k/ was high, with both targets produced as 87% correct. Post-therapy, double articulations had decreased, with 13% of both /t/ and /k/ targets produced as alveolar-velar double articulations.

Table 1: Percent of P’s /t/ and /k/ targets produced with alveolar (A) placement, velar (V) placement, or alveolar-velar double articulations (A+V).

<table>
<thead>
<tr>
<th></th>
<th>/t/ targets</th>
<th>/k/ targets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>V</td>
</tr>
<tr>
<td>Pre-therapy</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Transition</td>
<td>62</td>
<td>13</td>
</tr>
<tr>
<td>Post-therapy</td>
<td>87</td>
<td>0</td>
</tr>
</tbody>
</table>

4.3. Centre of Gravity (COG)
Mean and standard deviations for centre of gravity values are in Table 2, which also presents values for articulation data for similar speech material recorded from two typically developing children [9]. Before EPG therapy, values for /t/ and /k/ are seen to be identical and high, indicating anterior placement for both targets. A two-tailed paired sample t-test showed no difference in values for /t/ and /k/ targets (p < .05). At transition, values were lower for both /t/ and /k/, indicating more posterior placement compared to the 1st EPG recording. Unlike the 1st recording, a t-test showed a significant difference in /t/ and /k/ targets at the 2nd recording. Post-therapy COG indices record a further decrease for /k/ and an increase to pre-therapy values for /t/, indicating further distinction of tongue placement for these targets. P’s centre of gravity values from the 1st to 3rd recordings increasingly resembled those from the typically developing children’s.

Table 2: Mean centre of gravity values for /t/ and /k/ targets (standard deviations in parentheses) at the 1st, 2nd and 3rd EPG recordings. Values are given for 2 typically developing children (TDC1 aged 10 years; TDC2 aged 12 years) for similar speech material [9].

<table>
<thead>
<tr>
<th></th>
<th>/t/ targets</th>
<th>/k/ targets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>V</td>
</tr>
<tr>
<td>Pre-therapy</td>
<td>4.3 (0.15)</td>
<td>4.3 (0.16)</td>
</tr>
<tr>
<td>Transition</td>
<td>3.7 (0.61)</td>
<td>2.2 (0.60)</td>
</tr>
<tr>
<td>Post-therapy</td>
<td>4.2 (0.13)</td>
<td>1.8 (0.88)</td>
</tr>
<tr>
<td>TDC1</td>
<td>4.7 (0.20)</td>
<td>1.0 (0.23)</td>
</tr>
<tr>
<td>TDC2</td>
<td>3.8 (0.39)</td>
<td>0.9 (0.24)</td>
</tr>
</tbody>
</table>

S = significant at .05 level; NS = non-significant

4.4. Variability
Variability index values are tabulated in Table 3, which also shows values from articulation data for identical speech material recorded from an adult with normal speech [9].

Pre-therapy, the low index values for /t/ and /k/ indicate that P had stable contact patterns before therapy. Index values increased for both /t/ and /k/ at the 2nd recording, reflecting loss of stability at this stage. Post-therapy, index values decreased for /t/ signalling a return to stability for these targets, but values remained high for /k/ targets showing that this relatively newly-established velar place of articulation remained unstable.
Table 3: Variability index values for /t/ and /k/ targets in the words ‘tap’, ‘top’, ‘cap’, and ‘cop’ at three stages, and for the same speech material produced by an adult with normal speech.

<table>
<thead>
<tr>
<th></th>
<th>/t/ targets</th>
<th>/k/ targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-therapy</td>
<td>5.3</td>
<td>5</td>
</tr>
<tr>
<td>Transition</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Post-therapy</td>
<td>4.3</td>
<td>3</td>
</tr>
<tr>
<td>Normal</td>
<td>3.7</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 4 summarises visually the classification, COG, and variability index results by showing composite EPG frames at maximum contact for /t/ and /k/ targets. The EPG patterns show frequency of contact over the 16 repetitions. Contacts coloured black or white indicate stability, with grey shading indicating instability. The EPG patterns illustrate the results of the analyses described in previous sections. Velar fronting for /k/ targets can be seen before EPG therapy. Emergence of velar placement can be seen as therapy progressed.

The stability of /t/ and /k/ articulations pre-therapy is reflected in the predominance of black and white contacts. The high number of grey contacts for /t/ and /k/ at the transitional and final recordings reflects their instability. The table shows how, as therapy progressed, P’s EPG patterns for /t/ and /k/ increasingly resemble those of a typically developing child.

Table 4: Graphical summaries of classification, COG and variability showing progression through therapy.

<table>
<thead>
<tr>
<th></th>
<th>/t/ targets</th>
<th>/k/ targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-therapy</td>
<td>a)</td>
<td>b)</td>
</tr>
<tr>
<td>Transition</td>
<td>c)</td>
<td>d)</td>
</tr>
<tr>
<td>Post-therapy</td>
<td>e)</td>
<td>f)</td>
</tr>
</tbody>
</table>

5. DISCUSSION

The case study used here to exemplify the assessment procedure was originally analysed by manual selection and classification of each frame of maximum contact and transferring these frame values into a database, which then calculated the assessment scores [9]. In this paper we have indicated how it is possible to automate this process in order to make the assessment procedure more practical for use in clinical practice. However, the procedure is arguably still too time consuming for implementation by a clinician as a standard assessment and we are now investigating a modification to this procedure which is robust, fully automatic and results in the same assessment outcome within an acceptable tolerance.

In relation to therapy, a major issue still to be addressed is the extent to which others with articulation disorders will benefit from therapy with electropalatography. The portable training units have become available only recently. The units enable clients to practise and reinforce their production on a more frequent basis than would be possible with the clinic-based sessions alone.

6. CONCLUSIONS

The results of this case study show that EPG is a potentially useful therapy procedure for treatment of articulation disorders. The EPG classification, COG values, variability index and composite frames provide an objective record of progress during visual feedback therapy with EPG. The latest software available for use by clinicians is designed to simplify the recording of EPG data and provision of EPG therapy. The software also provides a semi-automatic means to achieve the objective assessment of progress as outlined in this paper.

7. REFERENCES


