**Treatment with a combination of intra-oral sensory stimulation and electropalatography in a child with severe developmental dyspraxia**

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**Abstract**

This paper describes the use of a combination of intra-oral sensory stimulation and electropalatography (EPG) in the treatment of a case with severe developmental verbal dyspraxia. A multiple-baseline design was used. The treatment duration was 11 months and started when the subject was 5 years old. The efficacy of the treatment was assessed by calculations of percentage of correctly articulated words, percentage of consonants correct, percentage of phonemes correct and percentage of words correct. Intelligibility assessments were conducted by both naive and expert listeners. The experts also assessed visual deviances in articulatory gestures from video recordings. Qualitative analysis of EPG data was made. The subject’s speech was significantly improved by the treatment in all aspects. The results and their generalization to other cases of developmental verbal dyspraxia are discussed.

**Key words:** Perceptual evaluation, speech development, treatment efficacy, verbal dyspraxia, visual feed-back

**Introduction**

Children with speech problems form a large but heterogeneous group. In many cases the causation is obvious, as for example in children with hearing loss or with structural abnormality of the vocal tract. One large subgroup, however, is children with articulatory problems without identifiable aetiology. It has been estimated that 3%–5% of all children between the ages 5 and 12 years fail to acquire intelligible speech without any known causing condition (1). A multitude of diagnostic terms has been used to describe speech disorders without organic pathology. The most commonly used include phonological disorders, functional articulation disorders and phonetic disorders (2).

A sub-group of speech problems are those referred to as motor speech disorders. Motor speech control is defined as the systems and strategies that control speech production (3). Traditionally it has been regarded as separate from phonological operations, but in gestural phonology, for example, issues in phonology and issues in articulation are addressed simultaneously (4). Among the motor speech control disorders, dyspraxia of speech is described to appear both as an acquired disorder in adults and developmentally as a childhood disorder. In the acquired form it is generally accepted as an impairment of the motor programming of speech movements as a result of a focal brain damage. The developmental form as a distinct speech disorder has been much debated. One reason for the controversy is that the term assumes a neurological basis for the disorder although clear neurological deficits rarely are found (2). Despite much research there is yet no singular perspective on the disorder. Among clinicians, however, it is widely used as an explanatory label for children with irregular and persisting articulation difficulties (5).

Research has shown that electropalatography (EPG) can be of help to the speech and language pathologist in the assessment, diagnosis and treatment of these children (6,7). EPG’s contribution to diagnosis is that the technique can reveal information relevant to underlying deficits (7). Gibbon (7) found, in a review of the EPG literature on school-aged children with sound system disorders, that a higher than normal amount of tongue-palate...
contacts was a distinctive characteristic of lingual consonants produced by this group. This type of EPG pattern is by Gibbon referred to as undifferentiated lingual gestures. Gibbon interprets this phenomenon as reflecting delayed or deviant control of functionally independent regions of the tongue.

EPG can also demonstrate differences between target phonemes that are neutralized in listeners' perceptions, covert contrasts. When covert contrasts are present it is interpreted as an indication that the child's productive knowledge is more sophisticated than would be assumed when transcription analysis is the sole assessment method (2).

EPG is however not useful for all children. Age and maturity are considered important criteria for subject selection (8). Since EPG appears to have a role in the remediation of those children whose speech problems have not responded to other treatment methods, it is important to detect these children before time and financial resources are spent on intervention which will prove unsuccessful (9).

It is generally accepted that orofacial sensory inputs from the periphery can alter the excitability of lower facial motor neurons and contribute to movement control (10). Among others, Rudolfo Castillo-Morales and co-workers (11) state that well coordinated orofacial function is a prerequisite for a clearly articulated speech. In their treatment concept for orofacial muscular disturbances, sensory stimulation is one therapy technique for improving control of the orofacial muscular activities. In both the treatment methods, developed by Castillo-Morales, vibrational stimulation is used. In Sweden, McAllister et al. (12), have been using an electric toothbrush as a vibration tool in their treatment concept for children with oral and/or verbal dyspraxia.

The purpose of the present study was to evaluate a combination of oral sensory stimulation and EPG-aided articulation therapy in a case of severe verbal dyspraxia.

**Method**

**Subject**

R was enrolled in this study at the age of 5 years and 1 month.

**Case history**

R was referred to the speech-language pathology service when she was 3 years and 6 months. She had a baby sister and attended day nursery where she had several friends. She was a happy talkative girl but utterly impossible to understand often even to her own family.

Besides speech R was normally developed. She had been a healthy child and had only had one episode of otitis media. She had normal hearing. She was breastfed during infancy and had no problems with the transition to solid food. She had had no drooling problem. Up till the age of 3½ years she used a pacifier, had a slight open-bite and a mouth breathing habit.

**Speech.** R used long sentences but had a very restricted sound repertoire. Her articulation pattern was deviant with visible groping behaviour. The articulation was also inconsistent. It was almost impossible for her to imitate single sounds. She had some problems with simple non-speech movements. She scored normal or above normal on tests of receptive grammar and vocabulary. Subsequently she was diagnosed as having developmental verbal dyspraxia.

**Treatment.** Weekly treatment at the clinic started immediately using a Swedish version of the Nuffield Centre Dyspraxia Programme, Praxis (13). The parents supported the therapy with regular homework. They were also told to phase out the pacifier.

After 9 months of training her oral motor skills had improved, the open-bite and the mouth-breathing habit had disappeared, but her speech was unaffected. She was then transferred to a language unit where more intense training was introduced. In the process of being qualified for the placement at the language unit, R was being assessed by a psychologist as having normal or above normal intelligence. After 10 months of training at the language unit, at the age of 5, R's volitional control of non-speech movements was improved but her speech was unchanged.

**Pre-testing**

Pre-testing included tests of language comprehension (14), vocabulary (15), grammatical production (16,17) oral motor skills (18), phonological memory using non-word and word repetition (19) and a test of auditory perception/discrimination using minimal pairs contrasting both place and manner of articulation (20).

**Base-line**

In order to establish a base-line, three consecutive assessments were made during a 2-month period to ensure that no spontaneous improvement of R's
speech was ongoing. The material used was developed by the first author and consisted of 70 illustrated words representing the Swedish phoneme inventory. The subject was asked to name the pictures one by one. The words were chosen to ensure that previous training would not influence the results. Another prerequisite was that the words should be fairly simple with regard both to pronunciation and vocabulary.

**Therapy procedure**

The overall aim with the therapy was to improve lingual gestures and place and manner of R's articulation. Therapy was given in two steps. An overview of the procedure is given in Table I. In step 1, general oral stimulation with vibration was given. As stimulator an electric toothbrush was used, and the stimulation programme was performed on a daily basis at home (3–5 minutes) during 3 months. No alteration of the programme was made during step 1. The stimulation was on the surface of the tongue, the lips and the alveolar ridge of the maxilla (Appendix 1). After this first therapy step a new assessment was made followed by a 3-month period of withdrawal. Step 2 consisted of articulatory training with EPG. It was divided into three phases with 5 weeks’ daily training (15–20 minutes) at home in each phase. Between each phase there was a 5-week withdrawal. In phase one of the EPG-therapy the target was to develop speed and accuracy in the volitional control of non-verbal movements of different parts of the tongue. Phase two targeted smooth and precise articulation of two contrasting speech sounds (/t/ and /k/), first each in isolation, then each in sequences, then the sounds in minimal pairs. In phase three, introduction of /s/ was the target. Here R had the /t/-pattern as a starting point for the work with the /s/-pattern. All target configurations were normal adult Swedish configurations for the sounds.

**Compliance**

Good compliance was obtained during both step 1 and step 2 in the therapy programme. The oral sensory stimulation was easily made in connection with daily oral hygiene, and R had no problem adapting to the EPG palate.

**Assessment battery**

Articulation was assessed with the 70-word list and with an EPG-picture-word list. The subject was asked to name the 70 pictures one by one. During the EPG recording the subject was asked to name a new picture when a new word was displayed on the computer screen. Assessment with the 70 words was administered before treatment started, after step 1 of the treatment and when treatment was finished. The EPG assessment was, due to tardiness with the delivery of the EPG plate, only made before step 2 and after treatment.

**Instrumentation**

Electropalatography data were recorded using the LinguaGraph, an electropalatography system developed at the University of Kent (http://medical.kent.ac.uk). The system works according to the Reading-system and the EPG palate consists of 62 electrodes imbedded according to individual anatomic landmarks. The 70-word list was audio recorded with Sony digital audiotape deck (DTC-ZE 700) and an AKG SE 300B microphone. The naming of the 70 words was also video recorded in order to document visually deviant pre-phonatory gestures.

In step 1 of treatment, an electric toothbrush was used. In step 2, articulatory training with EPG as a biofeedback tool was performed using a portable training unit (www.articulateinstruments.com). The portable training unit provides visual feedback without the need for a computer, and is therefore ideal for training outside the clinic.

**Analysis**

The 70-word assessments were transcribed phonetically by the first author using the transcription conventions of the International Phonetic Association (21). Calculations of percentage of consonants Correct, PCC (22), percentage of phonemes correct (PPC) and percentage of correctly articulated words (PCW) were made. The transcriptions were repeated after 3 weeks and intra-rater agreement was found to be 89.14%.
An intelligibility assessment of the 70 words before and after step 1 of therapy and at the end of the study was made by two listener panels. One panel was formed by experienced speech and language pathologists (SLPs), the other one by naïve listeners. The procedure used was word identification from audiotapes.

An assessment of the visually deviant articulatory gestures in the 70 words was made by three SLPs from the video recordings before and after therapy. The SLPs had a forced choice between normal or visually deviant articulatory gestures for each word. Before the actual assessment took place the SLPs had a training session with another video recording to get used to the assessment procedure. The results are presented as group means. Inter-rater agreement was calculated.

A qualitative analysis was made of the electro-palatography-material. The analysis consisted of examination of the EPG-pattern for each target phoneme at each assessment and comparison of these patterns with those of a normal subject.

**Statistical analysis.** *t*-tests were used to calculate the difference between PCC, PPC and PWC before therapy and after each step and between the two therapy steps, to analyse the difference between the different assessment points for each listener panel and to analyse the assessments from the video recordings.

Inter-rater reliability was calculated with a sign test.

**Results**

**Pre-testing**

On the test of language comprehension R had two errors at the age of 5;1 years. In the test the normal amount of errors in the age group is four. On the Peabody picture vocabulary test, at the age of 5;2 years, R had results equivalent to 7;9 years. The test of expressive grammar and especially R’s morphology, was hard to evaluate due to her restricted articulation. Nevertheless it was clear that she marked different morphologic categories correctly. Her syntax was normal according to the Ringsted test.

There was no difference between R’s production of non-words and real words in the non-word test indicating that she had no specific problem with phonological memory. She had no problems with the auditory discrimination test. The test of non-verbal oral motor skills did not reveal any persisting oral motor problem.

**Percentage of consonants correct (PCC)**

Due to small differences in the subject’s naming of the pictures between the different assessment points, the total number of consonants in the 70-word material if correctly articulated differed somewhat. There were 207, 207 and 206 consonants at the three assessments. Before therapy R had 19 consonants aurally perceived as correct (9.17%). After therapy step 1 (oral stimulation therapy) 82 consonants were aurally judged as correct (39.61%), and after therapy conclusion (oral stimulation therapy + EPG therapy), she had 121 correct consonants (58.23%). The difference in PCC before therapy and after step 1, and the difference between step 1 and 2 were both highly significant, *p* < 0.001 (Figure 1).

**Percentage of phonemes correct (PPC)**

In the material there were a total of 331, 332 and 330 phonemes at the three different assessments.

Before therapy R had 112 aurally perceived phonemes correct or 33.83%. After step 1, oral stimulation therapy, she had 188 correct phonemes or 56.62%, and after finishing therapy (oral stimulation + EPG) 242 correct phonemes or 73.33%. The differences in PPC before therapy and after step 1, and between step 1 and 2 were both significant, *p* < 0.001 (Figure 1).

**Percentage of words correct (PWC)**

Before therapy R had none of the 70 words perceived as correctly articulated. After step 1, oral stimulation therapy, she had 7 correct words (10%) and after finishing therapy (oral stimulation + EPG) 15 correct words or 21.43%. Also these results were significant, *p* = 0.003 and *p* = 0.032 (Figure 1).

**Intelligibility assessment**

Before therapy the naïve listeners could interpret 5.1% of the 70 words and the experts 10.9%. After step 1, the naïve listeners interpreted 22.6% of the words correctly and the experts 41.1%. After therapy step 2 (EPG) the naïve listener could interpret 45.3% correctly and the experts 65.2%. The differences between all the measuring points were highly significant for both the listener groups, *p* < 0.001 for all differences (Figure 2).

**Assessment of visual deviancy in the articulation**

Before therapy the SLPs assessed 57.6% of the 70 words as being articulated with a visually
Aurally perceived articulation

Figure 1. Percentage of consonants correct (PCC), percentage of phonemes correct (PPC) and percentage of words correct (PWC) before therapy, after oral stimulation therapy (step 1) and after finishing therapy (after step 2, electropalatography (EPG) therapy).

Inappropriate articulation gesture. After therapy the figure was 33.8% and the difference was statically significant ($p < 0.01$). The inter-rater agreement was 91% (Figure 3).

Pre-therapy EPG patterns were generally characterized by almost complete lingual contact with the palate. After therapy the contact patterns resembled those of normal speaking subjects (Figure 4). Unfortunately R was beginning to outgrow her EPG palate at the post-therapy EPG-testing. Had the EPG-palate had a better fit we believe that her post-therapy patterns would have been even better.

Discussion

The results show that the combination of intra-oral sensory stimulation therapy and EPG-aided articulatory training had beneficial effects on R's speech. However, the effect has been even greater than the results indicate. The PCC, PPC and PWC scores would be much higher if it was not for the fact that R

![Intelligibility of the 70 words](image)

Figure 2. Intelligibility of the 70 words, naive and expert listeners ($p < 0.001$ for all the differences).
did not produce the /r/-sound expected in her dialect correctly. The /r/-sound is present in 23 of the 70 words.

Despite the great improvement, R’s speech was far from age-adequate when the study was finished. She still had, for example, problems with vocal onset and subsequently has problems with the distinction of voiced/voiceless consonants. She was, however, easy to understand even when speaking spontaneously. She has now been transferred from the language unit to an ordinary school.

The effect also extended to decreased articulatory effort in the mimic muscles and tongue gestures that could be detected in the video recordings. Before therapy, initiation of speech was often made by a forced protrusion of the tongue well beyond the lips. This protrusion was pre-phonatory. After therapy most of this behaviour was eliminated, but a tendency with a lingual gesture not extending beyond the teeth was visible in some words. None of the effort in the mimic muscles seen before therapy was remaining after therapy.

Various factors could explain why this approach was successful when conventional training had failed. One is that EPG provides direct and precise feedback to the subject about the articulatory changes that are necessary. Another is the intensity of the training. The portable training unit enables frequent training at home. Even if R’s family were always supportive, they had not earlier been involved in the training on a daily basis. Yet another is that R was mature enough to give the necessary attention to the task.

Since most of the therapeutic work was conducted by R’s parents at home, the procedure has been relatively cheap. The cost of an individually manufactured EPG palate and a portable training unit is high, but is outweighed by the savings that can be made from therapy work done at home rather than at the clinic.

Since we evaluated a combination of two therapy techniques we cannot tell whether they have to be used together to get the desired effect. According to clinical experience with the use of intra-oral stimulation plates, the compliance is higher if a period of intra-oral stimulation with an electric toothbrush has preceded the therapy with the palatal plate (personal communication, The Oral Motor Centre, Danderyd’s Hospital, Stockholm).

Perhaps EPG-aided training alone would have been sufficient. In future research it is important to evaluate them separately.

Even if EPG seems to be a useful tool in the remediation of severe articulation disorders there are several reasons to why it should not exclude more traditional therapy techniques. When working with younger children, a certain level of maturity and cognitive level is required to get an appropriate interaction with the EPG system. The child needs to understand what it sees on the monitor, the relation to lingual activity and how it can manipulate the picture by changing the lingual palatal contacts. According to Dagenais (23) ‘children 7 years and older are good candidates while children under 5 years of age are considered poor candidates’. A child with a severe articulation disorder is likely to have been given a lot of traditional therapy before the age of 5, and EPG should only be considered when other methods have failed. Further, the cost of an individually manufactured plate is high and for a
child it will only fit for a limited period. It is therefore important that a collaborating dentist assess the candidate and inform about the optimal timing. Another important factor is that the parents are motivated to supervise the intense daily work at home.

For the future it is important to do a series of treatment evaluations to increase the knowledge of which clients benefit the most from EPG-aided therapy.

In this study the subject’s speech was improved by the intra-oral stimulation training (in step 1) alone. The training is easy to administer and the electric toothbrush cheap to buy. The training does not require any particular maturity of the child and can be used alongside conventional articulation training. In this study we did not investigate the subject’s intra-oral sensory function due to the fact that the clinic at the time did not have access to a test of intra-oral stereognosis. Oral stereognosis, the ability to identify shapes intra-orally, has been used to assess sensory function in patients with articulation difficulties (24) and in groups of children with different habitual breathing patterns (25). If a child’s speech problem is considered to be an articulation problem alone and intra-oral stereognosis is reduced, intervention could start with intra-oral sensory stimulation. However, further research of the effect of intra-oral sensory stimulation is needed before it can be generally recommended.

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Figure 4. Electropalatography (EPG) patterns for the target phoneme /s/ for the subject R pre and post step 2 training at onset, at maximum constriction and at release compared to patterns for a normal subject.
The procedures followed when carrying out this study were in accordance with the ethical standards of the responsible committee of human experimentation and with the Helsinki Declaration of 1975 as revised in 1983 and was approved by the local ethics committee on 16 December 2003 (No. 03-509).

References


Appendix 1

University of Linköping
Oral Motor Team
Speech and Language Department/Department of Oral Health

Intra-oral stimulation with an electric toothbrush

These exercises are to be performed on a daily basis in order to get optimal results. In order to increase your child’s sensory input and enhance his/her motor ability it is important to do each exercise three times. Use an electric toothbrush that vibrates.
1. Move the electric toothbrush from the corner of the mouth towards the ear and back on each side.

2. Move the electric toothbrush around the mouth outside the lips. Repeat the circular movements also on the lips.

3. Draw “sunbeams” with the toothbrush from the lips and outwards.

4. The tongue: Start at the back of the tongue and move the toothbrush forward. Ask your child to close the mouth and swallow. Repeat the procedure a couple of times.

5. Start on one side at the back of the tongue and move to the tip of the tongue on the opposite side. Repeat the exercise on the opposite side.

6. Move the toothbrush along the sides of the tongue starting at the back of the tongue.

7. Ask your child to stick out the tongue. Put the head of the toothbrush on the tip of the tongue.

8. Stimulate the tip and the tongue and the alveolar ridge in the upper jaw alternately several times. Then ask your child to try to put the tip of the tongue on the alveolar ridge.