Coarticulation in Children with Down's syndrome: an Electropalatographic Analysis

Claire Timmins[1], William Hardcastle[1], Joanne McCann[1], Sara Wood[1], Jennifer Wishart[2]
[1.] Queen Margaret University, [2.]University of Edinburgh
E-mail: ctimmins@qmu.ac.uk

Abstract

Speech production patterns of young people with Down's syndrome have been found to be variable and inconsistent, with preliminary studies finding higher than normal levels of variability and inconsistency in the articulation of stops and fricatives.

Previous studies on this population have identified similar characteristics to that found in Childhood Apraxia of Speech. One of the manifestations of Childhood Apraxia of Speech is incoordination of the speech articulators which can lead to abnormal patterns of coarticulation. To date there are no studies that have analysed the use of coarticulation in individuals with Down's syndrome but we would expect to find similar patterns to individuals with Childhood Apraxia of Speech.

Multiple repetitions of the phrases 'a clock' and 'a red car' were analysed using Electropalatography to assess temporal and spatial aspects of coarticulation. Measures of both temporal and spatial variability were taken from speakers with Down's syndrome and a group of typically developing children. Results show that both groups of children show intra-speaker variability for the /kl/ and /d#k/ coarticulation contexts and a large difference is apparent between children and adults in both sequences.

1. Introduction

Speech production in children with Down's syndrome has been found to be variable and inconsistent [3]. Individuals with Down's syndrome have general motoric difficulties (e.g. during finger tapping [7]) and it is hypothesized that these difficulties may result in many of the articulatory problems observed in this group. Previous studies have suggested that the speech disorder in DS may be similar to Childhood Apraxia of Speech (CAS) [6]. CAS is characterized by slow speaking rate and incoordination of speech articulation which can lead to abnormal and idiosyncratic patterns of coarticulation. The coarticulation patterns of individuals with Down's syndrome have not been studied to date but we would expect this process to be unstable in this population, providing further evidence for an apraxic-type disorder in DS. This paper aims to determine whether there is evidence of increased temporal and spatial coarticulatory variability in the sequences /kl/ and /d#k/ of speakers with DS compared to typical children matched for cognitive abilities and typical adults.

2. Electropalatography

Electropalatography (EPG) is an analysis tool that records the timing and location of tongue-to-palate contact during continuous speech production. When used with Articulate Assistant™ software, the technique records both acoustic and articulatory information simultaneously, allowing for synchronized analysis.

EPG has been found to be an effective instrumental tool in detecting small articulatory events in coarticulation. Previously studies have focused on coarticulation in adult speakers, finding that there are varying degrees of coarticulation (e.g. in /kl/ sequence, [5]). A recent study of coarticulation in speakers with acquired apraxia of speech is using EPG as the main analysis tool [1]

3. Method

3.1 Electropalatography

The WinEPG system and Articulate Assistant™ software were used to record linguapalatal contact.

The speaker is required to wear an artificial palate custom-made to fit the hard palate. The palate contains 62 electrodes, arranged in eight rows according to identified anatomical landmarks. For the purpose of this study, tongue contact in the anterior 4 rows of electrodes can be considered an alveolar articulation and contact in the posterior 4 rows, a velar articulation.

3.2 Participants

Six children with Down's syndrome aged 9;2-15;6 years were chosen from a larger data set of 25 children with Down's syndrome recruited for an MRC funded project assessing the use of EPG as an analysis and treatment technique. These children were selected as they all had similar cognitive ages (range: 5;0-5;10 years, Mean= 5;5 , SD=0.71). They were compared with six typically developing children between the ages of 3;8 and 7;1 (Mean=6;3, SD=1.23). A further set of data was recorded from 6 typical adult speakers.

3.3 Speech data

The sequences /kl/ and /d#k/ were elicited from a read wordlist containing the phrases 'a clock' and 'a red car' in order to assess temporal overlap (in the /kl/ sequence) and spatial assimilation in the /d#k/ sequence (whether the speakers produce an alveolar or assimilate to a velar plosive). The list contained 6 other phrases and was repeated 10 times at the speaker's habitual rate.

4. Data analysis

Coarticulation and variability of /kl/ was analysed using the Overlap index. A qualitative analysis was made of the /d#k/ sequence in order to assess the presence or absence of coarticulation and the variability of the patterns used. These measures are described below, along with information regarding the annotations required for the measurements. Cluster reduction and final consonant deletion are prevalent in this group of children so care was taken to only measure children and data where these processes did not occur. All 6 children showed no evidence of final consonant deletion of /d/ elsewhere in single words produced as part of a standardised phonology assessment [2]. Two of the children produced /klɔk/ as [kɔk] 50% of the time and these productions were removed from the analysis.

4.1 Qualitative Analysis

The EPG patterns of the sequence /d#k/ were assessed and 4 categories of production types were identified: full alveolar contact (no evidence of overlap), partial assimilation (partial contact in alveolar region), double articulation (simultaneous alveolar and velar contact) and full assimilation (no alveolar contact).

4.2 Overlap Index

Timing between the contact for /l/ and release of /k/ was calculated using the Overlap Index [4]. The index is calculated from the approach of the /k/ closure (AC), the release of the /k/ closure (SR) and the approach to lateral closure (LC). The index can be expressed as follows:

$$OI = \frac{AC - LC}{AC - SR} \times 100$$

If OI = 100, then the /k/ release and the /l/ approach occur simultaneously. An OI value of less than 100 shows overlap (thus presence of coarticulation), while a value greater than 100 shows no overlap and a delay between articulation of the two segments.

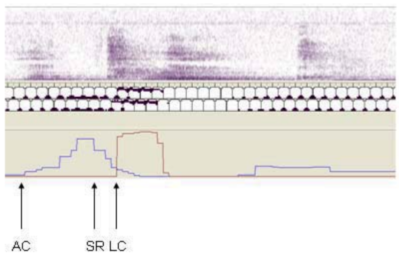

Figure 1: *Acoustic and EPG pattern of 'clock' with arrows indicating annotation marks (as described above)*

Each time point was annotated from the analysis chart window in Articulate Assistant which displayed an alveolar contact and velar contact measure (Figure 1 above).

A coefficient of variation (standard deviation/mean) measure was calculated from the overlap index results to investigate variability within the speaker groups.

5. Results and Discussion

5.1 /kl/ sequence

The Overlap index measure was only taken from the /kl/ sequence. Individual means of the OI index are presented in figure 2 below as greater or less than 100, where 100 indicates that the release of the velar and the approach of the lateral occur simultaneously. The chart in figure 2 shows either a value lower than 100 (where value represents amount of overlap of /k/ and /l/ production) or above 100 (where value represents delay in /l/ production). The adult speakers show little sign of coarticulation of the /kl/ sequence, with only Speaker 3 showing any overlap. The two child groups are more alike but the children with DS show more overlap (particularly speakers 2, 3 and 4) which is also longer than the overlap values in the other speaker groups. The group is not consistent, with speakers 1, 5 and 6 showing no sign of overlap.

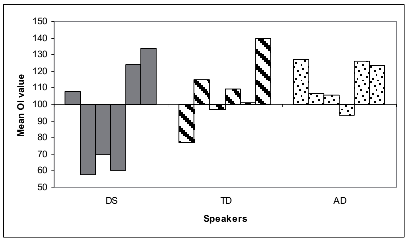

Figure 2: *Mean Overlap index measure of /kl/ sequence per speaker*

Figure 3 presents the mean coefficient of variation measure for OI for each group. The children with Down's syndrome show more variability than the other two speaker groups and both groups of children are more variable than the adult group, however this is not a significant finding.

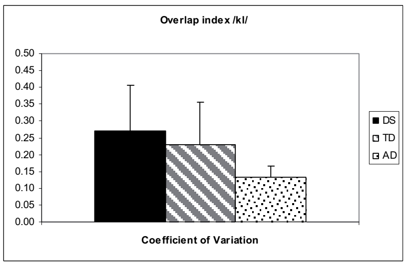

Figure 3: *Mean and standard deviation measures of Coefficient of variation of Overlap Index (OI) measures of /kl/*

5.2. /d#k/ sequence

For the /d#k/ sequence, the four spatial patterns were identified and presented for each group (figure 4): Full alveolar contact (FA), Partial assimilation (PA), Double articulation (DA) and Full assimilation (FAS). The groups show different patterns with the adult speakers showing little sign of assimilation and maintaining consistent patterns. Both groups of children use all four patterns but the typically developing children show most variation (the children with DS are more likely to use full assimilation than the other spatial patterns).

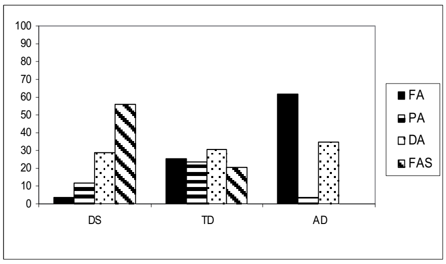

Figure 4: *Percentage usage of assimilation patterns for the three speaker groups for target /d#k/ sequence*

The maximum frame of contact from the /dk/ sequence was analysed in order to capture the different assimilation patterns used by all the speakers. A composite pattern was created from all ten repetitions for each speaker (see figure 5 below). The patterns for the group with DS show a lack of alveolar contact, which reflects the results shown in figure 4 above. The TD group are varied with some speakers showing little alveolar contact and others showing a lot. The adult speakers show a lot of both alveolar and velar contact, with the majority of speakers showing double articulation patterns.

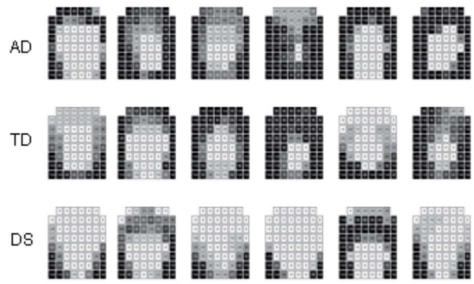

Figure 5: *Composite EPG frames of maximum contact from /d#k/ sequence for the three speaker groups*

6. Conclusion

There are two main findings of interest in this study. One noticeable finding is the increased tendency to overlap in the /kl/ sequence at least in the children with Down's syndrome. This inability to synchronise the alveolar gesture for the /l/ with the tongue-body velar gesture for the /k/ may well be an indication of a motor programming problem for at least some of these speakers.

The second finding is the high presence of full assimilation in the children with Down's syndrome for the /d#k/ sequence. At first this seems a surprising finding, however it could be argued that assimilating the /d/ into a velar is motorically more straightforward than the production of alveolar contact and may be favoured by these children.

This study has raised some interesting questions which will warrant further investigation. Further analysis would benefit from using a more specific age range of typically developing children as variability in typical development changes over short time periods. Speech rate could be controlled, as some speakers (particularly the adults) were producing controlled, slow speech, which may affect the individual's use of coarticulation.

References

[1] Bartle, C., Murdoch, B., & Goozee, J., An EPG Investigation of Consonant Clusters in AOS. Paper presented at *5th International EPG symposium*, Edinburgh. 2008.

[2] Dodd, B. Hua, Z. Crosbie, S. Holm, A. & Ozanne, A., Diagnostic Evaluation of Articulation and Phonology (DEAP), *London: The Psychological Corporation*, 2002.

[3] Dodd, B. & Thomson, L., Speech disorder in children with Down's syndrome. *Journal of Intellectual Disability Research* 45 (4):308-316, 2001.

[4] Gibbon F., Hardcastle, W. & Nicolaidis, K., Temporal and spatial aspects of lingual coarticulation in /kl/ sequences: A cross linguistic investigation. *Language and Speech*, 36(2,3): 261-277, 1993.

[5] Hardcastle, W., Some phonetic and syntactic constraints on lingual co-articulation during /kl/ sequences. *Speech Communication*, 4: 247-263, 1985

[6] Kumin, L., Speech Intellibility and childhood verbal apraxia in children with Down syndrome. *Down Syndrome Research and Practice,* 10(1): 10-22, 2006.

[7] Latash, M., Kang, N. & Patterson, D. Finger coordination in persons with Down Syndrome: atypical patterns of coordination and the effects of practice. *Experimental Brain Research* 146:345-355, 2002.