Developmental dysarthria in a young adult with cerebral palsy: A speech subsystems analysis

Anja Kuschmann & Rebecca Neill

University of Strathclyde, Glasgow, UK
anja.kuschmann@strath.ac.uk

ABSTRACT

The speech of children with cerebral palsy (CP) and dysarthria is associated with limited breath control, voice quality changes and imprecise articulation. These problems can reduce speech intelligibility, which can act as a barrier to successful interactions. Whilst the impact of the speech problems is well recognised, research on the nature of the speech impairment is relatively limited. This study aims to provide a detailed description of the speech production abilities of a 16-year old boy with CP using a speech subsystems approach. It will examine which subsystems might be affected that could impact upon intelligibility in this speaker. To achieve this, various speech samples were analysed regarding a range of acoustic and linguistic parameters and subsequently compared to the performances of his typically developing twin brother. Results showed that changes in respiration, phonation and articulation may contribute to the intelligibility issues experienced by the speaker with CP.

Key words: cerebral palsy, dysarthria, intelligibility, speech

1. INTRODUCTION

Cerebral palsy (CP) is a motor disorder affecting movement and posture that is caused by damage to the developing brain. The motor deficits are frequently accompanied by additional impairments including cognitive and sensory impairment as well as difficulties in communication [1]. It is estimated that about 50% of children with CP have some form of communication disorder [7]. The most common communication impairment in CP is developmental dysarthria, a motor speech disorder that can be characterised by shallow, irregular breathing, reduced pitch variation and imprecise articulation. It is generally assumed that at least one - but often all - speech subsystems are affected, i.e. respiration, phonation, resonance as well as articulation.

All of these speech features can impact upon speech intelligibility in this speaker group [5, 9, 12]. Reduced intelligibility can affect children's social participation, their development of relationships, and educational achievement. Despite these far reaching consequences, research on the nature of speech characteristics in children with CP is limited and often only interpreted in relation to gross-motor function [6]. However, a comprehensive description of individual abilities and deficits is crucial for tailored speech and language intervention.

The few studies that analysed speech features in children with CP in greater detail primarily relied on perceptual evaluations. Workinger and Kent [11], for instance, used rating scales to establish dysarthria features in children with spastic and dyskinetic CP. The authors found that hypernasality, breathy voice and an atypical voice quality were the most common perceptual speech characteristics in children with spastic dysarthria. Problems with the coordination of articulatory movements were apparent in children with dyskinetic CP. The observations made by Workinger and Kent [11] were confirmed by a recent study by Nordberg et al. [6] who investigated consonant production in children with CP. Narrow phonetic transcription of single words revealed that the majority of children showed considerable problems with the articulation of consonants with voicing errors, omissions and substitutions being the most common processes reported.

Articulation was also considered to be the key issue in a study by Lee and colleagues [4] that examined the functioning of different speech subsystems in children with CP using a range of acoustic measures. Lee et al. [4] selected nine acoustic variables reflecting articulatory, velopharyngeal and laryngeal speech subsystems, and compared performances of children with CP with and without dysarthria to those of typically developing children. Findings showed that children with CP and dysarthria only differed significantly from the other two groups in terms of articulation. Based on these findings the authors concluded that the articulatory subsystem appears to be the primary contributor to reduced speech intelligibility.

With the exception of Lee et al. [4] studies focused on perceptual aspects associated with single speech subsystems. As a result, only very few detailed descriptions exist for children with CP that cut across all subsystems involved in the speech production process; and even less is known for young adults with dysarthria and CP.

The aim of the present single case study was to start filling this gap by analysing a range of phonetic and linguistic parameters associated with respiration, phonation, resonance and articulation in a Scottish 16-year old with spastic CP and dysarthria. This established which speech characteristics associated with the four subsystems could potentially affect the speaker's intelligibility.

2. METHOD

2.1. Participants

To achieve this aim, speech recordings by the young adult with spastic CP and dysarthria were analysed with regard to various linguistic and acoustic-phonetic parameters, and subsequently compared to the performances of the typically developing twin brother. Spastic CP is the most common form of CP and characterised by an abnormally increased muscle tone, i.e. hypertonia, which can lead to tight muscles. This tightness can lead to spasms, i.e. sudden and involuntary movement of the muscles. No cognitive or sensory impairment was reported that could have affected the speech recordings.

2.2. Materials

Three types of connected speech samples were collected from the participants including 1) spontaneous speech, where the participants talked about a hobby, 2) story retelling and 3) picture description. They were complemented by a recording of 50 single words, forming part of the Children's Speech Intelligibility Measure [10], as well as various clinical tasks to assess voice quality, e.g. sustained vowel. All data were recorded using an Edirol R-09HR MP3 recorder.

2.3. Measures

For each speech subsystem, i.e. respiration, phonation, resonance and articulation, a range of parameters were selected, and linguistic analyses and/or acoustic measures were conducted. The data were annotated using PRAAT [2]; acoustic values were extracted using scripts. Statistical analyses were conducted using a range of parametric and non-parametric tests.

For *respiration*, the mean length of two attempts to sustain the vowel /a/ was measured in seconds. Furthermore, the mean number of syllables produced per phrase, i.e. breath group, across all connected speech samples was calculated. In terms of *phonation*, F0 values (mean, minimum and maximum) and voice quality measures including shimmer, jitter and harmonic-to-noise-ratio were analysed. *Resonance* was evaluated with regard to vowel quality (F1 and F2 formant measures) using relevant single word data. The *articulatory subsystem* was investigated by calculating the percentage of correctly produced consonants [PCC, 8] using the single word data. The phonetic transcription was further used to establish the types of errors made, e.g. omissions and substitutions.

Intelligibility for the connected speech samples was established by calculating the percentage of correctly identified syllables. Intelligibility on single word level was measured using the CSIM [10]. In this test, the participant repeats 50 one- and two-syllabic words spoken by the examiner. Subsequently, a judge listens to each word identifying from a list of 12 phonetically similar words the target word s/he believed the child produced. The intelligibility analyses for this study were conducted by the second author.

3. RESULTS AND DISCUSSION

3.1. Intelligibility

Table 1 presents the results of the speech intelligibility measures for both speakers and all speech samples investigated. It can be seen that the control speaker was generally more intelligible than the speaker with CP. Furthermore, the results show that for both speakers connected speech was easier to understand than the single words. This is likely to be due to the fact that in connected speech additional features such as context and syntactic structures are available to the listener to help interpret the information received.

Table 1: Levels of speech intelligibility per speaker and types of speech data in %.

Speech data	Speaker with CP	Control speaker
Single words	40	90
Spontaneous speech	87	97
Story retelling	95	100
Picture description	91	100
Connected speech total	91	99

3.2. Acoustic and linguistic measures

Respiration: The results of the linguistic analyses revealed that the speaker with CP produced phrases which were about 7 to 8 syllables long, whereas the control speaker produced about 12 syllables per phrase, i.e. breath group (cf. table 2). This finding suggests that the speaker with CP produced considerably shorter phrases than the control speaker. Breath support issues were also reflected in the maximum performance data, which revealed that the speaker with CP sustained the vowel /a/ on average for 8.4 seconds compared to 10.1 seconds by the control speaker. According to the basic protocol for functional assessment of voice by the European Laryngological Society (ELS) the performance of the speaker with CP points to a moderate impairment of respiration and respiratory control [3]. Adequate breathing is a pre-requisite for speech, and failing to control respiration and respiratory muscles appropriately may reduce speech intelligibility.

Table 2: Average number of syllables per speaker and phrase, i.e. breath group.

Speech data	Speaker with CP	Control speaker
Spontaneous speech	6.1	12.9
Story retelling	7.6	11.1
Picture description	8.9	12.1
Connected speech total	7.5	12.0

Phonation: In terms of phonation, the speaker with CP was found to have significantly higher mean, minimum as well as maximum F0 values across all connected speech samples than the control speaker (cf. table 3; MEAN F0: spontaneous speech: $t(32)=4.03$, $p<.001$; story retelling: $t(24)=8.55$, $p<.001$; picture description: $t(13)=15.76$, $p<.001$; MINIMUM F0: spontaneous speech: $t(32)=3.89$, $p<.001$; story retelling: $t(24)=10.55$, $p<.001$; picture description: $t(13)=11.76$, $p<.001$; MAXIMUM F0: spontaneous speech: $t(32)=2.55$, $p=0.016$; story retelling: $t(24)=5.30$, $p<.001$; picture description $t(13)=10.70$, $p<.001$). This is likely to be the result of a generally increased muscle tone as well as increased vocal fold tone, which represents one of the key features of spastic dysarthria.

The analyses further revealed that the participant with CP displayed lower levels of jitter and shimmer than the control speaker, but showed a higher percentage of harmonic-to-noise ratio (cf. table 4). These findings suggest that both speakers had a hoarse quality to their voices. However, it is possible that the participants yield atypical measurements for voice quality due to their age and the physical changes associated with it.

Table 3: Mean F0 values (mean, minimum, maximum) per speaker and connected speech sample.

Speech sample	Speaker with CP	Control speaker
MEAN		
Spontaneous speech	131.2	117.9
Story retelling	140.2	118.5
Picture description	140.0	111.2
MINIMUM		
Spontaneous speech	119.4	107.4
Story retelling	130.8	108.7
Picture description	126.2	105.8
MAXIMUM		
Spontaneous speech	143.0	128.6
Story retelling	149.5	128.2
Picture description	155.2	116.7

Table 4: Voice quality measures per speaker.

Type of voice measurement	Speaker with CP	Control speaker
Local Jitter	0.49%	0.88%
Local Shimmer	9.08%	14.97%
Harmonic-to-noise ratio	14.96dB	8.94dB

Resonance: Table 5 provides an overview of the formant measures captured from the single word data. The results of the analyses did not show any significant differences between the formant values of the speaker with CP and the control speaker ($U=5.0$, $p=.386$). This finding suggests that velopharyngeal dysfunction was not present in the speaker with CP. The absence of hypernasality in the speech data confirms observations by Nordberg et al. [6] who found hypernasality in their speaker group to be rare.

Table 5: Mean values for formant measures using single word data per speaker.

Speech data	Speaker with CP	Control speaker
Mean F1	421.5	468.2
Mean F2	1365.6	1614.7

Articulation: The analysis of the percentage of correctly produced consonants (PCC) revealed a considerably better performance for the control speaker than for the speaker with CP. Whilst the former produced 95.3% of all consonants correctly, only 55.6% of consonants produced by the speaker with CP were clearly identifiable. The speaker with CP thus performed well below the norms expected for his age [8] – a finding, which points to deficits within the articulatory speech subsystem of the participant. Given the relatively low percentage of correctly produced consonants it is likely that articulation deficits - as identified by Lee et al. [4] - may be the primary contributor to reduced speech intelligibility in this speaker with dysarthria and CP. A subsequent analysis of type of errors showed that the speaker with CP either omitted or substituted consonants, confirming previous findings from Nordberg et al. [6] and Workinger and Kent [11].

4. CONCLUSION

This single case study revealed that in three of the four speech subsystems investigated, i.e. respiration, phonation and articulation the acoustic and linguistic results of the speaker with CP differed from those of his twin brother. Hence, deficits in several subsystems may affect speech intelligibility in this speaker with spastic CP.

In terms of clinical management the findings suggest that the speaker with CP may benefit from an intervention with focus on the following aspects:

- Improving breath support, control and coordination
- Increasing range and accuracy of articulatory movements.

Following therapy, the same measurements could be taken and compared to the performances prior to therapy to evaluate the success of the intervention. Overall, the results show that a detailed analysis of the different speech subsystems can be beneficial for identifying therapy goals as well as establishing the results of the intervention. The present study is a single case study, and results should therefore be interpreted carefully. Subsequent studies should evaluate whether speakers of the same type of CP show similar behaviours. It would also be important to explore whether an analysis of the performances observed with regard to the different speech subsystems can predict severity of the motor speech impairment.

Acknowledgements: This work was supported by a British Academy Postdoctoral Fellowship awarded to the first author and a Carnegie Vacation Scholarship awarded to the second author.

5. REFERENCES

[1] Bax, M., Goldstein, M., Rosenbaum, P., Leviton, A., Paneth, N., Dan, B., Jacobsson, B., Damiano, D. 2005. Proposed definition and classification of cerebral palsy. *Developmental Medicine and Child Neurology.* 47, 571–576.

[2] Boersma, P., Weenick, D. 2015. *Praat: doing phonetics by computer.* Available at: http://www.fon.hum.uva.nl/praat/.

[3] Dejonckere, P. H. , Bradley, P., Clemente, P., Cornut, G., Crevier-Buchman, L., Friedrich, G., Van De Heyning, P., Remacle, M., Woisard V. 2001. A basic protocol for functional assessment of voice pathology. Guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS). *European Archives of Otorhinolaryngology*. 258, 77-82.

[4] Lee, J., Hustad, K. C., Weismer, G. 2014. Predicting Speech Intelligibility With a Multiple Speech Subsystems Approach in Children With Cerebral Palsy. *Journal of Speech, Language, and Hearing Research.* 57, 1666-1678.

[5] Love, R. J. 1992. *Childhood Motor Speech Disability*. Boston: Allyn & Bacon.

[6] Nordberg, A., Miniscalco, C., Lohmander, A. 2014. Consonant production and overall speech characteristics in school-aged children with cerebral palsy and speech impairment. *International Journal of Speech-Language Pathology.* 16, 386-395.

[7] Pennington, L., Miller, N., Robson, S., Steen, N. 2010. Intensive speech and language therapy for older children with cerebral palsy: a systems approach. *Developmental Medicine and Child Neurology.* 52, 337-344.

[8] Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., Wilson, D. L. 1997. The percentage of consonants correct (PCC) metric: Extensions and reliability data. *Journal of Speech, Language, and Hearing Research*. 40, 708-722.

[9] Strand, E. A. 1995. Treatment of motor speech disorders in children. *Seminars in Speech and Language.* 16, 126–139.

[10] Wilcox, K., Morris, S. 1999. *Children's Speech Intelligibility Measure.* Pearson.

[11] Workinger, M. S., Kent, R. D. 1991. Perceptual analysis of the dysarthrias in children with athetoid and spastic cerebral palsy. In: Moore, C. A., Yorkston, K. M., Beukelman, D. R. (eds), *Dysarthria and Apraxia of Speech: Perspectives on Management*. Baltimore, MD: Paul Brookes, 109-126.

[12] Yorkston, K.M., Beukelman, D.R., Strand, E.A., Hakel, M. 2010. *Management of motor speech disorders in children and adults (3rd edition).* Proed: Texas.