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Contributors to Intelligibility in Preschool- Aged Children with Cerebral Palsy

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Abstract

Purpose—We investigated the contribution of vowel space, articulation rate, maximum utterance length, and language skills to intelligibility in 30-36 month old children with CP. We also examined differences among variables for 3 subgroups of children with CP and a small group of typically developing (TD) children.

Method—Nineteen children with CP and 5 TD children provided speech samples, and 120 listeners transcribed the speech samples. Acoustic analysis of temporal and vowel spectral measures was completed on single-word productions.

Results—Vowel space was the only variable that made a significant and independent contribution to intelligibility, though all variables collectively accounted for 74% of the variance in intelligibility scores. TD children tended to have larger vowel spaces, than children with CP, even among children with CP who had intelligibility scores within the range of TD children.

Conclusions—Of children with CP who were able to talk at 30-36 months of age, 60% had clinical speech or language deficits. Production of vowels appears to make an important contribution to intelligibility; and for many children with CP, considerable deficits in intelligibility may be evident by the age of 3. Early interventions targeting both speech and language may improve intelligibility and functional communication skills.

Keywords

intelligibility; dysarthria; cerebral palsy; pediatrics

Children with cerebral palsy (CP) are at risk for a variety of communication problems, most notably dysarthria. Reductions in intelligibility are pervasive in children with dysarthria, and often have significant negative consequences for functional communication, social participation, and quality of life (Dickinson et al., 2007). Studies examining contributors to speech intelligibility have largely focused on adults with dysarthria. Although a few studies have examined children with dysarthria above the age of 5 years (Higgins & Hodge, 2002), to our knowledge there have been no studies examining intelligibility and the variables that contribute to it in preschool children with CP or typical children in early stages of speech development. Early identification of intelligibility problems in children at risk for dysarthria is critical to ensure that children receive treatment to enhance their communication abilities.

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The identification of variables that contribute to intelligibility in early development may advance the identification of treatment targets for enhancing speech intelligibility in these children.

Research questions for this study were as follows: 1) What is the contribution of acoustic spectral and temporal variables as well as language variables to intelligibility in young children with CP? 2) What are the differences in speech production among children who: a) are typically developing (TD group; n = 5); b) have CP and typical language with speech intelligibility that is within the range of typical children (CP NL; n = 8); c) have CP and typical language with speech intelligibility that is below the range of typical children (CP NL II; n = 8); and d) have CP and language and/or cognitive involvement, regardless of intelligibility range (CP LD; n = 3)?

Method

Participants

Nineteen children with cerebral palsy between the ages of 30-36 months participated. Inclusion criteria required children to: (a) have a medical diagnosis of cerebral palsy; (b) be a native speaker of American English; (c) have hearing within normal limits; and (d) be able to produce single word utterances. Children with CP included 9 boys (mean age 33.79 months (SD 1.76)) and 10 girls (mean age 32.75 months (SD 1.64)).

Five typically developing (TD) control children also participated in this study. All children passed speech, language and hearing screening to ensure that their development was age appropriate. TD children included 3 boys (mean age 32.47 months (SD 2.04)) and 2 girls (mean age 31.37 months (SD 1.72)). Demographic information for all children is provided in Table 1.

One hundred twenty listeners between the ages of 18-40 years with normal hearing made intelligibility judgments of the children (24 children × 5 listeners = 120 listeners).

Materials

All children produced 38 different words and up to 61 sentences following an adult model. Stimuli were taken from the TOCS+ (Hodge & Daniels, 2007) and thus were semantically and syntactically appropriate for young children. Speech samples from children were recorded in a quiet environment on digital audio recording equipment.

Procedures

The research protocol was administered by a speech-language pathologist and included standardized language assessment and elicitations of utterances from the TOCS. Productions were digitally recorded at a 44.1 Hz sampling rate (16-bit quantization).

Speech samples were presented to listeners using an in-house computer program. Listeners orthographically transcribed speech samples immediately following a single presentation of each utterance. The order of stimulus words and sentences was randomized. Intelligibility

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scores were calculated as number of words identified correctly divided by the number of possible words multiplied by 100.

For acoustic analyses, the following variables were of interest: vowel area, articulation rate, and maximum utterance length. To obtain temporal and vowel spectral measures, single word productions of the words sheet, seat, hoot, boot, top, hot, bad, hat were analyzed using a wideband spectrographic display, fast fourier transform (FFT), and linear predictive coding (LPC) in TF 32 (Milenkovic, 2002) via established acoustic analysis procedures (Kent, Weismer, Kent, Vorperian, & Duffy, 1999). The following measures were obtained: 1) Duration of each of the eight target words and 2) First and second formant frequencies (F1 and F2, respectively) for each of the eight target words containing corner vowels. Formant values were used to calculate vowel space following Johnson and colleagues (Johnson, Flemming, & Wright, 2004). Inter- and intra-judge reliability was calculated for all acoustic measures on 15% of the stimuli. Pearson product-moment correlations were above .90 for all inter- and intra- judge measures.

To address the first research question examining contributors to intelligibility in children with CP, two different regression analyses were employed. For the second research question regarding subgroup differences, pairwise comparions between language and intelligibility subgroup were examined using non-parametric statistics; alpha was partitioned using the Bonferroni procedure.

Results

Contributors to intelligibility—Simultaneous regression revealed an R^2 value of .744 ($F_{4,13} = 10.168$; $p < .001$), indicating that the collective contribution of all variables to intelligibility for the children with CP was significant. Zero-order correlations between intelligibility and individual variables revealed that three variables had significant correlations with intelligibility: vowel space, maximum utterance length, and language score. Figure 1 shows the relationship between vowel space and intelligibility.

Stepwise regression revealed an R^2 value of .625 ($F_{1, 17} = 28.297$; $p < .001$) when vowel space was the only predictor in the model. When maximum utterance length was added to the model as a predictor, R^2_{change} was .082, however this was not statistically significant ($F_{change\ 1, 16} = .051$). No other predictor variables met inclusion criterion. Results indicate that although several variables had significant correlations with intelligibility, vowel space was the only independent contributor to intelligibility, explaining approximately 63% of the variability in intelligibility scores for young children with CP. This value is greater than observed in previous studies of vowel space and intelligibility (i.e. Higgins & Hodge, 2002; Liu et al., 2005; Turner et al., 1995), and may reflect the critical contribution of vowels to early speech development

Speech production differences based on language and intelligibility subgroups—For vowel space, all but one of six pairwise group differences was significant (See Figure 2). The difference between children in the CP LD group and the CP NL II group was not significant, supporting the notion that there may be complex interactions between severity of speech motor involvement and language / cognitive abilities in young children.

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For maximum utterance repetition length, four of six pairwise differences were significant (See Figure 3). Children in the TD group did not differ from children in the CP NL group; and children in the CP NL II group did not differ from children in the CP LD group. Results suggest that children with more speech motor or language involvement have greater difficulty producing longer utterances. For articulation rate, none of the pairwise group differences were significant (See Figure 4). However, it is important to note that data were obtained from single word utterances and may not provide a representative indicator of performance during multi-word utterances.

Discussion

Results of this study suggest that collectively, vowel space, maximum utterance length, articulation rate and language comprehension abilities make a large and significant contribution to speech intelligibility in young children with CP. However, only vowel space made a significant independent contribution to intelligibility in these children. This finding highlights the important contribution of vowels in early speech development.

When children with CP were sub-divided into groups based on their likeness to typically developing children with regard to intelligibility and language / cognitive development, several additional findings emerged. First, children with CP who appear to be typically developing (CP NL), in fact had speech production characteristic that were the same as typically developing age mates with regard to utterance repetition length and articulation rate; however their vowel spaces were smaller than those of same age TD peers. Children with CP who were atypically developing (with reduced intelligibility, language delay, or both) appeared similar for all speech variables (vowel space, maximum utterance length, and articulation rate) regardless of the nature of their developmental delays, suggesting complex interactions between speech motor development and language / cognitive development in children with CP.

Overall, results suggest that more than half (60%) of young children with CP who are able to produce speech show clear evidence of a clinical speech or language disorder before the age of three years (e.g. reduced intelligibility; language / cognitive delay). It is notable that many children with CP in this age range were not yet talking (and therefore were excluded from the present study), thus the incidence of speech and language problems among toddlers with CP is likely to be considerably higher than 60%. Results of this study suggest that one avenue for improving speech intelligibility in young children with CP may be to target production of vowels, particularly vowel contrastivity.

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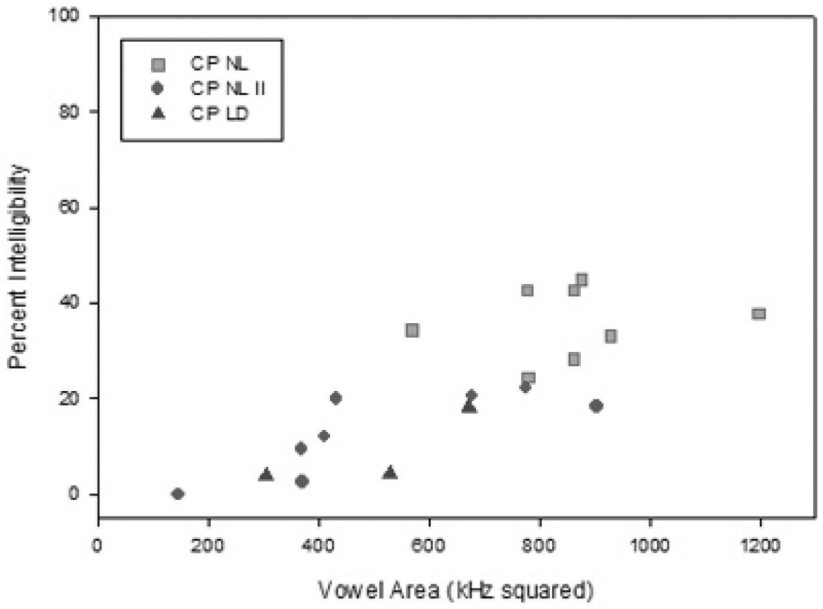

Figure 1.

Vowel area as a function of intelligibility by language and intelligibility subgroup. CP NL refers to children with CP and normal language (intelligibility within the range of typical age mates); CP NL II refers to children with CP, normal language, and intelligibility below that of typical age mates; and CP LD refers to children with CP who have language delay.

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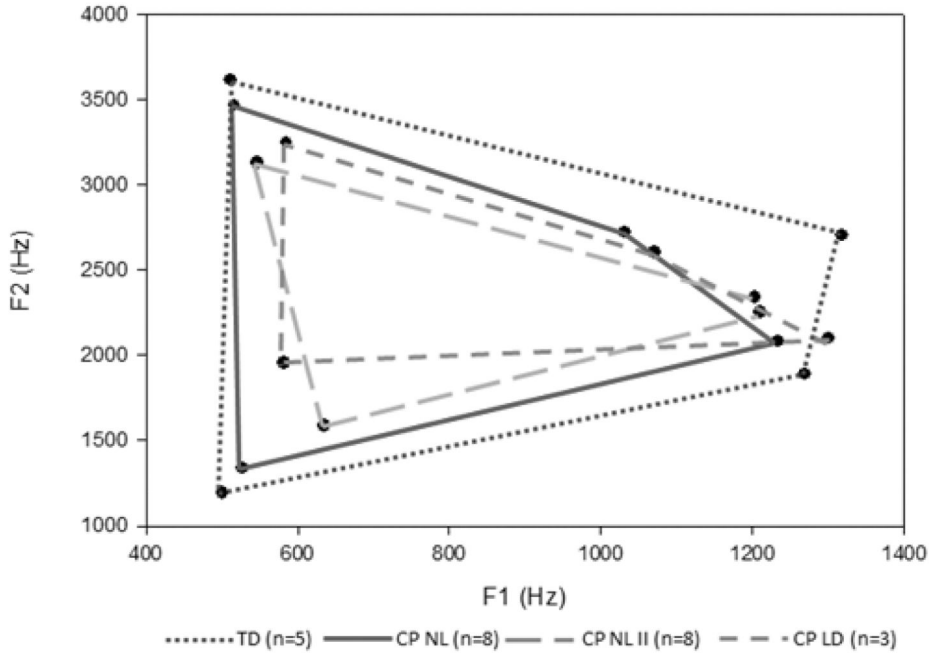

Figure 2.

Vowel quadrilaterals by language and intelligibility subgroup. CP NL refers to children with CP and normal language (intelligibility within the range of typical age mates); CP NL II refers to children with CP, normal language, and intelligibility below that of typical age mates; and CP LD refers to children with CP who have language delay.

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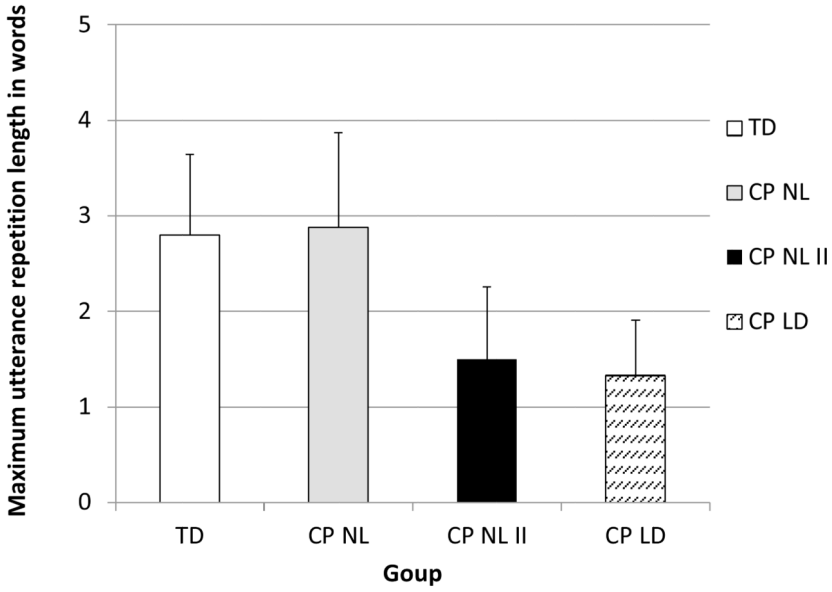

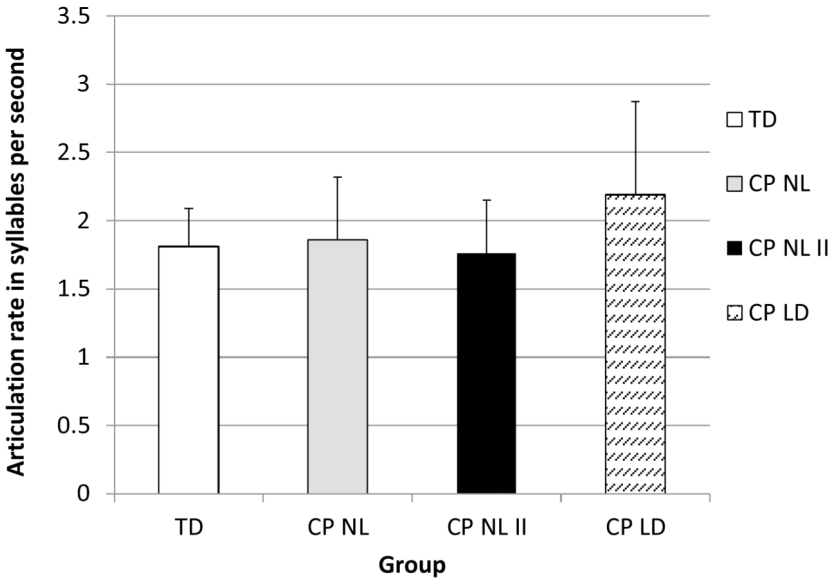

Figures 3 and 4.

Maximum utterance repetition length (Fig. 3) and Articulation rate (Fig. 4) by language and intelligibility subgroup. CP NL refers to children with CP and normal language (intelligibility within the range of typical age mates); CP NL II refers to children with CP, normal language, and intelligibility below that of typical age mates; and CP LD refers to children with CP who have language delay.

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Table 1

Characteristics of children with CP. Note that CA = chronological age in months; GMFCS = Gross Motor Function Classification System level (Palisano et al., 1997); Intelligibility = percent of words identified correctly across 5 different listeners; and Std. Language Score = standard score on language measure.

Child	Group	CA (in months)	Sex	CP Diagnosis	GMFCS	Intelligibility	Std. Language Score
1	CP NL	31.00	M	Hemiparesis	2	37.83	89
2	CP NL	30.16	F	Spastic diplegia	4	33.08	102
3	CP NL	33.71	F	Hemiplegia	2	24.32	92
4	CP NL	33.67	F	Spastic diplegia	2	42.62	118
5	CP NL	35.41	M	unknown	2	44.92	117
6	CP NL	35.09	M	unknown	2	34.35	89
7	CP NL	32.42	M	unknown	2	28.21	91
8	CP NL	35.58	M	Spastic quadriplegia	5	42.63	118
9	CP NL II	33.34	F	Spastic hemiplegia and diplegia	3	20.00	93
10	CP NL II	31.41	F	Spastic diplegia	2	22.19	135
11	CP NL II	32.65	M	Dyskinetic	3	0.00	92
12	CP NL II	31.18	F	Hemiparesis	3	2.50	107
13	CP NL II	33.67	M	Hemiplegia	4	9.46	92
14	CP NL II	32.00	F	Hemiparesis	2	20.53	94
15	CP NL II	35.87	M	Ataxia	2	12.05	98
16	CP NL II	35.81	F	Spastic diplegia	4	18.38	110
17	CP LD	32.42	F	Triplegia	2	18.13	84
18	CP LD	33.77	F	Spastic quadriplegia	2	4.38	75
19	CP LD	32.42	M	unknown	5	4.10	84
20	TD	30.16	F	N/A	N/A	58.97	N/A
21	TD	32.62	M	N/A	N/A	70.14	N/A
22	TD	30.35	M	N/A	N/A	22.69	N/A
23	TD	34.43	M	N/A	N/A	68.38	N/A
24	TD	32.59	F	N/A	N/A	69.33	N/A