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Research Article

Communication Modes and Functions in Children With Cerebral Palsy

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Purpose: This study seeks to determine how speech-language impairments relate to the frequency and diversity of communication modes and functions produced by children with cerebral palsy (CP) during interactions with their mothers.
Method: We studied 40 children with CP (M_{age} = 62 months) comprising three groups: those who were unable to speak and had anarthria (n = 15), those with speech motor impairment and language comprehension impairment (SMI-LCI; n = 15), and those with speech motor impairment and typical language comprehension (SMI-LCT; n = 10). Mother–child play interactions were coded for child modes and functions. Generalized linear regression models were used to examine the relationship between profile group and frequencies of communication modes and functions.
Results: Results indicated groups SMI-LCI and SMI-LCT had significantly higher mean frequencies of vocalizations, vocalizations + gestures, comments, initiations, and requests than the group of those who were unable to speak and had anarthria. All children used vocalizations primarily, though these vocalizations were often not understood. SMI-LCI and SMI-LCT differed on two measures: frequency of gestures and frequency of initiations. The majority of children in this sample did not have access to augmentative and alternative communication devices.
Conclusion: Results of this study highlight the need for parent-mediated interventions for children with CP that emphasize multimodal communication tailored to impairment profiles.
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Cerebral palsy (CP) is the most common physical disability in childhood, affecting 3 per 1,000 in the United States and internationally (Arneson et al., 2009; Christensen et al., 2014). Impaired motor function is the hallmark feature of CP, and many children have significant limitations across functional domains, including mobility, feeding, and self-care (Chiarello et al., 2009; Clancy & Hustad, 2011; Smits et al., 2011). Conservative estimates suggest that at least 60% of children with CP have some type of speech or language impairment that can vary in severity from "very mild" to "profound" (Bax et al., 2006). CP can impact expressive and receptive language, cognition, and speech motor control, with movement disorders disturbing facial expressions, body movements, gesture, and speech (Pennington et al., 2013). Individuals with CP often have dysarthria, ranging from slightly slurred speech and/or poor voice quality to little or no intelligible speech (Pennington et al., 2005). In a systematic review of studies describing comorbidities of children with CP, over half also had intellectual disability (Novak et al., 2012). Much like other children with intellectual and developmental disabilities (IDD), who also have communication impairments, children with CP may have problematic social interactions, putting them at risk for later peer rejection and social isolation (Thomas-Stonell et al., 2012). Lifelong difficulties in social interaction present as early as infancy in interactions with parents. Understanding how children with CP behave within interactions with familiar partners is essential for developing interventions that optimize early interactions between parents and children (Pennington & Thomson, 2007; Pennington, Thomson, et al., 2009).

Research over the last 20 years has documented many aspects of the "well-choreographed dance" that occurs within typical parent–child interactions, with young children producing a variety of signals and caregivers providing appropriate input while responding to child signals in predictable patterns (Olswang et al., 2006). The study of parent–child interaction using fine-grained coding of behaviors allows for a direct quantification of communicative

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participation. In contrast to children who are typically developing, the expected reciprocal patterns of interaction are interrupted in children with IDD, in large part due to the child's inconsistent or unclear communicative signals (Warren & Brady, 2007). Any number of features commonly seen in children with IDD, either in isolation or in combination with other features, may pose challenges for parents when interacting, such as atypical eye gaze, reduced speech intelligibility, limited expressive language, poor short-term memory, or slow response times (Warren & Brady, 2007). Data from mother–child interactions in children with IDD serve as an important window into the transactional process, enabling quantification of a child's communicative strengths and weaknesses and allowing for a characterization of the ways in which mothers facilitate children's communication, despite challenges.

While some children with CP share many of the same features as children with IDD, those with CP experience unique challenges stemming from motor impairments that are stable and persistent through life. Studies examining the relationship between gross motor function and communication impairments suggest that, in general, children with more severe gross motor impairments are more likely to have more severe communication impairments (Majnemer et al., 2010; Parkes et al., 2011; Shevell et al., 2009). However, the impact of motor impairments on behavior within a dyadic interaction has received limited attention in the study of CP (Pennington & McConachie, 1999, 2001a, 2001b). Importantly, most study samples have not included children representing a range of diverse impairment profiles.

Previous work has shown that some children with CP experience challenges in conversations with their parents due to their underlying impairments, beginning early in life (Light et al., 1985a, 1985b, 1985c; Pennington & McConachie, 1999, 2001a, 2001b). A series of early studies describe parent–child interaction patterns in eight mothers and their young children with significant physical impairments who relied on augmentative and alternative communication (AAC) to communicate. This series of studies characterizes three essential elements of interactions: discourse patterns, communication modes, and communication functions (Light et al., 1985a, 1985b, 1985c). Examining the modes that children use to communicate a range of communicative functions is of primary importance for understanding how children participate in interactions. Communication modes are the channels by which messages are conveyed, and even individuals who have severe speech impairments tend to rely on unaided modes of communication (vocalization/speech, facial expression, gesture) more often than aided AAC modes (communication board/book, speech-generating devices; Light et al., 1985a; Pennington & McConachie, 1999, 2001a, 2001b). Communication modes are not mutually exclusive, and more than one mode can be used in combination within a single communication act. While Light et al. (1985a) found considerable individual variation, children used multiple modes of communication typically including low-tech communication boards, vocalizations, and gesture. In a cross-sectional study of 20 children with CP who ranged in age from 2 to 10 years, had severe motor impairments, and could not speak, Pennington and McConachie (1999) found patterns of interactions similar to those found by Light et al. (1985a, 1985b, 1985c). In particular, children predominantly used vocalizations and gestures, with verbalizations, physical movements (nonsymbolic), and AAC used less frequently.

Communication functions define the intent or purpose of a speaker's message. The frequency, type, and range of functions produced by children with CP have been described previously by Light et al. (1985b), who found that children generally fulfilled their turns using minimal (yes/no) responses and produced a limited range of communicative functions, despite using multiple communication modes. Pennington and McConachie (2001a) found that children who produced intelligible speech initiated more conversations and performed a wider range of communicative functions than children who could not speak. A follow-up study suggested that reduced speech intelligibility was the main predictor of restricted interaction patterns in children with CP, over motor function, cognitive, or language skills (Pennington & McConachie, 2001b). While this study suggests the severity of speech intelligibility deficits better predicts dyadic patterns of interaction than the child's level of motor function, this relationship was examined in a sample of children with CP who had quadriplegia and spanned an age range from 2 to 10 years. However, it remains unknown whether there are differences in the diversity of communicative functions expressed by children with CP who are classified in a more refined manner, based on the presence or absence of speech impairments and/or language comprehension impairments, rather than the broad distinction of speaking versus nonspeaking status.

In this study, we examined a broad range of children with CP who varied in their speech-language impairment profiles. We separated children into subgroups using a classification system that is drawn from impairment-based direct assessments of speech motor involvement and receptive language skills. In this classification system, there are four profile groups in children with CP: (a) children without speech motor involvement (NSMI), (b) children with speech motor involvement and typical language skills (SMI-LCT), (c) children with speech motor involvement and impaired language skills (SMI-LCI), and (d) children who have anarthria and are unable to speak (ANAR). Characterizing children on these two important dimensions results in qualitatively different groups that also have distinct profiles in terms of speech intelligibility and social function (Hustad et al., 2010, 2012; McFadd & Hustad, 2013). The purposes of this study were to identify the most frequent modes and functions used by children in each group when interacting with their mother and to examine how groups differ in the frequency of each type of communication mode. The following research questions were addressed:

1. Are there differences in the types of communication *modes* produced by children with different speech-language impairment profiles?

2. Are there differences in the diversity of communication *functions* produced by children with different speech-language impairment profiles?

The expected outcome of this study is a characterization of child communication behaviors within parent–child interactions for the three profile groups of interest: children with ANAR, children with SMI-LCI, and children with SMI-LCT. We hypothesize that, when compared to the other two groups, the typical language comprehension skills in group SMI-LCT will support the more frequent use of communication acts overall and within each type of communication mode and function. In particular, because these children have age-level language comprehension abilities, we expected them to be able to engage in communication behaviors that were more like those of their typically developing peers (despite their speech motor and gross motor challenges) than children who had language comprehension impairment. It is important to note, however, that the hypothesized differences between the two groups of children with speech motor impairment are more exploratory, as no study has previously distinguished between children with speech motor impairment based on their language comprehension skills. Therefore, there is a possibility that the motor impairments and co-occurring speech intelligibility deficits observed in group SMI-LCT may mask their underlying stronger language skills, yielding no significant differences between the two groups of children with speech motor impairment in terms of the frequency of communication modes and functions. We expect that children in group SMI-LCI will produce a greater frequency of communication acts and within each type of communicative mode and function when compared to children in group ANAR. This hypothesis is supported by previous research indicating that children who had speech that was understood by their parents initiated more conversations and used the communication for a wider range of communicative functions than children who were unable to speak (Pennington & McConachie, 2001a).

Given the limited use of communication modes and limited range of communicative functions observed in previous studies of patterns of interaction of children with CP who were unable to speak (Light et al., 1985a, 1985b, 1985c; Pennington & McConachie, 1999, 2001a, 2001b), we expect that children in group ANAR will produce the lowest frequency of communication modes with the most restricted repertoire of communication functions. Implications of this study will provide a framework for evaluating dyadic strengths and weaknesses that will enable refinements to parent-mediated speech-language interventions, tailored to the unique profiles of children with CP.

Method

Participants

Participants were selected from a larger cohort of children with CP participating in a longitudinal study of speech and language development (n = 139). This study was approved by the University of Wisconsin–Madison Education and Social/Behavioral Sciences Institutional Review Board (2013–1258). Criteria for inclusion in the larger study required that children (a) have a medical diagnosis of CP and (b) have hearing abilities within normal limits. To be included in this study, additional criteria required that children (c) had completed a data collection session between the ages of 60 and 65 months, (d) had played with their mother at the visit and were visible on camera for a full 10 min of the mother–child play session, and (e) did not have a co-diagnosis of autism spectrum disorder. The age range of 60–65 months was selected as the age band of interest for this study because it was expected that classifying children into speech-language profiles would be possible. At earlier ages, children with CP are frequently not producing enough speech to determine the presence or absence of speech motor involvement, and collapsed categories for classification have been proposed (Hustad et al., 2014). A total of 40 children from the larger cohort met our inclusion criteria; these children were seen between 2006 and 2013.

Children with CP were classified into speech-language profile groups (Hustad et al., 2010) on the basis of data collected during the assessment session. Research speech-language pathologists made the classification. Procedures have been reported previously, and high levels of reliability based on these procedures are regularly attained (Hustad et al., 2016, 2018). Classifications into profile groups were made based on both formal measures and informal observations.

Children who were able to produce speech were evaluated for the presence or absence of speech motor impairment. Children with speech motor impairment had clinical evidence of dysarthria, which was identified by a visual observation of the speech musculature (e.g., facial asymmetry, drooling, reduced facial movements, or evidence of increased or decreased muscle tone in the face) and by perceptual features of speech (e.g., hypernasality; short breath-groups; breathy, harsh, or wet vocal quality; imprecise articulation; and consonant or vowel substitutions, distortions, or omissions that were not age appropriate). Observations of speech motor ability were made from spontaneous speech samples between the child and a parent or between the child and a clinician as well as from speech samples obtained from the production of utterances from the Test of Children's Speech Plus (Hodge & Daniels, 2007). Intelligibility data were not used in the classification of children.

Children with evidence of speech motor impairment were further classified based on the presence or absence of co-occurring language comprehension impairment. We obtained language comprehension data on each child as part of the standard assessment protocol, using one of two standardized tests, depending on the developmental skills of each child. Administration of the Test for Auditory Comprehension of Language–Third Edition (TACL-3; Carrow-Woolfolk, 1999) was attempted for all children. For children who were unable to understand graphic representations and were thus unable to attain a basal score on the TACL-3, the Auditory Comprehension subtest of

the Preschool Language Scale–Fourth Edition (PLS-4; Zimmerman et al., 2002) was administered. The PLS-4 assesses earlier acquired skills, and some items can be administered via a parent interview. For children with significant motor impairments who needed accommodations for items involving manual manipulation, standard administration procedures were adapted for the PLS-4, guided by instructions in the technical manual. Accommodations were made to circumvent the child's motor limitations whenever possible. Children who received standard scores of 85 or less (1 *SD* below the mean of 100) on either the TACL-3 or the Auditory Comprehension subtest of the PSL-4 were classified as having language comprehension impairment. Children who received standard scores of 86 or higher were classified as having typical language skills.

Children who were unable to produce more than five words or word approximations per parent report and per clinical observation during the session were classified into the anarthric group. This group consisted of children with a range of language comprehension abilities, but primarily of children who had significant language comprehension impairments. Although unable to produce more than five words, 10 of the 15 children in group ANAR were able to communicate with intent, using a combination of modes. The ability to communicate with intent was informally assessed using clinical judgment by two research speech-language pathologists by reviewing written reports from each child's laboratory visit at 60–65 months of age, in which the child's use of communication modes to convey a variety of functions within a scripted communication assessment was described.

Children with no clinical evidence of speech motor impairment were classified as NSMI. Children in this group were not included in this study, as they did not have communication disorders. The primary focus of this study was to understand children who require speech-language intervention and to identify unique features related to speech-language profile avenues that may help inform partner-mediated interventions in this population. The numbers of children in the three profile groups of interest were as follows: SMI-LCT (n = 10), SMI-LCI (n = 15), and ANAR (n = 15). Group SMI-LCT had a mean language comprehension standard score of 106.3 (SD = 14.4), group SMI-LCI had a mean language comprehension standard score of 70.1 (SD = 11.7), and the ANAR group had a mean language comprehension standard score of 52.3 (SD = 6.3). The following results from pairwise comparisons using a Kruskal–Wallis test showed that all pairwise differences were statistically significant: SMI-LCT versus SMI-LCI (z = 2.95, p = .003), SMI-LCT versus ANAR (z = 5.58, p = .000), and SMI-LCI versus ANAR (z = 2.95, p = .002). Group SMI-LCT had a mean intelligibility score of 41.98 (SD = 24.1), and group SMI-LCT had a mean intelligibility score of 34.56 (SD = 21.05). Results from a t test comparing mean intelligibility scores between groups SMI-LCT and SMI-LCI were not statistically significant. The mean age of children in this study was 61.9 months (SD = 1.9 months). There were 22 girls and 18 boys. See Table 1 for additional demographic information on the children by profile group. Note that medical diagnoses were made by physicians, and information was obtained through a review of intake records.

Materials and Procedure

Data Collection Sessions

Data collection sessions for the larger longitudinal study were approximately 2 hr in length and involved a comprehensive battery of formal and informal speech and language assessments. For this study, we examined communication behaviors in a dyadic interaction during free-play interaction with a parent. Sessions were audio- and video-recorded using professional quality equipment in a sound-attenuating room. The same protocol was used for all children.

Mother–Child Interaction Samples

Free-play samples were collected in the laboratory participant room, which is equipped with toys appropriate for children aged 24–72 months. Mothers were instructed to "play with your child as you would at home" and were encouraged to select any toys they felt their child would like to play with. The same toys were available in the room (books, a farmhouse, a bus with figurines, noisemakers, a doctor kit, sound/music boxes, and a baby doll) for each dyad. The video camera was positioned in the corner of the room, approximately 10 ft from a table where mothers and children interacted and 15 ft from a shelf containing toys. If the dyad requested to sit on the floor, the table was moved out of the view of the camera. The camera was monitored on a television by a research assistant, seated in an observation room, who operated the pan–zoom–tilt head to ensure that both the mother and the child were visible as much as possible. For each dyad, a 10-min digital video clip of the mother–child free-play was analyzed. To ensure that the child's speech signal was as clear as possible, coding was not completed for periods in which the child was eating and resumed when the child was no longer eating until a full 10 min of interaction was coded. Ten-minute free-play samples have frequently been used in prior studies of parent–child interaction (Bornstein et al., 2008).

Coding Procedures

The coding procedures used for this study include components integrated from several different studies, based on their applicability in capturing the unique features of communication behaviors in children with CP. We adapted a coding scheme developed by Warren et al. (2010) for children with fragile X syndrome because children with CP experience some of the same challenges as children with fragile X syndrome, including speech intelligibility deficits and language impairments. In order to capture the features of communication of children with a wider range of challenges (including anarthria and significant gross motor challenges) than those experienced by children with other IDD, we also included elements from coding systems designed for children who use AAC (Light et al., 1985a, 1985b,

Table 1. Demographic and clinical characteristics of children with CP.

Variable	ANAR (n = 15)	SMI-LCI (n = 15)	SMI-LCT (n = 10)
M_{age} (*SD*)	62.0 (2.2)	62.5 (1.6)	61.1 (1.7)
Male (female)	6 (9)	12 (3)	4 (6)
Race			
American Indian or Alaskan Native	0	0	0
Asian	0	0	0
Black or African American	0	1	0
Hispanic or Latino	1	1	0
Native Hawaiian or other Pacific Islander	0	0	0
White	13	13	10
Other	1	0	0
Type of CP			
Spastic diplegia	0	3	2
Hemiplegia (left)	0	2	1
Hemiplegia (right)	0	3	2
Triplegia	0	1	1
Quadriplegia	5	3	1
Dyskinetic	0	1	2
Ataxic	0	0	0
Mixed	3	0	1
Unknown	7	2	0
GFMCS[a]			
I	0	5	3
II	0	5	3
III	0	1	3
IV	3	3	2
V	12	1	2
Mean language comprehension score (*SD*)[b]	52.3 (6.3)	70.1 (11.7)	106.3 (14.4)
Mean speech intelligibility score (*SD*)	n/a	34.56 (21.05)	41.98 (24.1)
Mean maternal years of education (*SD*)	14.6 (2.8)	14.1 (2.6)	14 (2.9)

Note. No additional socioeconomic status data available. ANAR = children who have anarthria and are unable to speak; SMI-LCI = children with speech motor impairment and language comprehension impairment; SMI-LCT = children with speech motor impairment and typical language comprehension; CP = cerebral palsy; n/a = not applicable.

[a]Gross Motor Function Classification System rating (I = *no/mild impairment*, V = *severe impairment*). [b]Test for Auditory Comprehension of Language–Third Edition or Preschool Language Scale–Fourth Edition standard score (M = 100, SD = 15).

1985c) and children with CP who are nonspeaking but have typical language skills (Pennington & McConachie, 1999). We included the following modes and functions from Warren et al.'s coding scheme: modes, namely, (a) vocalization, (b) sign language, (c) gesture, and (d) AAC; and functions, namely, (a) comment, (b) imitation, (c) initiation, (d) request, (e) protest, (f) response, (g) repair, and (h) unknown. Since children with CP have gross motor impairments and present with a wide range of potential speech production impairments, an additional method for identifying vocal behaviors for children with speech motor impairments and associated intelligibility deficits (see the Vocalization subsection following) was included. Operational definitions of each code are described below.

Video clips were coded by a primary coder using Noldus Observer XT, a software program specially designed for quantitative behavior coding and analysis (Grieco et al., 2010). Coding was performed using a continuous, timed-event recording paradigm by digitally marking which participant was acting (mother or child) and the times at which behaviors begin and end. Timed-event recording provides "greater richness in data and analytic options" than untimed-event recording (Bakeman et al., 2009). Within this paradigm, we used both state- and point-based codes. State-based codes have onset and offset times marked and capture both the frequency of occurrence of the behavior as well as the duration of the behavior. Child speech/vocalizations were coded with state-based codes. Point-based codes are behaviors that have relatively short durations, and therefore, their presence is noted to measure only the frequency of occurrence. For this project, gestures, signs, and use of AAC were point based. Given the structure of this behavioral coding scheme, branched-chain coding was constructed within Observer XT and used for assigning multiple codes to single events (Bakeman et al., 2009), with a child communication act first coded with a mode and subsequently coded with its function.

Child Communication Modes

Communication modes are the channels by which messages are conveyed, and even individuals who have severe speech impairments tend to rely on unaided modes of communication (vocalization/speech, facial expression, gesture) more often than aided AAC modes (communication board/book, speech-generating devices; Light et al., 1985a; Pennington & McConachie, 2001a). In this study,

communication modes are not mutually exclusive, and more than one mode can be used in combination within a single communication act. Each type of communication mode is described below.

Vocalization. Child vocalizations were all vocal behavior, including nonword vocalizations, vocal play, single-word, multiword, or multisentence utterances, and utterances that contain unintelligible speech. Specifically, vocalizations were operationally defined as any perceptible sound produced by the child from the speech mechanism, regardless of whether it conveyed or attempted to convey lexical information. This approach was selected to capture the ways in which all children in the sample use their voices within interactions with their mothers, regardless of their stage of prelinguistic or linguistic development.

Child vocalizations, regardless of whether they conveyed lexical information, were of interest for this study because it was hypothesized that all children, even those with the most severe communication impairments, would be able to at least produce gross, undifferentiated vocalizations that may not have a clear communicative intent and to which mothers could respond. A key reason for pooling all vocalizations into one category was because, for many children in the sample, we were unable to reliably differentiate unintelligible word approximations from other vocal behaviors due to the severity of their speech motor impairments.

Sign language. Signs included distinct hand forms/movements from American Sign Language and other forms of sign language, such as Signed Exact English, used to convey specific words or phrases. Signs differ from gestures in that gestures convey communicative intent but do not represent specific words or phrases. Use of sign language is included in the coding scheme because a small number of children with CP have been reported to use manual signs as a communication mode (Sigurdardottir & Vik, 2011).

Gesture. Gestures include common body movements, such as pointing, head nodding, shaking, or reaching to request an object, that are distinct from signs described above. Gestures were coded to capture nonverbal communication acts, which include body movements that have recognizable meanings. Gestures produced in isolation or in combination with vocalizations have been recognized as a mode of communication for children with CP (Light et al., 1985a; Pennington & McConachie, 1999, 2001a, 2001b).

AAC. For the purposes of this study, the code AAC was applied when the child communicates using an aided AAC mode, which includes the use of picture communication symbols, picture communication boards/books, switches with prerecorded messages, speech-generating devices, or an iPad with an augmentative communication application. In this study, 15 children were reported by parents to have an AAC system in place (SMI-LCT: $n = 1$, SMI-LCI: $n = 5$, ANAR: $n = 9$), although only one child used an AAC device during the interaction.

Child Communicative Functions

Communicative functions define the intent or purpose of a speaker's message. In this study, communicative functions are mutually exclusive. A coder assigns a communicative function code primarily according to the apparent effect of the child's act on the mother. Each type of communicative function is described below.

Comment. A comment serves to continue an action within the interaction when a response is not obligatory, is not issued in direct response to the mother's question (response), and does not try to obtain the object (request).

Imitation. An imitation is coded when the child immediately copies the words, sounds, signs, or gestures of the mother.

Initiation. A self-initiated communication act is any act where the child draws the mother's attention to something, is not directly responding to the mother's directive or question, and does not try to obtain the object (request).

Request. A request has the effect of drawing the mother's attention to an object, her assistance in obtaining that object, or some action upon it.

Protest. A protest occurs in response to an adult's action or verbalization and has the effect of ending an activity or removing an object.

Response. A response directly follows maternal requests for verbal or behavioral compliance.

Repair. A repair occurs only when a breakdown has taken place between the child's communication act and the mother's interpretation of that act.

Unknown. Unknown acts are coded when a child's communicative intent cannot be determined because the child's speech/vocalizations were unintelligible or the intent behind a child's vocalization, gesture, sign, or AAC could not be deciphered by the coder based on the parent's behavior following the child's act.

Coder Training and Reliability

Using a training module, the principal investigator and a second coder completed side-by-side coding of a core set of three representative mother–child interaction samples that were each 10 min in length. A fourth 10-min sample was then coded separately, and interobserver reliability exceeded our minimum criteria of 80%. Interrater reliability statistics were calculated in Observer XT and reviewed individually to obtain detailed information on the correspondence between two observations of the same video sample. Interrater reliability was monitored and assessed throughout the study by having two trained coders independently code 20% of each sample, which was represented by randomly selected segments that were 2 min in length, from each of the 40 samples. Cohen's kappa was used to quantify reliability and determine that agreement exceeds chance levels (Cohen, 1960). Intrarater reliability procedures were also conducted at regular intervals, with a range of 3–6 weeks passing between the completion of the initial coding and the coding of a randomly selected segment of each sample in Observer XT. Cohen's kappa results across all samples ranged from .836 to .992 for intrarater reliability

and from .769 to 1.0 for interrater reliability. Kappa results over .75 are considered excellent (Fleiss et al., 1981).

Analysis

To determine whether there are differences in the types of communication modes and the types of communication functions produced by children with different speech-language impairment profiles, descriptive results were examined at the most detailed level possible within the coding scheme, and the most frequent communication mode and function combinations were identified (see Supplemental Material S1). It is important to note that methods for grouping behaviors for analysis across children with CP who have highly variable skill profiles have not been established. Therefore, in the absence of a paradigm for selecting and grouping behaviors, the relationship between profile group and mean frequency of the most common child communication modes as well as the relationship between profile group and mean frequency of the most common child communicative functions were examined in separate semiparametric analyses, specifically, generalized linear regression models with unspecified reference distributions (Rathouz & Gao, 2009). This semiparametric analysis was selected over other options for several reasons. First, normality could not be assumed with count data, as negative counts of behaviors were not possible. Additionally, there was reason to believe that assumptions in analysis of variance would be invalid, as overdispersion in the data was noted, with higher variances observed than would be assumed in a normal distribution. Generalized linear models with unspecified reference distributions are especially flexible, in that fewer assumptions are made about the data, with the estimation of the reference distribution being made from the data.

To evaluate the relationship between profile group and type of communication modes, a series of three generalized linear regression models with unspecified reference distributions were used, with mean frequency of vocalizations, vocalizations + gestures, and gestures alone as the outcome variables and profile groups (ANAR, SMI-LCI, and SMI-LCT) as the predictor variables (Rathouz & Gao, 2009). Group ANAR was the reference group in these regression models. It was expected that children who could talk would exhibit different patterns than children in group ANAR; therefore, three additional regression models were used to examine how groups SMI-LCI and SMI-LCT differed in their use of vocalizations, vocalizations + gestures, and gestures alone, with group SMI-LCI as the reference group.

To evaluate the relationship between profile group and type of communicative functions, again, a series of five generalized linear regression models with unspecified reference distributions were used, with mean frequency of comments, requests, responses, initiations, and unknown acts as the outcome variables and profile groups (ANAR, SMI-LCI, and SMI-LCT) as the predictor variables. These five communicative functions were selected for analysis in the regression models as they were the most common functions used across the three profile groups. Group ANAR was the reference group in these regression models. Again, it was expected that children who could talk would exhibit different patterns than children in group ANAR; therefore, five additional regression models were used to examine differences in the frequency of comments, requests, responses, initiations, and unknown acts between groups SMI-LCI and SMI-LCT, with group SMI-LCI as the reference group.

Results

The mean frequencies of communication modes and functions in groups ANAR, SMI-LCI, and SMI-LCT were examined. Data suggest, in general, that all children, regardless of profile group, primarily communicated using vocalizations. Within the two groups of children who could use speech to communicate, there was wide variability in the use of communication modes and functions. See Supplemental Material S2 for details regarding coding procedures.

Child Communication Modes

Group mean differences in the frequency of communication modes used by all three groups were analyzed using two sets of generalized linear regression models with unspecified reference distributions (Rathouz & Gao, 2009). This analysis method was selected as overdispersion was noted in the data. Large standard deviations were observed in child communication modes, suggesting interchild variability, and as a result, we examined individual child data in order to understand how individual children may have contributed to group results. Acts conveyed via vocalizations + signs and AAC were not analyzed statistically because they were not produced by all three groups. Mean frequencies and standard deviations of modes are shown in Table 2.

Communication Mode: Vocalizations

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of vocalizations (see Table 3 and Figure 1) revealed a significant overall omnibus test ($F = 19.4$, $p < .0001$). Pairwise follow-up contrasts showed that children in group SMI-LCI produced an average of 52.6 more vocalizations within an interaction than children in group ANAR, and this result was statistically significant, $\Pr(> |t|) < .0001$. Children in group SMI-LCT produced an average of 47.57 more vocalizations within an interaction than children in group ANAR, and this result was statistically significant, $\Pr(> |t|) < .0001$. Children in group SMI-LCT produced an average of 5.03 fewer vocalizations than children in group SMI-LCI, but this difference was not statistically significant, $\Pr(> |t|) = .59$.

Communication Mode: Vocalizations + Gestures

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of vocalizations + gestures revealed a significant overall omnibus test ($F = 12.4$, $p < .0001$). Pairwise follow-up

Table 2. Mean frequency, standard deviation, and total number of communication modes produced by each group.

Communication mode	ANAR			SMI-LCI			SMI-LCT		
	M	*SD*	Total	*M*	*SD*	Total	*M*	*SD*	Total
Total vocalizations	10.53	0.07	158.00	63.13	24.61	947.00	58. 10	21.43	581.00
Total vocalizations + gestures	0.07	0.26	1.00	5.00	6.69	75.00	2.40	3.69	24.00
Total vocalizations + signs	0.07	0.27	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Total gestures	1.20	2.45	18.00	3.13	3.09	47.00	0.70	1.25	7.00
Total AAC	1.71	6.41	31.00	0.87	3.36	13.00	0 00	0.00	0.00

Note. ANAR = children who have anarthria and are unable to speak; SMI-LCI = children with speech motor impairment and language comprehension impairment; SMI-LCT = children with speech motor impairment and typical language comprehension; AAC = augmentative and alternative communication.

contrasts showed that children in group ANAR produced very few acts consisting of vocalizations combined with gestures ($M = 0.07$, $SD = 0.26$; see Table 3). Children in group SMI-LCI produced an average of 4.93 more acts consisting of vocalizations + gestures than children in group ANAR, and this result was statistically significant, $Pr(> |t|) = .0061$. Children in group SMI-LCT produced an average of 2.33 more acts consisting of vocalizations + gestures than children in group ANAR, and this result was statistically significant, $Pr(> |t|) = .0265$. Children in group SMI-LCT produced an average of 2.60 fewer acts consisting of vocalizations + gestures than children in group SMI-LCI, but this result was not statistically significant, $Pr(> |t|) = .2004$.

Communication Mode: Gestures

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of gestures revealed a significant overall omnibus test ($F = 3.35$, $p = .0458$). Pairwise follow-up contrasts showed that the difference in mean frequency of gestures between groups ANAR and SMI-LCI was not statistically significant, $Pr(> |t|) = .053$ (see Table 3). The difference between groups ANAR and SMI-LCT was also not statistically significant, $Pr(> |t|) = .484$. As shown in Table 3, children in group SMI-LCT produced an average of 2.4 fewer gestures than children in group SMI-LCI, and this result was statistically significant, $Pr(> |t|) = .0113$.

Child Communicative Functions

In order to emphasize what children were able to do instead of what they were unable to do, the most frequent types of functions produced by all three groups were identified. Mean frequencies and standard deviations of functions are shown in Table 4. Group mean differences in the frequency of the five communicative functions discussed below were analyzed using generalized linear regression models with unspecified reference distributions (Rathouz

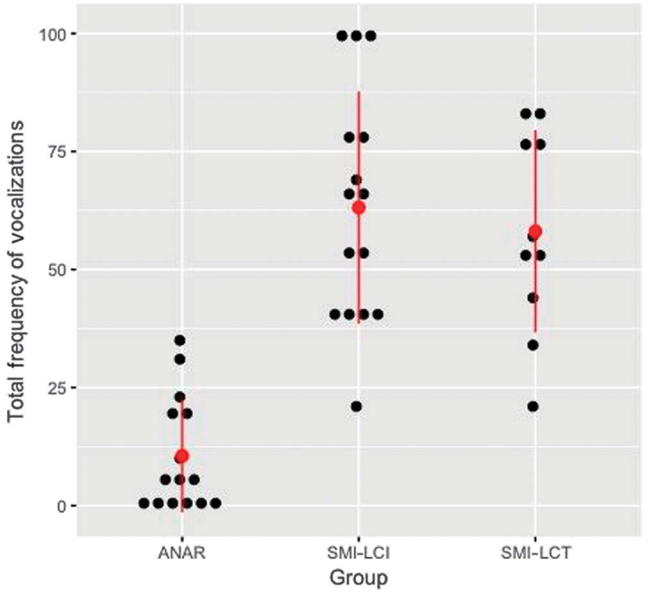
Table 3. Results of the generalized linear regression model testing the relationship between profile group and mean frequency of vocalizations.

Modes	Coefficients					
	Estimate	*SE*	*t*	Significance code	*F*	*p*
Vocalizations						
Groups					19.4	< .0001
SMI-LCI vs. ANAR	52.6	6.55	8.04	***		< .0001
SMI-LCT vs. ANAR	47.57	7.66	6.21	***		< .0001
SMI-LCT vs. SMI-LCI	–5.03	9.15	–0.55			.59
Vocalizations + gestures						
Groups					12.4	< .0001
SMI-LCI vs. ANAR	4.93	1.7	2.91	**		.0061
SMI-LCT vs. ANAR	2.33	1.01	2.31	*		.0265
SMI-LCT vs. SMI-LCI	–2.6	1.97	–1.32			.2004
Gestures						
Groups					3.35	.0458
SMI-LCI vs. ANAR	1.93	0.97	2			.053
SMI-LCT vs. ANAR	–0.5	0.71	–0.71			.484
SMI-LCT vs. SMI-LCI	–2.43	0.88	–2.75	*		.0113

Note. SMI-LCI = children with speech motor impairment and language comprehension impairment; ANAR = children who have anarthria and are unable to speak; SMI-LCT = children with speech motor impairment and typical language comprehension. Degrees of freedom: ANAR as the reference group: 2, 37; SMI-LCI as the reference group: 1, 23.

Significance codes: *0.01; **0.001; ***0.

Figure 1. Total frequency of vocalizations by group. ANAR = children who have anarthria and are unable to speak; SMI-LCI = children with speech motor impairment and language comprehension impairment; SMI-LCT = children with speech motor impairment and typical language comprehension.



& Gao, 2009). Imitations, protests, and repairs seldom occurred in any of the three groups; therefore, these results were not analyzed statistically. Group ANAR serves as the reference group in the first set of generalized linear regression models (see Table 5). The relationship between profile group and each of the five communicative functions was analyzed in secondary sets of generalized linear regression models that included only groups SMI-LCI and SMI-LCI, as it was expected children who could talk would communicate differently than children in group ANAR (see Table 5).

Communicative Function: Comments

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of comments revealed a significant overall omnibus test ($F = 20.7$, $p < .0001$). Pairwise follow-up contrasts showed that children in group SMI-LCI produced an average of 16.8 more comments than children in group ANAR, and this result was statistically significant, $Pr(> |t|) < .0001$ (see Figure 2). Children in group SMI-LCT produced an average of 22.7 more comments than children in group ANAR, and this result was statistically significant, $Pr(> |t|) < .0001$. The difference in mean frequency of comments between children in group SMI-LCI and children in group SMI-LCT was not statistically significant, $Pr(> |t|) = .27$.

Communicative Function: Initiations

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of initiations revealed a significant overall omnibus test ($F = 19.8$, $p < .0001$). Children in group ANAR did not produce any initiations, children in group SMI-LCI produced an average of 5.53 initiations, and children in group SMI-LCT produced an average of 2.10 initiations (see Figure 3). Children in group SMI-LCT produced an average of 3.43 fewer initiations than children in group SMI-LCI, and this result was statistically significant, $Pr(> |t|) = .0098$.

Communicative Function: Requests

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of requests revealed a significant overall omnibus test ($F = 20.3$, $p < .0001$). Children in group ANAR did not produce any requests, children in group SMI-LCI produced an average of 8.60 requests, and children in group SMI-LCT produced an average of 7.90 requests. Children in group SMI-LCT produced an average of 0.70 fewer requests than children in group SMI-LCI, and this result was not statistically significant, $Pr(> |t|) = .826$.

Communicative Function: Responses

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of responses revealed a significant overall

Table 4. Mean frequency, standard deviation, and total number of communicative functions produced by each group.

Communicative function	ANAR			SMI-LCI			SMI-LCT		
	M	*SD*	Total	*M*	*SD*	Total	*M*	*SD*	Total
Comment	0. 13	0.52	2.00	16.93	11.68	254.00	22.80	14.91	228.00
Imitation	0.00	0.00	0.00	1.27	2.12	77.00	0.30	0.48	21.00
Initiation	0.00	0.00	0.00	5.53	3.94	25.00	2.10	2.51	3.00
Protest	0.67	1.84	10.00	0.67	0.90	10.00	0.10	0.32	1.00
Repair	0.00	0.00	0.00	0.80	1.32	12.00	0.80	1.03	73.00
Request	0.00	0.00	0.00	8.60	10.09	129.00	7.90	2.88	39.00
Response	3.60	6.65	54.00	15.87	6.66	238.00	14.60	10.56	146.00
Unknown	9.53	10.82	143.00	22.33	19.33	337.00	12.30	7.85	126.00

Note. ANAR = children who have anarthria and are unable to speak; SMI-LCI = children with speech motor impairment and language comprehension impairment; SMI-LCT = children with speech motor impairment and typical language comprehension.

Table 5. Results of the generalized linear regression model testing the relationship between profile group and mean frequency of comments, initiations, requests, responses and unknown functions.

	Coefficients					
Functions	**Estimate**	***SE***	***t***	**Significance code**	***F***	***p***
Comments						
Groups					20.7	< .0001
SMI-LCI vs. ANAR	16.8	3.11	5.39	***		< .0001
SMI-LCT vs. ANAR	22.67	4.17	5.44	***		< .0001
SMI-LCT vs. SMI-LCI	5.87	5.2	1.13			.27
Initiations						
Groups					19.8	< .0001
SMI-LCI vs. ANAR	5.53	1.00	5.51	***		< .0001
SMI-LCT vs. ANAR	2.1	0.69	3.05	**		.0043
SMI-LCT vs. SMI-LCI	–3.43	1.22	–2.82	**		.0098
Requests						
Groups					20.3	< .0001
SMI-LCI vs. ANAR	8.60	2.08E+00	4.14	***		< .0001
SMI-LCT vs. ANAR	7.90	2.30E+00	3.44	**		.0015
SMI-LCT vs. SMI-LCI	–0.70	3.10	–0.23			.8233
Responses						
Groups				*	9.29	.0005
SMI-LCI vs. ANAR	12.27	2.59	4.74	***		< .0001
SMI-LCT vs. ANAR	11.00	3.03	3.63	***		< .0001
SMI-LCT vs. SMI-LCI	–1.27	3.29	–0.39			.7
Unknown						
Groups				***	3.57	.0383
SMI-LCI vs. ANAR	12.8	5.33	2.4	*		.0214
SMI-LCT vs. ANAR	2.77	3.92	0.71			.4846
SMI-LCT vs. SMI-LCI	–10.03	5.45	–1.84			.079

Note. SMI-LCI = children with speech motor impairment and language comprehension impairment; ANAR = children who have anarthria and are unable to speak; SMI-LCT = children with speech motor impairment and typical language comprehension. Degrees of freedom: ANAR as the reference group: 2, 37; SMI-LCI as the reference group: 1, 23.

Significance codes: *0.01; **0.001; ***0.

omnibus test ($F = 9.29$, $p = .0005$). Pairwise follow-up contrasts showed that children in group SMI-LCI produced an average of 12.27 more responses than children in group ANAR, and this result was statistically significant, $Pr(> |t|) < .0001$. Children in group SMI-LCT produced an average of 11 more responses than children in group ANAR, and this result was statistically significant, $Pr(> |t|) < .0001$. Differences in the mean frequency of responses between groups SMI-LCI and SMI-LCT were not significant.

Communicative Function: Unknown

Results of the generalized linear regression model testing the relationship between profile group and mean frequency of unknown acts revealed a significant overall omnibus test ($F = 3.57$, $p = .0383$). Pairwise follow-up contrasts showed that children in group SMI-LCI produced an average of 12.80 more unknown acts than children in group ANAR, and this result was statistically significant, $Pr(> |t|) = .02141$. Children in group SMI-LCT produced an average of 2.77 more unknown acts than children in group ANAR, and this result was not statistically significant, $Pr(> |t|) = .4846$. Differences in the mean frequency of unknown acts between groups SMI-LCI and SMI-LCI were not significant, $Pr(> |t|) = .079$.

Discussion

The purpose of this study was to evaluate the relationships between types of speech-language impairment profiles and frequency of child communication modes and functions. This study was the first to examine mother–child interactions in children with CP who represent a range of speech-language impairment profiles. Free-play interaction samples from 40 mother–child interactions were analyzed using a behavioral coding scheme that examined individual child communication behaviors. When compared to a group of children with ANAR, two groups of children with speech motor impairments (groups SMI-LCI and SMI-LCT) had significantly higher frequencies of vocalizations and vocalizations + gestures. Additionally, children in groups SMI-LCI and SMI-LCT produced greater diversity of communicative functions at significantly higher frequencies than children in group ANAR. The two groups of children with speech motor impairments, distinguished based on the presence or absence of receptive language impairment, differed

Figure 2. Total frequency of comments by group. ANAR = children who have anarthria and are unable to speak; SMI-LCI = children with speech motor impairment and language comprehension impairment; SMI-LCT = children with speech motor impairment and typical language comprehension.

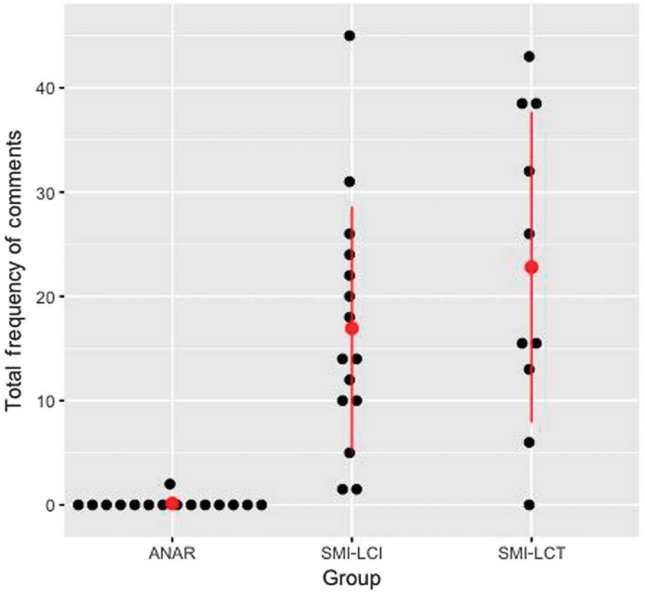
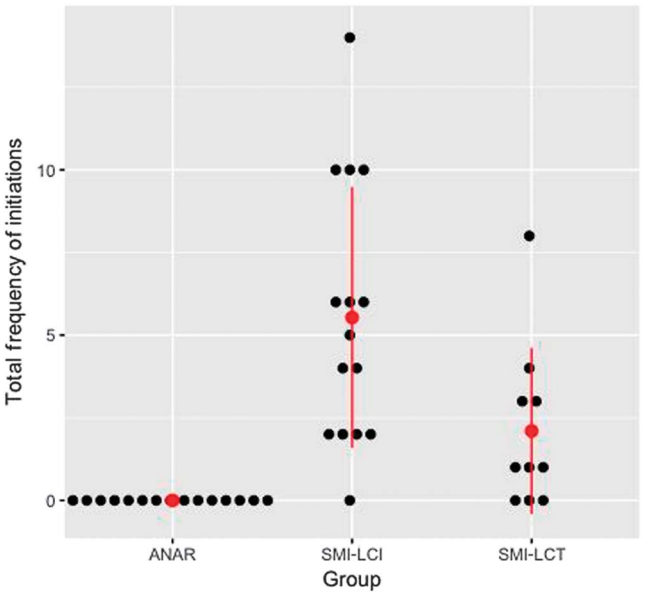


Figure 3. Total frequency of initiations by group. ANAR = children who have anarthria and are unable to speak; SMI-LCI = children with speech motor impairment and language comprehension impairment; SMI-LCT = children with speech motor impairment and typical language comprehension.



only on two measures: frequency of gestures and frequency of initiations. Key findings are discussed in detail below.

Child Communication Modes and Functions

Nearly all children with CP primarily communicated using vocalizations regardless of their speech-language impairment profile. This is noteworthy, given that the majority of the children in this study have significant difficulties using speech. Although children in group ANAR could not produce more than five words (as operationally defined by group inclusion criteria) and seldom produced communication acts that had clear functions, they used their voices within interactions. However, the distinction between group ANAR and groups SMI-LCI and SMI-LCT is important, in that it was expected the children in groups SMI-LCI and SMI-LCT would use words to communicate. Many children in groups SMI-LCI and SMI-LCT had significantly reduced intelligibility: 12 out of 15 children in group SMI-LCI and five out of 10 children in group SMI-LCT had intelligibility scores below 50%. Nevertheless, children in both groups used vocalizations alone (rather than undifferentiated vocalizations) to convey the majority of their messages. The use of multimodal communication (vocalizations + gestures, vocalizations + signs, vocalizations + AAC) was observed infrequently across all three groups, although children in groups SMI-LCI and SMI-LCT produced vocalizations + gestures more frequently than children in group ANAR. These findings are the first to document the primary use of vocalizations for communication derived from direct observations of interactions across children with CP who are anarthric (ANAR), who are with speech motor impairment and language comprehension impairment (SMI-LCI), and who are with speech motor impairment and typical language comprehension (SMI-LCT). Previous studies of mother–child interaction in children with CP have only included samples of children who have typical language skills or children who are unable to speak (Light et al., 1985a, 1985b, 1985c; Pennington & McConachie, 1999, 2001a, 2001b).

Group ANAR

When compared to groups SMI-LCT and SMI-LCI, results showed that children in group ANAR produced significantly fewer communication acts overall and across communication mode and function types. This was not an unexpected result, as children in group ANAR could not use speech to produce words for communication. Children in group ANAR primarily communicated using vocalizations, and the majority of these vocalizations were coded as having an unknown function. This is important to note, since an act is only coded as unknown when the coder cannot determine the communicative function based on the child's behavior and the mother's response. Although vocalizations were not coded in more detail, given that children in group ANAR could not produce more than five recognizable words, the unknown vocalizations observed in this group were primarily open-vowel vocalizations.

When children in group ANAR were able to communicate with a clear function, they primarily produced responses (see Table 4), which were conveyed via yes/no vocal responses.

Group ANAR included 15 children who were unable to produce more than five recognizable words. Table 1 shows that the mean receptive language standard score for group ANAR was 52.3 (*SD* = 6.3), and although cognitive skills were not measured in this study, many children in this group had intellectual disability as well. However, some children in this group may have typical receptive language and cognitive skills, but due to significant gross motor limitations, they were not able to show the full extent of their knowledge in formal testing. The diminished language and cognitive skills within this sample is a notable distinction from samples of children with CP in previous studies who could not use speech to communicate but had typical language skills (Light et al., 1985a, 1985b, 1985c; Pennington & McConachie, 1999, 2001a, 2001b). Additionally, children in group ANAR all had significant gross motor limitations, with Gross Motor Function Classification System levels in this group ranging from Level IV to Level V (see Table 1).

Given the variation in language and cognitive skills within this group, it is important to consider differences between individual children, particularly when considering that this group included children with profound impairments who did not produce intentional communication acts. However, data showed that some children in this group did convey intentional messages using a variety of modes, although these acts occurred in very small numbers. Furthermore, individual children made disproportionately large contributions to specific communication modes. Given their extremely restricted speech production abilities, it was expected that more children in group ANAR would have communicated using AAC; however, only one child in group ANAR used an AAC system during the interaction samples. This child also had the highest frequency of acts that had a clear communicative function (24 responses and seven protests), all conveyed via AAC. Given their extremely limited spoken language skills, all children in group ANAR would have benefited from the use of an AAC system, resulting in higher frequencies and wider varieties of communicative functions.

Results from this study describing the modes and functions used by children in group ANAR align with results of previous studies, indicating that children with CP who are unable to speak exhibit highly restricted patterns of communication (Light et al., 1985a, 1985b, 1985c; Pennington & McConachie, 1999, 2001a, 2001b). While the body of literature on AAC interventions specifically for children with CP who are severely unintelligible or anarthric is small, parent-mediated interventions for this subgroup have shown promise in increasing the frequency and diversity of communicative functions using a variety of communication modes, including AAC (Pennington & Thomson, 2007; Pennington, Thomson, et al., 2009).

Group SMI-LCI

Children in group SMI-LCI were able to talk, producing more than five recognizable words. However, due to dysarthria, there was considerable variation in speech production abilities in group SMI-LCI, ranging from producing single-word utterances to producing multiword utterances, and a group mean speech intelligibility score of 34.56 (*SD* = 24.05), with scores ranging from 1% to 68%. The mean receptive language standard score for group SMI-LCI was 70.1 (*SD* = 11.7). Although the criterion for receptive language impairment in this study was a standard score greater than 1 *SD* below the mean, it is worth noting that two of the 15 children in this group had language scores between 1.5 and 1 *SD* below the mean, and the rest had scores at least 1.5 *SD*s below the mean. As with group ANAR, many children in this group potentially had intellectual disability in addition to speech-language impairments. In group SMI-LCI, complex interactions between concomitant speech and language disorders within individual children are likely, resulting in the wide variability in the use of communication modes and functions observed in this study.

Children in group SMI-LCI were able to use words to communicate, and results indicated they had more advanced interaction skills than children who were anarthric, in that they were able to convey a wider range of communicative functions more frequently. All children in group SMI-LCI communicated using vocalizations and produced at least six total vocalizations (up to 103) that had communicative functions other than unknown. This observation is similar to that from a previous study that revealed disparities in the use of communicative functions between two groups of children with CP who differed in their ability to speak (Pennington & McConachie, 2001a). However, group SMI-LCI also had the highest mean frequency of acts that had unknown functions, indicating that, while making frequent attempts to communicate, the intent of their communication acts was not always clear. While examining how unknown communication acts impacted communication effectiveness was not a goal of this study, these acts may represent missed opportunities for a child to communicate more clearly within the interaction.

Several individual children in group SMI-LCI produced a greater frequency of unknown vocalizations than the total number of vocalizations that had clear communicative functions. Children who had a higher frequency of unknown acts compared to their total frequency of acts that had a clear communicative function are children who show a clear need for an AAC system. An AAC system would give access to symbols that would allow them to convey a wide range of communicative intents, thus making their expressive communication acts more readily understood than when using vocalizations alone. Results from this study are largely consistent with results from previous studies on communication behaviors in children with CP, as children in group SMI-LCI produced a greater frequency of communication modes and functions than children in group ANAR. It is important to note that

the interaction patterns of children in group SMI-LCI have not been documented prior to this study, as previous studies have focused only on children with CP who do not have language comprehension impairments (Light et al., 1985a, 1985b, 1985c; Pennington & McConachie, 1999, 2001a, 2001b).

Interestingly, the only statistically significant difference between groups SMI-LCI and SMI-LCT was on measures frequency of gestures and frequency of initiations. It was expected that, due to their receptive language impairment, children in group SMI-LCI would produce fewer gestures than children in group SMI-LCT; however, children in group SMI-LCI produced an average of 2.4 more gestures than children in group SMI-LCT. Contrary to expectations that children who had receptive language impairments would produce fewer initiations than children who had typical language skills, children in group SMI-LCI produced an average of 3.43 more initiations than children in group SMI-LCT. There were no statistically significant differences between groups SMI-LCT and SMI-LCI on any other measures. Findings regarding the frequency of communication modes and functions used by children in group SMI-LCI provide new information about potential strengths and weaknesses in the communication of children with CP who experience impairments in both speech production and language comprehension.

Group SMI-LCT

Children in group SMI-LCT are also able to talk, producing more than five recognizable words. As with group SMI-LCI, due to dysarthria, there is considerable variation in speech production abilities in group SMI-LCT, ranging from producing single-word utterances to producing multiword utterances, and a group mean speech intelligibility score of 41.98 (SD = 24.1), with scores ranging from 1% to 73%. Speech production abilities in group SMI-LCT were very similar to those in group SMI-LCI; however, children in group SMI-LCT are distinguished from those in group SMI-LCI by their typical receptive language skills, with a mean receptive language score of 106.3 (SD = 14.4). Group SMI-LCT consisted of children whose communication is likely negatively impacted primarily by dysarthric speech.

Children in group SMI-LCT all share the ability to use speech to communicate and have better language comprehension than children in groups SMI-LCI and ANAR. Children in group SMI-LCT produced significantly higher mean frequencies of vocalizations and vocalizations + gestures than children in group ANAR, which were expected results. Children in group SMI-LCT also produced significantly higher mean frequencies of comments, initiations, requests, and responses than children in group ANAR. Again, since children in group SMI-LCT could speak, it was expected that they would produce a wide range of communicative functions.

It was unexpected that children in group SMI-LCT did not produce significantly higher mean frequencies of vocalizations and vocalizations + gestures than children in group SMI-LCI. It is possible that the similarities observed in vocal communication in both groups of children with speech motor impairment are due to the fact that the significant speech production problems observed in group SMI-LCT masked the group's more advanced language comprehension skills, in that they were not able to leverage these skills within interactions. It is also possible that, because of their more advanced language comprehension skills, children in group SMI-LCT were able to convey their ideas in fewer communication acts than was required for children in group SMI-LCI, reflecting more efficient communication. In order to confirm these, the length and complexity of utterances in terms of mean length of utterance and syntax should be examined further. Additional measures of expressive language skills would allow for a more complete understanding of how language comprehension skills relate to expressive communication in this sample, using methods specifically designed for analyzing expressive language in individuals with speech intelligibility problems (Binger et al., 2016). Also contrary to expectations, children in group SMI-LCT produced significantly fewer gestures than children in group SMI-LCI. While gestures were produced relatively infrequently when compared to vocal communication in both groups, it was expected that the stronger language skills in group SMI-LCT would result in a higher frequency of gestures than group SMI-LCI. However, gross motor skills, as reflected in Gross Motor Function Classification System scores, were similar between the two groups (see Table 1), suggesting that impaired motor skills observed in both groups meant that children used gestures to communicate infrequently.

Descriptively, group SMI-LCT produced a higher mean frequency of comments and responses than mean frequency of unknown acts (see Table 4), suggesting that a greater proportion of the acts produced by children in group SMI-LCT had a clear communicative function. Additionally, although not statistically significant, group SMI-LCT produced fewer unknown communication acts than group SMI-LCI (see Table 4). In contrast to the results from the study of Pennington and McConachie (2001a), where responses were the most common communicative function produced by children who could speak, children in group SMI-LCT produced comments more frequently than responses, which may serve as evidence against the theory that children with speech motor impairments are passive communicators. Further study including children with CP who do not have speech and/or language comprehension disorders would aid in a more refined characterization of children's interaction profiles and would serve as a more robust test of the theory of passive communication in this population.

Clinical Implications

Preschool-age children with CP are not always receiving the types of interventions that would benefit them, such as speech-language therapy focused on AAC (Hustad & Miles, 2010). The fact that nearly all children in this

study produced vocalizations suggests that therapy focused on speech production is a valid and important target of intervention, and research to guide such interventions is currently growing (Levy, 2014; Pennington et al., 2018; Pennington, Miller, & Robson, 2009; Pennington & Noble, 2010; Pennington, Rauch, et al., 2019; Pennington et al., 2013; Pennington, Stamp, et al., 2019). For example, in a pilot randomized controlled trial, children with CP and moderate-to-severe speech motor impairments and their parents reported that intensive speech therapy focusing on creating a stronger voice and a steady speech rate increased the intelligibility of their speech (Pennington, Rauch, et al., 2019). However, the high frequency of unknown vocalizations observed within all three groups of children in this study suggests that children with CP who have little to no intelligible speech also would benefit from the use of AAC (Clarke & Price, 2012). Children in this study were interacting with their mothers, who are likely their most familiar communication partner, and even in this context, their communication acts were not always understood. This study highlights the need for multimodal communication, especially considering that, between the ages of 60 and 65 months, they are entering kindergarten and expected to communicate with a number of peers, teachers, and less familiar partners daily. Although only two children in this study communicated using AAC, those who did were able to communicate using a wider range of functions than the other children in their groups. The Hanen training program "It Takes Two to Talk," which involves a multimodal communication approach, has been tested in exploratory studies of preschool-age children with CP and showed increases in maternal responses to child communication as well as increases in child initiations, requests, and provisions of information (Pennington & Noble, 2010; Pennington & Thomson, 2007; Pennington, Thomson, et al., 2009). Results of this study indicate that these are appropriate intervention targets for children with CP in this age group.

Limitations and Future Directions

Children with CP are heterogenous, making it difficult to capture a representative sample of children and their abilities. A key limitation of this study is the small sample size ($n = 40$), which limits statistical power and generalization. We examined children in a narrow age range, which allowed us to control for the effects of chronological age on development; however, this limits generalization beyond this age. It is important to note that a group of children with CP who do not have speech motor impairments was not included in this study. This is a limitation that should be addressed in future work, as including children with CP who do not have speech motor impairments in studies would enable an investigation of whether the levels of gross motor impairment or speech motor impairment best predict the frequency of communication modes and functions within mother–child interactions.

This study examined the frequency and types of communication modes and functions that children with CP used. Future studies of interaction in children with CP would benefit from a detailed expressive language sample analysis and a standardized expressive language assessment with accommodations to determine how the frequency of behaviors relates to the complexity of children's expressive communication and the complexity of language input from the child's communication partner. Pairing results of behavioral coding with measures derived from language sample analysis have the potential to serve as robust outcome measures of communication intervention studies.

It will be critical for future studies to examine the change in mother–child interaction patterns in older and younger age groups and, longitudinally, to determine whether speech-language impairment profiles can predict the trajectories of change in these patterns. In particular, researchers have suggested that early patterns of interaction in infants with CP "fossilize" and remain throughout childhood (Hanzlik & Stevenson, 1986). Testing this hypothesis in the context of a longitudinal study may reveal the times in development at which profile groups of children with CP begin to diverge in their trajectories of communication behaviors.

Future work focusing on interactions of children with CP should also describe the roles of partners within interactions. The behavior of one member of each dyad, the child, was studied. This is an important limitation to note, as parent-mediated interventions have shown promise for this population (Pennington & Thomson, 2007; Pennington, Thomson, et al., 2009). In particular, sequential analyses examining both maternal and child behaviors would evaluate dyadic strengths and weaknesses that will enable refinements to parent-mediated speech-language interventions. Previous work has shown that, in a sample of children with CP who had quadriplegia, the severity of speech intelligibility deficits better predicts dyadic patterns of verbal interaction than the child's level of motor function (Pennington & McConachie, 2001b); however, it remains unknown whether this relationship is observed in a wider range of profiles of children with CP.

Another limitation to this study is that interactions were recorded in a laboratory setting. Previous studies of parent–child interaction in children with IDD used interaction samples that were recorded in the home. In-home interactions are clearly more natural, and it would be beneficial to obtain in-home interaction samples from children with CP in future studies, as they may have greater access to familiar toys and books, adaptive equipment, and spaces in which they are more comfortable maneuvering.

As described previously, nearly all children in this study used their voices to communicate. However, vocalizations were coded broadly, and children in this sample presented with a wide range of speech production abilities, ranging from brief open-vowel vocalizations to multiword utterances. Grouping all vocal behaviors within one category, vocalizations, and not distinguishing between vocal behaviors that include words or word approximations that were unintelligible and vocal behaviors that contain nonwords is a limitation. Currently, there is only a limited

number of studies that have sought to reliably code vocalizations in children with severe speech motor impairments. Methods from this study build upon coding procedures outlined in the study of Hustad et al. (2014), in which child vocal utterances from toddlers with CP included all types of vocalizations, such as babbling, jargon, and unintelligible words and word approximations. Future research with more refined coding of vocal behaviors in children with speech motor impairments would improve characterizations of expressive language skills in this population. For example, methods for language sample analysis in preschoolers with severe speech impairments and typical language skills have been proposed (Binger et al., 2016), which may allow for finer grained distinctions of vocalizations, but expanding the procedures to include children who also have language impairments was beyond the scope of this study.

It would be beneficial to develop refined coding schemes of vocalizations in future studies, to include operational definitions of open-vowel vocalizations, canonical vocalizations, word approximations, and single-word and multiword utterances, as this would allow an understanding of how speech-language profile groups relate to the child's speech production skills and use of vocalizations and verbalizations for a range of communicative functions. Similarly, this study used a narrow definition for gesture, and aspects such as facial expression, eye gaze, or idiosyncratic body movements were not coded, although many children with CP and IDD do communicate using these modes. Coding of these modes would require more flexible, multiview camera angles, which were not available for this study. In particular, the use of triadic eye gaze as a signal of coordinated joint attention would be especially useful for advancing our understanding of prelinguistic communication in this population. Dynamic assessment methods for evaluating triadic eye gaze in children with severe physical disabilities have been validated (Olswang et al., 2013). One randomized controlled study of a behavioral intervention for increasing triadic eye gaze has shown promise in improving early communication skills in children with severe gross motor impairments who are not yet speaking (Olswang et al., 2014).

Future research should examine interactions of children with CP with other partners, including fathers, siblings, and peers. Peer interactions of children with CP have received attention more recently, but these studies have been limited to children who use AAC devices (Anderson et al., 2011). Children in this study were observed interacting with toys, and observations from other contexts, such as book reading or during activities of daily living, may result in different patterns of communication. Contrasting patterns of interaction across communication partners and contexts may reveal a more refined understanding of a child's communication strengths and challenges.

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References

Anderson, K., Balandin, S., & Clendon, S. (2011). "He cares about me and I care about him." Children's experiences of friendship with peers who use AAC. *Augmentative and Alternative Communication, 27*(2), 77–90. https://doi.org/10.3109/07434618.2011.577449

Arneson, C. L., Durkin, M. S., Benedict, R. E., Kirby, R. S., Yeargin-Allsopp, M., Van Naarden Braun, K., & Doernberg, N. S. (2009). Prevalence of cerebral palsy: Autism and Developmental Disabilities Monitoring Network, three sites, United States, 2004. *Disability and Health Journal, 2*(1), 45–48. https://doi.org/10.1016/j.dhjo.2008.08.001

Bakeman, R., Quera, V., & Gnisci, A. (2009). Observer agreement for timed-event sequential data: A comparison of time-based and event-based algorithms. *Behavior Research Methods, 41*(1), 137–147. https://doi.org/10.3758/BRM.41.1.137

Bax, M., Tydeman, C., & Flodmark, O. (2006). Clinical and MRI correlates of cerebral palsy: The European Cerebral Palsy Study. *JAMA, 296*(13), 1602–1608. https://doi.org/10.1001/jama.296.13.1602

Binger, C., Ragsdale, J., & Bustos, A. (2016). Language sampling for preschoolers with severe speech impairments. *American Journal of Speech-Language Pathology, 25*(4), 493–507. https://doi.org/10.1044/2016_AJSLP-15-0100

Bornstein, M. H., Tamis-LeMonda, C. S., Hahn, C.-S., & Haynes, O. M. (2008). Maternal responsiveness to young children at three ages: Longitudinal analysis of a multidimensional, modular, and specific parenting construct. *Developmental Psychology, 44*(3), 867–874. https://doi.org/10.1037/0012-1649.44.3.867

Carrow-Woolfolk, E. (1999). *TACL-3: Test for Auditory Comprehension of Language*. Pro-Ed.

Chiarello, L. A., Almasri, N., & Palisano, R. J. (2009). Factors related to adaptive behavior in children with cerebral palsy. *Journal of Developmental & Behavioral Pediatrics, 30*(5), 435–441. https://doi.org/10.1097/DBP.0b013e3181b4ec54

Christensen, D., Van Naarden Braun, K., Doernberg, N. S., Maenner, M. J., Arneson, C. L., Durkin, M. S., Benedict, R. E., Kirby, R. S., Wingate, M. S., Fitzgerald, R., & Yeargin-Allsop, M. (2014). Prevalence of cerebral palsy, co-occurring autism spectrum disorders, and motor functioning—Autism and Developmental Disabilities Monitoring Network, USA, 2008. *Developmental Medicine & Child Neurology, 56*(1), 59–65. https://doi.org/10.1111/dmcn.12268

Clancy, K. J., & Hustad, K. C. (2011). Longitudinal changes in feeding among children with cerebral palsy between the ages of 4 and 7 years. *Developmental Neurorehabilitation, 14*(4), 191–198. https://doi.org/10.3109/17518423.2011.568467

Clarke, M., & Price, K. (2012). Augmentative and alternative communication for children with cerebral palsy. *Paediatrics and Child Health, 22*(9), 367–371. https://doi.org/10.1016/j.paed.2012.03.002

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*(1), 37–46.

Fleiss, J. L., Levin, B., & Paik, M. C. (1981). The measurement of interrater agreement. *Statistical Methods for Rates and Proportions, 2*(212–236), 22–23.

Grieco, F., Loijens, L., Zimmerman, P., & Spink, A. (2010). *The Observer XT reference manual*. Noldus Information Technology.

Hanzlik, J. R., & Stevenson, M. B. (1986). Interaction of mothers with their infants who are mentally retarded, retarded with cerebral palsy, or nonretarded. *American Journal of Mental Deficiency, 90*(5), 513–520.

Hodge, M., & Daniels, J. (2007). *TOCS+ Intelligibility Measures* [Computer software]. University of Alberta.

Hustad, K. C., Allison, K., McFadd, E., & Riehle, K. (2014). Speech and language development in 2-year-old children with cerebral palsy. *Developmental Neurorehabilitation, 17*(3), 167–175. https://doi.org/10.3109/17518423.2012.747009

Hustad, K. C., Gorton, K., & Lee, J. (2010). Classification of speech and language profiles in 4-year-old children with cerebral palsy: A prospective preliminary study. *Journal of Speech, Language, and Hearing Research, 53*(6), 1496–1513. https://doi.org/10.1044/1092-4388(2010/09-0176)

Hustad, K. C., & Miles, L. K. (2010). Alignment between augmentative and alternative communication needs and school-based speech-language services provided to young children with cerebral palsy. *Early Childhood Services (San Diego), 4*(3), 129–140.

Hustad, K. C., Oakes, A., McFadd, E., & Allison, K. M. (2016). Alignment of classification paradigms for communication abilities in children with cerebral palsy. *Developmental Medicine & Child Neurology, 58*(6), 597–604. https://doi.org/10.1111/dmcn.12944

Hustad, K. C., Sakash, A., Broman, A. T., & Rathouz, P. J. (2018). Longitudinal growth of receptive language in children with cerebral palsy between 18 months and 54 months of age. *Developmental Medicine & Child Neurology, 60*(11), 1156–1164. https://doi.org/10.1111/dmcn.13904

Hustad, K. C., Schueler, B., Schultz, L., & DuHadway, C. (2012). Intelligibility of 4-year-old children with and without cerebral palsy. *Journal of Speech, Language, and Hearing Research, 55*(4), 1177–1189. https://doi.org/10.1044/1092-4388(2011/11-0083)

Levy, E. S. (2014). Implementing two treatment approaches to childhood dysarthria. *International Journal of Speech-Language Pathology, 16*(4), 344–354. https://doi.org/10.3109/17549507.2014.894123

Light, J., Collier, B., & Parnes, P. (1985a). Communicative interaction between young nonspeaking physically disabled children and their primary caregivers: Part I—Discourse patterns. *Augmentative and Alternative Communication, 1*(2), 74–83. https://doi.org/10.1080/07434618512331273561

Light, J., Collier, B., & Parnes, P. (1985b). Communicative interaction between young nonspeaking physically disabled children and their primary caregivers: Part II—Communicative function. *Augmentative and Alternative Communication, 1*(3), 98–107. https://doi.org/10.1080/07434618512331273591

Light, J., Collier, B., & Parnes, P. (1985c). Communicative interaction between young nonspeaking physically disabled children and their primary caregivers: Part III—Modes of communication. *Augmentative and Alternative Communication, 1*(4), 125–133. https://doi.org/10.1080/07434618512331273621

Majnemer, A., Shevell, M., Hall, N., Poulin, C., & Law, M. (2010). Developmental and functional abilities in children with cerebral palsy as related to pattern and level of motor function. *Journal of Child Neurology, 25*(10), 1236–1241. https://doi.org/10.1177/0883073810363175

McFadd, E., & Hustad, K. C. (2013). Assessment of social function in four-year-old children with cerebral palsy. *Developmental Neurorehabilitation, 16*(2), 102–112. https://doi.org/10.3109/17518423.2012.723762

Novak, I., Hines, M., Goldsmith, S., & Barclay, R. (2012). Clinical prognostic messages from a systematic review on cerebral palsy. *Pediatrics, 130*(5), e1285–e1312. https://doi.org/10.1542/peds.2012-0924

Olswang, L. B., Dowden, P., Feuerstein, J., Greenslade, K., Pinder, G. L., & Fleming, K. (2014). Triadic gaze intervention for young children with physical disabilities. *Journal of Speech, Language, and Hearing Research, 57*(5), 1740–1753. https://doi.org/10.1044/2014_JSLHR-L-13-0058

Olswang, L. B., Feuerstein, J. L., Pinder, G. L., & Dowden, P. (2013). Validating dynamic assessment of triadic gaze for young children with severe disabilities. *American Journal of Speech-Language Pathology, 22*(3), 449–462. https://doi.org/10.1044/1058-0360(2012/12-0013)

Olswang, L. B., Pinder, G. L., & Hanson, R. A. (2006). Communication in young children with motor impairments: Teaching caregivers to teach. *Seminars in Speech and Language, 27*(3), 199–214. https://doi.org/10.1055/s-2006-948230

Parkes, J., Caravale, B., Marcelli, M., Franco, F., & Colver, A. (2011). Parenting stress and children with cerebral palsy: A European cross-sectional survey. *Developmental Medicine & Child Neurology, 53*(9), 815–821. https://doi.org/10.1111/j.1469-8749.2011.04014.x

Pennington, L., Goldbart, J., & Marshall, J. (2005). Direct speech and language therapy for children with cerebral palsy: Findings from a systematic review. *Developmental Medicine & Child Neurology, 47*(1), 57–63. https://doi.org/10.1111/j.1469-8749.2005.tb01041.x

Pennington, L., Lombardo, E., Steen, N., & Miller, N. (2018). Acoustic changes in the speech of children with cerebral palsy following an intensive program of dysarthria therapy. *International Journal of Language & Communication Disorders, 53*(1), 182–195. https://doi.org/10.1111/1460-6984.12336

Pennington, L., & McConachie, H. (1999). Mother–child interaction revisited: Communication with non-speaking physically disabled children. *International Journal of Language & Communication Disorders, 34*(4), 391–416. https://doi.org/10.1080/136828299247351

Pennington, L., & McConachie, H. (2001a). Interaction between children with cerebral palsy and their mothers: The effects of speech intelligibility. *International Journal of Language & Communication Disorders, 36*(3), 371–393. https://doi.org/10.1080/13682820110045847

Pennington, L., & McConachie, H. (2001b). Predicting patterns of interaction between children with cerebral palsy and their mothers. *Developmental Medicine & Child Neurology, 43*(2), 83–90. https://doi.org/10.1111/j.1469-8749.2001.tb00720.x

Pennington, L., Miller, N., & Robson, S. (2009). Speech therapy for children with dysarthria acquired before three years of age. *Cochrane Database of Systematic Reviews,* (*4*), Article CD006937. https://doi.org/10.1002/14651858.CD006937.pub2

Pennington, L., & Noble, E. (2010). Acceptability and usefulness of the group interaction training programme It Takes Two to Talk to parents of pre-school children with motor disorders. *Child: Care, Health and Development, 36*(2), 285–296. https://doi.org/10.1111/j.1365-2214.2009.01054.x

Pennington, L., Rauch, R., Smith, J., & Brittain, K. (2019). Views of children with cerebral palsy and their parents on the effectiveness and acceptability of intensive speech therapy.

Disability and Rehabilitation. Advance online publication. https://doi.org/10.1080/09638288.2019.1577504

Pennington, L., Roelant, E., Thompson, V., Robson, S., Steen, N., & Miller, N. (2013). Intensive dysarthria therapy for younger children with cerebral palsy. *Developmental Medicine & Child Neurology, 55*(5), 464–471. https://doi.org/10.1111/dmcn.12098

Pennington, L., Stamp, E., Smith, J., Kelly, H., Parker, N., Stockwell, K., Aluko, P., Othman, M., Brittain, K., & Vale, L. (2019). Internet delivery of intensive speech and language therapy for children with cerebral palsy: A pilot randomised controlled trial. *BMJ Open, 9*(1), e024233. https://doi.org/10.1136/bmjopen-2018-024233

Pennington, L., & Thomson, K. (2007). It Takes Two to Talk—The Hanen Program and families of children with motor disorders: A UK perspective. *Child: Care, Health and Development, 33*(6), 691–702. https://doi.org/10.1111/j.1365-2214.2007.00800.x

Pennington, L., Thomson, K., James, P., Martin, L., & McNally, R. (2009). Effects of It Takes Two to Talk—The Hanen Program for parents of preschool children with cerebral palsy: Findings from an exploratory study. *Journal of Speech, Language, and Hearing Research, 52*(5), 1121–1138. https://doi.org/10.1044/1092-4388(2009/07-0187)

Rathouz, P. J., & Gao, L. (2009). Generalized linear models with unspecified reference distribution. *Biostatistics, 10*(2), 205–218. https://doi.org/10.1093/biostatistics/kxn030

Shevell, M. I., Dagenais, L., & Hall, N. (2009). Comorbidities in cerebral palsy and their relationship to neurologic subtype and GMFCS level. *Neurology, 72*(24), 2090–2096. https://doi.org/10.1212/WNL.0b013e3181aa537b

Sigurdardottir, S., & Vik, T. (2011). Speech, expressive language, and verbal cognition of preschool children with cerebral palsy in Iceland. *Developmental Medicine & Child Neurology, 53*(1), 74–80. https://doi.org/10.1111/j.1469-8749.2010.03790.x

Smits, D.-W., Ketelaar, M., Gorter, J. W., van Schie, P., Dallmeijer, A., Jongmans, M., & Lindeman, E. (2011). Development of daily activities in school-age children with cerebral palsy. *Research in Developmental Disabilities, 32*(1), 222–234. https://doi.org/10.1016/j.ridd.2010.09.025

Thomas-Stonell, N., Oddson, B., Robertson, B., & Rosenbaum, P. (2012). Validating the FOCUS (Focus on the Outcomes of Communication Under Six). *Developmental Medicine & Child Neurology, 54,* 32–33.

Warren, S. F., & Brady, N. C. (2007). The role of maternal responsivity in the development of children with intellectual disabilities. *Mental Retardation and Developmental Disabilities Research Reviews, 13*(4), 330–338. https://doi.org/10.1002/mrdd.20177

Warren, S. F., Brady, N. C., Sterling, A., Fleming, K., & Marquis, J. (2010). Maternal responsivity predicts language development in young children with fragile X syndrome. *American Journal on Intellectual and Developmental Disabilities, 115*(1), 54–75. https://doi.org/10.1352/1944-7558-115.1.54

Zimmerman, I., Steiner, V., & Pond, R. (2002). *Preschool Language Scale–Fourth Edition*. The Psychological Corporation.