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Longitudinal development of communication in children with cerebral palsy between 24 and 53 months: Predicting speech outcomes

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Abstract

Objective—To determine whether communication at 2 years predicted communication at 4 years in children with cerebral palsy (CP); and whether the age a child first produces words imitatively influences change in speech production.

Method—30 children (15 males) with CP participated and were seen 5 times at 6 month intervals between 24 and 53 months (mean age at time 1 = 26.9 months (SD 1.9)). Variables were communication classification at 24 and 53 months, age that children were first able to produce words imitatively, single word intelligibility, and longest utterance produced.

Results—Communication at 2 years was highly predictive of abilities at 4 years. Speaking earlier led to faster gains in intelligibility and length of utterance and better outcomes at 53 months than speaking later.

Conclusion—Inability to speak at 24 months indicates greater speech and language difficulty at 53 months and a strong need for early communication intervention.

Keywords

dysarthria; speech; language; intelligibility; communication development; longitudinal study

Introduction

The majority of children with cerebral palsy (CP) experience some type of speech, language, and/or communication problem. In fact, estimates suggest that 60% [1] of children with CP may experience some type of communication difficulty. Problems may include: dysarthria, a

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Declaration of interest

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speech motor disorder that often has critical detrimental impacts on speech intelligibility and is estimated to affect about half of children with CP [2]; language and/or cognitive difficulties, also affecting approximately half of children with CP [3, 4]; or a combination of both speech and language/cognitive problems [5]. Communication deficits have been shown to have significant negative impacts on social participation, educational participation and overall quality of life [6, 7].

Speech, language, and communication skills are acquired developmentally and emerge gradually over time, with production of first words being an early and observable milestone emerging at about one year of age in typically developing children. Many children with CP are delayed in their early speech and language development [8], yet frequently do not receive the speech and language therapy they need [9]. Identification of speech, language, and communication problems at the youngest possible age is critical to enable delivery of interventions that maximize outcomes [10].

Speech, language, and communication interventions encompass a wide array of options, ranging from reducing underlying impairments in body functions and structures to augmentative and alternative communication (AAC) systems and strategies which can be used in place of speech, or to enhance comprehensibility of productions [10, 11]. At present, there is no way to predict at an early age which children with CP will develop functional speaking abilities and which children will have persisting difficulty with functional communication necessitating long-term use of AAC systems and/or strategies. Choosing the best intervention direction for young children can be difficult when long term prognoses for the development of functional speech are unknown. Thus, there is an urgent need to identify early predictors of later outcomes.

In earlier work, we developed a model for classifying speech and language profiles in 4-year old children with CP [5, 12]. Using prospective behavioral speech and language data from 4-year old children, this research employed a four profile group model based on the presence or absence of speech motor involvement and the presence or absence of receptive language involvement. Specifically, we tested how well 4-year old children could be classified into four profile groups as follows: those with no speech motor involvement (NSMI); those with speech motor involvement and language comprehension in the typical range (SMI-LCT); those with speech motor involvement and language comprehension impairment (SMI-LCI); and those with anarthria who were unable to produce speech (ANAR). Results showed that children in the sample with CP could be classified into these profile groups with up to 97% consistency. Of the children in the sample, 24% were in the NSMI group, 26% were in the SMI-LCT group, 18% were in the SMI-LCI group, and 32% were in the ANAR group at 4 years of age.

In another study [8], our group examined early speech and language ability clusters of children with CP at 2 years of age. Because definitive determination of the presence or absence of speech motor involvement, a key component of our classification model, is difficult or even impossible at 2 years of age for some children, particularly those with mild or subtle deficits, our 4-group profile model could not be employed at this age level. Thus we sought to identify an alternative classification paradigm relevant to younger children with

CP. To do this, we examined communication samples obtained through parent-child interaction that were quantitatively analyzed using language transcript analysis, parent report of expressive vocabulary, and standardized language comprehension test scores. Results revealed three clusters of children for which the primary differentiating variables were expressive language skills. The first cluster comprised children who were not yet talking as indicated by almost no words or word approximations and limited vocal play (44% of the sample). The second cluster comprised children who were emerging talkers as indicated by a small productive repertoire of words and few word combinations, limited intelligibility, and the presence of considerable vocal play and unintelligible vocalizations (41% of the sample). The third and smallest cluster comprised children who were established talkers as indicated by expressive language skills that were within the range of typical age-level expectations (15% of the sample).

A critical question that has not been addressed previously is the extent to which early communication clusters at 2 years of age predict later speech and language profile group membership at 4 years of age. Similarly, the question of whether the age at which children begin producing single words has predictive value for later speech development has not been previously addressed. Such information could have important intervention implications, especially for the early implementation of AAC systems and strategies for children who are unlikely to develop functional speaking abilities later. In the present study, the following specific questions were addressed:

1. Does communication ability at 2 years of age (as indicated by early cluster group membership) predict speech and receptive language outcomes at 4 years of age (as indicated by later speech language profile group membership)?
2. Does the age by which a child begins imitating single words predict change over time in speech production abilities, as indicated by longitudinal-measures of speech intelligibility and maximum length of utterance?

Method

Participants

Participants were selected from a cohort of children with CP who were participating in a larger prospective longitudinal study of communication development. Children were recruited through local and regional neurology and physiatry clinics in the upper Midwestern region of the United States. Recruitment efforts sought to capture a representative sample of children with CP that was not biased for or against the presence of speech or language problems. Criteria for inclusion in the larger study required that children: 1.) have a medical diagnosis of CP; and 2.) have hearing abilities within normal limits as documented by either formal audiological evaluation or distortion product otoacoustic emission screening; and 3.) be between the ages of 18 and 54 months upon initial enrollment. All children who met these criteria were included in the larger study. Children were seen at 6 month intervals for comprehensive speech-language evaluations.

In the present paper, we were interested in examining early predictors of speech and language outcomes observed at 4 years of age, a time when children are expected to have well-established speech and language skills. We selected 2 years as our earliest sampled time point for this study because this is an age when speech and expressive language milestones such as word production should be readily observable in typical children. In addition, we were interested in determining how well early clusters, identified in our previous study [8], predicted later speech and language ability profiles [5]. Therefore, we included the subset of children who contributed data to the larger study at both 24–29 and also at 48–53 months of age. A total of 33 children were seen for data collection between 24–29 months of age. Of these, two were lost to attrition and were not seen at 48–53 months of age; and one received a co-diagnosis of autism spectrum disorder and was thus excluded. We chose to omit this child because children on the autism spectrum have a range of unique and specific communication characteristics that differ considerably from those associated with CP. A total of 30 children were included in the present study; all children contributed 5 longitudinal data points at 6 month intervals, starting at age 24–29 months. There were no missing data in this sample.

Collectively, children reflected the upper Midwestern region of the United States with regard to socioeconomic status and race (i.e. primarily middle and upper middle class families; primarily Caucasian). All children were from homes where American English was the primary language. Children were born in the United States between 2003 and 2009. Mean ages across children for each 6 month longitudinal sampling point were as follows: 24–29 month age band = 26.9 months (SD 1.9); 30–35 month age band = 32.8 months (SD 1.72); 36–41 month age band = 38.7 months (SD 1.8); 42–47 month age band = 44.2 months (SD 1.7), and 48–53 month age band = 49.9 months (SD 1.7). The sample comprised 15 males; 15 females.

Materials and Procedures

For the larger longitudinal study, a prospective speech-language evaluation protocol was administered by a research speech-language pathologist (SLP) in a sound-attenuating suite. The same testing room, stimulus materials, and assessment tools were employed for each child at each longitudinal data collection session. The play-based sessions lasted approximately two hours; all children tolerated this without difficulty. All sessions were audio and video recorded with professional-quality recording equipment [Audio-Technica AT4040 microphone; Marantz PMD 570 audio recorder; Canon XHA1s video camera]. The research protocol included administration of a standard assessment battery focused on speech production, receptive and expressive language, and spontaneous communication in a parent-child interaction. For the present study, key measures of interest were obtained using speech stimuli from the Test of Children's Speech (TOCS+) [13], which is based on a set of developmentally appropriate words and sentences that systematically vary in length between 1 and 7 words. We used a subset of stimuli from the TOCS that were the same for each child and each longitudinal visit. These stimuli included 42 single words, and 10 sentences each comprised of 2, 3, 4, 5, and 6 words. During administration of the TOCS+ stimuli, children are asked to repeat each stimulus item following an adult model presented on a computer.

Children were classified at 24–29 months of age into one of three early profile groups following our earlier work [8]: 1.) not yet talking; 2.) emerging talkers; and 3.) established talkers. Note that 27 of the 30 children in the present study comprised the full sample of our earlier study aimed at identifying these early classification groups. For those 27 children, classifications were empirically derived in the previous study and are used in the present study. The three children who were not included in the earlier study joined the project at a later point in time and were classified by a research SLP based on quantitative examination of number of words produced in spontaneous speech, mean length of utterance in spontaneous speech, and speech intelligibility. Table 1 presents demographic characteristics of the children according to classification group at 24–29 months of age. At this age range, only 4 of the 30 children were established talkers.

At 48–53 months, children were classified into one of four speech language profile groups (SLPG) [5, 12] based on prospective clinical measurement of speech motor and language abilities. Children with no speech motor involvement (NSMI) had no clinical evidence of speech or language comprehension impairment. Children with speech motor involvement and typical language comprehension abilities (SMI-LCT) had clinical evidence of dysarthria as described in our previous work (see Hustad and colleagues, 2010, 2015) and language comprehension skills as measured by standardized test scores that were within one standard deviation from the mean. Children with speech motor involvement and language comprehension impairment (SMI-LCI) met the same criteria for speech motor involvement, but had standardized language comprehension scores below one standard deviation from the mean. Children who were unable to speak were classified as anarthric (ANAR). We defined anarthria as the ability to produce fewer than 5 words or word approximations using natural speech. Children in the ANAR group had a range of language abilities, with all children having language impairment as indicated by standardized test scores. Classifications were made by a research SLP based on empirical data (i.e., language comprehension scores, intelligibility scores, oral motor performance) and on review of videotaped spontaneous communication samples, as needed. This SLP was not involved in data collection from any of the children. However, the research SLP was personally familiar with the children, having interacted with all children multiple times at older ages. A second person also classified all children using the same data as the first rater. Classification agreement was 100%. Table 2 presents demographic characteristics of children by SLPG. At 4 years of age, 19 of the 30 children were verbal communicators.

Because many children in the sample began consistently talking between the ages of 2 and 4, we wanted to include a measure that reflected timing of speech onset. For the purpose of this study, this was operationalized as the age band at which each child was first able to produce at least single word utterances from the TOCS+ [13] in an elicitation task. To meet criteria for being categorized as “talking”, children were required to produce approximations of all 42 of the single word TOCS+ items. We note that this is a stringent criteria upon which to base a judgement of whether a child is talking or not. It is possible that some of the children in our sample were producing a limited number of words or even sentences in spontaneous interaction, but were not able to complete the single word TOCS+ elicitation task. However, in our extensive laboratory experience collecting speech data from young children, the vast majority of typically developing children are able to complete at least single word elicitation tasks using TOCS+ stimuli by 24 months of age. Thus, we felt that this index was a reasonable, although crude, indicator relative to chronological age expectations.

In addition, the maximum utterance length each child was able to produce from the TOCS+ was noted and employed as a variable for each longitudinal session. Maximum utterance length was operationally defined as the longest utterance length (ranging from single words to 7 word utterances) for which each child was able to produce 5 or more (from 10 possible) sentences imitatively from the TOCS+ standard corpus used for the larger longitudinal project.

Intelligibility scores for children who were able to produce speech were obtained using standard intelligibility measurement procedures [11]. Specifically, 5 unfamiliar listeners individually made orthographic transcriptions of audio recordings from each child producing single words from the TOCS+. Different listeners were employed for each longitudinal session for each child to avoid a potential learning effect. Listeners completed this task in a sound proof booth. Presentation levels of speech stimuli were controlled and were held constant at a peak loudness level of 75dB SPL. Intelligibility was scored as the percent of words identified correctly by each listener, averaged across the 5 listeners per child per longitudinal time point. Intelligibility was calculated separately for each longitudinal session in which children were able to produce speech.

Collectively, the following variables were examined for each child in the present study: 1.) speech-language classification at 24–29 months of age following our previous work [8]; 2.) speech-language profile group (SLPG) at 48-43 months of age following our previous work [5]; 3.) age by which the child began producing single words from the TOCS+ imitatively ; 4.) intelligibility of single words from the TOCS+ at each longitudinal time point; and 5.) maximum utterance length the child was able to produce from the TOCS+ at each longitudinal time point.

Statistical analysis

We hypothesized that communication cluster group membership at 2 years would predict speech-language profile group at 4 years and tested this hypothesis with Fisher's exact test applied to the 3-by-4 table. To examine whether and to what extent the age by which a child begins producing single word utterances in imitation influences change over time in speech production abilities, as indicated by measures of single word speech intelligibility and longest utterance produced, we employed linear mixed effects regression models [14]. We used either word intelligibility score or longest utterance produced as the longitudinal response variable, and age at which children first produced single words in imitation, time since children first produced single words in imitation, and the interaction between age of first imitative single word productions and time since first imitative single word productions as key predictors. Time since first imitative single word productions (versus age) was the key measure of longitudinal time in order to meaningfully quantify and compare developmental trends from the point in time when imitative productions began. To fully account for and exploit the longitudinal design to increase statistical efficiency, we included a random intercept term for each subject in the model.

Results

Predicting 4-year old profile groups

Table 3 shows the relationship between communication cluster group membership at 2 years of age and speech-language profile group membership at 4 years of age. Using Fisher's exact test, results indicated that children who were not talking at 2 years of age (time 1) were more likely to be unable to speak (ANAR) at 4 years of age (time 5). Emerging and established talker groups at 2 years of age were more likely to be in SMI-LCT or NSMI profile groups at 4 years of age, with established talkers having the best outcomes (p-value=0.0001).

Predicting longitudinal speech production abilities

The relationship of word intelligibility score (%) to age of first imitative single word productions and time since first imitative single word productions is presented in Figure 1; the analogous relationship for longest utterance (count) is shown in Figure 2. Three observations are noteworthy from these figures. First, as expected, word intelligibility dramatically increased with age once children began producing single words in imitation. Second, the rate of increase (slope) for intelligibility and length of utterance as a function of age was qualitatively similar for the three groups (i.e., children who began producing single words in imitation at 24, 30, and 36 months), although somewhat attenuated for children who began producing single words in imitation at older ages (this effect is statistically significant in the regression models). Third, children who began producing single words in imitation by 24 months, by 30 months, or by 36 months all had mean initial intelligibility around 20% and length of utterance of 1–2 words when they began producing single words in imitation.

Mean word intelligibility was estimated to increase at a rate of 1.10 percentage points per month from the age of first imitative single word productions for a child who began speaking at 36 months (Table 4, p<.002). The rate of word intelligibility gain after first imitative single word productions was estimated to be slightly lower (−0.07 percentage points per month, p=.05) for every additional month of age of onset for single word production, so that those who started producing single words in imitation *later* increased intelligibility *more slowly*. Finally, the effect of age at first imitative single word productions on mean word intelligibility was not significant (p=0.55), indicating that intelligibility did not differ among children at the age of their first imitative single word productions, regardless of how old they were. Nevertheless, the overall effect of age at first imitative single word productions, jointly on the mean level and on the slope was significant (F=4.30 (2 df), p=0.018).

Very similar results were obtained for longest utterance. The word count for mean longest utterance was estimated to increase at a rate of 0.10 word per month for a child with first imitative single word productions at 36 months (p=0.0004). Again, the rate of gain for mean longest utterance after first imitative single word productions was lower (−0.008 words per month, p=.0002) for every additional month of age of first imitative single word productions, so that those who started producing single words *later* increased length of utterance *more* *slowly*. Finally, as expected, the longest utterance at the age of first imitative single word productions was relatively constant, between one and two words, regardless of how old they were ($p<0.22$). Overall, the joint effect of age at first single word imitative production, on mean level and on the slope was significant ($F=5.72$ (2 df), $p=0.005$).

Discussion

In this prospective longitudinal study, we examined how well communication abilities at 2 years of age predicted speech and language abilities at 4 years of age in children with CP. We also examined the extent to which the age at which a child is first able to imitate single word productions influences change over time in speech production abilities. There were three key findings from the present study. First, communication abilities at 2 years of age were highly predictive of outcomes at 4 years of age. In particular, children who were not yet talking at 2 years of age were very likely to have significant communication challenges at 4 years of age. Second, when children began consistently producing single words in imitation, they tended to look similar at that point in development in terms of intelligibility and length of utterance, regardless of the age at which this milestone occurred. Third, the age at which children began consistently producing single words in imitation had a significant impact on the rate of change in intelligibility and utterance length, such that children who produced single words in imitation at earlier ages tended to make faster gains in intelligibility and faster gains in length of utterance. Key findings are discussed below.

Predicting speech-language profile group at 4 years

At 2 years of age, it is challenging to separate speech development from language development as they are integrally connected in early communication. Specifically, having something to say (language) drives the desire to speak, though speech motor skills must be sufficient for the production (or even approximation) of words. If a child with CP is not talking at 2 years of age, it is difficult to determine whether the cause relates to language and / or cognitive delay, to speech motor deficits, or to both. In this study, speech and language abilities were characterized using two empirically-based classification paradigms, one based on early (2 years of age) communication behavior with an emphasis on expressive language [8], and the other based on observed speech and language profiles at 4 years of age with an equal emphasis on speech motor abilities and receptive language [5]. We sought to examine how well early classification group membership predicted later classification group membership.

Results indicated that 73% of children in this sample who were not yet talking at 2 years of age, were still unable to speak (anarthric) at 4 years of age. The remaining 27% of children who were not talking at 2 years of age went on to develop speech by 4 years of age, but all had speech motor involvement. None of the children in this study who were not talking at 2 years of age went on to have typical speech and language abilities at 4 years. Thus, early expressive communication abilities or the lack thereof appear to be an important indicator of later communication problems.

Of those children who were emerging talkers at 2 years of age, 27% had no evidence of speech motor involvement (NSMI group) at 4 years of age and thus appeared to be typically developing, having caught up to age level expectations for both speech and language. However, 73% had speech motor involvement, suggesting that the presence of early expressive communication delay in children with CP at 2 years of age may be a good indicator of later communication problems for most, but not all, children. It is noteworthy that 81% of the emerging talkers at 2 years of age had age appropriate language comprehension skills at 4 years of age (of these 27% had no speech motor involvement; 54% had speech motor involvement and typical language comprehension skills), thus early expressive communication delays may be more predictive of speech motor involvement than of language abilities.

Finally, established talkers at 2 years of age had the best outcomes at 4 years of age, with all children having intact language comprehension abilities, and 25% of children having no evidence of speech motor involvement. However, 75% of these children had speech motor involvement and thus would be expected to experience some communication difficulty, in spite of what appears to be strong early communication abilities.

Impact of age at first imitative single word productions on speech characteristics and change over time

In this study, when children first began producing single words in imitation from the TOCS +, their intelligibility on average was about 20%, regardless of the age by which they became able to do so. In addition, the longest utterance that children were able to produce was similar, at about 1–2 words, at the time children became able to produce single words in imitation, regardless of their age. Single word intelligibility of early word productions in typically developing children has not been empirically quantified, making findings of this study difficult to interpret relative to age expectations. However, it is well known that length of utterance when children begin speaking (around 1 year of age), is at a single word level. Thus, length of utterance for children with CP in this study is generally consistent with what we expect in typical children when they begin producing spoken language.

Children who began producing single words in imitation earlier made faster gains in intelligibility and length of utterance than children who began producing single words in imitation later. In addition, outcomes for intelligibility and utterance length at 53 months of age varied among groups of children who began producing single words in imitation at different ages. In particular, those who began producing single words in imitation earlier tended to have the highest intelligibility and produce the longest utterances later. Interestingly, even the most advanced children, who began producing single words in imitation by 24 months of age, as a group, had reduced intelligibility relative to what would be expected for 4-year old children who are typically developing [15]. This finding suggests that delays in intelligibility development may be a feature of early communication among children with CP. Other groups of children with later onset of single word imitative production showed even larger reductions in speech intelligibility at 4 years of age, indicating a persistent need for intelligibility-related intervention throughout the preschool years. Collectively results suggest that children with CP may experience intelligibility delays through 4 years of age, regardless of when they became able to produce single word utterances in imitation or their speech and language profile group membership.

Overall, results of this study suggest that communication abilities at 2 years of age may be predictive of later abilities at 4 years of age for children with spastic CP and that earlier onset of more advanced communication abilities is a good sign for later outcomes. In addition, early speech production ability, specifically the age at which children begin to speak well enough to consistently produce single words in imitation is predictive of later speaking abilities, in particular how intelligible children become and the longest utterance that children are able to produce leading up to 4 years of age. Because many children who are not talking at 2 years of age do not have functional speaking ability by 4 years of age, one clear implication of this work is that AAC interventions should be considered as a means for fostering functional communication, expressive language development and speech development by 2 years of age for those who are not yet talking as well as for those with emerging expressive communication skills.

Limitations

This study had several important limitations. First the sample size was small, and is not fully representative of the larger population. Specifically, all children in this study had spastic CP. Other types of CP including dyskinetic and ataxic were not represented in our sample. In addition, the measure we used as an early predictor of speech ability, the age at which a child was first able to produce single words in an imitation task, has some limitations. This measure is a general index of early speech production ability, which may under-estimate the onset of speech production in more naturalistic environments. For example, children in the sample may have been able to produce some words or even some sentences spontaneously, but yet not have been able to complete a single word imitation task. Although our findings were robust with regard to how well early imitative ability predicts later speech abilities (intelligibility and length of utterance), data should be interpreted with caution. Data presented here reflect change to 53 months of age. We fully expect that children will continue to make gains in their speech, language and communication ability beyond 53 months of age, thus a longer duration of longitudinal study is necessary to advance our understanding of rates and limits of change through childhood. Future studies should examine change in speech and language variables with more children and over a longer window of time to further our understanding of other variables that may predict outcomes at later ages.

Future studies

AAC systems and strategies have the potential to advance functional communication skills in meaningful and important ways and to uncover latent language skills that are not otherwise observable using traditional measures. Future studies should examine change over time in communication development simultaneously with AAC interventions to characterize what may be possible given the right intervention early in life.

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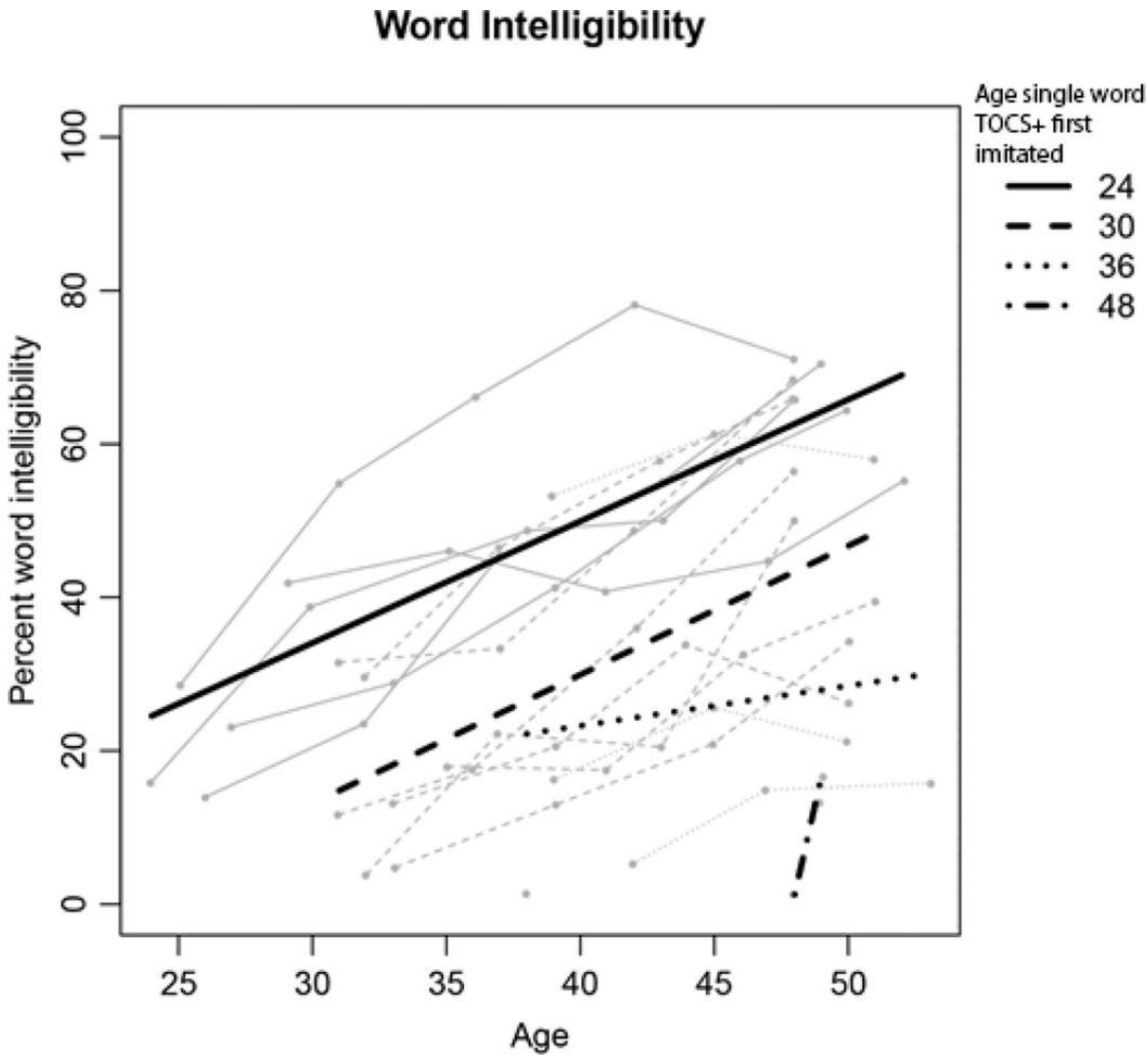

Figure 1.

Longitudinally-assessed TOCS+ word intelligibility score (%) by age and age single word TOCS+ was first imitated1. Thin lines are individual children. Thick lines are group-specific least squares regression fits as a function of time (months) since onset of single word production.

[1] None of the participants had an age of onset for single word productions in the 42 month age interval.

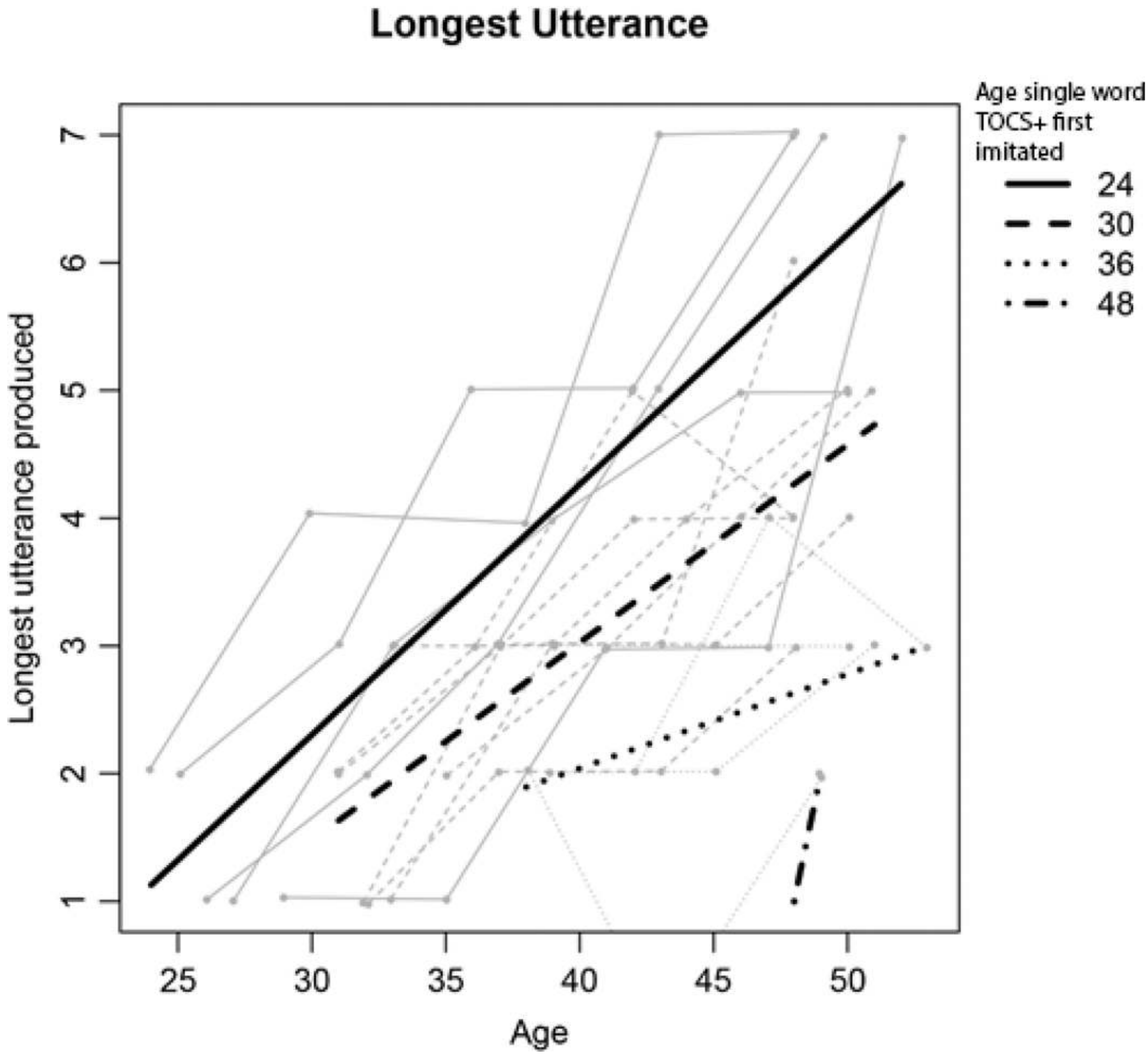

Figure 2.

Longitudinally-assessed TOCS+ longest utterance by age and age single word TOCS+ was first imitated2. Thin lines are individual children. Thick lines are group-specific least squares regression fits as a function of time (months) since onset of single word production.

[2] None of the participants had an age of onset for single word productions in the 42 month age interval.

Table 1

Demographic and clinical characteristics of children with CP at 2 years of age by early talker group classification (time 1).

	Established talkers n = 4	**Emerging talkers n = 11**	**Not yet talking n = 15**	**All children**
Mean Age (Std. Deviation)	26.3 (2.2)	26.8 (1.4)	27.1 (2.1)	26.9 (1.9)
Male: Female ratio	2: 2	4: 7	9: 6	15:15
Type of CP				
Spastic*				
Diplegia	1	2	0	3
Hemiplegia (left)	0	3	1	4
Hemiplegia (right)	2	5	1	8
Triplegia	0	0	0	0
Quadriplegia	1	1	13	15
Unknown	0	0	0	0
GMFCS at 2 years	2	5	1	8
I	0	2	0	2
II	1	2	1	4
III	1	2	3	6
IV	0	0	10	10
V				
Vision at 2 years	2	4	2	8
Within normal limits	0	2	2	4
Corrected	0	0	0	0
Uncorrected	0	0	6	6
Cortical Visual Impairment	2	4	3	9
Strabismus	0	1	2	3
Other				

*Note that there were no children in the present study with dyskinetic or ataxic CP. Thus, findings of this study should be considered primarily as pertaining to children with spastic CP

Table 2

Demographic and clinical characteristics of children with CP at 4 years of age (in months) by speech language profile group (time 5).

	ANAR n = 11	SMI-LCI n = 4	SMI-LCT n = 11	NSMI n = 4
Mean Age (SD)	50.6 (1.8)	50.8 (2.06)	49.6 (1.29)	48.3 (.5)
Male: Female ratio	7: 4	1: 3	4: 7	3: 1
Type of CP				
Spastic				
Diplegia	0	1	2	0
Hemiplegia (left)	0	0	2	2
Hemiplegia (right)	0	2	4	2
Triplegia	0	0	0	0
Quadriplegia	11	1	3	0
GMFCS at 4 years	0	0	4	4
I	1	0	1	0
II	0	2	3	0
III	1	0	1	0
IV	9	2	2	0
V				
Standard language comprehension score at 4 years (SD)*	50.0 (0)	75.3 (17.6)	97.5 (10.0)	104.5 (10.1)
Single word intelligibility score (%) at 4 years (SD)	NA	35.1 (17.5)	37.5 (23.2)	69.0 (2.4)
Age at which child began producing single words**	0	0	3	2
24–29 mos	0	2	3	2
30–35 mos	0	1	3	0
36–41 mos	0	0	0	0
42–47 mos	0	0	2	0
48–53 mos				
Longest utterance (words) at 4 years of age (SD)	NA	2.8 (2.1)	3.9 (2.0)	6.0 (1.4)

*Language comprehension standard scores were obtained from the Test of Auditory Comprehension of Language – 3, or from the Preschool Language Scale - 4

**Note that age at which child began producing single words is not reported for children who were not talking by the 48–53 month data collection session.

Table 3

Speech-language profile group membership at age 4 years versus early communication cluster group membership at 2 years of age.

	ANAR	SMI-LCI	SMI-LCT	NSMI
Not Talking	11 (73.3%)	2 (13.3%)	2 (13.3%)	0 (0%)
Emerging Talkers	0 (0%)	2 (18.2%)	6 (54.5%)	3 (27.3%)
Established Talkers	0 (0%)	0 (0%)	3 (75%)	1 (25%)

Fisher's exact test p=0.0001

Table 4

Word intelligibility score (%) and Longest utterance (count) versus Time since onset of single word productions and Age at first single word production

Word Intelligibility (%)	**Estimate**	**Std. Error**	**Df**	**t value**	**Pr(>|t|)**
(Intercept)	12.83	4.91	17.7	2.61	0.017810
Time (months) since single word production	1.10	0.32	30.8	3.42	0.001784
Age at first single word production (months)[1*]	−0.34	0.56	16.7	−0.60	0.554200
Time × Age[*]	−0.07	0.03	21.3	−2.11	0.046970

Longest Utterance (count)	**Estimate**	**Std. Error**	**df**	**t value**	**Pr(>|t|)**
(Intercept)	1.47	0.30	28.6	4.87	0.0000375
Time (months) since single word production	0.10	0.03	53.5	3.76	0.0004257
Age at first single word production (months)[1**]	0.04	0.03	23.2	1.26	0.2186000
Time × Age[**]	−0.008	0.00	50.6	−3.21	0.0023160

[*] Simultaneous test of Age at first single word production and Time × Age: F=4.30 (2 df), p=0.018.

[1] Age at first single word production was centered at age=36 months.

[**] Simultaneous test of Age at first single word production and Time × Age: F=5.72 (2 df), p=0.005.

[1] Age at first single word production was centered at age=36 months.