Comprehension of spoken language in non-speaking children with severe cerebral palsy: an explorative study on associations with motor type and disabilities

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ABBREVIATIONS

C-BiLLT	Computer-based instrument for low motor language testing
MACS	Manual Ability Classification System

AIM To assess spoken language comprehension in non-speaking children with severe cerebral palsy (CP) and to explore possible associations with motor type and disability.
METHOD Eighty-seven non-speaking children (44 males, 43 females, mean age 6y 8mo, SD 2y 1mo) with spastic (54%) or dyskinetic (46%) CP (Gross Motor Function Classification System [GMFCS] levels IV [39%] and V [61%]) underwent spoken language comprehension assessment with the computer-based instrument for low motor language testing (C-BiLLT), a new and validated diagnostic instrument. A multiple linear regression model was used to investigate which variables explained the variation in C-BiLLT scores. Associations between spoken language comprehension abilities (expressed in *z*-score or age-equivalent score) and motor type of CP, GMFCS and Manual Ability Classification System (MACS) levels, gestational age, and epilepsy were analysed with Fisher's exact test. A p-value <0.05 was considered statistically significant.
RESULTS Chronological age, motor type, and GMFCS classification explained 33% ($R=0.577$, $R^2=0.33$) of the variance in spoken language comprehension. Of the children aged younger than 6 years 6 months, 52.4% of the children with dyskinetic CP attained comprehension scores within the average range (z-score ≥-1.6) as opposed to none of the children with spastic CP. Of the children aged older than 6 years 6 months, 32% of the children with dyskinetic CP reached the highest achievable age-equivalent score compared to 4% of the children with spastic CP. No significant difference in disability was found between CP-related variables (MACS levels, gestational age, epilepsy), with the exception of GMFCS which showed a significant difference in children aged younger than 6 years 6 months ($p=0.043$).
INTERPRETATION Despite communication disabilities in children with severe CP, particularly in dyskinetic CP, spoken language comprehension may show no or only moderate delay. These findings emphasize the importance of introducing alternative and/or augmentative communication devices from early childhood.

Cerebral palsy (CP), primarily a motor disorder, is often accompanied by a range of impairments including disabilities in communication.[1] It has been shown that the severity of motor impairment in CP (expressed in Gross Motor Function Classification System [GMFCS] level)[2] is related to the prevalence of disabilities in communication.[3–5] Indeed, disabilities in expressive and/or receptive communication are present in 50 to 75% of children with CP corresponding to GMFCS levels I to III, increasing to 100% in children with severe CP (corresponding to GMFCS levels IV and V).[5] Children with severe CP often have severe dysarthria (unintelligible speech) or anarthria (absence of speech) besides involuntary movements and/or restrictions in manual abilities (expressed in Manual Ability Classification System [MACS] level)[6] that affect gesturing. Therefore, discrepancies are likely to occur between expressive communication abilities (language production or gesturing) and receptive communication abilities (language comprehension).

Early insight in communication abilities is important as it affects the way communication partners choose to interact with the child.[7] Additionally, insight in communication abilities provides valuable information on what type of education program and/or which augmentative and/or alternative communication system would best support the individual child.[8–10] Most studies involving communication in children with CP have focused on expressive language, (verbal) intelligence, and overall communication abilities concerning all GMFCS levels.[3–5,7] The present study focuses on receptive communication abilities in children with CP with the most severe motor limitations (i.e. GMFCS levels IV and V).

In clinical practice, different diagnostic tests are available to assess the comprehension of spoken language (for a review see Geytenbeek et al.[11]). However, all these tests require motor action, such as manipulating or handling small objects on command or pointing at pictures or objects. Extensive or substantial efforts have been made to adjust the access methods and/or modify the test procedures for children with severe CP.[12–14] Nevertheless, most children with CP who are eligible and included in these studies still showed at least some manual ability or were (to some extent) able to communicate orally. For children with CP with severely limited mobility (including the absence of manual ability skills), and with the most severe communication disabilities (i.e. absence of verbal communication abilities), the test scores based on available diagnostic measures may not be a true reflection of their language abilities, as it remains unclear whether test errors arise from the child's difficulty in performing the motor skills required to provide a response (e.g. pointing to a response item) or from poor language comprehension.[11,15,16]

To address this problem, our group developed the C-BiLLT (computer-based instrument for low motor language testing) that requires minimal, if any, motor action (for details see Geytenbeek et al.[8,17]). Reliability and validity measures of the C-BiLLT have been investigated in an extensive sample throughout the Netherlands in both Dutch children with typical development (*n*=806) aged from 1 year 6 months to 7 years and children with severe CP (*n*=87) aged from 1 year 7 months to 11 years 11 months. The intra- and interobserver reliability scores were excellent for children with typical development as well as for children with CP (as measured by interclass correlation coefficients and standard error of measurement). Good validity measures were found: factor analysis resulted in a unidimensional factor with an explained variance of 76%; a high correlation with other language tests (the Reynell developmental language scales[18] and the Peabody picture vocabulary test[19]); and a low correlation with a non-verbal logic reasoning test (Coloured progressive matrices[20]). Reliability and validity measures were good and appropriate for the use of diagnostic measures.[17,21] Moreover, C-BiLLT assessments were accessible for children who were often unable to participate in earlier standardized assessments.[8,17] Results indicated that the C-BiLLT scores of children with typical development sufficiently discriminate between different age groups of children with typical development and between groups of children with typical development and children with CP. The C-BiLLT is standardized for children from age 1 year 6 months to 6 years 6 months and provides *z*-scores (for children with severe CP aged <6y 6mo) as well as age-equivalent scores (for children with severe CP aged >6y 6mo) derived from the control group (*n*=806) of Dutch children with typical development.[16] With these normed data, the C-BiLLT can provide information on the performance of (Dutch) spoken language comprehension of children with severe CP relative to their peers without disabilities.

What this paper adds

- In the recruited sample, non-speaking children with spastic CP had more severe language comprehension difficulties than children with dyskinetic CP.
- The majority of children with dyskinetic CP have severely impaired or no speech, but may show moderate or even age-appropriate spoken language comprehension.
- It is important to distinguish between expressive (speech and gestures) and receptive language (language comprehension) when diagnosing non-speaking children with severe CP.

The aims of the present explorative study are to assess spoken language comprehension in a group of children with severe CP (GMFCS levels IV and V) using the C-BiLLT, and to explore the relation with motor type of CP and disability. We hypothesized that discrepancies are likely to occur between expressive communication abilities (language production or gesturing) and receptive communication abilities (language comprehension) in children with severe CP, and that despite a similar level of disability (GMFCS), children with different motor types of CP will vary in their spoken language comprehension abilities.

METHOD

Participants

The participants consisted of 87 children (44 males, 43 females; age range 1y 9mo–12y, mean age 6y 8mo [SD 2y 11mo]) recruited from rehabilitation centres, special schools, and day-care centres throughout the Netherlands.

Inclusion criteria were: (1) medical diagnosis of CP according to Surveillance of Cerebral Palsy in Europe criteria;[22] (2) severe motor impairment classified as GMFCS levels IV or V; (3) productive spoken vocabulary of fewer than five words; (3) no diagnosed or otherwise documented history of auditory (threshold level for the better ear of ≥31 dB) or severe visual perceptive problems (visual acuity of <0.3 in the better eye [with correction], cerebral visual impairment or blindness); and (5) chronological age between 1 year 6 months and 12 years.

Gestational age was categorized into very preterm (24–31wks[6]), preterm (32–36wks[6]), and term (>37wks). Epilepsy was defined as diagnosed epilepsy after the neonatal period and reported as such in medical reports.

Assessment of spoken language comprehension

Administration of the C-BiLLT provides information on the child's ability to comprehend spoken sentences of increasing difficulty in vocabulary and in grammar by means of responding to items presented orally by the test leader, and simultaneously visually on a personal computer. The C-BiLLT comprises a 'pre-test' and two computer test parts of (in total) 77 items (the maximum C-BiLLT raw score is 77). The pre-test of the C-BiLLT is used to explore whether a child is able to communicate a choice between two concrete objects (or digital photographs of the objects) when provided with the spoken name of the objects. If the child was able to identify at least five out of eight objects or photographs correctly, the child preceded to the computer test part of the C-BiLLT. The test arrangement is equipped with different access methods such as a 19-inch touch screen, adjustable input switches, switch activators on a flexible and bendable shaft, the child's own (electric) wheelchair head support, eye gazing, and eye gaze computer control (for details see Appendix SI, supporting information published online).

Administration of the C-BiLLT took place in a distraction-free room at the educational environment of the child, by an experienced speech and language pathologist (JG). Administration of the C-BiLLT took between 15 minutes and 60 minutes.

Ethics

The Medical Ethics Committee of the VU University Medical Center Amsterdam approved the study. All parents gave their written informed consent.

Statistical analyses

Chronological age, C-BiLLT score, and CP-related variables were evaluated for normality by means of residual plots and normality tests. All these analyses confirmed that data were normally distributed.

Descriptive statistics as well as logistic regression analyses (backward logistic regression method) were used to describe the demographic and individual test administration. Associations between CP characteristics (variables entered were GMFCS, age, and type of CP) and passing the pre-test or not, were calculated using odds ratios (OR) with 95% confidence intervals (CI) estimated from the logistic regression models. Fisher's exact test was used to analyse differences in proportions between subgroups on a nominal or categorical level. Pearson's correlation coefficient was used to investigate the relation between chronological age and C-BiLLT raw score. Comparison of C-BiLLT raw scores between different types of CP and between GMFCS levels were performed with Student *t*-tests. Analysis of variances was performed to analyse differences in C-BiLLT raw scores between subgroups based on gestational age and on MACS levels. A multiple linear regression model (backward method) was performed to explore how independent variables (predictors) explained the variation in C-BiLLT raw scores (dependent variable). Independent variables that were significant in the univariate analyses were entered in the model ($p<0.10$). Independent variables entered in the multiple linear and logistic regression models were continuous (chronological age) as well as categorical (type of CP, GMFCS). Normal plots for residuals were made and showed that the residuals were normally distributed. To compare performance of spoken language comprehension relative to the norm, both *z*-scores (for children aged <6y 6mo) and age-equivalent scores (for children aged >6y 6mo) were calculated using a control group of children with typical development (n=806) as reference sample.[18] A *z*-score is the number of standard deviations a test score is above the mean in the reference sample. Age-equivalent scores indicate the typical age of control participants with typical development who obtain the given score. For children aged younger than 6 years 6 months, a *z*-score of ≥-1.6 was defined as average to mild disability in spoken language comprehension and a score <-1.6 as moderate to severe disability. For children aged older than 6 years 6 months, an age-equivalent score of ≥6 years 6 months was defined as average to mild disability and an age-equivalent score of <6 years 6 months as moderate to severe disability in spoken language comprehension. Associations between spoken language comprehension abilities and type of CP, GMFCS and MACS levels, gestational age, and epilepsy were analysed with Fisher's exact test.

All statistical analyses were performed with SPSS-20 for IBM (SPSS Inc., Chicago, IL, USA). A *p*-value <0.05 was considered statistically significant.

RESULTS

Characteristics of the children

Table I presents the demographic characteristics of the children with CP. Proportions of age, sex, and GMFCS and MACS levels were equally distributed between the

Table I: Demographic and CP-related characteristics of children with severe CP (n=87)

	n	%	Mean (SD)
Age (mo)			80.76 (35.02)
Sex			
Males	44	50.6	
Females	43	49.4	
Type of CP			
Spastic	47	54.0	
Dyskinetic	40	46.0	
Epilepsy			
Yes	33	37.9	
No	53	60.9	
Missing	1	1.2	
Gestational age (wks)			37.46 (4.78)
Very preterm (24–31wks[6])	12	13.8	
Preterm (32–36wks[6])	10	11.5	
Term (≥37wks)	65	74.7	
Birthweight (g)	81	93.1	2878 (970)
Missing	6	6.9	
GMFCS (level)			
IV	34	39.1	
V	53	60.9	
MACS (level)			
NA (age <4y)	19	21.8	
II	3	3.4	
III	14	16.1	
IV	17	19.5	
V	34	39.2	

CP, cerebral palsy; GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System; NA, not applicable; SD, standard deviation.

subsets of children with spastic and dyskinetic CP. Proportions of age, sex, gestational age, and type of CP were equally distributed between GMFCS and MACS levels. However, MACS levels could not be classified in 19 (22%) children because their age was less than 4 years. In our sample, significantly more children with spastic CP than with dyskinetic CP were born (very) preterm, 17 (36%) versus 5 (12%) children respectively (p=0.011). Epilepsy was diagnosed in 33 (38%) children of whom 24 (73%) with spastic and 9 (27%) children with dyskinetic CP (p=0.008). No other significant association was found between demographic and CP-related characteristics (see Table SI, supporting information published online).

Access methods

Overall, 19 children (22%) did not pass the pre-test. In the logistic regression model only the type of CP (OR 4.2; 95% CI 1.3–14.1) was independently associated with 'passing the pre-test'. The odds of not passing the pre-test and thus not preceding to the computer test was 4.2 times higher for a child with spastic CP than with dyskinetic CP.

In children who passed the pre-test (n=68), no significant difference in the later applied access method for computer test administration was found between the types of CP (p=0.649). The touch screen function (with forehead, nose, hand, feet, or whole arm movement) was used by 26 (38%) children, the child's own wheelchair head support was used by 16 (24%) children, eye gazing by 14 (20%) children, and 12 (18%) children used combined access methods to indicate their responses (e.g. eye gazing to indicate left displayed images, and input switch with right arm/hand to indicate right displayed images). A significant difference in access method was found between GMFCS levels (p<0.001) and MACS levels (p<0.001). Most children with GMFCS IV used the touch screen function whereas children with level V used either eye gazing or head support. Most children with MACS II to IV were inclined to use the touch screen function, whereas children with MACS V used either eye gazing or head support.

All ages: C-BiLLT raw scores of spoken language comprehension

A significant positive correlation was found between chronological age and C-BiLLT raw score (r=0.36, p<0.001). C-BiLLT raw scores showed a significant difference between children with dyskinetic and spastic CP (t=−3.092, CI −26.14 to −5.68, p=0.003) with higher raw scores in children with dyskinetic CP. There were significant differences in raw scores between the GMFCS levels (t=2.270, CI 1.518–22.921, p=0.026) with higher scores in GMFCS level IV than in level V. There was no significant difference in raw scores between the MACS levels (children >4y, and level II and III combined, n=67) (F=1.731, p=0.170), or between children with or without epilepsy (t=1.646, CI −1.887 to 20.026, p=0.103), or between subgroups of gestational age (F=1.326, p=0.271). Results are shown in Table SI.

Regression analyses revealed that the type of CP, GMFCS, and chronological age of the child explained 33% of the variance in raw scores (R=0.577, R^2=0.33) (Table II).

Children aged younger than 6 years 6 months: C-BiLLT *z*-scores of spoken language comprehension

C-BiLLT z-scores showed a significant difference between children with spastic and dyskinetic CP (F=14.903, p<0.001). More than half (52.4%) of the children with dyskinetic CP attained comprehension scores within the average range (z-score ≥−1.6) as opposed to none of the children with spastic CP. Significant differences in z-scores were found between GMFCS levels (F=4.546, p=0.043), but not between MACS levels (n=22; F=0.173, p=1.000), gestational age (F=2.981, p=0.161), or epilepsy subgroups (F=0.837, p=0.458). Results are presented in Table III.

Children aged older than 6 years 6 months: C-BiLLT age-equivalent -scores of spoken language comprehension

Children with spastic CP had significantly lower age-equivalent scores than children with dyskinetic CP (F=6.428, p=0.031). Age-equivalent scores of <6 years 6 months were found in all children with spastic CP, except in one child (96.2%). The highest achievable age-equivalent score of ≥6 years 6 months was found in seven children with CP (15.6%; n=1 spastic CP and n=6 dyskinetic CP). Of the children with dyskinetic CP, 32% reached the highest achievable age-equivalent score of >6 years 6 months compared to 4% of the children with spastic CP. No difference was found between GMFCS (F=0.085, p=1.000) and MACS levels (F=0.650, p=0.655), or between gestational age (F=4.145, p=0.077), or between epilepsy subgroups (F=0.008, p=1.000). Results are presented in Table IV.

DISCUSSION

The present study focuses on comprehension of spoken language in a group of children who cannot speak or gesture as a result of severe CP. Their gross motor functioning is classified as GMFCS level IV and V, and their manual abilities as MACS level III to V. The use of the C-BiLLT (a specifically designed language assessment instrument) allowed us to reliably assess spoken language comprehension in this specific subset of children with severe CP.

Table II: Multiple linear regression model

	B	SEB	β	CI	p
Constant	57.491				
Type of CP	18.10	4.503	0.36	9.15–27.06	<0.001
GMFCS	−15.56	4.623	−0.30	−24.75 to −6.39	<0.001
Age[a]	0.299	0.065	0.42	0.170–0.429	<0.001

[a]Chronological age of the child. Dependent variable: C-BiLLT raw score (n=87, R=0.577, R^2=0.33). CI, confidence interval; CP, cerebral palsy; GMFCS, Gross Motor Function Classification System; SEB, standard error regression coefficient.

Table III: Spoken language comprehension performance in *z*-scores of children aged younger than 6 years 6 months with severe CP according to subtype, GMFCS & MACS level, gestational age and epilepsy (n=42)

	z-score <−1.6 moderate to severely delayed *n* (%)	*z*-score ≥−1.6 average to mild *n* (%)	Total *n* (%)	*p*	*F*
Type of CP					
Spastic	21 (100)	(0)	21 (100)	<0.001[a]	14.903
Dyskinetic	10 (47.6)	11 (52.4)	21 (100)		
GMFCS					
Level IV	11	8	19 (45.2)	0.043[a]	4.546
Level V	20	3	23 (54.8)		
MACS[b]					
NA <4y	14	5	19 (45.2)	1.000	0.173
Level II	1	–	1 (2.4)		
Level III	3	1	4 (9.5)		
Level IV	7	3	10 (23.8)		
Level V	6	2	8 (19.0)		
Gestational age					
Very preterm	5	–	5 (11.9)	0.161	2.981
Preterm	2	–	2 (4.8)		
Term	24	11	2 (4.8)		
Epilepsy[c]					
Yes	11	2	13 (31.7)	0.458	0.837
No	20	8	28 (68.3)		
Total *n* (%)	31 (73.9)	11 (26.1)	42 (100)		

[a]Statistically significant. [b]Children <4y excluded and MACS level II/III and IV/V combined. [c]Data missing for one child. CP, cerebral palsy; *F*, Fisher's exact test; GA, gestational age; GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System; *n*, number of children; NA, not applicable.

Table IV: Spoken language comprehension performance in age-equivalent scores of children aged older than 6 years 6 months with severe CP according to subtype, GMFCS and MACS level, gestational age, and epilepsy (n=45)

	AE <6y 6mo *n* (%)	AE ≥6y 6mo *n* (%)	Total *n* (%)	*p*	*F*
Type of CP					
Spastic	25 (96.2)	1 (3.8)	26 (100)	0.031[a]	6.428
Dyskinetic	13 (68.4)	6 (31.6)	19 (100)		
GMFCS					
Level IV	13	2	15 (33.3)	1.000	0.085
Level V	25	5	30 (66.7)		
MACS					
Level II	2	–	2 (4.4)	0.655	0.650
Level III	9	1	10 (22.2)		
Level IV	5	2	7 (15.6)		
Level V	22	4	26 (57.8)		
Gestational age					
Very preterm	7	–	7 (15.5)	0.077	4.145
Preterm	8	–	8 (17.8)		
Term	23	7	30 (66.7)		
Epilepsy					
Yes	17	3	20 (44.4)	1.000	0.008
No	21	4	25 (55.6)		
Total *n* (%)	38 (84.4)	7 (15.6)	45 (100)		

[a]Statistically significant. AE, age-equivalent; CP, cerebral palsy; *F*, Fisher's exact test; GA, gestational age; GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System.

Comprehension of spoken language varied considerably between children with severe CP and was overall significantly delayed compared to children with typical development. Delays in spoken language comprehension were less frequent in dyskinetic CP than in spastic CP. Half of the children with dyskinetic CP younger than 6 years 6 months scored within the average range of typically developing children and one-third of the children with dyskinetic CP older than 6 years 6 months attained the highest achievable age-equivalent score. Also, the probability of not proceeding to the computer test (i.e. not able to communicate a choice between two concrete objects) was considerably affected by the motor type of CP, with most attrition among children with spastic CP. That language comprehension seems more favourable in dyskinetic than in spastic CP is in agreement with earlier studies in children, adolescents, and adults with CP.[13,23] However, these latter studies do not describe the motor disabilities of CP, other than reporting that participants are unable to walk unaided, or have a high level of dependence in all activities, or (in a minority of the sample) have impaired speech.

Our data are less explicit regarding how GMFCS levels are associated with receptive language. C-BiLLT raw scores were found to be poorer in children classified as level V than in level IV, and the level of gross motor functioning made a significant contribution to the variability in spoken language comprehension. Moreover, when calculated in *z*-scores, a significant association was found between GMFCS level and spoken language comprehension abilities. However, when calculated in age-equivalent scores, the association between GMFCS level and spoken language comprehension was no longer significant. This inconsistency in outcome may be caused by the differences between the subsamples and/or because of several limitations associated with age-equivalent scores.[24] For example, age-equivalent scores do not provide information on the child's individual test performance relative to the norm. For example, when two children of different ages (e.g. 7y and 11y) attain the same age-equivalent score, the examiner can only assume that they answered the same number of items correctly. In addition, the highest achievable score on the C-BiLLT corresponds to an age-equivalent score of 6 years 6 months; for children aged older than 6 years 6 months who achieved the maximum C-BiLLT score, ceiling effects may have occurred.

Because of their (young) age, 22% of our sample could not be classified using the MACS; this resulted in the analysis of small subgroups and loss of power. Although a strong relation has been shown between the higher MACS and GMFCS levels,[25,26] more studies are needed on MACS levels in relation to language comprehension performance.

In the present study sample, for the distribution of motor subtype of CP, gestational age, and the presence of epilepsy, prevalence data are representative for children with GMFCS levels IV and V.[23,27] In our sample of children, neither gestational age nor epilepsy seem to be associated with language comprehension as assessed by the C-BiLLT. On the other hand, gestational age or epilepsy may play a moderating, rather than a mediating, role in spoken language comprehension. This may indicate that the motor type of CP (and its underlying pathology and severity) has more influence on the outcome of language comprehension than gestational age or epilepsy itself. This hypothesis is supported by a population-based study showing that the presence of epilepsy was associated with CP subtype, with a higher prevalence of epilepsy in children with dyskinetic or bilateral spastic CP than in children with unilateral spastic CP; moreover, more than half of those children with epilepsy were unable to walk.[27]

Overall data suggest that the underlying brain lesions resulting in different types of CP not only have an effect on the extent and characteristics of the motor impairment, but also on language abilities, at least on receptive abilities. The assumption that spoken language comprehension may be relatively spared in dyskinetic CP stresses the importance of distinguishing between expressive language (speech and gestures) and receptive language (language comprehension) when diagnosing non-speaking children with severe CP.

The present study has some intrinsic limitations. The sample of children who participated in the present study is considered to be representative of the population of children with severe CP in terms of motor type of CP (i.e. dyskinetic vs spastic).[28,29] Moreover, in line with prevalence data in Europe, the majority of our CP sample was born at term.[29,30] However, the number of children in our study is small and interpretation of the results regarding variables that may influence the C-BiLLT results requires some caution. Moreover, future studies should (ideally) use a birth cohort of children with CP with a more homogeneous age range and a longitudinal design. Furthermore, although cognition and language are highly correlated,[31] the development of a reliable assessment measure for a broader level of cognitive functioning in children with severe CP is preferred.[16] This would allow to interpret spoken language comprehension in the context of cognitive levels. However, cognitive assessment of children with severe CP remains a challenge since cognitive testing demands precise physical and verbal responses which, therefore, limits reliable assessment.[16] It is reported that measures of language comprehension can provide an estimate of skills that is less influenced by the motor impairment of the child with physical impairments than non-verbal cognition measures.[32] Therefore, assessment based on receptive language may be more feasible for estimating cognitive levels in children with severe CP, particularly when the domain of interest is related to verbal cognition or language skills.[33]

CONCLUSION

In the present study, language comprehension varied considerably in children with severe CP and was generally delayed. However, children with dyskinetic CP performed better than spastic children despite a comparable level of functional limitations, including gross motor and communication disabilities. Of the children with dyskinetic CP, in those aged under 6 years 6 months, more than 50% attained comprehensive language scores within the normal range. Awareness that comprehension of spoken language can surpass (verbal) expression may emphasize the need to extend language assessment and provide children with adequate alternative and/or augmentative communication aids from an early age onwards.

The authors have stated that they had no interests that might be perceived as posing a conflict or bias.

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SUPPORTING INFORMATION

The following additional material may be found online:

Appendix SI: Computer-based instrument for low motor language testing (C-BiLLT).

Table SI: Mean differences in comprehension score on the computer-based instrument for low motor language testing (C-BiLLT) according to type of CP, GMFCS and MACS level, epilepsy, and gestational age.

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