DOES VERBAL AND GESTURAL EXPRESSION ABILITY PREDICT COMPREHENSION ABILITY IN CEREBRAL PALSY?[1, 2]

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Summary.—Some people with cerebral palsy have motor and associated impairments that may hinder verbal and gestural expression to various extents. This study explores whether the ability to produce verbal or gestural expressions may be related to the comprehension of verbal communications and gestures. The influence of severity of motor impairment, general cognitive performance, and age on comprehension ability was also explored. Forty people with cerebral palsy were assigned to different groups according to their verbal and gestural expression abilities. A neuropsychological assessment of comprehension abilities and general cognitive performance was carried out. Multiple linear regression analysis was applied to identify the possible influence of expression abilities on comprehension abilities and also to detect the possible contribution of severity of motor impairment, general cognitive performance, and age. Results indicate that verbal and gestural comprehension was mainly predicted by general cognitive performance. Severity of motor impairment and age did not contribute to predicting comprehension abilities. Only verbal grammar comprehension was significantly predicted by verbal expression ability. Verbal expression ability may be an important marker for cerebral palsy therapies. In non-ambulant patients with bilateral cerebral palsy, impaired gestural expression should not be taken as an indicator of impaired gestural comprehension.

Cerebral palsy has been associated with several cognitive deficits such as language and verbal skills, visual-spatial and perceptual skills, learning and memory, and executive function (Straub & Obrzut, 2009). Among these, language is the best-compensated function in cerebral palsy (Krägeloh-Mann & Cans, 2009). It is well known that brain plasticity facilitates language acquisition after early brain lesions (Reed & Warner-Rogers, 2008).

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However, difficulties in communication are very common in children with cerebral palsy (Bax, Tydeman, & Flodmark, 2006) depending on the level of impairment (Straub & Obrzut, 2009). Children with more severe cerebral palsy, including motor impairment and associated deficits such as low intelligence and dysarthria or anarthria, show greater deficits in verbal and language abilities when compared to children without these associated impairments (Sandberg & Hjelmquist, 1996; Card & Dodd, 2006; Pirila, van der Meere, Pentikainen, Ruusu-Niemi, Korpela, Kilpinen, *et al.*, 2007).

In relation to cognitive ability, Pirila, *et al.* (2007) found that fewer children with IQ above 70 had problems in their expression and comprehension skills than children with IQ below this level. The presence of pervasive language difficulties in children with IQ below 70 is not yet clearly understood. A possible explanation could be found in language impairment models, which propose that language difficulties may be due to a more general, non-linguistic deficit (Pennington & Bishop, 2009). Authors such as Bates (2004) have argued that domain-general deficits in cognitive and perceptual systems are sufficient to account for language impairment. Moreover, intelligence as well as frequency of communicative acts have been considered predictor factors of language development (Reed & Warner-Rogers, 2008).

In cerebral palsy, motor difficulties that inhibit speech ability, such as dysarthria or anarthria, affect the frequency of communicative acts (Reed & Warner-Rogers, 2008). It has been suggested that non-speaking children often experience problems in the pre-linguistic period when babbling and games of a turn-taking character provide infants with rules for communication and procedures for initiating and participating in interaction (Falkman, Sandberg, & Hjelmquist, 2002). In the study by Falkman, *et al.* (2002) the amount of linguistic communication used by the non-speaking preschool children with severe cerebral palsy and normal intelligence was much lower than could be expected. This finding suggests a relation between a lack of pre-linguistic experiences and poor linguistic expression ability in the future. In addition, comprehension abilities may also be affected. Sandberg and Hjelmquist (1996) found that non-vocal children with cerebral palsy appeared to have impaired verbal comprehension and impaired reading and spelling skills when compared to controls. In the same line of reasoning, Bishop and Robson (1989) and Bishop, Brown, and Robson (1990) reported that young people with cerebral palsy and impaired speech had poorer vocabulary comprehension than people with cerebral palsy and normal speech. In their sample, Bishop, *et al.* (1990) found no differences in the comprehension of grammatical structures between participants with and without motor speech disorders (with anarthria or severe dysarthria). This finding is of interest because studies in other central nervous system disorders have found that problems with articulation lead to difficulties in grammatical processing (Porta-Etessam, Nunez-Lopez, Balsalobre, Lopez, Hernandez, & Luna, 1997). It would be interesting to analyze the relationship between deficient or sufficient verbal expression ability and verbal comprehension ability by using measures that involve more complex grammatical structures.

Regarding verbal ability, verbal language is closely related to gesture (Bates & Dick, 2002). It has been found that imitation skills in normal infants at nine months of age are associated with subsequent production of communicative gestures (Heimann, Strid, Smith, Tjus, Ulvund, & Meltzoff, 2006). The motor impairment in cerebral palsy makes imitation experience difficult and thus may interfere with the correct development of communicative gestures, such as praxis (Borod, Fitzpatrick, Helm-Estabrooks, & Goodglass, 1989). Other cerebral palsy studies have suggested that movement experience may be a prerequisite for understanding the order of movement (Rothman, 1987). However, the relationship between the production of purposeful skilled movements (praxis production) and their comprehension (praxis comprehension) has not been analyzed.

Apart from severity of motor impairment, intelligence, and difficulties with verbal or gestural expression, it is important to take into account that communicative abilities also change in relation to age. In fact, according to Bishop and Robson (1989) and Bishop, *et al.* (1990) the vocabulary comprehension difficulties found in young people with cerebral palsy and impaired speech may simply be due to a delay in vocabulary acquisition. These studies only included young people, ages 10 to 18 years (Bishop & Robson, 1989; Bishop, *et al.*, 1990). One way to test the hypothesis that vocabulary changes with age would be to investigate not only young people but also adults with cerebral palsy. A study including adult participants would be expected to relate vocabulary performance with age, but not with speech disorder, if it is the case that the delay in vocabulary acquisition in speechless individuals is compensated over time.

It has been suggested that the comprehension skills of people with cerebral palsy may be related to severity of motor impairment, intelligence, expression ability, and age, but to date it has not been analyzed which of these factors most influences their receptive communication abilities. The coincidence of severity of motor impairment with general cognitive impairment and oral or gestural impediments may make it difficult to clarify which of these factors are most closely related with the development of communicative abilities. To study this relationship it would be interesting to analyze the specific contribution of each of these factors (expression ability, motor severity, general cognitive performance, and age) in explaining the variability in comprehension ability.

The goal of this study was to identify the specific influences of verbal and gestural expression ability in verbal (passive vocabulary and comprehension of grammatical structures) and gestural comprehension in people with cerebral palsy, compared to the influence of motor impairment, general cognitive impairment, and age.

Method

Participants

Individuals with cerebral palsy were recruited from schools or occupational centres for the physically disabled with high dependence in everyday activities. Exclusion criteria were hearing abnormalities or severe visual difficulties that precluded neuropsychological assessment. The inclusion criterion was the capacity to understand instructions. This information was provided by psychologists and teachers at each centre and corroborated by the neuropsychologist. Medical reports complemented the information about the participants. Finally, in cases in which the information provided was insufficient, interviews with the parents were conducted. All the participants or their families gave informed consent prior to participating in the study.

The study sample included 40 participants with neurological diagnoses of cerebral palsy, aged between 6 and 38 years ($M = 22.3$, $SD = 9.3$). Fifteen participants were female and 25 were male. Eleven were born preterm (gestational age < 37 weeks) and 29 at term. Regarding motor symptoms, six were dyskinetic, 14 spastic, and 18 were mixed forms. In two participants, the type of motor symptoms was unknown. As regards the affected extremities, all participants had bilateral cerebral palsy: 22 had diplegia, six triplegia and 12 tetraplegia. Although different numbers of extremities were affected, the gross motor skill impairment was serious in all participants (Krageloh-Mann, Hagberg, Meisner, Schelp, Haas, Eeg-Olofsson, *et al.*, 1994). None of the participants were able to ambulate at all, and the whole sample had high dependence in everyday activities. Fine motor skill impairment was classified as mild, moderate, or severe following the criteria of Claeys, Deonna, and Chrzanowski (1983): mild if pincer grasp or individual finger movements were possible and used in daily life, moderate if only global hand use was possible without individual finger movements, and severe if no voluntary prehension was possible. Applying these criteria, impairment was defined as mild in 23 participants, moderate in 5, and severe in 12. The affected extremities and fine motor skills were used as measures of severity of motor impairment.

Verbal expression ability was defined as sufficient in nine participants who could perform spontaneous comprehensible phrases of three words minimum, and deficient in 31 who gave only one-word answers or did not use verbal expressions to communicate. These evaluations were corroborated by psychologists and teachers at each centre.

Gestural expression ability was defined as sufficient in 16 participants who performed three purposeful skilled movements without error (waving good-bye, saluting, and beckoning "come here"), and deficient in 24 who performed fewer than three or none of these intransitive limb gestures. Table 1 shows the individual motor and communication characteristics.

Measures

Verbal comprehension.—To examine verbal comprehension ability, one receptive vocabulary test and two grammatical comprehension tests of different complexities were administered. *Receptive vocabulary* was assessed by means of the Peabody Picture Vocabulary Test–Revised (Pereda, 1985). This test consists of picture plates, each with four pictures and one plate for each word. There is a total of 150 words which are arranged in order of difficulty. The participant points at or gives the number of the picture which matches best with the stimulus word. The raw score is obtained by subtracting the number of errors from the highest element reached. The maximum score that can be obtained is 150. This test correlates with other well known tests of vocabulary such as the Vocabulary subtest of the WISC (.37 to .83) and WAIS (.60 to .67) (Pereda, 1985). The Peabody Picture Vocabulary Test – Revised is recognized as a valid instrument for patients with impaired verbal communication and motor functions (Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006) and has been widely used to assess individuals with cerebral palsy (Levine, Huttenlocher, Banich, & Duda, 1987; Rothman, 1987; Bishop & Robson, 1989; Harris, 1989; Bishop, *et al.*, 1990; Feldman, Janosky, Scher, & Wareham, 1994). For the statistical analysis, the Peabody Picture Vocabulary Test–Revised raw scores were transformed into z scores.

Receptive grammatical abilities were evaluated with the receptive part of the Screening Test of Spanish Grammar, which is similar to the test used by Bishop, *et al.* (1990). It consists of picture plates, each with four pictures, one plate for every group of two sentences with the grammatical expressions arranged in order of difficulty. The participant points at or gives the number of the picture which matches the phrase best. There are a total of 46 sentences and one point is awarded for each correct sentence-picture association, up to 46 points. Bishop, *et al.* (1990) stated that mean scores on the grammatical comprehension test used in their study may remain invariable from 12 years to adulthood. To assess more complex grammatical comprehension, a shortened version of the Token Test was administered (De Renzi & Faglioni, 1978), which comprises 20 tokens cut from thin sheets of plastic in two shapes (circles and squares), two sizes (large and small) and five colors. The tokens are laid out in four parallel rows. The test consists of a series of 36 oral commands, given in five sections of increasing complexity and each correct response earns 1 point on the

TABLE 1
MOTOR AND COMMUNICATION CHARACTERISTICS OF THE SAMPLE

ID	Motor Symptoms	Affected Extremities	Fine Motor Skills	Verbal Expression	Gestural Expression
1	Mixed	Diplegia	Mild	Deficient	Deficient
2	Mixed	Tetraplegia	Severe	Deficient	Deficient
3	Mixed	Tetraplegia	Severe	Deficient	Deficient
4	Mixed	Diplegia	Moderate	Deficient	Deficient
5	Mixed	Diplegia	Mild	Deficient	Deficient
6	Mixed	Diplegia	Mild	Deficient	Deficient
7	Mixed	Tetraplegia	Severe	Deficient	Deficient
8	Spastic	Diplegia	Mild	Deficient	Deficient
9	Spastic	Diplegia	Mild	Sufficient	Deficient
10	Dyskinetic	Tetraplegia	Severe	Deficient	Deficient
11	Dyskinetic	Diplegia	Moderate	Deficient	Sufficient
12	Mixed	Diplegia	Moderate	Deficient	Deficient
13	Mixed	Diplegia	Mild	Sufficient	Sufficient
14	Dyskinetic	Tetraplegia	Severe	Deficient	Deficient
15	Spastic	Diplegia	Mild	Sufficient	Deficient
16	N/A	Diplegia	Mild	Deficient	Sufficient
17	Mixed	Diplegia	Mild	Sufficient	Sufficient
18	Spastic	Tetraplegia	Severe	Deficient	Deficient
19	Spastic	Diplegia	Mild	Sufficient	Sufficient
20	Spastic	Tetraplegia	Severe	Deficient	Deficient
21	Spastic	Diplegia	Mild	Sufficient	Sufficient
22	Spastic	Triplegia	Mild	Deficient	Deficient
23	Mixed	Diplegia	Mild	Deficient	Sufficient
24	Dyskinetic	Triplegia	Mild	Deficient	Sufficient
25	Mixed	Diplegia	Mild	Deficient	Sufficient
26	Mixed	Triplegia	Moderate	Deficient	Sufficient
27	Spastic	Triplegia	Mild	Deficient	Deficient
28	Dyskinetic	Triplegia	Moderate	Deficient	Deficient
29	Dyskinetic	Diplegia	Mild	Sufficient	Sufficient
30	Mixed	Tetraplegia	Severe	Deficient	Deficient
31	N/A	Diplegia	Mild	Deficient	Sufficient
32	Spastic	Tetraplegia	Severe	Deficient	Deficient
33	Mixed	Tetraplegia	Severe	Sufficient	Deficient
34	Spastic	Tetraplegia	Severe	Deficient	Deficient
35	Mixed	Triplegia	Mild	Deficient	Sufficient

(continued on next page)

Note.—ID is the participant's identity number. N/A means not available.

TABLE 1 (CONT'D)
MOTOR AND COMMUNICATION CHARACTERISTICS OF THE SAMPLE

ID	Motor Symptoms	Affected Extremities	Fine Motor Skills	Verbal Expression	Gestural Expression
36	Mixed	Diplegia	Mild	Deficient	Sufficient
37	Spastic	Diplegia	Mild	Deficient	Deficient
38	Mixed	Diplegia	Mild	Deficient	Sufficient
39	Spastic	Diplegia	Mild	Sufficient	Sufficient
40	Spastic	Tetraplegia	Severe	Deficient	Deficient

Note.—ID is the participant's identity number. N/A means not available.

36-point scale. This version has been used in hemiplegic cerebral palsy (Vargha-Khadem, O'Gorman, & Watters, 1985; Carlsson, Uvebrant, Hugdahl, Arvidsson, Wiklund, & von Wendt, 1994). In commands that require movement and placement of small tokens, participants with no voluntary prehension were requested to answer yes or no to guide the neuropsychologist examiner in performing the task. Reliability coefficients are higher with more impaired populations. The Token Test presents high test-retest reliability with a correlation coefficient between .92 and .96 when measured in aphasic patients (Strauss, *et al.*, 2006).

For statistical analysis, the Screening Test of Spanish Grammar and Token test raw data were transformed into z scores and then summed as a measure of verbal grammatical comprehension ability.

Gestural comprehension.—For gestural comprehension ability, a praxis task was used, similar to the one proposed by Leiguarda, Pramstaller, Merello, Starkstein, Lees, and Marsden (1997) to examine patients with motor deficits. The examiner pantomimed five actions (using a hammer, brushing teeth, having a shower, opening a bottle, and combing one's hair). Each act was performed by a model in one of three ways: a well-executed movement, a clumsily executed movement, or a movement using a body part as the object. Pictures of the five movements were then presented, and the participant was asked to recognize which of these pictures matched the gestures that had been pantomimed, without evaluating the performance. Each correct matching was scored 1, and the possible range of the total score was zero to five points. Each act was then repeated in the three different ways and the participant had to discriminate well-performed from badly performed movements. Each correct discrimination was scored 1, up to a maximum of five points. Recognition and discrimination were scored separately. In the discrimination task, body part as object errors are considered normal for children up to 12 years old. Two more items were included (lighting a cigarette and using an axe) to ensure that the tasks had been understood. For the scoring, the recognition and discrimination raw data were transformed into z scores and then summed to create gestural comprehension ability scores.

Cognitive ability.—Raven's Coloured Progressive Matrices Test was used as a measure of general cognitive performance. It was presented in a simplified, 36-item paper format (Raven & Court, 1996). Each item contains a pattern problem with one part removed and six pictured inserts, of which one contains the correct pattern. Participants point to the pattern piece they select or to its number. Each correct answer is scored one point; the maximum score is 36. This test provides a measure of general cognitive functioning related to linguistic, visual-perceptual, and memory performance in cerebral palsy (Pueyo, Junqué, Vendrell, Narberhaus, & Segarra, 2008) and has been used in previous cerebral palsy studies (Sandberg & Hjelmquist, 1996; Falkman, *et al.*, 2002). Furthermore, Raven's Coloured Progressive Matrices Test presents acceptable test-retest reliability ($r > .8$). For the statistical analysis, the Raven's Coloured Progressive Matrices raw scores were used.

Procedure

The same neuropsychologist (RP) examined all the participants. Functions were assessed alternately. Short and long tasks were also alternated. The session length was flexible, depending on the person's fatigue.

Statistical Analysis

Statistical analysis was carried out using PASW Statistics 18 (SPSS Inc., USA). Factors that influenced comprehension ability in cerebral palsy were analyzed. Comprehension ability was analyzed separately for verbal and gestural communication. Moreover, in verbal comprehension ability, passive vocabulary and comprehension of grammatical structures were also analyzed separately. Multiple linear regression analysis was used to assess the influence of expression ability, severity of motor impairment (affected extremities and fine motor skills), general cognitive performance, and age (independent variables) on comprehension ability (dependent variable). A forced-entry method was used in which all predictor variables were entered into the model simultaneously. The selection of possible predictor variables was based on the literature review. This method was selected to identify which of these variables make the largest contributions to predicting comprehension ability in cerebral palsy. A summary of the multiple regression model and the specific coefficients obtained were presented for each analysis.

Assumptions of residual normality, linearity, and equality of variances were checked. Cook's distance was used to check for influential data points. Statistical significance was defined as $p < .05$.

Results

Verbal comprehension ability was analyzed separately for passive vocabulary and comprehension of grammatical structures. In relation to passive vocabulary, the multiple linear regression analysis showed that vocabulary comprehension measured by the Peabody Picture Vocabulary Test–Revised was mainly explained by the general cognitive performance measured by the Raven's Coloured Progressive Matrices (Table 2). Verbal expression, severity of motor impairment (affected extremities and fine motor skills), and age did not contribute to predicting passive vocabulary outcome. The model regression summary showed that 71% of the variability in the verbal passive vocabulary was accounted for by general cognitive performance (Table 3).

TABLE 2

Coefficients for Multiple Regression Predicting Verbal Comprehension Ability (Passive Vocabulary) from Verbal Expression Ability, Affected Extremities, Fine Motor Skills, General Cognitive Performance, and Age

Predictor	Unstandardized Coefficients		Standardized Coefficients	*t*	*p*
	B	SE	β		
(Constant)	–2.83	0.47		–6.03	<.001
Verbal expression ability	0.45	0.23	.19	1.94	.06
Affected extremities	0.05	0.24	.05	0.22	.83
Fine motor skills	0.14	0.23	.12	0.59	.55
General cognitive performance	0.11	0.01	.78	7.61	<.001
Age	0.02	0.01	.17	1.63	.11

Note.—Cohen's $f^2 = 2.45$.

TABLE 3

Summary of Multiple Regression Model Predicting Verbal Comprehension Ability (Passive Vocabulary) from Verbal Expression Ability, Affected Extremities, Fine Motor Skills, General Cognitive Performance, and Age

R	R^2	Adj R^2	SE of Estimate	Change Statistics				
				ΔR^2	ΔF	df_1	df_2	p
.85	.71	.67	.57	.71	17.00	5	34	<.001

Note.—Predictors: (Constant), General cognitive performance, Verbal expression ability, Fine motor skills, Age, Affected extremities.

In relation to comprehension of grammatical structures, the regression analysis indicated that grammar comprehension, measured by the Screening Test of Spanish Grammar and the Token Test, was substantially predicted by general cognitive performance and verbal expression ability (Table 4). Severity of motor impairment and age did not contribute to predicting verbal grammar comprehension outcome. The model regression summary showed that about 70% of the variability in the verbal comprehension of grammatical structures was accounted for by general cognitive performance and verbal expression ability (Table 5).

TABLE 4

COEFFICIENTS FOR MULTIPLE REGRESSION PREDICTING VERBAL COMPREHENSION ABILITY (GRAMMAR) FROM VERBAL EXPRESSION ABILITY, AFFECTED EXTREMITIES, FINE MOTOR SKILLS, GENERAL COGNITIVE PERFORMANCE, AND AGE

Predictor	Unstandardized Coefficients		Standardized Coefficients	t	p
	B	SE	β		
(Constant)	–2.54	0.46		–5.51	<.001
Verbal expression ability	0.79	0.23	.35	3.45	.002
Affected extremities	–0.02	0.23	–.02	–0.10	.92
Fine motor skills	0.24	0.23	.22	1.04	.31
General cognitive performance	0.10	0.01	.78	7.44	<.001
Age	0.01	0.01	.07	0.63	.53

Note.—Cohen's $f^2 = 2.33$.

TABLE 5

SUMMARY OF MULTIPLE REGRESSION PREDICTING VERBAL COMPREHENSION ABILITY (GRAMMAR) FROM VERBAL EXPRESSION ABILITY, AFFECTED EXTREMITIES, FINE MOTOR SKILLS, GENERAL COGNITIVE PERFORMANCE, AND AGE

R	R^2	Adj R^2	SE of Estimate	Change Statistics				
				ΔR^2	ΔF	df_1	df_2	p
.83	.70	.65	.56	.70	15.57	5	34	<.001

Note.—Predictors: (Constant), General cognitive performance, Verbal expression ability, Fine motor skills, Age, Affected extremities.

Comprehension ability was analyzed separately for verbal and gestural processes. In relation to gestural comprehension ability, general cognitive performance was the only significant predictor (Table 6). Gestural expression ability did not contribute to explaining variability in gesture comprehension; nor did severity of motor impairment or age. Table 7 shows that the model obtained only predicted 25% of the variability in gestural comprehension ability.

TABLE 6

COEFFICIENTS FOR MULTIPLE REGRESSION PREDICTING GESTURAL COMPREHENSION ABILITY FROM GESTURAL EXPRESSION ABILITY, AFFECTED EXTREMITIES, FINE MOTOR SKILLS, GENERAL COGNITIVE PERFORMANCE, AND AGE

Predictor	Unstandardized Coefficients		Standardized Coefficients	*t*	*p*
	B	SE	β		
(Constant)	–0.57	0.49		–1.16	.25
Gestural expression ability	–0.04	0.35	–.03	–0.12	.91
Affected extremities	–0.25	0.26	–.33	–0.95	.35
Fine motor skills	0.37	0.26	.50	1.44	.16
General cognitive performance	0.05	0.02	.51	2.36	.02
Age	–0.01	0.01	–.11	–0.63	.53

Note.—Cohen's $f^2 = 0.33$.

TABLE 7

SUMMARY OF MULTIPLE REGRESSION PREDICTING GESTURAL COMPREHENSION ABILITY FROM GESTURAL EXPRESSION ABILITY, AFFECTED EXTREMITIES, FINE MOTOR SKILLS, GENERAL COGNITIVE PERFORMANCE, AND AGE

R	R^2	Adj R^2	SE of Estimate	Change Statistics				
				ΔR^2	ΔF	df_1	df_2	p
.50	.25	.14	.63	.25	2.24	5	33	.07

Note.—Predictors: (Constant), General cognitive performance, Affected extremities, Age, Gestural expression ability, Fine motor skills.

DISCUSSION

In this study, verbal and gestural comprehension abilities of children, adolescents, and adults with cerebral palsy were mostly related to their general cognitive performance. Only grammar comprehension was also predicted by verbal expression abilities.

The relationship between verbal comprehension skills (passive vocabulary and comprehension of grammatical structures) and intelligence has already been described in a sample of children with cerebral palsy (Pirila, *et al.*, 2007). However, in that study severity of motor impairment was also related to verbal comprehension skills. In contrast, severity of motor impairment did not account for any more of the variability in verbal comprehension than that already explained by the general cognitive impairment. This may be due to the fact that severity of motor impairment is not indicative of cognitive disability, especially when cases with dyskinetic cerebral palsy are considered (Pueyo, *et al.*, 2008; Pueyo, Junqué, Vendrell, Narberhaus, &

Segarra, 2009). Apparently, the relationship found in the present study between gestural comprehension and IQ in cerebral palsy has not been previously described. The results reinforce the relationship between language development and general cognitive deficits (Bates, 2004; Reed & Warner-Rogers, 2008; Pennington, & Bishop, 2009).

Interestingly, verbal expression abilities contributed to explaining grammar comprehension skills. As expected, the effect of grammatical comprehension was found using a measure that assessed increasingly complex grammatical structures, which is a more difficult task than the one used by Bishop, *et al.* (1990). So, the findings expand on those obtained by these authors.

This finding may be related to the fact that the lack of vocalizations and motor dysfunction may affect linguistic development. It is possible that people with more severe vocal and motor disabilities have not acquired the same level of understanding of more complex linguistic constructions as less affected participants. Falkman, *et al.* (2002) suggests that problems in the prelinguistic period, such as not babbling or not taking part in conversations, may account in part for the lack of linguistic expression in preschool children with cerebral palsy. If a lack or a limitation of previous experience affects linguistic expression, but not prelinguistic modes of communication, it is reasonable to assume that the understanding of more complex grammatical constructions, which is more dependent on linguistic analysis than prelingual communication, may also be affected.

An interesting parallel is the finding that deaf people who use sign language also have difficulties in language comprehension (Hamilton, 2011). This issue has been linked with the fact that sign structure has something intrinsic that hinders certain processing strategies, which are necessary for language comprehension (Geraci, Gozzi, Costanza, & Cecchetto, 2008; Hamilton, 2011). Sign languages require simultaneous components such as the expression of different types of information by means of different systems (hands, eyes, shoulders, body position, etc.). So, it is likely that sign language may not be suited for serial recall, as suggested by Hanson (1982). Indeed, deaf people show worse short term and working memory than hearing people, which may influence the comprehension of long and grammatically complex sentences (Geraci, *et al.*, 2008; Hamilton, 2011). In light of these interesting findings, the gestural or alternative communication systems used by the current participants with deficient verbal expression may not facilitate the development of the cognitive strategies which are necessary for oral grammar comprehension.

Moreover, the finding that verbal expression abilities contributed to explaining grammar comprehension skills is consistent with prior neuroimaging studies showing that speech production and grammatical processing activate common brain regions such as Broca's area (Blank, Scott, Murphy, Warburton, & Wise, 2002; Sahin, Pinker, & Halgren, 2006). This finding may also be linked to the fact that comprehension of complex grammatical structures demands working memory capacity. Along these lines, some authors have found deficits in working memory in people with cerebral palsy (Kolk & Talvik, 2000; Jenks, Moor, & van Lieshout, 2009; van Handel, Sonneville, de Vries, Jongmans & Swaab, 2012).

In summary, grammatical processing in the participants in this study may be related to the alteration of the same brain region involved in speech production and other cognitive functions as well as to a diminished interaction with the environment. In this regard, Bottcher (2010) argued that deficits in cerebral palsy are both the consequence of early brain injury and the result of the particular interaction between child and environment.

Pennington and McConachie (2001) found that poor speech intelligibility was the main predictor of restrictive cerebral palsy communication patterns. Those authors recommended therapy to increase the intelligibility of these children's speech. The present findings may also suggest that verbal expression abilities are important markers for cerebral palsy therapies.

Unlike Bishop, *et al.* (1990), we did not find that verbal expression ability explained the performance in vocabulary comprehension. Both Bishop, *et al.*'s study and the current study used the Peabody Picture Vocabulary Test, but the current sample was older (*M* ages 22 vs 14 years). Results suggest that in adult subjects with cerebral palsy, vocabulary performance is unrelated to speech disorder. So the results appear to corroborate those of Bishop, *et al.*, who suggested that the delay in vocabulary acquisition in non-verbal individuals might be compensated over time. However, perhaps due to the small sample size, the statistical analysis in our study did not reveal a significant effect of age, and so we were unable to analyze vocabulary comprehension abilities at different ages. Nor did we find the expected effect of age in grammar comprehension and gestural comprehension. The reason for this result may have been the small sample size, or the possible ceiling effects of the tests we used.

Finally, unlike the findings for verbal expression ability, gestural expression ability did not explain the variance in gestural comprehension. The cerebral palsy study by Harbourne (2001) found that movement error detection skills were also unrelated to motor ability. Moreover, a dissociation between praxis production and comprehension has already been suggested for patients with anterior or posterior lesions (Heilman & Valenstein, 2003; Watson, Fleet, Gonzalez-Rothi, & Heilman, 1986).

In conclusion, the relationship between expression and comprehension in cerebral palsy does not have the same implications for verbal communication as for gestural communication. In this sample of non-ambulatory patients with bilateral cerebral palsy, verbal expression ability was related to grammar comprehension skills, but impaired gestural expression should not be taken as an indicator of impaired gesture comprehension. Although the results may be interesting for clinical settings, neuroimaging studies with greater and more homogeneous cerebral palsy samples are needed to assess the relationship between verbal expression and comprehension.

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