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Predictors of Reading Comprehension in Children with Cerebral Palsy and Typically Developing Children

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Abstract

Predictors of reading comprehension were evaluated in 41 children with cerebral palsy and 74 typically developing children between the ages of 6 and 12 years. Regression analyses were conducted to determine the relative contributions of measures of phonemic awareness, receptive vocabulary, and general reasoning to variance in reading comprehension. All three independent variables were statistically significant predictors of reading comprehension in both groups of participants. The impact of phonemic awareness on reading comprehension was moderated by age, but only in the typically developing group. Within the group with cerebral palsy, there was an indirect effect of functional expressive ability on reading comprehension, mediated by phonemic awareness. It is concluded that largely the same variables predict reading comprehension in children with cerebral palsy as in typically developing children, but that children with cerebral palsy continue to rely on phonological processing for a more protracted period of time.

Keywords

Psychological Assessment; Children; Reading Comprehension; Cerebral Palsy

INTRODUCTION

One out of every four children in the United States fails to achieve basic reading skills by the eighth grade (NCES, 2009). In the population of children with neurodevelopmental conditions, data suggest that these failure rates are even higher. Among transition age students (14 – 18) receiving special education services, 25.4% of those with physical impairments and 68.9% of those with severe multiple impairments have not achieved functionally independent reading levels (NLTS-2, 2002). In the population of children with spastic cerebral palsy (CP), it has been estimated that over 50% of children have a learning disability or a specific learning impairment, though literacy outcomes are not known (Schenker, Coster & Parush, 2005).

CP results from an insult to the developing central nervous system, with motor impairment as the key defining characteristic. Additionally, there is a wide range of comorbid symptoms, depending on individual factors such as the location, size, nature/severity, and timing of the lesion (Blondis, 2004). Infants diagnosed with CP are at such high risk for developmental disorders that they typically receive early intervention to address developmental problems in visual and perceptual skills, cognitive processing, speech and language skills, and social-emotional functioning, as well as motor skills (Fennell & Dikel, 2001). While higher risk for

learning disorders, including reading failure, is related in part to generally lower intellect in children diagnosed with CP, research also suggests that risk for learning disorders stems from multifactorial influences. That said, there is ongoing controversy regarding the stability of individual differences in reading through the elementary school years, with recent evidence indicating important instabilities that appear to highlight the potential for change in skill levels (Phillips, Norris, Osmond, & Maynard, 2002; Verhoeven & Van Leeuwe, 2008).

In addition to the motor impairments central to the diagnosis of CP, brain dysfunction may also result in cognitive problems, including learning disorders such as reading difficulties or speech and language skills. Learning disorders can be manifested by significant problems in the acquisition and use of listening, speaking, reading, writing, and/or mathematics. Learning disorders may occur, independent from intellectual problems. Children with learning disorders can be successful in their academic pursuits; early intervention and special education services increase the likelihood of higher proficiency (Blauw-Hospers & Hadders-Algra 2005).

Phonological awareness is generally recognized as one of the strongest predictors of early reading acquisition. Phonological awareness is defined as the capacity to consciously represent and reflect on phonological properties, independent of focus on the meaning of spoken stimuli (Smith, 2005). This awareness covers a broad range of abilities, one of which is phonemic awareness. Phonemic awareness refers to the explicit awareness of phonemes as units of sound, and is associated with alphabetic literacy (Perfetti, Beck, Bell, & Hughes, 1987). While there is ongoing controversy regarding the nature of phonological processing (Anthony & Lonigan, 2004), there is much evidence that instruction in phonemic awareness is a critical part of effective intervention for many students with early reading delays; including preliminary evidence that specific phonemic awareness instruction can increase reading skills in children with severe speech impairments (Blischak, Shah, Lombardino, & Chiarella, 2004).

The relationship between phonological awareness and literacy appears to be more complex among children with CP. Recent research by Peeters, Verhoeven, de Moor, and van Balkom (2009) demonstrated that although phonological awareness and phonological short-term memory were the most important precursors for word decoding skills in typically developing children, for children with CP, the most important precursor for word decoding was speech production. Thus, children with CP who are vulnerable to speech impairments related to oral-motor difficulties, such as dysarthria, are also at increased risk for literacy problems (Peeters et al., 2009). Dysarthria in CP does not necessarily preclude development of phonological processing skills. Among children with CP and dysarthria, those who could read had higher phonological processing scores than the nonreaders (Sandberg & Hjelmquist, 1997). Children with CP exhibit lower performance on specific phonological processing tasks, including rhyming tasks (Larsson & Sandberg, 2008). Rhyme is one of the earliest aspects of phonological processing to develop (Lonigan, Burgess, & Anthony, 2000). Children with CP and dysarthria have been shown to exhibit specific impairments in detecting rhyme in written words, segmenting syllables, and manipulating phonemes (Card & Dodd, 2006). Recent findings indicate that preschool children with CP show lower rhyme perception skills (Peeters, Verhoeven, van Balkom, & de Moor, 2008). Key predictors of these early phonological awareness skills in the children with CP included nonverbal reasoning and a measure of articulation. In contrast, among typically developing preschoolers, only auditory perception was associated with phonological awareness.

While phonemic awareness is a critical predictor of early word decoding skill, there is long-standing evidence that other language skills, including semantic skills and vocabulary, are key predictors of reading comprehension (Roth, Speece, & Cooper, 2002; Verhoeven & Van Leeuwe, 2008). Receptive vocabulary in particular has been associated with reading comprehension through the elementary school years (Verhoeven & Van Leeuwe, 2008). This

association between breadth of receptive vocabulary and reading comprehension, however, may be mediated by depth of vocabulary as reflected in ability to define words (Ouellette, 2006).

Apart from a number of very small sample or multiple case studies, there is a paucity of research that examines predictors of reading comprehension in children with CP (Dorman, 1987; Sandberg, 2006; Sandberg & Hjelmquist, 1997). Sandberg (2006) has shown that children with severe dysarthria or anarthria can learn to read, but the sample sizes were small, precluding multivariate analyses. In the only study to date that utilized multivariate analysis, Dorman (1987) examined predictors of reading comprehension, assessed with the Reading Comprehension subtest of the Peabody Individual Achievement Test, in 31 adolescents with CP. Findings included a significant bivariate correlation between Verbal I.Q. and reading comprehension, but in a multiple regression analysis, Verbal I.Q. was no longer significant and the sole predictor of reading comprehension was a measure of auditory perception.

In summary, there is evidence that children with CP are at risk for reading disabilities, and more specifically for impairments in aspects of phonological awareness, a critical predictor of reading acquisition. It is not clear whether, or to what extent, correlates of development of early phonological awareness skills in children with CP differ from those in typically developing peers. Similarly, little is known about the key predictors of reading comprehension in school-aged children with CP. To build on previous research findings, this study examined group differences in predictors of reading comprehension in children with and without CP. Independent variables included measures of phonemic awareness, receptive vocabulary, and general reasoning. Although phonemic awareness has been specifically associated with reading acquisition, rather than later reading comprehension, we included it as one of the more well understood domains in the study of reading in the population of children with CP. Given the findings of differences in predictors of reading at different grade levels, age effects were examined. In children with CP, the direct and indirect influences of functional abilities, including motor skills and speech, were also examined.

It was hypothesized that variance in reading comprehension could be predicted based on specific measures of receptive vocabulary, phonemic awareness, and general reasoning in children with CP as in typically developing children. Second, we expected that the impact of phonemic awareness on reading comprehension would be moderated by age in both groups. This was expected because at younger ages, phonemic awareness is necessary for children to be able to sound-out words when they are learning to read; thus, higher mastery of phonics is expected to be associated with better reading fluency. However, once the children become fluent readers with age and experience, the effect of phonemic awareness on reading comprehension should diminish (Church, Coalson, Lugar, Petersen, Schlaggar, 2008; Crowley, Mayer, & Stuart-Hamilton, 2009; Roman, Kirby, Parrila, Wade-Woolley, & Deacon, 2009; Scarborough, Ehri, Olson, & Fowler, 1998). Additionally, we did not expect functional level of physical independence (gross motor and fine motor skills) to have a direct influence on reading comprehension, but we did hypothesize that functional language levels (receptive and expressive communication skills) could be a mediating factor, and thus have an indirect effect via either receptive vocabulary or phonemic awareness.

METHOD

Participants

After receiving Institutional Review Board (IRB) approval, participants were recruited through flyers and websites at two Midwest medical rehabilitation centers, according to the following criteria: between the ages of 6 and 12 years, medically stable, no history of an acquired brain injury (for children with CP: no event subsequent to those potentially associated with the

etiology of the condition), hearing and vision within functional limits (corrective lenses or hearing aid allowed), no recent significant changes in medications that might affect cognitive functioning, and able to make a consistent choice from multiple options. An additional specific inclusion criterion for the children with CP included oral communication ability sufficient to participate in the assessment of phonemic awareness testing.

The final sample included 41 children with Cerebral Palsy (CP) and 74 typically developing (TD) children. The CP group was primarily Caucasian in ethnicity ($n = 35$, 85.37%) and consisted of 20 boys and 21 girls with a mean age of 9.18 yrs ($SD = 1.66$) and a mean Hollingshead level of SES of 3.08 ($SD = 1.04$). Ten of these children (24%) had a seizure disorder. The vast majority ($n = 37$, 90.24%) received at least some special education support; of those, 18 participated in Resource Room, 1 was in a Self-Contained Classroom, 36 participated in Speech/Language Therapy. The Gross Motor Functional Classification System (GMFCS; Palisano, Rosenbaum, Walter, Russell, Wood, & Galuppi, 1997), Manual Ability Classification System (MACS; Eliasson et al., 2006), Expressive Production Rating Scale (ExPRS), and Receptive Understanding Functional Classification Scale (RUFCS) each used a five-level ordinal rating scale to describe the level of functional ability including use of assistive devices and technology in each of those four domains. The level of limitations and/or need for assistive devices characterized the distinctions between levels (1 to 5). The parent chose the statement that best fit the child's need for each domain, with a score of "1" indicating normal or near normal functioning, "2" having mild difficulty, "3" having moderate difficulty, "4" being significantly limited and needing adaptive assistance, and a score of "5" being severely limited in functional ability for the specific domain, even with the use of assistive technology. Functional levels according to the GMFCS (criteria were as follows for the CP group: Level I (31) 75.61%, Level II (1) 2.44%, Level III (8) 19.51%, and Level IV (1) 2.44%. MACS ratings for this group included Level I (10) 24.39%, Level II (25) 60.98%, and Level III (6) 14.63%. The ExPRS levels in the CP group were Level I (27) 65.85%, Level II (13) 31.71%, and Level III (1) 2.44%. Finally, on the RUFCS, children in the CP group were rated as Level I (33) 80.49% and Level II (8) 19.51%. Nearly all of the 74 children in the TD group achieved a Level I on all 4 of these ordinal functional classification scales with the exception of one child (1.35%) who was rated as Level II on the GMFCS (i.e., mild restriction in walking but no assistive device needed), and one child (1.35%) who was rated as Level II on the ExPRS (i.e., mildly slowed speech but still intelligible). The TD group was also primarily Caucasian ($n = 63$, 85.14%) and consisted of 28 boys and 46 girls with a mean age of 9.20 years ($SD = 1.69$), and a mean Hollingshead level of socioeconomic status of 2.95 ($SD = 0.95$). Although the proportion of boys was slightly lower in the TD group (38%) than in the CP group (49%), this difference fell well short of statistical significance, $z = 1.14$, $p > .25$.

Procedure

Participants and their parents provided, respectively, informed assent and written consent for participation in the research program in accordance with IRB guidelines. The children completed the test battery while their parent or legal guardian completed a set of survey instruments describing their child's medical and psychosocial history, as well as basic demographic information. The adult completing the forms was a primary caregiver of the participant; in most cases, the participant's mother. All families were paid \$50 for their participation.

Measures

Instruments utilized to test the hypothesis for this study included the *Peabody Picture Vocabulary Test – 3rd Edition* (PPVT; Dunn & Dunn, 1997), Raven's Colored Progressive Matrices (RCPM; Raven, Raven, & Court, 1998), the Reading Comprehension subtest of the Peabody Individual Achievement Test-Revised / Normative Update; (PIAT; Markwardt,

1998), and the Elision subtest of the *Comprehensive Test of Phonological Awareness* (CTOPP; Wagner, Torgesen, & Rashotte, 1999). Parents completed a form about demographic, medical, and functional characteristics of the child. This included questions about the participants' gross motor functioning (Gross Motor Functional Classification Scale; GMFCS; Palisano et al., 1997), ability to use their hands for functional tasks (Manual Ability Classification System; MACS; Eliasson et al., 2006), general understanding of language (RUFCS) and expressive language production (ExPRS). The ExPRS and RUFCS were developed by the current researchers to parallel the GMFCS and MACS and provide gross assessment of functional abilities in expressive communication.

Peabody Picture Vocabulary Test – 3rd Edition (PPVT)—The PPVT is an individually administered test designed to measure single word receptive vocabulary through a multiple choice format. For each test item, participants were shown a page with four black and white illustrations, and a target word was orally presented. The participant identified the picture that best described the word by either pointing to, or saying the number of the correct picture. The psychometric properties for the PPVT have been well established, and the test is widely used and accepted as a measure of receptive vocabulary with diverse clinical and sociodemographic groups (Strauss, Sherman, and Spreen, 2006).

Raven's Coloured Progressive Matrices (RCPM)—The RCPM was developed as measure of Spearman's *g* or general intellect / reasoning and was designed to measure this construct, independent of language or formal schooling. The RCPM measures a person's ability to reason by analogy and to develop abstract perceptual relations of visually presented items. There are three 12-item sets, presented in a multiple choice format. Individual items consist of a pattern with a missing element; the participant identifies the element that correctly completes the figure from a set of six choices. The psychometric properties of the RCPM are established as a reliable and valid measure of nonverbal reasoning in children (Strauss, Sherman, and Spreen, 2006).

Peabody Individual Achievement Test-Revised / Normative Update; Reading Comprehension subtest (PIAT)—The PIAT was used in this study because it is a screening measure of reading comprehension that has the potential to be adapted for use on the computer with response via assistive technology devices. Specifically, the PIAT is an individually administered achievement test designed to measure performance in six different academic domains using a multiple choice format. This study utilized the standardized score of the Reading Comprehension (RC) subtest to measure comprehension of sentences. Administration of the RC requires that the participant first complete the first 18 items of the Reading Recognition (RR) subtest without reaching the ceiling. Per PIAT protocol, if the child does not reach the test ceiling (five errors in seven consecutive items) prior to item 18, they qualify to proceed to RC. All participants completed the first 18 items of the RR subtest, and thus, demonstrated sufficient word reading skills to be able to complete the RC subtest. Participants read a sentence (silently) and were then presented with a choice of four pictures to describe the previously read statement. Reliability and validity measures for the PIAT are documented as quite high and the test is generally accepted as a standard means for measuring achievement abilities in the pediatric population (Markwardt, 1998).

Comprehensive Test of Phonological Awareness; Elision subtest (CTOPP)—The Elision subtest of the CTOPP requires the participant to analyze phonological information. Participants were presented with spoken words, and asked to repeat the word. They were then asked to remove a phonemic segment of the word. For example, the participant was asked to say "cat" without /k/. The correct response "at" demonstrates mastery of phonemic elision skills. The CTOPP evidences a high degree of reliability and is purported to be a valid measure

of phonological processes based on statistical analyses of its psychometric properties (Wagner, Torgesen, and Rashotte, 1999).

Data Analyses

A series of multiple regression analyses were conducted to determine if reading comprehension ability (i.e., PIAT), could be predicted, based on measures of receptive vocabulary (PPVT), phonological awareness (CTOPP) and general nonverbal reasoning (RCPM). Two multiple regression analyses were initially completed; one to analyze data for the TD group, and the second for the CP group. Next, the relationship between phonological awareness and reading comprehension was analyzed in terms of whether age was a moderating factor. A moderator variable specifies the conditions under which a given predictor is related to an outcome; for example, the association between the predictor (e.g., phonemic awareness) and an outcome variable (e.g., reading comprehension) might depend on the level of a moderating functional variable (e.g., age). Finally, in the CP group, we evaluated the potential impact of functional motor or language skills on reading comprehension; and more specifically, the mediating role of either receptive vocabulary or phonemic awareness in this regard. A mediating variable is one that explains the process or mechanism by which a predictor variable affects an outcome variable, such that the predictor (e.g., verbal expressive ability) is associated with the mediator (e.g., phonemic awareness), which in turn affects the outcome measure (e.g., reading comprehension). To interpret proportions of variance explained by the regression models we used the criteria suggested by Murphy and Myers (2004), who suggested that R^2 values less than .10 can be classified as small, R^2 values between .10 and .25 as medium, and R^2 values greater than .25 as large.

RESULTS

Table 1 presents the mean performances of both groups of participants on the main variables of interest. Although the level of performance of the TD group exceeded that of the CP group on all four cognitive test variables ($F [4, 110] = 13.30, p < .0001, \eta^2 = 0.33$), it should be noted that the mean performance of the latter group was still well within normal limits. Using the 10th percentile in the standardization norms distribution as the cut-off point for below-average performance, the total number of children in the CP group who fell below that criterion were, respectively, 11 (27%) on CTOPP, 6 (15%) on RCPM, 5 (12%) on PIAT, and 2 (5%) on PPVT.

We first performed two sets of multiple regression analyses, one using the TD group and the other one using the CP group, to determine to what extent reading comprehension, as assessed by the PIAT, could be predicted on the basis of the following independent variables: receptive word knowledge (PPVT), phonological awareness (CTOPP), and general reasoning (RCPM). These findings are presented in Table 2. Inspection of this table suggests that the regression models were very similar in both groups, with PPVT, CTOPP, and RCPM all being statistically significant predictors of PIAT performance in both the CP group, $F (3, 37) = 14.54, p < .0001, R^2 = 0.54$, and the TD group, $F (3, 70) = 36.31, p < .0001, R^2 = 0.61$. Review of collinearity diagnostics did not reveal any threat to the validity of these models (e.g., all variance inflation factors < 1.25 in both groups).

Next, we evaluated the degree to which the relationship between phonological awareness and reading comprehension was moderated by age. For this purpose, the interaction term between age and CTOPP performance was added to the regression models presented in Table 2. In the CP group, this created problems with collinearity (i.e., variance inflation factors > 5.85 for both CTOPP and the interaction term), but such problems were not encountered in the TD group. Table 3 presents the resulting model in the TD group, $F (4, 69) = 30.44, p < .0001, R^2 = 0.64$. As can be seen in this table, the interaction term was a statistically significant predictor of PIAT performance in this group, along with the three psychometric test variables, suggesting

that the effect of phonological awareness on reading comprehension was moderated by age. This moderating effect can also be demonstrated by considering the Pearson product-moment correlations between the CTOPP and PIAT variables in younger *v.* older children, with the dividing point being the median (9.00 years) in the TD group. In the younger age group ($n = 25$), this relationship was much stronger ($r = 0.75, p < .0001$) than in the older age group ($n = 49, r = 0.42, p < .003$), indicating that the effect of phonological awareness on reading comprehension was relatively more robust in younger children in the TD group. This difference was statistically significant, $z = 2.02, p < .03$, suggesting that the effect of phonological awareness on reading comprehension was relatively more robust in younger children in the TD group. In contrast, no such difference was noted in the CP group in terms of the correlations between CTOPP and PIAT in the younger ($n = 15, r = 0.49, p < .07$) and older ($n = 26, r = 0.54, p < .005$) age groups, $z = 0.21, p > .41$.

Finally, we determined the degree to which performance on the PIAT in the CP group was related to the overall functional abilities of the children, as reflected in the GMFCS, MACS, ExPRS, and RUFCS ratings. Spearman correlations revealed that only level of expressive language, as assessed by ExPRS, covaried in a statistically significant manner with PIAT performance ($r = -0.47, p < .002$), with greater verbal expressive impairment being associated with lower reading comprehension. Correlations between the other functional ability ratings and PIAT performance fell well short of statistical significance ($p > .15$ for all three variables).

Because of the statistically significant negative correlation between PIAT and ExPRS, we wanted to explore in the CP group the degree to which the latter variable made an independent contribution to the prediction of reading comprehension, separate from the various cognitive abilities, or whether its effect was mediated by one of them. In light of the fact that ExPRS was statistically significantly correlated, not only with PIAT but also with PPVT ($r = -0.38, p < 0.02$) and with CTOPP ($r < -0.32, p < 0.04$) but not with RCPM ($r = -0.26, p > 0.10$), it was plausible that the effect of expressive language ability on reading comprehension might be mediated by either verbal word knowledge or phonological ability. We evaluated this by means of a series of hierarchical regression analyses in the CP group, and these are presented in Table 4.

Inspection of Table 4 suggests that when ExPRS was the only variable entered into the model, it was a statistically significant predictor of PIAT performance, explaining about 23% of the variance. When PPVT was added to the model, the total amount of variance accounted for was doubled, but ExPRS remained statistically significant, suggesting that it made an independent contribution to the prediction of PIAT performance, separate from general verbal word knowledge. However, when CTOPP was then added as an additional independent variable, the influence of ExPRS was grossly attenuated to the point that it became statistically non-significant, whereas both CTOPP and PPVT made statistically significant contributions to the prediction of PIAT performance, with the total model explaining about 7% additional variance. This indicated that the influence of ExPRS on PIAT was mediated by phonological awareness, as measured by the CTOPP. This interpretation of a mediating effect was supported by means of a Sobel test ($z = -2.22, p < .03$). Inspection of collinearity diagnostics again did not reveal any threats to the validity of this final model (e.g., all variance inflation factors < 1.25).

DISCUSSION

The purpose of this study was to examine similarities and differences in the predictors of reading comprehension in children with cerebral palsy (CP) and typically developing (TD) peers. As was hypothesized, reading comprehension (as assessed by PIAT) could be predicted by measures of receptive vocabulary (PPVT), phonemic awareness (CTOPP), and general reasoning (CPM) in both the CP and TD groups. The hypothesized moderating effect of age

on the association between phonemic awareness and reading comprehension was found only in the TD group. Finally, as hypothesized, we found that within the CP group, fine or gross motor abilities had no statistically significant impact on reading comprehension, but there was an indirect effect of verbal expressive ability, which was mediated by phonemic awareness.

Our results expand on the previous findings of Peeters et al. (2009) who found that verbal expressive ability was the most important predictor of reading ability in children with CP. Specifically, our findings clarify that the effect of oral communication ability (as measured by ExPRS) was mediated by phonological awareness (as measured by CTOPP). Thus, there appears to be an association between the ability of a child with CP to be aware of the sound structure of language and his/her articulation skills, and this association in turn affects reading comprehension. Recent research suggests this kind of association between articulation rate and phonological awareness may also affect other areas of cognitive functioning in children with reading disabilities, such as their verbal short term memory (Kibby, 2009).

The current findings suggest that children with CP who are able to communicate verbally have low-average but not pervasively impaired phonemic awareness. The fact that better phonemic awareness was associated with improved reading comprehension is consistent with previous findings in children with CP who were anarthric (Sandberg & Hjelmquist, 1997). Furthermore, in the current investigation, the level of reading comprehension in children with CP was essentially predicted by the same key variables as in children without CP. These findings add to the previous literature on children with CP (Dorman, 1987) and indicate that in this population, receptive vocabulary and general reasoning abilities play independent roles in reading achievement.

One aspect in which children with CP appeared to differ from TD children was with regard to the moderating effect of age. In the TD group, the influence of phonemic awareness on reading comprehension became less pronounced at older ages, which fits with the expectancy that as children become more fluent in reading, they no longer rely as much on phonics to sound-out and read individual words. However, based on the results of this study, the same cannot be said for children with CP, in whom there was no moderating effect of age. One explanation could be that children with CP, although not pervasively impaired in phonemic awareness, do not achieve the same level of efficiency in this area as TD children, and that they continue to rely on these skills for a longer period of time. An alternative interpretation of the difference may be that children in the CP group have more modest reliance on phonemic awareness throughout their development compared to children in the TD group. These possibilities should be explored in future research, using functional neuroimaging procedures to determine if, in comparison with TD children, individuals with CP recruit activity from different brain regions, or need longer or more intense activation in the same regions, during reading.

Finally, the fact that fine and gross motor abilities did not have an influence on reading comprehension in children with CP underscores the importance of not equating physical disability with cognitive impairments. Furthermore, any influence of abilities in oral communication on reading comprehension appeared to be indirect; more specifically, mediated by level of phonemic awareness. This reinforces the above-mentioned suggestion that phonemic awareness is a crucial determinant of reading comprehension in children with CP. Given the high percentage of children with CP who are severely dysarthric or anarthric, findings highlight the need to develop tests of phonemic awareness that do not require verbal responses.

Potential limitations of this investigation must also be considered. The TD group had a relatively high level of intellect, and replication with a sample of generally average intelligence is needed. In addition, this study did not include children with CP who were not able to use oral expression as a means of communication. It would be helpful for future studies to include

a group of children who are nonverbal to determine if similar findings are observed in that population. This would likely require development of adaptive measures of phonemic awareness, a goal that has been somewhat elusive in recent research (Warschausky et al., 2009). It should be noted that we only evaluated one aspect of reading comprehension; i.e., at the sentence level. A different pattern of findings might have been observed if a different reading comprehension test was used, such as a measure that required contextual passage interpretation, or that had time limits. Different tests of reading comprehension may yield different results, as each method may challenge a slightly different set of cognitive abilities (Cutting & Scarborough, 2006). Clearly, a more extended assessment of reading at the level of multiple paragraphs would be necessary to allow for a more precise differentiation of component skills such as inference making, comprehension monitoring, and understanding text structure, all of which are important aspects of higher-level reading comprehension (Cain, Oakhill, & Bryant, 2004).

This study also did not control for variables such as therapies or special education support services that the children may have received. It is possible that some of the children had more experience than others with focused training on phonics skills. The impact of specific phonemic training on reading ability in children with CP is another goal for future research. Likewise, we did not assess executive functioning skills in this study, for example, to determine if the shift from reliance on basic phonemic skills to higher level executive skills was present in both groups. Future research may also include measures of executive functioning, as Sesma and colleagues (2009) have suggested a contribution of executive skills to reading comprehension.

With these reservations in mind, we conclude that children with CP who are able to communicate verbally are able to achieve a level of reading comprehension that is within the normal range for their age. Furthermore, this reading level is determined largely by the same variables that predict reading comprehension in TD children, with the exception that phonemic awareness continues to influence the reading ability of children with CP for a more prolonged period of time.

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Table 1

Cognitive Test Performance in Children with Cerebral Palsy (CP; $n = 41$) and Typically Developing Children (TD; $n = 74$)

Variable	CP group		TD group	
	M	SD	M	SD
CTOPP ^a	8.00	3.48	11.39	2.69
PPVT ^b	100.49	16.58	112.73	11.43
RCMP ^b	98.16	15.51	110.27	9.86
PIAT ^b	97.39	17.49	110.83	14.41

^a scaled score ($M = 10$, $SD = 3$).

^b Standard score ($M = 100$, $SD = 13$).

^c Raw score.

Note: CTOPP = Elision subtest of the Comprehensive Test of Phonological Awareness. PPVT = Peabody Picture Vocabulary Test – 3rd Edition. RCMP = Raven's Coloured Progressive Matrices. PIAT = Reading Comprehension subtest of the Peabody Individual Achievement Test-Revised / Normative Update.

Table 2

Regression Models for PIAT in Children with Cerebral Palsy (CP; n = 41) and Typically Developing Children (TD; n = 74)

Variable	CP Group			TD Group		
	SRC	t	p <	SRC	t	p <
PPVT	0.46	3.83	.0005	0.50	6.21	.0001
CTOPP	0.26	2.13	.04	0.40	5.02	.0001
RCPM	0.26	2.13	.04	0.18	2.35	.02

Note: PIAT = Reading Comprehension subtest of the Peabody Individual Achievement Test-Revised / Normative Update. SRC = standardized regression coefficient. CTOPP = Elision subtest of the Comprehensive Test of Phonological Awareness. PPVT = Peabody Picture Vocabulary Test – 3rd Edition. RCPM = Raven’s Coloured Progressive Matrices.

Table 3

Revised Regression Model for PIAT in Typically Developing Children (n = 74)

Variable	SRC	t	p <
PPVT	0.46	5.80	.0001
CTOPP	0.62	5.12	.0001
RCPM	0.18	2.46	.02
Age*CTOPP	−0.27	−2.37	.02

Note: PIAT = Reading Comprehension subtest of the Peabody Individual Achievement Test-Revised / Normative Update. SRC = standardized regression coefficient. CTOPP = Elision subtest of the Comprehensive Test of Phonological Awareness. PPVT = Peabody Picture Vocabulary Test – 3rd Edition. RCPM = Raven's Coloured Progressive Matrices.

Table 4
Revised Hierarchical Regression Model for PIAT in Children with Cerebral Palsy (n = 41)

Step	Variables	SRC	t	p <	Model F	Model R ²
1	ExPRS	-0.47	-3.37	.002	11.35	0.23
2	ExPRS	-0.28	-2.17	.04		
	PPVT	0.51	3.93	.0003	15.51	0.45
3	ExPRS	-0.21	-1.64	.11		
	PPVT	0.46	3.65	.0008		
	CTOPP	0.29	2.33	.03	13.35	0.52

Note: PIAT = Reading Comprehension subtest of the Peabody Individual Achievement Test-Revised / Normative Update. ExPRS = Expressive Production Rating Scale. CTOPP = Elision subtest of the Comprehensive Test of Phonological Awareness. PPVT = Peabody Picture Vocabulary Test – 3rd Edition.