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Inspection Time and ADHD Symptoms in Children with Cerebral Palsy

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Abstract

Objective—To examine between-group differences in the associations between aspects of processing speed assessed with an inspection time task, and attention-deficit/hyperactivity disorder (ADHD) symptoms.

Research Design—Two groups comprised of 34 children with cerebral palsy (CP) and 70 nonaffected peers (Control), ages 8 – 16, participated in a prospective correlational study. Measures included a visual inspection time task and the Conners' Parent Rating Scale – Revised: Long Version.

Results—Children with CP exhibited significantly slower processing speed, and more symptoms of inattention and hyperactivity than Controls. Significant associations between inspection time and ADHD symptoms were found only in the Control group.

Conclusions—Findings have implications for clinical assessment and understanding of attentional risks associated with CP.

Keywords

cerebral palsy; attention; processing speed; Attention-Deficit/Hyperactivity Disorder (ADHD); visual inspection time; neuropsychology

Cerebral palsy (CP) is a group of permanent disorders of movement and posture attributed to nonprogressive disturbances in brain development that occurred in the developing fetal or infant brain (Rosenbaum et al., 2007). While the location of lesions in CP may vary, damage to periventricular white matter tracts is a common presentation (White & Christ, 2005). World-wide prevalence of CP is greater than two per thousand live births. In the United States, approximately 10,000 children a year are diagnosed with CP (Blair & Watson, 2006; Odding, Roebroek, & Stam, 2006). There is significant heterogeneity in the nature and severity of the motor abnormalities associated with CP. There also is significant heterogeneity in the comorbidities associated with the condition, which often include disturbances of sensation, perception, cognition, communication, and behavior, as well as seizures and secondary musculoskeletal problems (Rosenbaum et al., 2007).

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Individuals with CP appear to be at increased risk for a variety of cognitive impairments including attention and executive functions such as inhibitory control (Pirila, van der Meer, Korhonen, Nieminen, & Korpela, 2004; White & Christ, 2005). Studies have shown that the impairment in inhibitory control is apparent regardless of response modality (i.e., oral, manual, or ocular). There are also risks for impairments in selective visual attention (Craft, White, Park, & Figiel, 1994, Schatz, Craft, White, Park, & Figiel, 2001). At the more molar level, strategic planning difficulties have been demonstrated in children with CP (Pirila et al., 2004). Attention-Deficit / Hyperactivity Disorder (ADHD) is reported to be more common in children with CP than in the general population, with reported prevalence rates varying by study.

Recent estimates of overall prevalence of ADHD have been reported at 19% in children with CP (Schenker, Coster & Parush, 2005). Earlier population based research suggested that 25.5% of children with CP displayed hyperactive behaviors (McDermott, et al., 1996). Some studies have suggested that 40% of children with CP demonstrate severe difficulties with emotional regulation, behavior, and concentration (Parkes et al., 2008). Goodman (1998) reported a 31 percent prevalence rate of hyperactivity in a CP sample. Among school-age children with CP, symptoms of restlessness and inattentiveness were also strong predictors of persisting emotional or behavioral problems at four-year follow-up. Despite high prevalence rates, there is a limited understanding about the nature of ADHD symptoms in children with CP.

While the prominent diagnostic symptoms of ADHD are inattention and/or hyperactivity/impulsivity, it has been well-demonstrated that individuals with diagnoses of ADHD also have a higher incidence of co-occurring slowed processing speed (PS) than their typically developing peers (Chhabildas, Pennington, & Willcutt, 2001; Lahey et al., 1998; Mayes, Calhoun, Chase, Mink, & Stagg, 2009; Mayes & Calhoun, 2007; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002; Wassenberg et al., 2008). Similar to those with ADHD who are not affected by CP, individuals with CP diagnoses may be at risk for sluggish cognitive tempo in association with ADHD; though examination of this process is confounded by the speeded motor demands of most neuropsychological measures of PS.

In a study of children with CP, Christ, White, Brunstrom, & Abrams (2003) found that slowed PS initially appeared to drive inhibitory control deficits; however, after statistically controlling for PS, children with CP continued to show inhibitory control deficits. Christ et al. (2003) noted a primary difficulty in assessing PS, given the confound of motor speed for most measures of cognitive PS. To date, there have been no studies of cognitive PS in CP that have fully addressed this motor speed confound.

In order to investigate PS in children with CP who, by definition, have motor abnormalities, this study utilized a visual inspection time (IT) task that required a dichotomous discrimination choice regarding a perceived quality of a simple visual stimulus without a speeded response demand. Stimuli were presented with gradually reduced on-screen durations until the critical stimulus onset asynchrony, or shortest duration at which a participant can be successful, was obtained; this is the participant's IT threshold (Burns & Nettlebeck 2005; Fox, Roring, & Mitchum, 2009). Success is indicated by a reliable correct response at a given stimulus presentation speed, rather than response speed as utilized in traditional PS tasks (Edmonds et al., 2008). Thus, IT methodology significantly reduces or eliminates the confound of speeded motor responding.

Processing speed is not a unidimensional construct and factor analyses of PS measures suggest a four-factor solution defined as perceptual speed, visualization speed, decision time, and movement time. IT performance is significantly associated with general processing speed (Gs), but most closely associated with the visualization speed factor (O'Connor & Burns, 2003). In the Cattell-Horn-Carol factor analytically derived model of intelligence, IT is found to load on

PS and general intellect (Burns & Nettlebeck, 2003) and appears to be related to both PS and attentional control (Fox, Roring, & Mitchum (2009).

Children with CP are at risk for impairments in attention and executive functions as well as ADHD symptoms. Evidence also suggests that CP entails risk for slowed PS, which in turn has been associated with higher level cognitive difficulties and ADHD. This study utilized an IT task with untimed limited motor response demands, to examine the associations between aspects of PS and parent/guardian reports of ADHD symptoms in children with CP and unaffected control peers. It was hypothesized that children with CP and Control peers would show positive correlations between IT duration thresholds and parent/guardian ratings of ADHD symptom severity.

Method

Participants

Participants were 34 children with medical diagnoses of CP and 70 unaffected peers without CP (Control), ages 8-16 (Table 1). Data were collected as part of a larger ongoing study examining the psychometrics of modified accessible assessment strategies for children with CP. Study participants included those who completed the full complement of measures examined. Three children (two siblings) from the larger IT study were omitted from these analyses due to incomplete data sets in which Conners Parent Ratings were not completed by parents/caregivers. Inclusion criteria for the group with CP included ability to make a reliable dichotomous choice with a raw score of 12 or better on the Dichotomous Choice Screen (DCS) (Van Tubbergen, Warschausky, Birnholz, & Baker, 2008). Participation in the DCS requires adequate hearing to follow verbal instructions and adequate vision to judge characteristics of simple pictures. Regarding visual screening, in particular, in addition to passing the DCS, participants also were required to pass the step-wise IT training process that necessitates adequate ability to see stimuli sufficiently to proceed successfully through training to criterion. Children were required to have sufficient fine motor dexterity to reliably depress a single keyboard key. Children were excluded or participation was delayed if they had a change in medications with known psychoactive effects such as anticonvulsant medications, sedatives, and neurostimulant medications, within the previous month. There was one instance in which a recent medication change was reported during the course of participation and this child's data were excluded from analyses. Exclusion criteria also included history of an acquired brain injury, or other major neurological or psychiatric condition (for children with CP, this refers to events subsequent to the onset and diagnosis of CP); or inability of the parent/guardian to complete a child history and/or behavior rating measure.

In the group with CP, 82.8% of the sample exhibited spasticity. Functional levels using the Gross Motor Functional Classification System (GMFCS; Palisano, et al., 1997) criteria were as follows: Level I (21) 61.8%, Level II (3) 8.8% Level III (8) 23.5%, Level IV (2) 5.9%. Manual Ability Classification System (Eliasson, Krumlinde, & Rosblad, 2006) levels included Level I (11) 32.4%, Level II (17) 50.0%, Level III (5) 14.7%, Level IV (1) 2.9%. Sixty percent of the CP group had a history of prematurity.

As summarized in Table 1, group differences in age, socioeconomic status and receptive vocabulary were not statistically significant. The group with CP had a higher percentage of male participants (70.6% vs. 51.4%); however, gender was not significantly associated with IT performance. There were significant group differences in gestation, $F(1, 91) = 54.7, p < .01, \eta^2_p = .38$, and birth weight, $F(1, 101) = 57.6, p < .01, \eta^2_p = .37$. Data were not available on the length of gestation of 2 children with CP and 9 Controls. In addition, birth weight data were not available on 2 Controls. Gestation and birth weight were based on parent/guardian report.

Measures

Inspection Time Task: All participants were seated upright in either a standard desk chair (if motor function permitted), or in a personal wheelchair at an angle most closely approximating a standard desk chair while maintaining participant comfort and ability to respond. Participants able to sit in a standard chair were seated at a distance of approximately 60cm from the computer monitor (nose-to-screen) to maximize consistencies of stimulus visual angle among participants, though distance between participants and screen ultimately varied based on comfort and needs of individual participants. Screen angle and distance were adjusted for participants who used personal wheelchairs to an optimal distance and angle for participation rather than a standardized location.

The IT task was administered using a standard personal computer with MultiSync LCD 1860NX screen by NEC (Magna, UT). Stimuli were presented using *Presentation* stimulus delivery platform software (Neurobehavioral Systems, Inc, Albany, California).

The visual IT task employed in this study is summarized in Figure 1 steps A through F. As illustrated in Figure 1, participants were shown a fixation point for 3000ms (A) with brightening (B) lasting 1500ms to assist with orientation to impending stimulus presentation. A blank screen (C) was followed by the target Pi stimulus (π) presentation with varying on-screen duration (D). A visual stimulus mask (E) was used to prevent visual rehearsal of the target (on-screen mask duration = 1000ms – (Duration_{Target} + 25ms)). Mask stimuli were followed by a blank screen (F) which remained for the duration required for participant response using keyboard arrow keys to the question, “which side of the stimulus (as presented in figure 1D) had the longer leg” If the left leg of the Pi subtended a greater length the left arrow key was depressed, and likewise for the right side. After each response, participants indicated readiness to continue to the next trial and the examiner advanced the task. No accuracy feedback was provided during the formal IT task participation, and participants were encouraged to guess if uncertain of their answers.

Individual participant IT was determined by titration of the stimulus onset asynchrony, or SOA (i.e., the time between the onset of the target stimulus and the mask). To this end, after the initial stimulus presentation the SOA increased by 17ms after each incorrect response, and decreased by 17ms after a participant obtained 3 consecutive correct responses at a given SOA. IT was calculated by averaging the SOA over the response data spanning eight directional reversals of SOA. This stepwise time estimation technique is previously described by Wetherill and Levitt (1965). This titration of on-screen duration based on participant accuracy allowed for estimation of the threshold at which participants could accurately process information about the target stimulus without requiring speeded responding. Speed of visualization was carefully controlled by the experimenter at the time of stimulus presentation rather than scoring visualization performance based on participant motor reaction time.

Each child began the IT task with five pre-task training modules designed to provide scaffolded instruction of final task demands. In initial training modules, participants were required to demonstrate the ability to distinguish between Pi symbol targets (π) and lure shapes (triangle, circle) and ultimately to make fine distinctions about characteristics of the target stimulus. Specifically, Pi symbols were made to vary in leg-length to be either long or short on either the left or right side of the character (e.g. which side of the Pi stimulus subtended a greater length). Initial training stages require demonstration by participants of ability to distinguish accurately between target stimuli and lure stimuli, while later stages of training require demonstration of more subtle discrimination between two Pi stimuli. Although there may be risks for oculomotor impairments in a population of children with CP, the ability to demonstrate mastery of these target discrimination skills ensured adequate functional visual acuity for final IT task demands. Finally, to ensure comprehension of task demands, successful

participants were introduced to the requirements of a full trial run until a criterion (7/10 accuracy) was met, followed by the final task at increasing speeds. Participants who demonstrated adequate visual acuity and the ability to successfully complete training continued with the full set of experimental trials. Seven participants were unable to complete the training task to criterion and therefore their data were not included in the analyses.

Conners Parent Rating Scales – Revised (CPRS-R; Conners, 1997): The CPRS-R, administered to the accompanying parent/guardian of each participant, is a behavior rating scale that measures symptoms of Attention-Deficit/ Hyperactivity Disorder as well as a variety of common comorbid behaviors (Conners, 1997). The CPRS-R has a total of 14 subscales, seven of which were developed from the Diagnostic and Statistical Manual-IV criteria for Attention-Deficit/Hyperactivity Disorder (American Psychiatric Association, 1994.) The remaining seven scales were developed through factor analysis (Cognitive Problems; Oppositional; Hyperactivity; Anxious-Shy; Perfectionism; Social Problems; and Psychosomatic). Test-Retest reliabilities for the CPRS-R are moderate to high across the scales, ranging from .47-.85. The CPRS-R has good convergent and discriminant validity (Conners, 1997; Conners, Sitarenios, Parker & Epstein, 1998). For the purposes of this study, only the DSM-IV Inattentive and DSM-IV Hyperactive-Impulsive subscales were examined.

Peabody Picture Vocabulary Test – 3rd Edition (PPVT-III): The PPVT-III is an individually administered test designed to measure single word receptive vocabulary (Dunn & Dunn, 1997). The PPVT-III has a test-retest reliability ranging from .91 to .94 (median=.92). The PPVT-III has excellent validity as demonstrated by its high correlations with other measures of verbal ability (K-BIT vocabulary, .81 and WISC-III Verbal Comprehension Index, .91).

Gross Motor Function Classification System (GMFCS): Functional mobility was characterized using the Gross Motor Function Classification System (GMFCS) (Palisano et al., 1997). The GMFCS, originally designed for use with children with CP, assesses gross motor functioning and activity limitations with a five level ordinal scale. This scale differentiates between functional levels based on gross motor limitations and need for assistive devices for mobility. The GMFCS was administered by trained examiners at the time of study participation. Interrater reliability is 0.75 and both content and predictive validity are well-demonstrated in child and adult populations (Palisano et al., 1997; Sandstrom, Alinder, & Oberg, 2004; Wood & Rosenbaum, 2000).

Task Administration—All participants provided consent to participate and then proceeded to IT task training and IT task participation. Completion of the PPVT-III always followed completion of the IT task.

Participant Recruitment—Following institutional review board approval, participants were recruited through a variety of methods including community flyers and websites connected with the local United Cerebral Palsy Association and two Midwest medical rehabilitation centers over a period of approximately two years. Parents/guardians provided informed consent, and children provided witnessed assent for voluntary participation in the research program in accordance with Institution Review Board guidelines.

Data Analysis

Outliers were scrutinized which resulted in the removal of one participant, whose inspection time score was found to be invalid due to instrumentation error. Independent t-tests were conducted to examine group mean differences in IT thresholds and CPRS-R scale scores. The

associations between IT and the CPRS-R scale scores (Inattentive and Hyperactive-Impulsive) were examined by computing Pearson coefficients.

Results

Table 2 shows means and standard deviations for IT and CPRS-R scales by Group. There were statistically significant group differences in IT thresholds, with children in the CP group

requiring longer ITs, $t(103) = 13.1$, $p < .01$, $\eta^2_p = .11$. The mean differences in CPRS-R DSM-

IV: Inattentive scale, $t(103) = 16.76$, $p < .01$, $\eta^2_p = .14$ and the CPRS-R DSM-IV: Hyperactive-

Impulsive Scale, $t(103) = 16.76$, $p < .01$, $\eta^2_p = .14$ were statistically significant, with higher reported symptom elevations in the group with CP.

Bivariate correlations between IT threshold and CPRS-R scale scores are presented in Table 3, with correlations for the group with CP above the diagonal and Control group correlations below the diagonal. Statistically significant correlations are noted only in the Control group, with higher IT thresholds associated with higher CPRS-R scale elevations. There were statistically significant correlations between Hyperactive-Impulsive and Inattentive scale scores in both the group with CP ($p < .01$) and the Control group ($p < .01$).

Discussion

This study examined associations between IT and parent/guardian reported ADHD symptoms in children with CP and unaffected peers. Children with CP exhibited significantly slower IT and more reported symptoms of inattention and hyperactivity than the Control group. However, while correlations between IT durations and reported ADHD symptoms were significant in the Control group, no such finding was observed in the group with CP.

The lack of association between IT and CPRS-R scale scores in children with CP, may, in part, stem from psychometric issues that arise in using the CPRS-R to assess children with functional motor impairments, rather than absence of a true relationship between IT and ADHD symptoms. ADHD rating scales, such as the CPRS-R, include a significant number of questions that inquire about behaviors with heavy motor and/or communication demands. For example, the CPRS-R DSM-IV Hyperactive-Impulsive scale includes ratings for “children getting out of their seat and running around the table at mealtime” which may be less likely for children with motor difficulties independent of their true degree of attentional dysfunction. Previous research has found that caregivers of children with CP frequently do not answer several questions on the CPRS-R because of the inapplicable nature of some of these questions (Gross-Tsur, Shalev, Badihi, & Manor, 2002). Indeed, in our group of participants with CP, ten respondents had one or more unanswered items on the CPRS-R, while none of the CPRS-R completed by caregivers of Control participants were incomplete. Conversely, there may be several questions that could be associated with motor symptoms linked to CP-related spasticity or athetosis, rather than hyperactivity or impulsivity, that are over-endorsed by caregivers of children with CP; e.g., questions that ask about restlessness, excessive movements, and sloppiness.

While systematically biased patterns of caregiver responses on the CPRS-R may play a role in the findings for participants with CP, the IT task itself may also be measuring a different construct in children with CP in part due to the visuoperceptual demands of the stimuli. Neuropsychological findings for children with CP frequently note significant visual spatial deficits (Straub & Obrzut, 2009). It is possible that the visual IT task performance is being adversely affected by differences in visuospatial and visuoperceptual processing. Additionally,

children with CP can present with ocular motor apraxia secondary to white matter lesions, and this apraxia can result in difficulties with fixation (Jacobson & Dutton, 2000). Therefore the longer inspection times for children with CP may be partially accounted for by these differences.

This study provides a unique examination of the association between IT and ADHD symptoms, though certain limitations in methodology have implications for interpretation of findings as well as future directions. The majority of participants with CP were categorized at GMFCS levels I, II, and III for functional independence and had average cognitive ability. It is not clear if findings would be similar in children with lower levels of functional ability and/or intellect. It will be important to examine the effects of common CP comorbidities such as seizure disorder on IT and ADHD outcomes and associations in future studies. As noted, the visual nature of the task while most common for IT measures, may be suboptimal for a population of individuals with known risk for visuoperceptual deficits; future examinations of IT would optimally include an alternate sensory modality such as audition.

Regarding clinical implications, it will be important for clinicians and researchers to exercise caution in using ADHD rating scales such as the CPRS-R for children with CP. While the CPRS-R may be sensitive to ADHD symptoms in a sample of children with CP, the CPRS-R and similar measures may not have adequate specificity. The present study highlights the need for a diligent item-by-item review of endorsed items with appropriate follow-up with caregivers to produce a more accurate understanding of functioning in the context of rehabilitation planning.

In summary, the dissociation between inspection time and ADHD symptom ratings in children with CP highlights the need for further research on basic neuropsychological functions such as processing speed, utilizing instruments that are increasingly effective in parsing out confounds associated with condition-specific impairments and comorbidities. Findings also appear to support previously noted concerns that available caregiver report measures of ADHD symptoms may not adequately capture and describe relevant symptom complaints in those with CP and, potentially, in a larger subset of individuals who have other types of psychomotor impairments. Future psychometric studies are needed to promote the development of accessible instruments for individuals with neurodevelopmental conditions that include motor impairments.

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Figure 1.
Inspection Time Task

Table 1**Medical and Demographic Characteristics by Group**

Variable	CP (n=34)	Control (n=70)
Age; Mean (SD)	11.9 (2.3)	11.3 (2.6)
Gender	70.6% male	51.4% male *
SES (Hollingshead Index)	3.5 (1.0)	3.7 (1.1)
Seizure History	11.8% positive	1.4 % positive **
Birth weight (gms)	4.4 (2.6)	7.3 (1.3) **
Gestation (weeks)	32.1 (5.8)	38.3 (2.3) **
PPVT-III	102.3 (18.2)	107.9 (16.4)

Note: CP = Cerebral Palsy; SES = Socioeconomic Status; PPVT-III = Peabody Picture Vocabulary Test – III.

*
 $p < .05$

**
 $p < .01$

Table 2

Means and Standard Deviations for Inspection Time and CPRS-R scales

Measure	Group	
	CP (n=34)	Control (n=70)
Inspection Time (msec)	77.6 (78.7)	37.5 (34.7) **
Inattentive T score	57.3 (11.9)	46.2 (7.7) **
Hyperactive-Impulsive T score	55.4 (12.3)	47.5 (7.4) **

Note. CPRS-R = Conners' Parent Rating Scale – Revised: Long Version; Inattentive = CPRS-R DSM-IV: Inattentive scale; Hyperactive-Impulsive = CPRS-R DSM-IV: Hyperactive-Impulsive scale.

**
 $p < .01$

Table 3

Pearson Bivariate Correlations between CPRS-R and Inspection Time Variables by Group

	1	2	3
1. Inspection Time	-	.09	.16
2. Inattentive	.48**	-	.62**
3. Hyperactive-Impulsive	.44**	.67**	-

Note. CP group correlations above the diagonal and Control correlations below the diagonal. CPRS-R = Conners' Parent Rating Scale – Revised: Long Version; Inattentive = CPRS-R DSM-IV: Inattentive scale; Hyperactive-Impulsive = CPRS-R DSM-IV: Hyperactive-Impulsive scale.

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 $p < .01$