

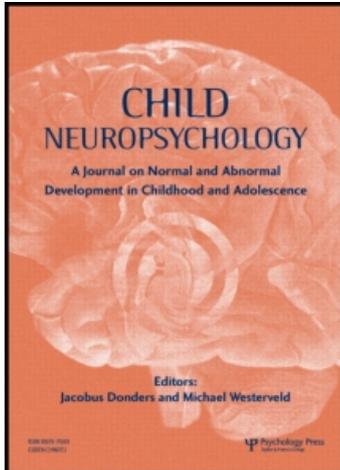
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CHILDREN WITH SPASTIC CEREBRAL PALSY, THEIR COGNITIVE FUNCTIONING, AND SOCIAL PARTICIPATION: A REVIEW

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White matter lesions are often seen in children with spastic cerebral palsy (CP). Evidence points to specific impairment of attentional, visuospatial, and executive functions; although both attention and executive functions are relatively unexplored in spastic CP. The few recent studies on language functions in mild or moderate CP point to well-functioning language. The presence of specific cognitive impairments may, in part, explain why children with spastic CP have a higher risk of learning disabilities and problems in peer relations. However, to understand the development of cognitive impairments, it is necessary to include how social participation feeds back on cognitive processes.

Keywords: *Cerebral palsy; Attention; Executive functions; Social participation; Cognitive development.*

For several decades, one key issue in developmental neuropsychology has been whether cognitive development is best understood as the gradual unfolding of innate modules or as the construction of processing systems from an equipotential neural substrate. However, the past two decades have seen research in neural and cognitive development that has led to a new approach: the constructivist-maturational model (Segalowitz & Hiscock, 2002). This approach conceives of development as a matter of self-constructing mental growth through the interaction between innate structures and environmental structuring. Researchers have described the immature neural system as one that harbors innate biological constraints while simultaneously being highly moldable through the child's active, ongoing selection and processing of environmental input (Greenough, Black, & Wallace, 1987; Karmiloff-Smith, 1998; Stiles, Reilly, Paul, & Moses, 2005).

The aim of the article is to examine how the cerebral lesions of children with spastic cerebral palsy (CP) function as specific biological constraints impacting on cognitive functioning and social participation. Through a review of studies examining different aspects of cognitive functioning and social participation in children with spastic CP, it will be argued that cognitive deficits in school-age children with spastic CP are not merely a function of an early brain lesion; they are also the result of the dynamic, ongoing interaction between the child and his or her environment, where the child participates in learning situations and interacts with his or her peers. The linkage of functioning with participation

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is in line with the World Health Organization (WHO) model of functioning and disability, which proposes that health conditions should be understood through inclusion of body functions (for example cognitive functions), activities, and participation (WHO, 2001).

CEREBRAL PALSY: SYMPTOMS AND CEREBRAL LESIONS

CP is a group of developmental disorders diagnosed by their disturbance of the subject's movement and posture. They are due to early nonprogressive lesions of the central nervous system and symptom severity varies substantially. CP is traditionally classified according to the type of motor symptoms (*spastic*, *dyskinetic*, or *ataxic*) and the location of impairment (hemiplegia, diplegia, or tetraplegia). The spastic subtype, which is the subject of this article, accounts for 66%–82% of CP cases, which makes it the most common type (Blondis, 2004).

The diagnosis of CP has been used since 1861 (“Little’s disease”), but the definition has been revised several times concurrently with the accumulation of knowledge about this condition. Its main symptoms are disorders of movement and posture, but more recently other symptoms have been included in the definition: disturbances of sensation and perception, global or specific cognitive difficulties, communication disorders, behavioral disorders, and seizures (Bax, Goldstein, Rosenbaum, Leviton, & Paneth, 2005). CP has a prevalence of 2–3 per 1000 births, which makes it the most common motor impairment in children (Uldall, Michelsen, Topp, & Madsen, 2001). Half of these births are preterm.

Neuropathology Associated with Spastic Cerebral Palsy

Although CP, by definition, is caused by an early nonprogressive brain lesion, the nature and scope of the particular lesions are wide-ranging. Only the most common will be described in the following.

Bilateral spastic CP (di- and tetraplegia) is first and foremost associated with *periventricular leukomalacia* (PVL), with or without additional lesions, in particular in children born preterm (Bodensteiner & Johnsen, 2006; Hoon, 2005; Krageloh-Mann et al., 1999; Krageloh-Mann et al., 2002; Okumura, Kato, Kuno, Hayakawa, & Wanatabe, 1997). Frequencies between 66% (Krageloh-Mann et al., 1995; Kwong, Wong, Fong, Wong, & So, 2004) and 88% (Okumura et al., 1997) have been reported. PVL is a condition involving dilation of the ventricles and reduction of the white matter. The interruption of the motor tracts is the cause of movement deficits in children with bilateral spastic CP, but it has been hypothesized that white matter tracts connecting prefrontal and posterior brain regions, the basal ganglia, and related dopaminergic pathways may be compromised also, which will affect other functions of the cerebral system (Christ, White, Brunstrom, & Abrams, 2003). Some children with bilateral spastic CP, who were born at term, have bilateral lesions of the basal ganglia and thalamic area in addition (Okumura et al., 1997). A substantial part of hemiplegic CP may also be caused by PVL, but the reported frequencies of PVL differ among studies (Cioni et al., 1999; Krageloh-Mann & Horber, 2007). Both unilateral and bilateral lesions are seen in children with hemiplegia (Cioni et al.; Okumura et al.).

Other types of lesions seen in children with hemiplegic CP are brain malformations and cortical/subcortical lesions due to infarcts, mostly in the middle cerebral artery (Cioni et al.; Krageloh-Mann & Horber, 2007; Nelson, 2002; Okumura et al., 1997; Yin, Reddihough, Ditchfield, & Collins, 2000).

Seizures are a common complication in spastic CP (Singhi, Jagirdar, Khandelwal, & Malhi, 2003; Wichers, Odding, Stam, & Van Nieuwenhuizen, 2005). Several studies report co-occurrence between epilepsy and lowered cognitive functioning in children with spastic CP (Cioni et al., 1999; Kolk & Talvik, 2000; Sigurdardottir et al., 2008; Singhi et al., 2003; Vargha-Khadem, Isaacs, Vanderwerf, Robb, & Wilson, 1992).

Cerebral Lesions as a Biological Constraint on the Development of Different Cognitive Functions

Children's development of cognitive functions requires a sufficient neural foundation. Older studies pointed to the degree of neurological involvement as a good predictor of the general level of cognitive functioning and this finding has been confirmed by more recent studies (Goodman & Yude, 1996; Krageloh-Mann et al., 2002). Particular patterns of lesions have mainly been correlated with cognitive functioning at a general level (e.g., Cioni et al., 1999; Krageloh-Mann et al., 1995; Krageloh-Mann et al., 2002; Serdaroglu, Tekgul, Kitis, Serdaroglu, & Gokben, 2004), except for visual-perceptual impairment, which has been linked to patterns of MRI-identified pathology in children with spastic CP as discussed further below.

The cerebral lesions associated with CP represent a biological constraint that affects the typical developmental trajectory of different cognitive functions and often entails mental retardation or specific cognitive impairments. Due to the nature of the underlying lesions, children with spastic CP can be expected to develop a wide array of cognitive impairments. Diffuse lesions in white matter tracts are reported to be the cause of a general, lower efficiency of information processing with a potential impact on several cognitive functions (Luciana, 2003). Attentional and executive dysfunctions can be expected in case of lesions in the periventricular white matter in anterior (Schatz, Craft, White, Park, & Figiel, 2001; White & Christ, 2005) or parietal regions (Pavlova, Sokolov, Birbaumer, & Krageloh-Mann, 2008). Lesions of the basal ganglia, the thalamic systems, or both may affect focused attention (Mirsky, 1989) as well as executive functions. Visual-perceptual deficits have been found to correlate with more severe kinds of PVL, even in the absence of decreased visual acuity or ocular motility dysfunctions (Fazzi et al., 2004). Memory impairments are seen in many groups of children with neurodevelopmental disorders (Catroppa & Anderson, 2007; Scott et al., 1998), either due to lesions affecting neural structures or connections that support aspects of memory (such as basal ganglia lesions, lesions to the capsula interna or the hippocampus) or secondary to encoding problems due to primary perceptual impairments.

The middle cerebral artery supplies several cortical (lateral surfaces of the parietal and temporal lobes) and subcortical areas (internal capsule, thalamus, and the basal ganglia) thought to support focused attention and the motor-executive function (Mirsky, 1989), language functions (Bates et al., 1997), and aspects of memory (Gathercole, 1998). The particular impairments depend on which hemisphere is injured and to what extent.

COGNITIVE FUNCTIONING IN CHILDREN WITH SPASTIC CP

Spastic CP has been associated with impaired participation in day-to-day activities in childhood (Ostensjo, Carlberg, & Vollestad, 2003) and with limitations of educational and vocational possibilities that cannot be explained by the motor impairments alone (Michelsen, Uldall, Kejs, & Madsen, 2005). A more specific examination of the cognitive

impairments of children with spastic CP is needed to understand how the neural lesions might constrain their life. A substantial proportion of children with spastic CP suffers from mental retardation, ranging from one third (Goodman & Yude, 1996) to two thirds (Wichers, Odding, Stam, & Van Nieuwenhuizen, 2005) of children with hemiplegia. Mental retardation is characterized as an impairment affecting the child's adaptive behavior (Switzky & Greenspan, 2003), and studies of children with mental retardation alongside spastic CP have therefore been excluded from this review.

This review will focus on attention, executive functions, visuoperception, and language functions.

Executive Functions and Attention in Children with Spastic CP

The academic literature has previously addressed attention and executive functions in separate sections, but these two aspects are now increasingly being collapsed because of the overlap especially in areas of working memory, self-regulation, and ability to inhibit and control actions (Korkman, 1999; Manly et al., 2001).

The executive system is a concept that covers several higher order functions aimed at self-regulation in cognitive, behavioral, and emotional domains (Powell & Voeller, 2004). It draws on five parallel frontostriatal circuits receiving connections from different brain structures, including the perceptual systems (Bradshaw, 2001; Cummings, 1993; Powell & Voeller, 2004). The behavior associated with disruption of the executive system depends on which particular circuits have been affected; resulting in for example distractibility, working memory impairment, or disinhibited and impulsive behavior (Powell & Voeller). Executive dysfunctions are therefore best characterized as dysfunctions of particular subdomain(s) and not as general executive dysfunction. Lesions of one or more subcortical segments of the system can also cause impairment in executive subdomains (Alexander & Stuss, 2000).

Attention is a series of processes that makes us capable of selecting and processing information despite resource limitations in our information-processing abilities (Mirsky, 1989). It is generally agreed that attention has several subcomponents, although extant literature uses different divisions and concepts (for example Douglas, 1984; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Posner & Petersen, 1990). The understanding of attention as consisting of separate entities is taken from adult models but is thought to apply to children from around the age of 6 (Manly et al., 2001). Similarly, different executive subdomains are considered to be present in children from around the same age or earlier, even though they do not reach adult level until late adolescence (Powell & Voeller, 2004).

Neither attentional nor executive functions have been systematically studied in children with spastic CP. Existing research in attention has concentrated on focused and sustained attention, whereas extant research in executive functions has focused on working memory, control, and inhibition of attention and metacognition (Table 1).

Focused attention. Focused attention is the ability to identify salient elements among a wide array of stimuli (Mirsky et al., 1991). During typical child development, the attentional system develops asymmetrically in the brain, but the asymmetry still allows typical children and adults to focus their attention to their nondominant side, either because their attention is attracted by stimuli on that side or because they are requested to attend to the nondominant side. The asymmetry of focused attention appears to be more

Table 1 Findings in Recent Studies of Attentional and Executive Functions in Children with Spastic CP.

Paper	N	Age	CP type	Measures	Findings
Attentional functions					
Hugdahl & Carlsson, 1994	31	11–16	Hemiplegia	Dichotic listening task	Impaired shift of focus to ear contralateral to lesion
Korkman & Von Wendt, 1995	33	5–12	Hemiplegia	Dichotic listening task, chimeric task	Impaired shift of focus to ear contralateral to lesion. Right Visual half-field advantage
Kolk & Talvik, 2000	31	4–9	Hemiplegia	Sustained attention, NEPSY	Impaired performance
Executive functions					
Kolk & Talvik, 2000	31	4–9	Hemiplegia	Memory span, NEPSY Impulse inhibition, NEPSY	Impaired performance Impaired, especially those with right hemisphere lesions
White et al., 1994; 1995	11	5–11	Diplegia	Word span	No impairment
Christ et al., 2003	13	6–18	Bilateral spastic, preterm	Stroop, stimulus-response reversal task, antisaccade task	Impaired inhibitory control in all tasks
White & Christ, 2005	16	6–18	Bilateral spastic, preterm	California verbal learning test-Children's version	Impaired use of spontaneous clustering. Impaired inhibition of inference material

Note. NEPSY= Neuropsychological test of children.

pronounced in children with spastic CP than in typically developing children, especially following early left hemisphere injury. Hugdahl and Carlsson (1994) studied children with hemiplegia using a design with dichotic listening tasks. They compared the performance of the children with hemiplegia to that of a group of age- and sex-matched children without signs of hemiplegia. The former were found to be impaired in their ability to shift their focus of attention to the ear contralateral to the lesioned hemisphere. Similarly, another study by Korkman and Von Wendt (1995) of a group of children with hemiplegic CP found that two thirds of the children with hemiplegia, left or right, differed from the control group of typical, age-matched children on a dichotic listening task. Children with left hemisphere lesions and left-ear advantage were also found to have a right visual half-field advantage.

Taken together, focused attention appears to be vulnerable following early left hemisphere lesions, both when the lesion is unilateral and when it is part of a bilateral lesion.

Sustained attention. Sustained attention covers the ability to be vigilant (Mirsky, 1989). Studies of sustained attention in children with spastic CP are very sparse, but they raise suspicion of impairments in this area, notably following right hemisphere lesions. Kolk and Talvik (2000) tested a group of children with left or right hemiplegia and unilateral lesions verified by CT or MRI scans. In tests of sustained attention, the hemiplegia group scored significantly below the control group that was matched on age,

sex, and socioeconomic status. Seizures were found to be a significant predictor of problems in both focused and sustained attention in the study by Kolk and Talvik (2000).

Working memory. Working memory is a system of online information processing of material or events that can hold, maintain, and manipulate a restricted amount of information (Baddeley, 1986; Mesulam, 2000). The system is considered essential for normal learning and cognitive functioning and it is therefore crucial to know how it is affected by spastic CP. Unfortunately, only a few studies have explored this issue and their results are contradictory. In tests of memory span, Kolk and Talvik (2000) studied children with spastic hemiplegia and compared them to a group of typical, age-matched children. Significant differences were found between the performance of children with hemiplegia and the control group. In contrast, a study of a group of children with spastic diplegia, White, Craft, Hale, and Park (1994) and White, Craft, Hale, Schatz, and Park (1995) compared the children's performance on a word-span task with that of a group of typical children. In contrast to Kolk and Talvik (2000), they found no difference between children with diplegia and the control group. More studies in the area are needed, preferably in combination with more precise information about lesion size and location.

Inhibition of impulses. Inhibition is a second domain of executive functions that mediates response selection during problem solving. Children with spastic CP, especially children with spastic CP due to right hemisphere or bilateral lesions, seem to have problems with inhibition compared with same-aged children without CP. In their study of children with spastic hemiplegia, Kolk and Talvik (2000) studied impulse inhibition and found that all children with hemiplegia, especially those with right hemisphere lesions, scored significantly lower than a group of age-matched controls without CP.

Christ et al. (2003) studied inhibitory control in children with bilateral spastic CP and found that their inhibitory control was impaired compared with that of same-aged children without CP. Age was found to correlate with the results and it was used as a covariate in all analyses. Unfortunately, there were too few children in the study to enable further exploration of the development of inhibitory functions in children with bilateral spastic CP.

Metacognitive processes. A third executive domain is metacognitive processes, which covers the ability to plan and solve problems through strategic behavior. Children with bilateral spastic CP have been found to use spontaneous strategic clustering as an aid in learning and subsequent retrieval of verbal material less often than same-aged children without CP (White & Christ, 2005). The difference held even when controlling for differences in general verbal ability. In addition, children with bilateral spastic CP were found to be impaired in their ability to inhibit interfering information from intruding on memory performance. This impairment was more pronounced in the younger children than in the older, even when the contribution of age to performance was included in the analysis.

Visuoperceptual and Visuoconstructive Functions in Children with Spastic CP

The presence of specific visuoperceptual functions in children with spastic CP was firmly established in the classic review by Abercrombie (1964), but the exact cause and

nature of the difficulties remain an open research area, fuelled during the last two decades by the introduction of noninvasive imaging methods such as MRI.

Visual perception is the complex processes that enable us to perceive a wide array of visual qualities such as movement, depth, spatial relations, facial expressions, and, eventually, the identity of objects. The normal functioning of the visual system is thought to hinge on both the integrity of the areas subserving visual-perceptual processes and early visual experience (Gilmore, 2003; Greenough et al., 1987). Several studies have associated visuo-perceptual impairment with reduction in the white matter in the parietal and occipital lobes in groups of children with spastic CP (Fazzi et al., 2004; Goto, Ota, Iai, Sugita, & Tanabe, 1994; Koeda & Takeshita, 1992). Fedrezzi et al. (1996) have associated visuo-perceptual impairment with lesions involving the optic radiation, the degree of ventricular enlargement, and thinning of the posterior body of the corpus callosum. Not all studies were able to establish an unequivocal correlation between MRI-identified pathology and cognitive measures (e.g., Guzzetta et al., 2001; Mercuri et al., 1996; Yokochi et al., 1991).

Studies in higher level visuo-perceptual functions. The visuo-perceptual impairments of children with spastic CP appear to be unrelated to general intelligence (Koeda & Takeshita, 1992), nonverbal intelligence, or the presence of epilepsy (Stiers et al., 2002). Pirila et al. (2004) found a correlation between visual impairments (mainly strabismus and amblyopia) and impairments in visuo-spatial processing in children with spastic diplegia. The impairments are seen in many different aspects of visuo-perceptual functions. Studies of children with spastic CP have explored visual organization, visual discrimination, visual-spatial discrimination, object recognition, and visuo-construction (Table 2).

Koeda and Takeshita (1992) found a lowered perceptual quotient (PQ) in their group of children with preterm diplegia. PQ was measured by the use of the Frostig developmental test of visual perception, which contains tests of eye-motor coordination, figure-ground relations, form constancy, position in space, and spatial relations. No significant differences were found between the different subtests.

Another study by Stiers et al. (2002) measured the ability to identify objects presented from different nonoptimal conditions. Their study group was children with different types of spastic CP of whom the majority had mental retardation (91% had IQ < 85). The performance of children with CP in tests of visual perception was compared to that of nondisabled children with a *chronological age* matched to the *performance age* of the children with CP estimated from nonverbal intelligence subtests. As long as the objects were depicted from the most conventional angle, children with spastic CP were as adept as the control group at recognizing the objects. In contrast, 40% of the children with spastic CP experienced problems identifying objects that were shown from unusual angles, partly occluded, or in otherwise nonoptimal conditions. The impairment was seen to the same extent in all subtypes of spastic CP (Stiers et al.).

Studies in visuo-constructional functions. Visuo-constructional functions describe the ability to construct or reproduce spatial relationships in two or three dimensions. They are guided by visuo-perceptual processes but require a certain level of motor function and eye-hand coordination as well (Benton & Tranel, 1993). Studies from the 1960s of children with spastic CP found that visuo-constructive impairments were often seen (Abercrombie, 1964; Nielsen, 1962). Despite this, the impaired performance of children with spastic CP in visuo-constructive tests such as the Block Design from Wechsler

Table 2 Findings in Recent Studies of Visual-Perceptual Functions in Children with Spastic CP.

Paper	N	Age	CP type	Measures	Findings
Visuoception					
Yokochi et al., 1991	34	3–10	Spastic diplegia	MRI, Tanaka-Binet, WPPSI or WISC	No correlation between MRI and cognitive measures
Koeda & Takeshita, 1992	18	5–9	Spastic diplegia, preterm	MRI, Frostig developmental test of visual perception	Impaired visuo-perceptual function related to MRI
Goto et al., 1994	41	4–8	Spastic diplegia, preterm	MRI, WPPSI, or WISC-R	PVL in parietal and occipital Regions correlated with Visual-spatial impairments
Fedrezzi et al., 1996	30	6–14	Spastic diplegia, preterm	MRI, WPPSI, or WISC-R	Correlation between PVL and performance IQ, but no correlation between PVL and verbal IQ
Fazzi et al., 2004	20	5–8	Spastic diplegia, preterm	MRI, DTVP	Impaired general visual-perceptual quotient
Pirila et al., 2004	15	5–12	Spastic diplegia, preterm	US, WISC-III or WPPSI-R, NEPSY	Impairments in visuo-perception. Not related to US
Mercuri et al., 1996	14	6–19	Hemiplegia	MRI, different tests of visual function	Visual abnormalities common, but not always correlated to MRI
Guzetta et al., 2001	47	Not spec	Hemiplegia	MRI, visual acuity, visual field, optokinetic nystagmus	Visual abnormalities common, but not always predicted by MRI
Stiers et al., 2002	69	4–21	Spastic CP	Visual-perceptual battery L94	40% were impaired in at least one task.
Visuoconstruction					
Koeda et al., 1997	35	8–18	Spastic diplegia, preterm	Test of visual acuity, stereoacuity, tests of visual perception. Picture completion, block design, WISC-R, WAIS-R	Impairments in test of visuoconstruction independent of visual acuity, stereoacuity or visual perception.

Note. MRI = Magnetic Resonance Imaging; US = Cranial Ultrasonography; NEPSY = Neuropsychological test for children; WPPSI = Wechsler Preschool and Primary Scale of Intelligence; WISC = Wechsler Intelligence Scale for Children; PVL = Periventricular Leucomalacia; DTVP = Developmental Test of Visual Perception.

Intelligence Scale for Children- revised (WISC-R) or Wechsler Intelligence Scale for Children, third version (WISC-III) is often analyzed under the heading of nonverbal intelligence or visuo-perceptual abilities (for example, Fedrizzi et al., 1993; Goodman & Yude, 1996; Koeda & Takeshita, 1992; Muter, Taylor, & Vargha-Khadem, 1997). Measurement of nonverbal thinking may therefore be confounded with impairments that may either be due to motor disability, visuo-perceptual, or visuoconstructive difficulties.

Visuoconstruction in children with spastic diplegia was studied by Koeda, Inoue, and Takeshita (1997). The performance of children with spastic diplegia and good hand manipulation skills was compared with that of an age- and gender-matched control group. The presence or absence of strabismus was also taken into consideration. Performance in block design (WISC-R) and figure copying were analyzed separately from performance in picture completion (WISC-R). Block design and figure copying both require transformation

of nonverbal thinking into coordinated movements, while picture completion can be accomplished with little or no motor involvement. Children with spastic diplegia performed significantly poorer in figure copying than the control group. The performance in all three tests was independent of strabismus. The children with spastic diplegia fell into two groups: one with a lowered performance in both picture completion and block design; the other with a near normal performance in picture completion but a much lower performance in block design. This is taken to suggest the presence of specific visuoconstructional impairment independent of visual disturbances.

Language Functions in Children with Spastic CP

Language functions cover receptive and expressive language, including phonological, syntactical, and semantic processes and later during school age the acquisition of reading, spelling, and writing abilities (Temple, 1997). The acquisition of language has been studied extensively in children with unilateral brain lesions in order to address questions regarding the plasticity of the immature brain. This review will focus on whether children with spastic CP develop language functions similarly to or differently from their nondisabled peers, with less attention paid to the location of the neural substance that supports the different language functions.

Many children with more severe spastic CP experience communication problems due to disturbed neuromuscular control of speech mechanism, i.e., dysarthria, that diminish the ability of the child to speak intelligible. However, substantial dysarthria are most often seen in children with severe CP and mental retardation, while most children with mild or moderate CP and average cognitive level of functioning have normal or near-normal expressive language and articulation skills (Pirila et al., 2007).

Studies in specific language functions. Focusing on recent studies of general language ability (WISC-R, WISC-III, or WPPSI-P), children with spastic hemiplegia or diplegia are repeatedly found to score in the average or low average range in verbal IQ, often together with lower scores in performance IQ (Goodman & Yude, 1996; Pirila et al., 2004; Sigurdardottir et al., 2008) (Table 3).

Turning to studies that include measurements of more specific parts of language functions, some studies report associations between spastic hemiplegia and impairments in verbal fluency, auditory analysis, comprehension, and relative concepts (Kolk & Talvik, 2000), while other studies fail to find consistent language impairments and conclude that verbal functions to a large extent are spared in children with hemiplegia (Korkman & Von Wendt, 1995; Krageloh-Mann, 2004). The inconclusive results regarding the presence of language impairments are puzzling, as the groups of children and the measures used were comparable. The sparing of language functions in cases of early unilateral brain lesion have been shown to be associated with neural reorganization, either intrahemispheric, interhemispheric, or both (Briellmann, Abbott, Caflisch, Archer, & Jackson, 2002; Krageloh-Mann, 2004). Differences in results might be due to differences in neural reorganization, for example, because of differences in timing, location, and extent of neural lesions (Liegeois et al., 2004).

Language functions are much less researched in children with bilateral spastic CP. One recent study found normal verbal skills in a large proportion of children with spastic diplegia in measures of specific language processes such as phonological processing, comprehension of instructions, and comprehension of sentences (Pirila et al., 2004, 2007).

Table 3 Findings in Recent Studies of Language Functions in Children with Spastic CP.

Paper	<i>N</i>	Age	CP type	Measures	Findings
Korkman & Von Wendt, 1995	33	5–12	Hemiplegia	All tests of language from NEPSY, Token Test	No impairments
Goodman & Yude, 1996	149	6–10	Spastic hemiplegia	WISC-R	VIQ > PIQ
Kolk & Talvik, 2000	31	4–9	Hemiplegia	All tests of language from NEPSY	Impaired performance
Briellman et al., 2002	1	15	Spastic hemiplegia	MRI, word retrieval, verb generation	Language in right, undamaged hemisphere.
Pirila et al., 2004	15	5–12	Spastic diplegia due to PVL	WISC-III/WPPSI-R, NEPSY	No impairment in phonological processing or verbal comprehension.
Pirila et al., 2007	36	1–9	Spastic CP preterm (22 diplegia, 5 hemiplegia, 9 tetraplegia)	WPPSI-R/WISC-R, Reynell, Bo Ege Speech Test, Mecham language scale	No impairment in verbal expressive and comprehension skills in children with IQ > 70.
Sigurdardottir et al., 2008	127	4–6	Mixed CP	WPPSI	VIQ in the normal range

Note. MRI = Magnetic Resonance Imaging; NEPSY = Neuropsychological test for children; WPPSI = Wechsler Preschool and Primary Scale of Intelligence; WISC = Wechsler Intelligence Scale for Children; PVL = Periventricular Leucomalacia; VIQ = Verbal Intelligence Quotient; PIQ = Performance Intelligence Quotient.

Impairments in specific language measures were mainly seen in the cases where the white matter lesions were extensive enough to cause general mental retardation (Pirila et al., 2007). Neural reorganization is generally assumed to be less extensive in cases of bilateral lesions (Nass, 2002), and the findings might be understood in light of the location of the lesions to areas other than typical language processing areas.

Summary: Cognitive Functioning in Children with Spastic CP

The integrity of the white matter and of the dopaminergic pathways is considered important to the development and normal functioning of both executive and attentional functions, which rely on an extensive and complex interconnectivity with other brain areas. As one or more of these areas are often compromised in children with spastic CP, impairments in the mentioned cognitive areas could be expected. Moreover, studies so far have found that these cognitive areas are only partially plastic; understood as able to be reorganized to other neural areas (Thomas, 2003), which possibly causes problems to continue or even to grow as the child grows older. Due to the limited amount of research performed in the areas of attention and executive functions, no overall picture of the developmental trajectory of attentional and executive impairments in children with spastic CP can be gathered at the moment.

Studies of attentional functions in children with hemiplegia mainly address focused attention and there is a lack of studies of attention in children with bilateral CP. Studies in executive functions are too few to allow a systematic description of the area. Existing studies in attention as well as in executive functions raise suspicions

about the presence of impairments in children with spastic CP and more research is needed. Especially the executive functions and their underlying neural bases are known to show prolonged development into late adolescence, but so far it remains a matter of speculation whether the reported dysfunctions represent a developmental delay or a more permanent impairment. Either way, attentional and executive impairments can be expected to impact both learning abilities and the developmental trajectory of the child with spastic CP.

Visual-perceptual problems have been found across the age span in children with spastic CP, especially in children with diplegia. All studies found visual-perceptual impairments; although discrepancies about the possible correlation between visual-perceptual impairments and MRI measures were, indeed, found. As visuo-perceptual functions and their underlying neural base only show limited plasticity (Stiles, 2000), ongoing impairments can be expected.

Studies of language functions in children with spastic hemiplegia point to none or subtle impairments. Only a few studies have focused on language functions in bilateral CP. They point to well-functioning language in children with mild or moderate spastic diplegia, as is the focus of this review. However, precautions need to be taken, as only a few recent studies exist in this area and more research is needed. Taken together, the studies point to sparing of language functions through brain reorganization. Early specific language impairments might dissolve due to the interaction between the initial neuropathology and the cognitive and neural developmental processes that incorporates atypical neural areas for language functions (Stiles et al., 2005).

COGNITIVE DYSFUNCTIONS AND RESTRICTIONS IN SOCIAL PARTICIPATION IN CHILDREN WITH SPASTIC CP

In the social model of disability proposed by the WHO, the concept of participation is defined as involvement in life situations (WHO, 2001). Social impairment is a disruption in the participation in typical age-appropriate social activities with a developmental trajectory towards positive adult functioning. For children with less severe spastic CP living in Europe and the United States, typical age-appropriate social activities often take place in mainstream schools. In addition to school activities, participation in relevant life situations could include activities in youth clubs, sports and friendship groups in the local environment. During the last couple of years, activities in “virtual” environments such as chat rooms and social networking Web sites (e.g., Facebook) may have gained significance, but a search in relevant databases (PsychInfo and PubMed) has not revealed any research on the possible effects of virtual environments on the participation in social life of children with disabilities.

Impairments in social participation may stem from deficiencies in motor functioning, intellectual functioning, or both; although these factors explain only part of the participation (Forsyth, Colver, Alvanides, Woolley, & Lowe, 2007; Imms, Reilly, Carlin, & Dodd, 2008; Morris, Kurinczuk, Fitzpatrick, & Rosenbaum, 2006). A complete understanding of the development of the activities and social participation would need to include environmental factors also: psychosocial pressures in family and school, financial difficulties, and inadequate public services (Mihaylov, Jarvis, Colver, & Beresford, 2004). Here, focus will be on constraints on social participation due to the neuroimpairments associated with spastic CP.

Social Participation in School and with Peers

CP is first and foremost a motor impairment; although it is often accompanied by other symptoms. Morris et al. (2006) reported that the intellectual ability of children with CP and their movement and manual skills scores correlated with the level of physical functional performance in the local community. It is therefore highly possible that it is the combination of significant motor impairments and cognitive dysfunctions that together impose restrictions on the child's participation, as pointed out by Schenker, Coster, and Parush (2005b).

Research in social participation in school reveals several differences between children with spastic CP and their classmates, besides differences in motor functioning. Children with hemiplegia have specific learning disabilities more often than their peers, even where their cognitive abilities are average. In a study of 149 children with hemiplegia, one third of the children met the criteria for having a specific learning disability in reading, spelling, or math, and nearly half of the children with learning difficulties had problems in two or three areas despite an average verbal IQ (Frampton, Yude, & Goodman, 1998). Learning disabilities have been shown to predict lower participation in children with CP (Schenker et al., 2005b).

Children with spastic CP are two to three times more likely to experience problems in their relations with peers than typical children (Nadeau & Tessier, 2006; Yude, Goodman, & McConachie, 1998). Friendship problems are also reported by the children with CP themselves (Mulderij, 1996, 1997). They often look different and one study found that visibility of disability (children with spastic CP mixed with children with other visible disabilities) was associated with an increased risk of being bullied at school compared with children with invisible abnormalities (Dawkins, 1996). However, further analysis revealed that the risk of being bullied was also associated with having fewer friends, being alone at playtime, being male, or requiring extra help in school. Once these variables were taken into consideration, visibility of handicap no longer predicted risk of being bullied. This is in line with another study by Yude and Goodman (1999) that found that visibility did not predict peer problems in children with hemiplegia in mainstream schools. Instead, lower IQ, disruptiveness, and hyperactivity (the last two teacher-reported) were found to predict peer problems such as peer rejection, lack of friends, and victimization.

Specific Cognitive Impairments and Social Participation

The presence of specific cognitive impairments in visual perception and attention and executive functions may, in part, explain why children with spastic CP have a higher prevalence of learning disabilities and problems with peer relations than other children. Speech problems and language impairments (Schenker et al., 2005b) have also been found to interfere with the child's level of participation in different settings at school, both during lessons and between lessons (Schenker, Coster, & Parush, 2005a). One possibility is that general cognitive functioning, represented by IQ, acts as a marker for the severity of the underlying neurological problems, which, in turn, make the child more susceptible to incur emotional or behavioral problems (Goodman & Graham, 1996). More specifically, the social adjustment problems and problems with establishing positive friendship relations experienced by many children with spastic CP could be due to delayed maturation or lesions to the neural system (Nadeau & Tessier, 2006; Yude et al., 1998). Especially lesions to areas supporting information processing relevant to social skills — for example,

executive functions — could be seen as placing the child at a risk of developing problems in social participation. Executive dysfunctions have been shown to impact social abilities and participation in other groups of children, for instance children with attention deficit/hyperactivity disorder (ADHD; Clark, Prior, & Kinsella, 2002) or prenatal alcohol exposure (Schonfeld, Paley, Frankel, & O'Connor, 2006). Visual-perceptual impairments have also been found to interfere with everyday functioning in children with CP (Schenk-Rootlieb, Van Nieuwenhuizen, Schiemanck, Van der Graaf, & Willemse, 1993); however, 86 % of the children in this study had mental retardation ($IQ < 80$) together with cerebral visual impairment, which might have accentuated the social adjustment problems associated with visual-perceptual impairments.

Taken together, children with CP and general or specific cognitive impairments are at risk of developmental trajectories characterized by lack of friends, peer rejection, and victimization. In a developmental perspective, spastic CP with learning disabilities has been correlated with outcome factors such as limitations in education and social relations (Beckung & Hagberg, 2002). Still, as mentioned in the introduction, cognitive development is the result of both biological factors and the experience of the individual. In the following section, the possible dynamics between cognitive dysfunctions and restrictions in social participation will be discussed from the perspective of the child as an active participant in his or her own cognitive development.

THE INTERACTION BETWEEN SOCIAL PARTICIPATION AND COGNITIVE IMPAIRMENT

In most, if not all of the studies mentioned, the assumed causality has been from the early brain lesion, through cognitive impairments to restrictions in participation in school or social relations as the end result (e.g., Aylward, 2002; Liptak & Accardo, 2004; Morris et al., 2006). However, studies of the interaction between social participation and development of cognitive functions in typical children suggest how participation in social learning situations may enhance cognitive development in several ways. Participation in learning situations with a group of peers offers opportunities to observe and imitate their behavior and strategies. Also, shared discussions and negotiations can lead the participants to a higher level of understanding than they were able to reach by themselves (Azmitia, 1988, 1996). While participation in social learning situations stimulates cognitive development, lack of opportunities to participate may slow down cognitive development. Early peer rejection has been shown to predict less favorable school perceptions, a high level of school avoidance, and lower performance in school among typical children (Ladd, 1990). As shown above, children with spastic CP do experience restrictions in social participation and a higher level of peer rejection; both of which may impede their ongoing development of cognitive functions and abilities, thereby enhancing the disparity between children with spastic CP and their typical peers. In order to understand the cognitive impairments of children with spastic CP, it is necessary to clarify how restricted social participation feeds back on their cognitive development.

Child Activity as an Integrated Part of Cognitive Development

Developmental psychology has a long tradition for including children's activity in the understanding of cognitive development and knowledge acquisition. A central conceptual pair has been assimilation/accommodation used by Piaget to describe the interaction

between children's experiences and their development of ideas and understanding of the world (Piaget & Inhelder, 1969). Other developmental psychologists such as Barbara Rogoff (2003), Sylvia Scribner (1997), and Jerome Bruner (1965, 1986) have elaborated on how participation and social interaction contribute to cognitive development. In their understanding, an essential condition for constructing knowledge of the world, for learning and for cognitive development is the child's active participation in social contexts (e.g., Rogoff). Through participation, a school child acquires different mental skills required to understand scientific concepts and to perform mathematical operations, which, in turn, allows the child to participate in new ways and in new and different settings, thereby propelling both cognitive and social development.

The neural lesions and subsequent cognitive impairments of a child with spastic CP impacts his or her ability to acquire these mental skills and through this to engage in unrestricted social interaction. This dynamic is reciprocal because the cognitive impairments impact the child's ability to participate in social activities in general and learning activities in particular. As mentioned earlier, restrictions in social participation can be expected to impact the development of cognitive functioning. With inspiration from Gilbert Gottlieb (2002, 2007), who's systems view of psychobiological development has inspired the constructionist perspective mentioned in the beginning (Segalowitz & Hiscock, 2002), the described dynamic can be captured in a model with multiple levels of ongoing interaction.

The model offers a perspective on how cognitive functions develop in and through social interaction and as such suggests a more encompassing approach to children with neurologically based developmental disabilities such as spastic CP that involve brain lesions and specific neuropsychological impairments. In the model, the pre- or perinatal brain lesion enters the developmental trajectory as a movable neurobiological constraint on the neural structure and cognitive functioning. The relative movability of a neurobiological constraint depends on its particular neurobiological nature and the child's social participation; both of which also depend on the particular conditions for social participation, a point taken from cultural-historical activity theory (Hedegaard, 2009). For example, cultural-historical traditions of either mainstreaming children with disabilities or placing them in special schools and institutions offer children with CP different conditions for social participation (in Figure 1 included in the social settings). In this understanding, the interactions between the different levels become a dialectical dynamic. The cognitive deficits associated with spastic CP are the result of a dynamic, ongoing interaction between the child and his or her environment through the child's participation in learning situations and through his or her interaction with peers. Restrictions in social participation

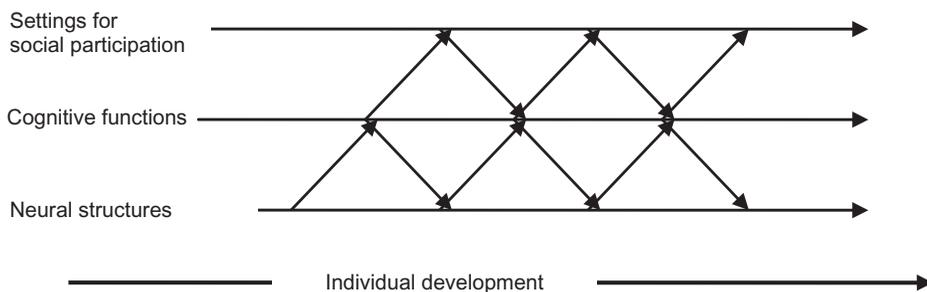


Figure 1 A multilevel approach to development of cognitive functions (Adapted from Gottlieb, 2002).

feed into this process. We need to know more about the interaction between biological maturation and development through cognitive development, learning, and participation in social settings in order to be able to track and explain the range of possible developmental trajectories of children with spastic CP. Designing studies exploring this junction between developmental neuropsychology and a socially oriented developmental psychology is by no means an easy enterprise, but it is a necessary one if we want to advance our knowledge about the mechanisms by which the cognitive abilities of children with spastic CP or other neurodevelopmental disabilities develop in real life.

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