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Arithmetic Achievement in Children With Cerebral Palsy or Spina Bifida Meningomyelocele

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The aim of this study was to establish whether children with a physical disability resulting from central nervous system disorders (CNSd) show a level of arithmetic achievement lower than that of non-CNSd children and whether this is related to poor automaticity of number facts or reduced arithmetic instruction time. Twenty-two children with CNSd (*M* age = 10.7 years old) were compared with two groups of typically developing children: a same-aged group ($n = 21$) and a younger group (by 1 year) matched on arithmetic achievement ($n = 23$). Although their intelligence was in the average range, the arithmetic achievement level of the CNSd group lagged nearly 1.5 years behind their typically developing peers. There was no strong evidence that this was due to a specific automaticity deficit. However, the difference on an arithmetic achievement test between the CNSd group and same-aged control group was fully accounted for by the difference in hours of arithmetic instruction.

Keywords: *learning difficulties; arithmetic; cerebral palsy; spina bifida*

Cerebral palsy (CP) and spina bifida meningomyelocele (SBM) are central nervous system disorders (CNSd) that originate early in development, result in a physical disability, and are typically characterized by diffuse brain lesions (Ewing-Cobbs, Barnes, & Fletcher, 2003; Folkerth, 2006; Hoon, 2005). A substantial proportion of children with these CNSd perform more poorly on cognitive and academic tasks (e.g., Carlsson, 1997; Dise & Lohr, 1998; Frampton, Yude, & Goodman, 1998; French, 1995; Iddon, Morgan, & Sahakian, 1996; Muter, Taylor, & Vargha-Khadem, 1997; Waugh et al., 1996). Frampton and colleagues (1998) investigated the prevalence of learning difficulties in children of average intelligence (IQ > 70) with unilateral CP and found that 36% of these children had at least one specific learning difficulty, 25% had difficulty in arithmetic, and 19% had reading difficulties. In a study investigating the frequency of learning disabilities in children with clinical disorders, Mayes and Calhoun (2006) found that 33% of children with spina bifida had arithmetic problems whereas 7% had reading difficulty. Arithmetic learning difficulties seem to be more prevalent in these children.

Arithmetic learning difficulties in children with CNSd may be attributable to problems with the automaticity of number facts—that is, the ability to respond quickly and accurately to simple number fact problems (e.g., 4 + 3 = ?). Whereas little is known about automaticity of number facts in CNSd, in other populations with arithmetic difficulties the automaticity of number facts has been cited as an important characteristic (e.g., Russell & Ginsburg, 1984; Zentall, 1990). Geary, Brown, and Samaranayake (1991) hypothesized that poor automaticity is related to limited working-memory resources because children with poor arithmetic performance often forget the initial sum by the time that they have finished counting. Consequently, it becomes difficult to make an association in long-term memory between the original problem and the correct answer. Given that previous research indicates that children with CP and children with SBM tend to have memory impairments (Carlsson et al., 1994; Jacobs, Northam, & Anderson, 2001), it may be that deficits

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in arithmetic ability in children with CNSd are related to automaticity deficits. If so, differences in number fact automaticity should explain performance differences on an arithmetic achievement test.

Alternatively, arithmetic learning difficulties in children with CNSd may be attributable to environmental factors (Heller, Alberto, & Meagher, 1996), such as the amount of arithmetic instruction time that the children receive. In the Netherlands, children with CP or SBM attend special schools for children with physical disabilities. In addition to offering education, these schools provide physical and other therapies during the school day (Zuidwijk, van Blerk, Ludeke, & Meihuizen-de Regt, 2003). Therefore, in comparison to mainstream schools, such schools may provide less arithmetic instruction time. It seems likely that reduced instruction time in special education is an issue in countries other than the Netherlands. For example, Mike (1995) carried out an ethnographic study of literacy instruction in a school for children with CP in the United States and reported that there was only little time available for academics owing to the various therapies that the students received. If the arithmetic learning difficulties in children with CNSd are due to limited arithmetic instruction time, then the amount of instruction time should explain performance differences on an arithmetic achievement test.

The purpose of the current study was, first, to confirm that children with CNSd have arithmetic difficulties and, second, to investigate whether such arithmetic difficulties are related to a specific deficit in the automaticity of number facts or to limited arithmetic instruction time. As such, the aim of the study was to confirm the presence of arithmetic difficulties in children with CNSd by comparing the performance of these children on an arithmetic achievement test to age-matched, typically developing children. We sought to answer the question of (a) whether the arithmetic ability of children with CNSd develops in the same way, although more slowly, as that of typically developing children or (b) whether children with CNSd have a specific impairment in the automaticity of number facts that can explain their poor arithmetic achievement. Therefore, we employed a logic that has been used effectively in reading disabilities studies that attempt to distinguish between developmental delay and specific impairment (Rack, Snowling, & Olson, 1992).

In the present study, the number fact automaticity of children with CNSd was compared to two control groups: first, typically developing children matched on age; second, younger, typically developing children matched on arithmetic achievement level (AAL). In other words, to answer the question of whether children with CNSd have a specific deficit in the automaticity of number facts and whether this explains their difficulties with arithmetic, the CNSd group was compared to a group of younger, typically developing children matched on AAL. If the CNSd group is deficient in automaticity of number facts only in comparison to age-matched, typically developing children, then this will be seen as evidence of a lag in the development of arithmetic ability. If, however, the CNSd group is also deficient in automaticity of number facts in comparison to younger children with the same AAL, then this will be seen as strong evidence that their arithmetic problems are due to a specific automaticity deficit.

To answer the question of whether arithmetic difficulties in children with CNSd are related to reduced instruction time, the performance of these children on an arithmetic achievement test was compared to that of same-age, typically developing children and to that of younger, typically developing children matched on AAL, while controlling for differences in instruction time.

In summary, the research questions of the current study were as follows: Do children with CNSd have a lower AAL than that of typically developing children? Are such differences due to a specific deficit of automaticity of number facts? Are differences in AAL related to differences in instruction time?

Method

Participants and Design

Participating in the study were 22 students (10 boys, 12 girls; *M* age = 10.7 years) from three special schools for children with physical disabilities and 44 students from three mainstream schools. The students selected from the special schools formed the CNSd group. Of this group, 15 children had been diagnosed with CP, and the remaining 7 children had been diagnosed with SBM with shunted hydrocephalus (for a description of CP, see Cans, 2000; for SBM, Dennis, Landry, Barnes, & Fletcher, 2006, respectively). Of the children with CP, 11 had bilateral CP, and 4 had unilateral CP. All the children with SBM underwent shunt placement within the first 8 weeks of life, and 5 of these children had one or more shunt revisions. The IQs of the students from the typically developing students were not known but were assumed to be in the average range. Therefore, an effort was made to select students from special schools with a Wechsler Intelligence Scale for Children IQ score in the average range. The resulting mean score (based on the school files) of the CNSd group as a whole was 95.3 (*SD* = 7.5, range = 83–112). Looked at separately, the mean IQs of the CP and SBM subgroups were 95.5 (*SD* = 7.3) and 95.0 (*SD* = 8.4), respectively.

The 44 typically developing students formed two control groups: one matched to the CNSd group on chronological age (CA), the other matched on AAL. The CA group consisted of 21 typically developing students (9 boys and 12 girls; *M* age = 10.5 years). AAL was measured with a standardized arithmetic achievement test, the *Cito Leerlingvolgsysteem Rekenen-Wiskunde* (Student Monitoring System for Arithmetic Performance). The AAL group consisted of 23 typically developing students (10 boys and 13 girls; *M* age = 9.3 years). None of the children from the latter two groups had any known neurological or motor problems. All children participated with consent of their parents and teachers.

The two groups with the same age (CNSd group vs. CA group) were compared to answer the question of whether children with CNSd do indeed lag behind their unaffected peers in arithmetic achievement. The two groups with the same AAL (CNSd group vs. AAL group) were compared to answer the question of whether children with CNSd show evidence of a specific deficit in automatization of number facts or develop arithmetic skill in the same way, although more slowly. The amount of arithmetic instruction time was compared among all three groups.

In an effort to verify the appropriateness of treating the CNSd group as a single group rather than as two subgroups (CP and SBM), *t*-tests were performed. The CP and SBM subgroups did not differ significantly on the arithmetic achievement test, $t(62) = 0.53$, $p = .60$, or on raw reaction times (RTs) on the number fact speed test, $t(62) = 1.38$, $p = .17$, nor did the subgroups differ in adjusted RTs, $t(60) = 0.67$, $p = .51$. Therefore, the CNSd group was treated as a single group.

Procedure

All children were tested in their own schools. The participants were all administered the same set of tasks in two testing sessions. In the first session, participants completed the *Student Monitoring System for Arithmetic Performance* to monitor their general arithmetic performance. In the second session, participants were presented with a number fact speed test to estimate their level of automaticity of simple number facts and a digit-writing task to assess their digit-writing speed.

Materials

The *Student Monitoring System for Arithmetic Performance* is a set of standardized group tests that are administered biannually throughout the primary school years in most schools in the Netherlands to measure the AAL of individual students as well as classes and schools (Janssen & Engelen, 2002). These tests are constructed in such a way (i.e. using item response theory) that the AAL measured at different times throughout the primary school years can be compared. The arithmetic achievement tests used in the current study are intended to test arithmetic knowledge, insight, and ability. Test items cover addition, subtraction, multiplication, and division in computational problems and in word problems relating to measurement, time, and money. This is not a timed test; therefore, students were given all the time that they needed to complete it. This arithmetic achievement test is considered highly reliable, with a reliability coefficient of .95.

In a separate session, the students were presented with a number fact speed test to assess their automaticity of simple number facts. We created this test, and it consists of two parts: 44 subtraction problems in the form of $a - b$ (such that both a and b were less than 10) and 48 addition problems with correct answers up to 10. After doing several practice problems, participants were given 1 min for the subtraction part of the test and 1 min for the addition part of the test. This was short enough to ensure that none of the children would be able to complete all the arithmetic problems within the available time. The raw RTs were calculated by dividing the total time (120 s) by the number of addition and subtraction problems completed, resulting in the average number of seconds per problem solved. This raw RT was assumed to be composed of the time to retrieve the answer from long-term memory, plus the time to write the answer.

Because children in the CNSd group might write more slowly as a result of their physical disability than the unimpaired control children, we created and administered a digit-writing speed test. In this task, the experimenter asked the students to write the numbers 1 to 10 legibly and to repeat this over and over again as quickly as possible until she said, "Stop" (after a period of 30 s). The average time needed to write a digit was computed by dividing the total time (30 s) by the number of digits written. This test was administered to all participants.

Adjusted RTs for all participants were computed by performing the following steps:

1. The estimated total time to write the answers in the number fact speed test was calculated by multiplying the number of digits written in the test by the average time needed to write a digit in the digit-writing speed test.
2. This total writing time was subtracted from the total duration of the number fact speed test (120 s).

3. The remaining time, presumed to be the total time required to retrieve the answers from long-term memory, was divided by the number of addition and subtraction problems completed in the number fact speed test.

The resulting adjusted RT was interpreted as the average time needed to retrieve a number fact from long-term memory.

The teacher of each child with CNSd was asked to register the number of minutes dedicated to arithmetic instruction time per child, per day, in a typical school week. The total amount of arithmetic instruction time that each individual child with CNSd had received in school was estimated by multiplying the actual number of hours of arithmetic instruction during 1 week by the total number of weeks that the child had attended school. For the typically developing students, the prescribed number of hours dedicated to arithmetic instruction per week as laid down in the school's curriculum was multiplied by the total number of weeks that the child had attended school. In the Netherlands, mainstream schools strictly adhere to hours of instruction as prescribed by the curriculum.

Results

Partial eta-squared values (η_p^2) are reported as an index of effect size. Effect sizes can be interpreted as being small (η_p^2 = .01), medium (η_p^2 = .06), or large ($\eta_p^2 \geq .13$; Cohen, 1988).

AAL

To answer the question of whether the CNSd group had a level of arithmetic achievement lower than that of children without neurological impairment, the scores on the arithmetic achievement test were subjected to a one-way analysis of variance (ANOVA) with group as factor (CNSd, CA, AAL; see Table 1). The effect of group was significant and large, $F(2, 63) = 4.69$, $p = .013$, $MSE = 263.69$, $\eta_p^2 = .13$. As expected, the CNSd performed significantly worse on the arithmetic achievement test than did their age-matched peers in the CA group, $t(63) = 2.62$, $p = .011$. As a result of the matching procedure, the CNSd and AAL groups did not differ significantly on AAL, $t(63) = 0.06$, $p = .95$.

A one-way ANOVA on chronological age showed a large significant group effect, $F(2, 63) = 4.88$, $p = .011$, $MSE = 2.61$, $\eta_p^2 = .13$. The CNSd group was, on average, 1.4 years older than the AAL group, $t(63) = 2.87$, $p = .006$, and as a result of the matching procedure, the CNSd and CA groups did not differ significantly on age, $t(63) = 0.37$, $p = .71$. Taken together, the results of these two analyses show that the AAL of the CNSd group is worse than that of their same-age peers and is comparable to that of children who are, on average, 1.4 years younger.

Table 1
Arithmetic Achievement Test Scores, Age, and Hours of Mathematics Instruction per Group

	CNSd		CA		AAL	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
Arithmetic achievement test	67.7	14.7	80.7	19.2	67.4	14.6
Age (years)	10.7	1.7	10.5	1.6	9.3	1.5
Hours of instruction	581.2	188.2	816.2	279.1	557.4	255.2

Note: CNSd = central nervous system disorder group (*n* = 22); CA = typically developing children matched to CNSd on chronological age (*n* = 21); AAL = younger, typically developing children matched to CNSd on arithmetic achievement level (*n* = 23).

Number Fact Retrieval

Table 2 shows the mean RTs per group for the digit-writing test and the number fact speed test (raw and adjusted RTs). Data for the number fact speed test of two children from the CA group were not available.

Digit-writing time. A one-way ANOVA on digit-writing time with group as factor (CNSd, CA, AL) yielded a significant and large effect of group, $F(2, 61) = 14.31$, $p < .001$, $MSE = 0.31$, $\eta_p^2 = .32$. As expected, the CA and AAL groups had significantly faster digit-writing RTs when compared to the CNSd group, $t(61) = 5.07$, $p < .001$, and $t(61) = 3.95$, $p < .001$, respectively. Controlling via an analysis of covariance for the influence of (a) the number of hours dedicated to arithmetic instruction or (b) the score on the arithmetic achievement test on the number of correctly solved problems of the number fact speed test also yielded significant group effects on writing time. These results underscore the importance of controlling for differences in writing time.

Raw number fact RTs. The effect of group on mean raw RTs on the number fact speed test was tested with a one-way ANOVA. As expected, the group effect was significant, $F(2, 63) = 9.85$, $p < .001$, $MSE = 2.23$, $\eta_p^2 = .24$. Both the CA group and the AAL group had RTs faster than those of the CNSd group, $t(63) = 4.35$, $p < .001$, and $t(63) = 2.94$, $p = .005$, respectively.

Adjusted number fact RTs. The adjusted number fact RTs, which were assumed to reflect the average time needed to retrieve a number fact from long-term memory,

Table 2
Reaction Times per Group

	CNSd		CA		AAL	
Test	*M*	*SD*	*M*	*SD*	*M*	*SD*
Digit writing	1.6	0.8	0.7	0.2	0.9	0.5
Number fact speed						
Raw	3.8	1.9	1.9	0.7	2.6	1.2
Adjusted	2.1	1.5	1.2	0.7	1.6	1.2

Note: CNSd = central nervous system disorder group (n = 22); CA = typically developing children matched to CNSd on chronological age (n = 21); AAL = younger, typically developing children matched to CNSd on arithmetic achievement level (n = 23).

were subjected to the same analysis. The main group effect, although somewhat smaller than that for raw RTs, was significant, $F(2, 61) = 3.69$, $p = .031$, $MSE = 1.36$, $\eta_p^2 = .11$. Although the mean adjusted RT of the CNSd group was slower than that of each control group, only the difference between the CNSd group and the CA group was significant, $t(61) = 2.70$, $p = .009$, whereas the difference in adjusted RT between the AAL and CNSd groups was not, $t(61) = 1.58$, $p = .12$. The fact that the CNSd group was significantly slower to retrieve number facts from long-term memory shows that the CNSd group lags behind their same-age peers in the automaticity of number facts. However, because the CNSd and AAL groups did not differ significantly, these results do not provide strong evidence for the automaticity-deficit hypothesis.

Arithmetic Instruction Time

The number of hours of arithmetic instruction was analyzed with a one-way ANOVA, and the effect of group (CNSd, CA, AL) was found to be significant and large, $F(2, 63) = 7.43$, $p = .001$, $MSE = 59.29$, $\eta_p^2 = .19$. As expected, the CNSd group had received fewer hours of arithmetic instruction than did the CA group, $t(63) = 3.16$, $p = .002$. However, the CNSd and the younger AAL group did not differ significantly on hours of arithmetic instruction time, $t(63) = 0.33$, $p = .74$. Therefore, the groups were compared again with regard to their arithmetic achievement, while controlling for the difference in hours of arithmetic instruction. An analysis of covariance on the scores of the arithmetic achievement test was performed with group as factor and with hours of arithmetic instruction as covariate. The sequentially tested pooled within-regression coefficient ($\beta = .61$) was significant, $t(63) = 6.67$, $p < .001$. The effect of group on AAL, which was present in the aforementioned analyses without hours of instruction as covariate, was not significant when hours of arithmetic instruction time was controlled for, $F(2, 62) = 0.42$, $p = .66$, $MSE = 176.53$. After controlling for hours of instruction, the adjusted mean arithmetic achievement scores for the three groups were as follows: $M_{CNSd} = 70.47$, $M_{CA} = 74.30$, $M_{AAL} = 71.10$. This analysis was repeated with the age of the children as an additional covariate, and it essentially yielded the same results: The effect of group was no longer significant when hours of instruction and age were controlled for.

Discussion

Arithmetic Achievement Level

The first research question was whether the CNSd group lagged behind in arithmetic achievement. As expected, the children with disorders of the central nervous system resulting in physical disability (the CNSd group) showed a level of arithmetic achievement lower than that of children of the same age without these disorders, although their intelligence was in the average range. This is in agreement with previous research that has found arithmetic difficulties among children with CP and SBM (e.g., Frampton et al., 1998; Mayes & Calhoun, 2006). Furthermore, the current study showed that children with these disorders lagged nearly 1.5 years behind children without such disorders.

Number Fact Retrieval

The second research question was whether the lag in arithmetic achievement was due to a specific deficit in the automaticity of number facts, as measured with a number fact speed test adjusted for writing time. Some evidence in this direction was found, given that the CNSd group showed a level of automaticity lower than that of their same-age peers. However, because the CNSd group did not differ from the younger, typically developing children on automaticity, there was no strong evidence that the observed lag in arithmetic achievement was due to a specific deficit in automaticity of number facts. Because the analysis of the raw RTs would have led to the faulty conclusion that there was strong evidence of a specific deficit of automaticity, these results underscore the importance of controlling for differences in writing time in this population.

We have demonstrated that a large amount of the variance of the raw RTs on the number fact speed test was due to differences in writing time. As such, these results underscore the importance of controlling for differences in writing time in this population. We should also note that children with CP or SBM may have been slower on the number fact retrieval test because they were slower to retrieve answers from long-term memory or because they may have used more counting. Future research will have to resolve this question by looking carefully, first, on a trial-by-trial basis at the strategy used to arrive at an answer (by counting or by retrieving an answer from memory) and, second, at the speed of counting (Geary, 1993).

Arithmetic Instruction Time

In looking for an alternative cause for the lower arithmetic achievement of CNSd group, the third research question asked whether there is a relationship between arithmetic achievement and arithmetic instruction time. The current study showed that children with CNSd who were attending special schools for children with physical disabilities received less instruction in arithmetic than that of typically developing children of the same age who were attending mainstream schools and that this difference was sufficient to explain the entire effect of group on an arithmetic achievement test.

Frampton et al. (1998) found evidence indicating a relationship between unilateral CP and learning difficulties, with a higher percentage of participants having arithmetic difficulties rather than reading difficulties. Although 10% of the participants attended special schooling, the authors did not mention any procedure to control for differences in hours of arithmetic instruction. It is possible that children with unilateral CP and learning difficulties had missed more instruction because of therapy given during the school day, when compared to that of children with unilateral CP without learning difficulties.

There are several reasons why children with CNSd in special education receive less arithmetic instruction. In addition to the provision of medical services and paramedical services, as mentioned in the introduction, these reasons include health-related problems and curriculum content (Zuidwijk et al., 2003). Health-related problems may comprise, for example, illness, visits to medical specialists in the hospital, and hospital stays. The curriculum in special education schools may emphasize reading, as opposed to arithmetic, and therefore provide less arithmetic instruction time. In the Netherlands, schools for children with physical disabilities provide not only education but, within the context of rehabilitation medicine, an array of medical, paramedical, and technical services. As we note above, reduced instruction time in special education appears to be an issue in countries outside the Netherlands as well (Mike, 1995). Given that the amount of arithmetic instruction is an important factor in explaining the difference in arithmetic performance, future research on the causes of poor academic performance of students with CP and SBM should take the amount of instruction time into consideration.

Implications

For the arithmetic education of children with CP or SBM, the conclusions of this study suggest that increasing the amount of arithmetic instruction time would lead to an improvement in arithmetic achievement. Special education practitioners should be aware of the possibility that another balance in the school day between time for arithmetic instruction and time for other activities could improve the arithmetic achievement of these children. However, because schools for children with physical disabilities provide medical and paramedical services, in addition to educational services, the question of what this additional arithmetic instruction would replace in the school day becomes difficult to answer. It would seem that either a portion of paramedical services or a portion of the additional arithmetic instruction would, by necessity, have to take place outside the school day. For example, it might be possible to give additional arithmetic instruction outside the school day, in the form of extra tutoring. However, because funding for tutoring could present an additional problem, it might not be the best option. Perhaps the best solution would be to make an effort to reduce the amount of medical and paramedical services provided during the school day, in favor of arithmetic instruction time. Although this option would probably necessitate visits to medical and paramedical service providers outside the school day, such visits may well place fewer cognitive demands on children and therefore be more appropriate as after-school activities. Future research will need to address these issues.

Limitations

We should note that for practical reasons, the way in which the number of hours dedicated to arithmetic instruction was estimated differed somewhat for the students who were attending special schools versus mainstream schools. Future research in this area should make an effort to improve the estimation of arithmetic instruction time and so use this as a control variable. Also, we should say a word about intelligence. Data on the intelligence of the control group was unavailable. Because it was not feasible to collect intelligence data on the control group in this study, we assumed (but cannot be sure) that their intelligence was in the average range. Although the mean intelligence of the children with disorders of the central nervous system in this study was in the average range, we cannot entirely rule out the possibility that differences in intelligence are responsible for the lag in arithmetic achievement. We should note that differences in educational setting (i.e., special vs. mainstream schools) could affect the arithmetic achievement of these children beyond the influence of hours of instruction time.

Conclusion

An important finding of this study is that the arithmetic learning difficulties of children with disorders of the central nervous system appear to be due in large part to instruction time. No strong evidence was found that would indicate that these arithmetic difficulties were due to a specific deficit in the automaticity of number facts. Therefore, one should beware of attributing learning difficulties in this population exclusively to neurocognitive factors. The results of this study are particularly relevant to practitioners who are interested in the remediation of such difficulties, because environmental factors such as instruction time seem to be more amenable to change than neurocognitive factors.

References

Cans, C. (2000). Surveillance of cerebral palsy in Europe: A collaboration of cerebral palsy surveys and registers. *Developmental Medicine and Child Neurology, 42,* 816-824.

Carlsson, G. (1997). Memory for words and drawings in children with hemiplegic cerebral palsy. *Scandinavian Journal of Psychology, 38,* 265-273.

Carlsson, G., Uvebrant, P., Hugdahl, K., Arvidsson, J., Wikland, L., & von Wendt, L. (1994). Verbal and non-verbal function of children with right- versus left-hemiplegic cerebral palsy of pre- and perinatal origin. *Developmental Medicine and Child Neurology, 36,* 503-512.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum.

Dennis, M., Landry S. H., Barnes, M., & Fletcher, J. M. (2006). A model of neurocognitive function in spina bifida over the life span. *Journal of the International Neuropsychological Society, 12,* 285-296.

Dise, J. E., & Lohr, M. E. (1998). Examination of deficits in conceptual reasoning abilities associated with spina bifida. *American Journal of Physical Medicine & Rehabilitation, 77,* 247-251.

Ewing-Cobbs, L., Barnes, M. A., & Fletcher, J. M. (2003). Early brain injury in children: Development and reorganization of cognitive function. *Developmental Neuropsychology, 24,* 669-704.

Folkerth, R. D. (2006). Periventricular leukomalacia: Overview and recent findings. *Pediatric and Developmental Pathology, 9,* 3-13.

Frampton, I., Yude, C., & Goodman, R. (1998). The prevalence and correlates of specific learning difficulties in a representative sample of children with hemiplegia. *British Journal of Educational Psychology, 68,* 39-51.

French, K. (1995). Mathematics performance of children with spina bifida. *Physical Disabilities: Education and Related Services, 14,* 9-27.

Geary, D. C. (1993). Mathematical disabilities: Cognitive, neuropsychological and genetic components. *Psychological Bulletin, 114,* 345-362.

Geary, D. C., Brown, S. C., & Samaranayake, V. A. (1991). Cognitive addition: A short longitudinal study of strategy choice and speed-of-processing differences in normal and mathematically disabled children. *Developmental Psychology, 27,* 787-797.

Heller, K. W., Alberto, P. A., & Meagher, T. M. (1996). The impact of physical impairments on academic performance. *Journal of Developmental and Physical Disabilities, 8,* 233-245.

Hoon, A. H. (2005). Neuroimaging in cerebral palsy: Patterns of brain dysgenesis and injury. *Journal of Child Neurology, 20,* 936-939.

Iddon, J. L., Morgan, D. J. R., & Sahakian, B. J. (1996). Cognitive dysfunction in patients with congenital hydrocephalus and spina bifida: Evidence for a dsexecutive syndrome? *European Journal of Pediatric Surgery, 6*(Suppl. 1), 41.

Jacobs, R., Northam, E. & Anderson, V. (2001). Cognitive outcome in children with myelomeningocele and perinatal hydrocephalus: A longitudinal perspective. *Journal of Developmental and Physical Disabilities, 13,* 389-405.

Janssen, J., & Engelen, R. (2002). *Verantwoording van de toetsen Rekenen-Wiskunde 2002* [Justification of the Cito student monitoring system for arithmetic performance, 2002]. Arnhem, Netherlands: Citogroep.

Mayes, S. D., & Calhoun, S. L. (2006). Frequency of reading, math, and writing disabilities in children with clinical disorders. *Learning and Individual Differences, 16,* 145-157.

Mike, D. G. (1995). Literacy and cerebral palsy: Factors influencing literacy learning in a self-contained setting. *Journal of Reading Behavior, 27,* 627-642.

Muter, V., Taylor, S., & Vargha-Khadem, F. (1997). A longitudinal study of early intellectual development in hemiplegic children. *Neuropsychologia, 35,* 289-298.

Rack, J. P., Snowling, M. J., & Olson, R. K. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly, 27,* 29-53.

Russell, R. L., & Ginsburg, H. P. (1984). Cognitive analysis of children's mathematics difficulties. *Cognition and Instruction, 1,* 217-244.

Waugh, J., O'Callaghan, M. J., Tudehope, D. I., Mohay, H. A., Burns, Y. R., Gray, P. H., et al. (1996). Prevalence and aetiology of neurological impairment in extremely low birthweight infants. *Journal of Paediatrics and Child Health, 32,* 120-124.

Zentall, S. (1990). Fact-retrieval automatization and math problem solving by learning disabled, attention-disordered, and normal adolescents. *Journal of Educational Psychology, 82,* 856-865.

Zuidwijk, G. G. N., van Blerk, H. P. J., Ludeke, W., & Meihuizen-de Regt, M. J. (2003). Onderwijs [Education]. In M. J. Meihuizen-de Regt, J. M. H. de Moor, & A. H. M. Mulders (Eds.), *Kinderrevalidatie* (pp. 222-237). Assen, Netherlands: Van Gorcum.

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