

Reading and writing skills in young adults with spina bifida and hydrocephalus

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Abstract

Reading and writing were studied in 31 young adults with spina bifida and hydrocephalus (SBH). Like children with this condition, young adults with SBH had better word decoding than reading comprehension, and, compared to population means, had lower scores on a test of writing fluency. Reading comprehension was predicted by word decoding and listening comprehension. Writing was predicted by fine motor finger function, verbal intelligence, and short-term and working memory. These findings are consistent with cognitive models of reading and writing. Writing, but not reading, was related to highest level of education achieved and writing fluency predicted several aspects of functional independence. Reading comprehension and writing remain deficient in adults with SBH and have consequences for educational attainments and functional independence. (*JINS*, 2004, *10*, 655–663.)

Keywords: Spina bifida, Adulthood, Literacy

INTRODUCTION

Poor adult literacy is associated with difficulties in independence, employment, productivity, and mental health (Rivera-Batiz, 1992; Spreen, 1989). Neurodevelopmental disorders place children at risk for literacy difficulties, although little is known about literacy, academic attainments and functional outcomes in adults with neurodevelopmental disorders. Information about adult literacy skills in neurodevelopmental disorders would be of practical value in guiding childhood intervention and adult services, and of theoretical value in informing models of literacy development.

Spina bifida myelomeningocele with hydrocephalus (SBH), the most common disabling birth defect in North America, is a neurodevelopmental disorder of considerable interest to the study of literacy. SBH involves a malformation of the spinal cord, with a loss of sensory and motor function below the level of the spinal lesion. More important for cognitive outcome, SBH affects brain development,

with dysmorphologies and hypoplasias that include abnormal formation and maturation of the cerebellum, midbrain, corpus callosum, and posterior brain regions (Fletcher et al., 1992, 2000). Hydrocephalus affects most children with spina bifida, and involves enlarged cerebral ventricles as well as a range of primary and secondary effects on the brain (reviewed in del Bigio, 1993; Fletcher et al., 2000).

Basic language skills such as vocabulary and syntax often develop to age-appropriate levels in individuals with SBH, as do language-related academic skills such as reading decoding, reading fluency, and spelling (Barnes & Dennis, 1992; Barnes et al., 2001; Halliwell et al., 1980; Prigatano et al., 1983). Not all literacy skills develop well in children with SBH, however. Reading comprehension and writing are less well-developed than reading decoding, even in children of average verbal intelligence (Barnes & Dennis, 1992, 1998; Barnes et al., 2001; Halliwell et al., 1980; Ziviani et al., 1990). The “decoding better than comprehension” pattern is common in children with spina bifida, particularly when measures tap inferential comprehension (Fletcher et al., in press), and occurs relatively less frequently in normal development (Cornoldi et al., 1996).

The goal of reading is to understand the meaning of the written text. Deficits in reading comprehension constitute

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significant barriers to literacy, in both childhood and adulthood. Reading comprehension requires both word-level skills, including word decoding accuracy, word decoding fluency, and vocabulary knowledge, as well as sentence- and text-level skills such as syntactic knowledge, inferencing and text integration (Adams, 1990; Cain & Oakhill, 1999; Cornoldi et al., 1996; Gough et al., 1996; Nation et al., 1999; Oakhill, 1993; Perfetti, 1985; Stothard & Hulme, 1992, 1996). Meta-cognitive skills such as comprehension monitoring (Cataldo & Cornoldi, 1998; Cornoldi et al., 1996) may also contribute to reading comprehension.

Poor reading comprehension in children with SBH is associated with text-level deficits in integration and inferencing, not only within text, but also between text and word knowledge (Barnes & Dennis, 1996, 1998; Barnes et al., 2004), a pattern similar to that found in children with no neurological impairment who are better decoders than comprehenders (Cain et al., 2001; Oakhill, 1993). Individuals with SBH thereby provide the opportunity to examine difficulties in reading comprehension not driven by deficits in word decoding (Barnes, 2002).

It is not known whether the “decoding better than comprehension” pattern is also found in adults with SBH. In the academic domain of mathematics, childhood math deficits persist into adulthood in individuals with SBH (Dennis & Barnes, 2002), so reading patterns in SBH might also be similar in childhood and adulthood. Alternatively, adults with SBH may have deficits in decoding even if they were good decoders in childhood. The logic here is as follows: Individuals with the “decoding better than comprehension” pattern gain less meaning from what they read than their peers. Failure to fully comprehend what is read, particularly as reading materials become more complex in the later grades, may be frustrating and curtail reading outside of school. Less common words are typically learned through exposure to print. If good decoders/poor comprehenders begin to read less when they reach the later grades their exposure to new words will be limited, which might truncate higher levels of lexical development (Cunningham & Stanovich, 1998; Nation & Snowling, 1998). The result by adulthood would be that individuals with SBH have poorer word decoding than their age peers. Difficulties in reading decoding and/or reading comprehension are likely to have consequences for educational attainments, employment, and functional independence in adults with SBH in keeping with what is known about the functional consequences of reading disabilities more generally (Spreen, 1989).

The issue of writing in young adults with SBH is also of interest. Children with SBH, even those with average intellectual skills, are slow writers (Anderson & Spain, 1977; Pearson et al., 1988; Ziviani et al., 1990). In children with learning disabilities, problems with slow printing or writing may lead to deficits in the quantity and quality of text composition (Berninger, 1999; Graham et al., 1997; Swanson & Berninger, 1996). The brain anomalies associated with SBH affect finger function as well as motor planning (Fletcher

et al., 1995; Hetherington & Dennis, 1999), and persistent deficits in these domains could disrupt writing skills in both childhood and adulthood. At present, it is not known whether writing is deficient in adults with SBH.

Writing has been less studied than reading, especially in individuals with specific neurodevelopmental disorders. Fine motor processes such as sequential finger movements (Berninger & Rutberg, 1992), handwriting speed, spelling (Graham et al., 1997), and verbal reasoning skills as tapped by verbal IQ (Berninger et al., 1994) are all related to writing in typically developing individuals. Verbal short-term memory and verbal working memory are related to developmental and individual differences in both the quality and quantity of written composition (Swanson & Berninger, 1996). Working memory, in particular, is implicated in the coordination of the component skills of writing such as transcription and text generation (Berninger, 1999). How each of these skills is related to writing may change over development (Graham et al., 1997). For example, finger function predicts beginning writing to a greater extent than it predicts writing in later grades (Berninger & Swanson, 1994).

Fully-developed literacy skills, including good reading decoding, reading comprehension and proficient writing may all contribute to independence and quality of life. Young adults with SBH provide the opportunity to study whether the strengths and deficits in these domains of literacy that characterize children with SBH are also present in adults with SBH. Adults with SBH have limited functional independence, and low levels of employment even when intelligence is broadly average (Castree & Walker, 1981; Hayden et al., 1979; Hetherington et al., in press; Hunt, 1990; Kennedy et al., 1998; Morgan et al., 1993; Stellman-Ward et al., 1993). Whether the pattern of literacy strengths and deficits in children is similar to that in adulthood is unknown, as is the relationship between various literacy skills and independence, academic achievement, and employment status of adults with SBH.

In this study, our general aim was to determine the pattern of reading decoding, reading comprehension and writing skills in young adults with SBH. Three questions were addressed. The first question was whether strengths and deficits in reading and writing found in children with SBH are also found in adults with SBH. Word decoding, reading comprehension, and writing fluency were studied in young adults with SBH to establish whether literacy patterns in children are also observed in adults with SBH. Under one hypothesis, the characteristic childhood deficits in reading comprehension and writing might resolve by maturity such that early problems in acquiring these literacy skills might constitute developmental delays rather than cognitive deficits. Under another, young adults with SBH might fail to achieve mastery of literacy skills, even those such as word decoding that are appropriately developed in children with SBH. The second question was whether the skills that predict reading comprehension and writing in typically devel-

oping individuals also predict reading comprehension and writing in adults with SBH. We considered whether reading comprehension was predicted by variability in word decoding and language comprehension skills, and whether writing was predicted by variability in finger skills, language ability, and short-term and working memory. The third question concerned the consequences of literacy level—how is literacy in young adults related to educational attainments and functional independence? Difficulties in reading and writing often co-occur and reading and writing have several component skills in common in typical development (Berninger et al., 1994). Individuals with SBH could provide an opportunity to study how poor writing in the context of well-developed reading decoding is related to academic attainments and functional independence in young adults with this neurodevelopmental disorder.

METHODS

Research Participants

Participants were 31 young adults with SBH (M age 26.9, SD 5.0, range 18.5–36.3; 15 females, 16 males; 25 right-handers, 6 left-handers). Each had been treated for hydrocephalus with a diversionary shunt shortly after birth or in infancy. Each had adult Verbal and Performance IQ scores of 70 or above on the adult Wechsler Adult Intelligence Scale–Revised (Wechsler, 1981). The mean Verbal IQ of the group was 95.4, SD 9.1, range 79–114 and the mean Performance IQ was 85.2, SD 10.2, range 70–114. The study group was the same as that in two previous reports of adults with spina bifida, one on numeracy outcomes (Dennis & Barnes, 2002), the other on quality of life in relation to medical, physical, and cognitive features of the condition (Hetherington et al., in press).

Twenty-eight individuals had graduated from high school. Of these, 4 had completed or were attending university, 14 had attended community college, and 10 had graduated from high school, mostly from general, rather than advanced level courses. Of the remaining 3 participants, 2 were still high school students at the time of testing and 1 had just completed high school, but had not yet begun a post-secondary program. For purposes of analyses, participants were grouped on the basis of those who had some post-secondary education ($n = 18$) and those who had completed secondary school only ($n = 10$).

Tasks

Reading and writing were assessed through standardized measures of word decoding accuracy, reading comprehension, and sentence composition in a speeded writing task. Those language, motor, and memory skills that have been related to reading and writing in other studies were used to determine the contribution of these particular skills to adult literacy outcomes.

Measures of literacy skills: reading decoding, reading comprehension, and writing

Letter–Word Identification (Woodcock, 1991) requires participants to decode single written words that increase in difficulty according to age- and grade-level. Reading accuracy (but not fluency) is measured. Scores are expressed as age based standard scores ($M = 100$, $SD = 15$).

Passage Comprehension (Woodcock, 1991) is a task that requires participants to silently read sentences and paragraphs and demonstrate understanding by providing a missing word. Scores are expressed as age based standard scores ($M = 100$, $SD = 15$).

Writing Fluency (Woodcock, 1991) is a timed sentence composition test in which the participant must write a sentence using a word provided. The task measures the number of complete sentences that can be composed and written in 7 min. Sentences are not scored for capitalization, punctuation, or spelling, although the sentences must use the word provided and be grammatically correct and semantically coherent. Scores are expressed as age based standard scores ($M = 100$, $SD = 15$).

Language, memory, and motor skills

Listening Comprehension (Woodcock, 1991) is a task in which the participant listens to a sentence or paragraph and supplies the final word of the passage. It is an oral comprehension analogue of the reading comprehension task described above. Scores are expressed as age based standard scores ($M = 100$, $SD = 15$).

Two tests of vocabulary knowledge were used (Woodcock, 1991). Picture Vocabulary is a receptive vocabulary task that requires the participant to listen to a spoken word and to point to one of four pictures that best represents that word's meaning. Oral Vocabulary requires the participant to provide antonyms or synonyms for spoken words. The vocabulary scores are expressed as age based standard scores ($M = 100$, $SD = 15$).

Verbal memory span was measured by the Numbers Forwards subtest of the Microcog™ Assessment of Cognitive Function (Powell et al., 1993) in which participants reproduce digit sequences (from string length of 2 to string length of 9) on the numeric keypad of a computer. The sequences appear on a screen sequentially, for one second. The highest number of digits recalled was used as the memory span measure and was expressed as age based and education adjusted standard scores ($M = 10$, $SD = 3$).

Working memory was measured by the Numbers Reversed subtest of the Microcog™ Assessment of Cognitive Function (Powell et al., 1993). On this task, participants hold and manipulate numbers in memory and reproduce visually presented digit sequences in reversed order on the numeric keypad of a computer. The task requires working memory by virtue of the concurrent storage and manipulation of material (Baddeley, 1986). The highest number of digits correctly recalled in reverse order was used as the working

memory measure and was expressed as an age based and education adjusted standard score ($M = 10$, $SD = 3$).

The Beads on Rod subtest from the McCarron Assessment of Neuromuscular Development (McCarron, 1997) was used as a measure of fine motor finger function. Beads on Rod requires the participant to hold a rod in the non-dominant hand while placing small beads on the rod with eyes open and with eyes closed. Standard scores ($M = 100$, $SD = 15$) are based on how many beads are placed on the rod in 30 s.

A measure of simple response time (Timers subtest of the Microcog™ Assessment of Cognitive Function) was used to control for speed of motor responses given that short term memory and working memory measures used in this study also involved a timed motor response. The Timers subtest measures elapsed time between the appearance of a visual signal on the computer screen and the participant's response.

Functional independence

The Scales of Independent Behavior–Revised (Bruininks et al., 1996) uses a structured interview self-report format to measure Broad Independence, as well as Motor Skills (gross and fine motor); Social Interaction and Communication Skills (social interaction, language comprehension, and language expression); Personal Living Skills (eating and meal preparation, toileting, dressing, personal self-care, and domestic skills); and Community Living Skills (time and punctuality, money and value, work skills, and home/community orientation). Scores are expressed as age-based standard scores ($M = 100$, $SD = 15$).

RESULTS

Results are shown in Table 1. Scores on the literacy tasks and other language, memory, and motor tasks were compared to population means for those tests using two-tailed, one-sample t tests. Effect sizes (r) were also calculated to supplement the results, particularly with respect to null-hypothesis findings. The performance of the adults with SBH on several of the tasks did not differ from the population means. The exceptions were as follows: Word Identification was higher than the population mean [$t(30) = 2.45$, $p = .02$; $d = .44$]; Writing Fluency was lower than the population mean [$t(30) = -3.04$, $p = .0048$; $d = .57$]. Numbers Forward [$t(30) = -3.11$, $p = .004$; $d = .58$], Numbers Reversed [$t(30) = -4.19$, $p = .0002$; $d = .70$], and Beads on a Rod [$t(30) = -4.91$, $p < .0001$; $d = .95$] were lower than the population means. No other comparisons reached statistical significance on the t tests (Passage Comprehension: $d = .31$; Picture Vocabulary: $d = .33$; Oral Vocabulary: $d = .19$; Listening Comprehension: $d = .17$). Even though some of the literacy and cognitive skills were lower than the population means, many skills were above the 25th percentile.

Table 1. Literacy and literacy-related skills in adults with SBH

	<i>N</i>	<i>M</i>	<i>SD</i>	Range
Reading and Writing				
Word Identification ^a	31	106.5	14.7	77–132
Passage Comprehension ^a	31	95.9	11.3	70–125
Writing Fluency ^a	31	91.0	16.5	57–128
Language, Memory, & Motor Skills				
Picture Vocabulary ^a	31	95.3	13.1	72–133
Oral Vocabulary ^a	31	102.7	12.5	78–131
Listening Comprehension ^a	31	102.5	14.2	77–132
Numbers Forwards ^b	31	8.2	3.2	3–15
Numbers Reversed ^b	31	8.0	2.7	4–15
Beads on a Rod ^a	31	84.6	17.4	31–118
Functional Independence				
Broad Independence ^a	27	86.3	26.9	19–133
Motor Independence ^a	27	54.7	37.6	0–131
Social-Language Independence ^a	29	101.3	17.3	51–129
Personal Independence ^a	29	97.8	23.2	41–129
Community Independence ^a	29	99.0	24.0	37–134

Note. ^a $M = 100$, $SD = 15$; ^b $M = 10$, $SD = 3$.

Based on studies of reading and writing in children with SBH, within-group comparisons of specific literacy skills within the SBH group were made. Word Identification was significantly higher than Passage Comprehension [$t(30) = 5.91$, $p < .0001$] and Writing Fluency [$t(30) = 6.41$, $p < .0001$]. Eighty-four percent of the sample had higher Word Identification scores than Passage Comprehension scores, and in 42% of the entire sample, the Word Identification score was 15 or more percentile points higher than the participant's corresponding Passage Comprehension score.

One basic model of reading hypothesizes that reading comprehension can be predicted by word decoding and listening comprehension, because the latter requires both word- and text-level comprehension skills (Gough et al., 1996). Because word decoding is a pre-condition for reading comprehension, Word Identification scores were forced into the regression model predicting Passage Comprehension scores, followed by Listening Comprehension. The model was significant [$F(2,30) = 34.05$, $p < .0001$], accounting for 69% of the variance in reading comprehension scores (Word Identification alone accounted for 53% of the variance).

A stepwise model was tested for Writing Fluency using measures of skills found to be related to writing literacy in previous studies. VIQ scores (the verbal ability measure often used in studies of writing), Word Identification (used as a proxy for spelling because most studies show no difference between reading decoding and spelling in children with SBH (Fletcher et al., 1995; Friedrich et al., 1991), Numbers Forward (a measure of verbal short term memory), Numbers Reversed (a measure of verbal working memory), and Beads on Rod (a measure of fine motor finger function) were used to predict Writing Fluency. A measure of simple response time was also added to the regression because the memory tasks required a timed manual response. No variables were forced into the regression. Forward and

Table 2. Relations between word decoding, verbal IQ, short-term verbal memory, verbal working memory, fine motor function, and simple response time

Variable	Standard coefficient	R^2
Step 1 Verbal IQ	.60	.40
Step 2 Fine motor	.47	.52
Step 3 Verbal working memory	.51	.58
Step 4 Verbal short-term memory	.37	.66

Note. These results are based on a forward stepwise model. Standard coefficient stands for the standard regression coefficient; R^2 stands for the proportion of variance (incrementally) explained at each step of the model. Word decoding and simple response time were not entered into the model.

backward solutions produced similar results. The results for the forward solution only are presented below and in Table 2. The regression was significant [$F(4,30) = 15.56$, $p < .0001$] and accounted for 66% of the variance in Writing Fluency scores with contributions of Verbal IQ, Numbers Forwards, Numbers Reversed, and Beads on Rod.

A qualitative analysis of the sentences produced by these adults revealed little relationship between writing fluency scores and the quality or form of the printing or handwriting itself (e.g., spacing, neatness, whether printed or cursive writing). Most of the sentences the adults with SBH produced were complete and included appropriate syntax and meaning, and almost all of the words were spelled correctly, suggesting that this aspect of transcription in adults with SBH may be intact. The main reason for low scores on this task appeared to be problems with speed of transcription.

Literacy outcomes were also studied with respect to gender, handedness, and educational attainment (i.e., those with only high school education *vs.* those with some post-secondary education). Gender and handedness were not associated with literacy scores. There was a significant effect of Educational Group for Writing Fluency only [$F(1,26) = 4.31$, $p < .05$, $d = .89$], with the post-secondary education group obtaining higher Writing Fluency scores than the secondary education only group. No other effects were significant ($ds < .3$). These results are shown in Table 3.

We also studied the predictors of independence. For the 29 individuals with ratings of Functional Independence, multi-

ple regressions were conducted on the Functional Independence subscale scores, with three regressors, Word Identification, Listening Comprehension, and Writing Fluency. The regression for Social Language and Communication skills was significant [$F(3,25) = 5.76$, $p = .004$] accounting for 34% of the variance with only Writing Fluency contributing significantly to Social–Language–Communication ($t = 2.42$, $p = .023$). The regression for Personal Living Skills was also significant [$F(3,25) = 5.72$, $p = .004$], accounting for 34% of the variance. Only Writing Fluency contributed significantly to Personal Living Skills ($t = 3.74$, $p = .001$). The regression for Community Living Skills was significant [$F(3,25) = 3.82$, $p = .02$] accounting for 23% of the variance. Writing Fluency contributed significantly to Community Living ($t = 2.86$, $p = .008$). The regression for Motor Independence was not significant.

DISCUSSION

This study provides novel information about literacy in adults with SBH, which is informative not only for understanding literacy acquisition in this disorder, but also for evaluating models of reading and writing. The data bear on the three questions posed in the Introduction: whether the pattern of literacy skills in adults with SBH is similar to that in children with SBH; whether the skills that predict literacy in typical development are similar to those that predict literacy attainments in SBH; and whether literacy skills are related to adult educational attainments and functional independence in this neurodevelopmental disorder.

In young adults with SBH, the pattern of literacy skills is similar to that of children with SBH. Reading accuracy is better developed than reading comprehension, just as it is in children with SBH (Barnes et al., 2001; 2004). However, reading comprehension was not significantly below the population mean. In children with SBH, reading comprehension is not only less well-developed than reading decoding, it is often poorer than reading comprehension in typically developing controls, although this sometimes depends on what aspects of comprehension are measured (Barnes & Dennis, 1992; Barnes et al., 2001; 2004; Fletcher et al., *in press*). The lack of a control group matched on important demographic features to the adult SBH group is a weakness of the current study. The status of reading comprehension in adults with SBH requires further investigation both in comparison to typical adults and in relation to different aspects of comprehension as discussed below. Writing was below the population mean in these young adults, which is similar to findings for children with SBH (Pearson et al., 1988; Ziviani et al., 1990), and writing was also less well developed than reading in these young adults. The findings for both reading and writing do not support the view that those components of literacy that are deficient in children with SBH, notably, reading comprehension and writing, resolve by adulthood. These data in adults with SBH are consistent with the idea that difficulties in reading

Table 3. Mean literacy scores (*SD*) for educational attainment groups

	Group	
	Secondary education $N = 10$	Post-secondary education $N = 18$
Word identification	104.0 (13.7)	108.0 (15.8)
Passage comprehension	93.1 (15.2)	96.8 (9.3)
Writing fluency	83.0 (9.3)	96.0 (18.4)

comprehension and writing may represent cognitive deficits rather than developmental delays. However, a full test of this hypothesis requires longitudinal studies of literacy skills in SBH and typically developing individuals.

The fact that comprehension is less well developed than decoding in both children and adults with SBH is relevant to questions about possible effects of deficient comprehension on the acquisition of adult word decoding skills. One hypothesis that has been raised in studies of good decoders/poor comprehenders is that even when early word decoding skills are good, poor comprehension may negatively affect the acquisition of new lexical knowledge in the higher grades. Longitudinal studies of good decoders/poor comprehenders are required to test this hypothesis. The status of childhood decoding and comprehension skills of the adults in this study is unknown. However, given that they show the “better decoding than comprehension” pattern also found in children with SBH, and in light of their strong decoding performance, deficient ability to derive meaning from text in childhood does not appear to constrain further lexical development in SBH.

Fine motor deficits exist in both children and adults with SBH (Hetherington & Dennis, 1999; Hetherington et al., in press; Shaffer et al., 1986) as do difficulties in writing. Writing skill in this group of young adults with SBH was strongly related to variation in fine motor or finger skills, which are also said to figure in the writing problems of children with SBH (Ziviani et al., 1990). This stands in contrast to studies of typical development in which finger function is a better predictor of beginning writing than it is of writing skill later in development (Berninger & Swanson, 1994). Consistency in results between child and adult studies of writing in SBH suggest that further research on whether and how fine motor difficulties affect the quantity and quality of written composition across the elementary and secondary grades would be of considerable interest. Whether aids to writing such as keyboarding skills alter these putative relationships between fine motor abilities and writing is also an issue of practical and scientific significance.

The data bear on models of the component skills of reading and writing. In keeping with models of normal development and of the normal reading process (Gough et al., 1996), word decoding skill and listening comprehension were good predictors of reading comprehension, and listening comprehension contributed to reading comprehension over and above decoding. Despite the similarity in the pattern of literacy strengths and deficits in childhood and adulthood, all components of reading decoding may not be unaffected by increasing age in individuals with SBH. For example, word decoding skill involves not only word reading accuracy, but also reading fluency. Although children with hydrocephalus from mixed etiologies who are accurate decoders are also fluent at reading single words (Barnes et al., 2001), it is not known whether adults with SBH maintain age-appropriate reading rates. Accurate but slow word-level processing in adulthood could have negative effects on reading comprehension.

That reading comprehension is less well developed than reading decoding in adult life is of some interest. Comprehension involves the coordination of several word- and text-level skills such as vocabulary and grammatical knowledge, as well as inferential and integrative processes, the latter two skills being particularly deficient in children with SBH (e.g., Barnes & Dennis, 1998; Barnes et al., 2004). The reading comprehension task used in this study did not explicitly measure processes such as inferencing, which operate over larger chunks of text. A recent study of children and adolescents with SBH found that comprehension difficulties are more apparent on tests of inferential and global comprehension than on tests that measure more literal and local aspects of comprehension such as pronominal reference (Fletcher et al., in press). Inferencing deficits may be particularly significant for educational attainment, because inferencing is important for learning from text (Kintsch, 1994).

This study represents one of the first investigations of the predictors of writing difficulties in adults with a neurodevelopmental disorder that is associated both with anomalous brain development and with poor writing skills. The model relating various cognitive and fine motor skills to writing fluency in adults with SBH is informative about developmental mechanisms that might produce deficits in writing. Adults with SBH had difficulties in fine motor finger movements, and in short term memory and working memory, all of which were related to speeded sentence composition in the present study. Sequential finger movements predict writing achievement (Berninger & Rutberg, 1992; Berninger et al., 1994), presumably because such measures tap the planning and programming of complex fine motor movements, which are necessary for handwriting. Handwriting speed itself is related to individual differences in compositional quality (Graham et al., 1997); fluent transcription skills may free working memory resources for composition-related language and cognitive processes (Berninger, 1999; Swanson & Berninger, 1996). Given that adults with SBH have difficulty in writing fluency and working memory, one would predict the quantity and quality of their written compositions to be poorer than that of their typically developing peers.

Although the findings suggest that adults with SBH might have difficulty in compositional quality, the writing task used in this study does not allow separate measures of fluency and quality of text composition. Writing Fluency measures handwriting speed for a series of unconnected sentences (Graham et al., 1997) in contrast to measures of text composition that require samples of sustained writing of connected narratives or expositions within a specified time frame. Studies of the development of writing in young children with SBH using theoretically derived tasks of writing and writing-related skills will be important for understanding writing development in this condition. Such theoretically-motivated studies might also be informative about the role of early fine motor and transcription-related deficits in the development of compositional quantity and quality in a clin-

ical group in which fine motor deficits are prominent (Fletcher et al., 1995; Hetherington & Dennis, 1999; Holler et al., 1995; Prigatano et al., 1983). Thus, SBH may be an appropriate neurodevelopmental condition in which to investigate brain structure-cognitive function relationships in the writing process.

Functional literacy, the use of reading to solve everyday problems and function effectively in one's environment, has not been found to be related to educational attainments or occupational status in SBH (Hetherington et al., in press). The current study more closely investigated the component skills of reading literacy—reading decoding and reading comprehension—in relation to academic attainment and functional independence. Given the high levels of word decoding skills in this group, it is not particularly surprising that reading skills are not related to functional independence or educational attainment. However, despite well-developed functional reading skills in many individuals half of those who had graduated with at least a secondary school diploma were unemployed. These employment outcomes seem related to relatively greater difficulties in other skill domains including numeracy (Dennis & Barnes, 2002), visual-spatial and fine motor function, and motor independence (Hetherington et al., in press).

In contrast to reading, writing was related to educational attainment: those individuals who had not gone past high school had writing scores that were, on average, below the 10th percentile. Children in the elementary grades spend about half of their classroom time engaged in printing and writing activities (McHale & Cermak, 1992), so children with SBH who have writing difficulties regardless of their motor and cognitive origins, are at a significant disadvantage with respect to engaging in common classroom activities. It is worth thinking about the potential long-term effects of writing problems given that writing was the only literacy skill predictive of post-secondary schooling. Although adults spend less of their time than school-age children in writing activities, early and persistent difficulties in printing and writing could constrain academic and vocational attainments for individuals with SBH regardless of reading skill.

In terms of functional independence, writing scores were not related to motor independence, which includes both gross and fine motor competencies. Writing was, however, related to aspects of functional independence having to do with communication, community living, and personal living skills. These results suggest that the problems in writing experienced by adults with SBH are related to more than just fine motor difficulties. For example, several items on those scales that assess social interaction and communication skills explicitly deal with written communication such as filling in forms and applications and writing reports for various purposes unrelated to school. As well, the language and working memory skills that are needed for oral communication likely overlap substantially with those needed for written communication. In the domain of personal living skills, many aspects of functional independence do require fine motor skills such as those needed for food preparation

and dressing, though some self care and domestic skills such as making medical appointments may draw on executive skills that also contribute to writing. Similarly, many aspects of functional independence in community living likely require working memory and executive skills involved in planning and scheduling around time and punctuality, and money- and work-related activities such as making reservations, receiving and paying bills, remembering to write down and check appointments, and so forth. In sum, functional independence in adulthood is partly defined by the ability to communicate through writing, and draws on language, working memory and executive skills that are assumed to also contribute to writing ability.

The current study provides information on literacy outcomes in adults with spina bifida. Because neuroimaging data were not available for this group, relations between the cognitive/academic phenotype and the neural phenotype in adults with spina bifida could not be tested. It will be important in future studies of adults with neurodevelopmental disorders to consider how medical, physical, and biological aspects of these conditions affect adult outcomes. In spina bifida, for example, medical features of the condition such as number of shunt revisions have, for the most part, not been found to be related to cognitive function in children (Fletcher et al., in press), though number of lifetime shunt revisions and other aspects of shunt revision history could very well be related to adult outcomes (e.g., Dennis et al., 2000). Similarly, spina bifida-related dysmorphologies in particular brain regions and the effects of hydrocephalus on brain structure and development will be of interest in relation to cognitive, motor, and social outcomes in both children and adults.

These findings add to an emerging picture of adult function in SBH. The early academic difficulties of children with SBH, including numeracy (Barnes et al., 2002) and writing, are also apparent in adulthood (see Dennis & Barnes, 2002), and have a serious impact on functional independence and educational attainments. Such findings have clear implications for early intervention in infants and children with SBH, but are also relevant for considerations of how to meet the educational and vocational needs of the growing population of young adults with SBH.

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