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Meaning construction and integration in children with hydrocephalus

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Abstract

Text comprehension processes were investigated in children with hydrocephalus, a neurodevelopmental disorder associated with good word decoding, but deficient reading comprehension. In Experiment 1, hydrocephalus and control groups were similar in processes related to activating word meanings and using context to enhance meaning. The hydrocephalus group was poorer at suppressing contextually irrelevant meanings. In Experiment 2, the hydrocephalus group had difficulty integrating information from an earlier read sentence to understand a new sentence as textual distance between the two propositions increased, suggesting difficulty in reactivation processes related to comprehension. Results are discussed in relation to cognitive and neurocognitive models of comprehension.

Keywords: Hydrocephalus; Children; Reading comprehension; Meaning activation; Suppression; Contextual enhancement; Reactivation

1. Introduction

The understanding of text and discourse builds on linguistic structural constraints such as syntax that operate within a language at the word and sentence level, but comprehension also requires meaning construction and memory processes (Clifton & Duffy, 2001; van den Broek, Young, Tzeng, & Linderholm, 1999). Theories of discourse and text comprehension specify how meaning is assembled as the text proceeds in time and interacts with the knowledge and goals of the reader (e.g., Graesser, Gernsbacher, & Goldman, 1997; Kintsch, 1988; Schmalhofer, McDaniel, & Keefe, 2002).

Unfolding over time, a series of lexical, contextual, and memorial processes result in comprehension of the situation described by the text. Within these time-sensitive processing cycles, an initial meaning construction phase involves the activation of information from general knowledge and from the particular text segment being processed. In this construction phase, a passive semantic process activates word meanings without respect to the context or sentence frame, so that more semantic information is activated than will form the mental representation of the situation described by the text (Schmalhofer et al., 2002). In the later, integration phase, contextually irrelevant meanings are suppressed or do not receive sustained activation and context-appropriate meanings are enhanced (Gernsbacher, 1990).

A current text segment may resonate with information in long-term memory from a previous processing cycle, so memory retrieval processes also play a role in the construction and integration of meaning (van den Broek et al., 1999). Long-term memory, therefore, is involved in assembling the meaning of the just read sentence and also in integrating current and previous text information (Albrecht & Myers, 1998; Albrecht & O'Brien, 1993).

The processes of meaning activation, suppression, and enhancement have been understood from studies of lexically ambiguous words and their unique properties. A lexically ambiguous word like SPADE, which can refer to a playing card or to a shovel, prompts activation of both meanings (SHOVEL and CARD), even when the sentence context biases toward one interpretation (e.g., *He dug with the spade*). Over time, activation of contextually irrelevant meanings are suppressed and activation of contextually relevant

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meanings are enhanced, so that only the still-activated contextually relevant meaning contributes to the situation model described by the text (Gernsbacher & Faust, 1991; Seidenberg, Tanenhaus, Leimen, & Bienkowski, 1982).

One neurodevelopmental disorder, early hydrocephalus, is of particular interest in the delineation of these meaning assembly processes because children with early hydrocephalus have generally intact word-level language skills, but selective deficits in text and discourse comprehension. Children with early hydrocephalus provide a window into what is involved in understanding a text because it is possible to investigate their construction of sentence-level and text-level meaning without reference to the word-level deficits typical of many individuals with reading and language disorders.

Hydrocephalus is the common outcome of a set of perturbations of brain development, originating from the unfolding of a genetic/embryological program, or from intrauterine and perinatal events. Hydrocephalus arises from congenital anomalies, such as those involved in spina bifida myelomeningocele, aqueduct stenosis, and Dandy–Walker syndrome, and also from severe intraventricular hemorrhage in children born prematurely. Hydrocephalus involves enlarged cerebral ventricles arising from an imbalance in cerebrospinal fluid biomechanics, and a range of primary and secondary effects on the brain (reviewed in Del Bigio, 1993; Fletcher, Dennis, & Northrup, 1999), notably in altered formation and maturation of the cerebellum, midbrain, and corpus callosum. (Fletcher et al., 1992, 1996; Hannay, 2000).

In children with hydrocephalus from the different etiologies described above, good single word skills stand in contrast to poor text comprehension (Fletcher, Barnes, & Dennis, 2002). Lexicon and syntax are often areas of absolute strength and they develop to age-appropriate levels (Barnes, Faulkner, & Dennis, 2001; Billard, Santini, Gilbert, Nargeot, & Adrien, 1986; Brookshire, Fletcher, Bohan, & Landry, 1995; Byrne, Abbeduto, & Brooks, 1990; Dennis, Hendrick, Hoffman, & Humphreys, 1987; Parsons, 1986; Schwartz, 1974). Text and discourse skills are areas of relative deficit, and children with hydrocephalus have difficulty making inferences, understanding literal story content, using context to understand novel metaphors (Barnes & Dennis, 1996, 1998; Dennis & Barnes, 1993), and producing coherent and cohesive narratives (Dennis, Jacennik, & Barnes, 1994). Reading shows a similar dissociation to oral language between relatively preserved single word decoding and relatively poor comprehension. Children with hydrocephalus have good reading decoding skills, but have poor understanding of what they read (Barnes & Dennis, 1992; Halliwell, Carr, & Pearson, 1980; Prigatano, Zeiner, Pollay, & Kaplan, 1983; Shaffer, Friedrich, Shurtleff, & Wolf, 1985), with their reading comprehension deficits not being due to decoding dysfluency (Barnes et al., 2001).

The dissociation between decoding and comprehension in children with hydrocephalus allows models of the comprehension process to be investigated, although the cognitive sources of comprehension impairments in these children are not well understood. In this paper, we investigate meaning construction and integration during reading of ambiguous words in children with early hydrocephalus. The method was based on cognitive models of discourse and text comprehension (e.g., Construction Integration theory; Kintsch, 1988; Structure Building Framework, Gernsbacher, 1990) using tasks that measure on-line comprehension (van den Broek et al., 1999).

It is not known whether meaning activation, meaning suppression, and meaning enhancement processes are intact or deficient in children with hydrocephalus. Although they understand single words on untimed vocabulary tests, they may still have deficits in meaning activation. Even when they activate meanings, they may be unable to suppress irrelevant meanings, or to use context to enhance the activation of contextually relevant meanings.

Our first question was whether children with hydrocephalus and typically developing children are equally able to activate word meanings, to suppress contextually irrelevant meanings, and to use context to enhance selection and maintain activation of meaning during sentence processing. This was addressed in Experiment 1, which investigated sentence comprehension processes by studying the activation, suppression, and contextual enhancement of word meanings in sentence contexts. We predicted that children with hydrocephalus would: (1) activate word meanings as well as typically developing control children given what is known about their vocabulary skills; (2) have more difficulty than controls in suppressing contextually irrelevant meanings at the appropriate time, as do other individuals with poor comprehension skills (Gernsbacher & Faust, 1991); and (3) be less efficient than controls at using context to enhance the activation of meaning given their difficulties in using context to interpret metaphors with more than one meaning.

Context operates over shorter or longer spans of text, and so memory processes are important in text and discourse comprehension. Memory holds the results of current semantic processing, reactivates or retrieves results of previous processing cycles, and helps access relevant background or general knowledge from long-term semantic memory (Barnes, Dennis, & Haefele-Kalvaitis, 1996; van den Broek et al., 1999). Fluent adult readers are slower to read sentences that are coherent with respect to immediately surrounding text, but that are inconsistent with information that has been presented several sentences earlier (Albrecht & O'Brien, 1993). Children with hydrocephalus have difficulty retrieving prior knowledge from semantic memory to make inferences during story comprehension (Barnes & Dennis, 1996, 1998). Whether they also have difficulty retrieving or reactivating information from prior comprehension cycles is not known, although such deficits would disrupt the construction of meaning.

Our second question was whether children with hydrocephalus have more difficulty than typically developing children in integrating information across longer chunks of text. This was addressed in Experiment 2, which investigated how intervening textual distance affects the reactivation memory processes involved in discourse comprehension. We predicted that children with hydrocephalus would show steeper textual distance effects, that is, they would be less able than controls to reactivate information from previous sentences over longer stretches of text.

2. Experiment 1: Activation, suppression, and contextual enhancement

Experiment 1 compared meaning activation, suppression, and enhancement in children with hydrocephalus and typically developing controls. Activation and suppression were measured in Experiment 1a, and enhancement of contextually appropriate meaning was measured in Experiment 1b. Materials were constructed (based on Gernsbacher & Faust, 1991) in which the activation of the meanings of ambiguous words was measured in different sentence contexts and at different time points in the construction of meaning during online processing.

2.1. Method

2.1.1. Participants

The same children participated in Experiment 1a and 1b. Twenty-eight children and adolescents with hydrocephalus and 28 controls were tested. Fifteen of the hydrocephalus group had spina bifida with myelomeningocele, the most common etiology of early hydrocephalus, 4 had a diagnosis of aqueduct stenosis, 4 had Dandy–Walker Syndrome, and 5 had intraventricular hemorrhage. Each individual in the hydrocephalus group had reading decoding at or above the 25th percentile on the Word Identification subtest of the Woodcock Reading Mastery Test-Revised (Woodcock, 1987) to ensure that no child had a disability in reading decoding (Fletcher et al., 2002). Each participant with hydrocephalus also had a verbal intelligence score above 80 on either the Weschsler Intelligence Scale for Children-III (Wechsler, 1991) or the Stanford–Binet Intelligence Scale-IV Edition (Thorndike, Hagen, & Sattler, 1986).

Control children were identified by their teachers as performing in the middle quartiles of their classrooms in reading and language arts. Consistent with previous work using a similar participant identification strategy (see Barnes & Dennis, 1992) the selection rules used by teachers resulted in a group of 45 children in grades 5–8 with mean scores on several tests of decoding and reading comprehension ranging between the 55th and 65th percentiles (Barnes, unpublished data). We were not able to collect intelligence test data on control children. The controls for the two experiments were chosen from this sample based on the criteria discussed below.

Children with hydrocephalus were matched to controls on the basis of age, grade, and word decoding skill. Consistent with previous studies of reading in children with hydrocephalus (Barnes & Dennis, 1992; Barnes et al., 2001), the reading comprehension scores of the hydrocephalus group were lower than those of the control group on Passage Comprehension from the WRMT-R ($p = .01$) and Paragraph Reading from the Test of Reading Comprehension (Brown, Hammill, & Wiederholt, 1995; $p < .01$). In contrast to controls, the reading decoding scores in the hydrocephalus group were significantly higher than either their IQ or their reading comprehension scores (also see Barnes & Dennis, 1992, 1998; Wills, Holmbeck, Dillon, & McLone, 1990). There were 17 males, 11 females in the hydrocephalus group and 15 males, 13 females in the control group. Group characteristics are shown in Table 1.

2.2. Experiment 1a: Activation and suppression

2.2.1. Materials and procedure

Two context sentences were constructed for each ambiguous word or homograph (e.g., SPADE). In the ambiguous condition, the final word of each sentence was a homograph (e.g., He dug with the spade). In the control condition, the final word was an unambiguous synonym (e.g., He dug with the shovel). A test word (e.g., ACE) was chosen for each homograph such that it did not fit with the meaning of the sentence containing

Table 1
Group characteristics for hydrocephalus and control groups in Experiment 1: Means (SD)

	Group	
	Hydrocephalus	Control
Age (years.months)	12.8 (1.8)	12.1 (1.2)
Grade (years.months)	6.9 (1.9)	6.7 (1.5)
Word identification[a]	65.5 (20.7)	57.2 (16.7)
Passage comprehension	49.2 (27.90)	66.5 (20.3)
Paragraph reading	39.7 (25.2)	61.5 (27.1)
Verbal IQ	43.2 (21.9)	—
Performance IQ	18.6 (21.5)	—

[a] Test scores are presented as percentiles based on age at test.

the homograph. Thirty-two ambiguous words/homographs were used, chosen from published norms (Nelson, McEvoy, Walling, & Wheeler, 1980) with the constraint that each word had two, equally frequent meanings. Each participant received 16 of the homographs tested after the ambiguous condition and 16 homographs tested after the control condition. Filler items were also constructed to produce an equal number of yes and no trials, for a total of 64 trials per participant. Materials were counterbalanced across type of context sentence (ambiguous vs. control) and test interval (250 vs. 1000 ms). The 250 ms trials constituted the activation portion of the experiment; the 1000 ms trials constituted the suppression portion of the experiment.

Each sentence was presented on a Macintosh computer one word at a time for 500 ms, followed by a 150 ms pause between each word. After the last word of the sentence left the screen, the test word was presented either 250 or 1000 ms later. The participant's task was to decide whether the test word fitted the meaning of the sentence. The response to the critical trials is "no." Participants were told to respond as quickly but as accurately as possible by pressing a "yes" or "no" button labeled on the computer's keyboard. The computer recorded the time taken to initiate the response from when the test word appeared on the screen. In a posttest, the children were asked to select two meanings for each ambiguous word in the experiment from two foils. Any words that did not produce two correct meanings were removed from analysis for that child so as to ensure that any failure to activate both meanings of the words was not due to a lack of familiarity with the dual meaning of the ambiguous words.

2.3. Results

The 250 ms trials were used to tap meaning activation, whereas the 1000 ms trials tapped meaning suppression. The logic of the experimental manipulation differs according to how activation and suppression are measured. If there is *activation* of both meanings of the ambiguous word regardless of the context, then it should be difficult to say that ACE does not fit the meaning of the ambiguous condition sentence "He dug with the spade"; that is to say, ACE should interfere with the "no" response at 250 ms and the time to make a decision in the ambiguous condition should be longer than for the control condition. *Suppression* is deemed to occur by 1000 ms, by which time the irrelevant meaning of SPADE should have been suppressed, and so it should no longer be difficult to decide that ACE does not fit the ambiguous sentence; that is to say, ACE should not interfere with the "no" response at 1000 ms and the difference between ambiguous and control conditions should be closer to zero.

Correct response times to ambiguous and control trials were used as dependent measures. Trials containing ambiguous words for which two meanings were not identified during the posttest were removed from analysis. A 2 Group (Hydrocephalus vs. Control) $\times$ 2 Test Interval (Short vs. Long SOA [stimulus onset asynchrony, or the interval between the offset of the last word of the sentence and the onset of the test word]) $\times$ 2 Condition (Ambiguous vs. Control) was conducted. There was a main effect of Group ($F(1,54) = 6.379$, $p < .05$ such that the hydrocephalus group had longer overall response times than the control group. There was a main effect of Test Interval ($F(1,54) = 7.026$, $p < .05$, that was qualified by an interaction with group ($F = 8.497$, $p < .01$), such that the hydrocephalus group (but not the control group) had longer response times at short SOAs vs. long SOAs. There was a significant effect of Condition ($F(1,54) = 4.891$, $p < .05$), with longer response times on ambiguous than control trials. The three-way interaction was not significant ($F = 2.574$, $p = .11$). An error analysis revealed a main effect of Test Interval ($F(1,54) = 8.923$, $p < .01$), with more errors at short vs. long SOAs; and a main effect of Condition ($F(1,54) = 10.331$, $p < .01$), with more errors in the Ambiguous vs. the Control condition. Response times and accuracy rates are in Table 2.

Although the three-way interaction was not reliable, analyses of the results separately for short and long test intervals revealed no interaction between group and condition at the short SOA ($F < 1$), but a significant

Table 2
Response times in milliseconds (SD) and % correct (SD) for Experiment 1a

Group	Short interval		Long interval	
	Ambiguous	Control	Ambiguous	Control
Hydrocephalus				
Response time	2057 (1267)	2002 (1351)	1922 (1291)	1670 (872)
% Correct	91 (12)	94 (13)	93 (10)	96 (10)
Controls				
Response time	1403 (459)	1267 (346)	1337 (397)	1355 (436)
% Correct	91 (10)	98 (4)	98 (6)	99 (3)

interaction at the long SOA ($F = 3.958$, $p = .05$). These results can be seen in Table 2. A positive difference between the ambiguous and control condition signifies an interference effect (i.e., where ACE slows down or interferes with producing a "no" response). At the short SOA, both groups demonstrated an interference effect, suggesting that, immediately after having read an ambiguous word, both meanings were activated regardless of context for both groups, although only the hydrocephalus group continued to show interference 1000 ms after having read an ambiguous word.

2.4. Experiment 1b: Use of enhancing context

2.4.1. Materials and procedure

Materials were constructed such that an ambiguous word occurred in a sentence that *biased* one meaning of the ambiguous word (e.g., He dug with the spade), or a sentence that was *neutral* with respect to the meaning of the ambiguous word (e.g., He picked up the spade). The sentences were presented in the same way as in Experiment 1a, but the critical trials were those on which the response was "yes". Here, the test word for each sentence would be GARDEN. The test word was always presented after 1000 ms.

Materials were counterbalanced across participants so that each participant responded to 16 trials in each of the biased and neutral conditions. There were 32 filler trials. To the extent that participants are able to use a biasing context to enhance the appropriate meanings of the ambiguous words, they should require less time to say "yes" to the test word after biasing sentences than after neutral sentences (a facilitation effect). To the extent that participants use the context ineffectively, the facilitation effect should be smaller.

2.5. Results

A two-Group (Hydrocephalus vs. Control) × 2 Context Conditions (Bias vs. Neutral) repeated measures ANOVA was conducted on correct response times. The results are expressed in Table 3. A positive difference between the neutral and biasing contexts yields a facilitation effect where a biasing context speeds up or facilitates a 'yes" response.

Table 3
Response times in milliseconds (SD) and % correct (SD) for Experiment 1b

Group	Bias	Neutral
Hydrocephalus		
Response time	1497 (919)	1708 (852)
% Correct	89 (14)	70 (19)
Controls		
Response time	1001 (335)	1145 (366)
Error rate	91 (12)	72 (19)

Both groups showed similar facilitation effects in their ability to use context to enhance or select meaning. There was a main effect of group ($F(1, 54) = 9.382$, $p < .01$), with longer response times for the hydrocephalus group, and a main effect of context condition ($F(1, 54) = 12.27$, $p < .001$), such that there was a facilitation effect of a biasing context. The interaction was not significant. An analysis of errors revealed similar error rates in the two groups and a main effect of context condition ($F(1, 54) = 43.627$, $p < .001$) such that both groups made more errors in the control vs. the bias condition. These results are presented in Table 3.

In sum, children with hydrocephalus and typically developing children both initially activated word meanings, and were able to use context to select meaning and enhance activation of context-appropriate meaning. The children with hydrocephalus, however, were slower at activating meaning, less successful at suppressing meanings over time, and continued to show interference from context-irrelevant meanings beyond the point at which typically developing children had successfully suppressed irrelevant meaning.

3. Experiment 2: Reactivation of text for meaning integration

Participants. In Experiment 2, 26 children with hydrocephalus and 26 controls were tested, a subset of the children in Experiment 1 who were again matched to controls on the basis of age, grade and word decoding accuracy: There were 13 children with spina bifida myelomeningocele, 4 with aqueduct stenosis, 4 with Dandy–Walker Syndrome, and 5 with intraventricular hemorrhage. There were 15 males and 11 females in the hydrocephalus group and 13 males and 13 females in the control group. Participant characteristics for Experiment 2 are in Table 4.

Materials and procedure. The general goal of Experiment 2 was to use ambiguity resolution to test the integration of meaning across text, rather than the activation and integration of meaning within sentences. Six-sentence paragraphs were constructed that were to be read by participants followed by a seventh test sentence. The task was to decide whether the test sentence

Table 4
Group characteristics for hydrocephalus and control groups in Experiment 2

	Hydrocephalus	Control
Age (years.months)	12.9 (1.8)	12.1 (1.2)
Grade (year.month)	7.0 (1.9)	6.8 (1.5)
Word identification[a]	68.0 (19.2)	58.7 (16.4)
Passage comprehension	50.0 (28.5)	68.4 (19.9)
Paragraph reading	40.2 (24.9)	63.4 (27.2)

[a] Test scores are presented as percentiles based on age at test.

was a logical continuation of the preceding paragraph. In the Far Integration condition, the critical sentence appeared as the second sentence of the paragraph (five sentences before the test sentence). In the Near Integration condition, the critical sentence appeared as the fifth sentence of the paragraph (two sentences before the test sentence). An example of the critical sentence is "This Saturday John and Eddie were planting some bushes for John's mother." This sentence provides the context that is necessary for correctly interpreting the last sentence of the paragraph. The final sentence of the paragraph contained an ambiguous word, without providing information as to how the word was to be interpreted (e.g., "John laughed as he picked up a spade"). The remaining five sentences in the paragraph were filler sentences that fitted the flow of the paragraph but that did not specify the meaning of the ambiguous word in the sixth sentence. The seventh test sentence could be either "It was the queen" or "He began to dig." Materials were counterbalanced across the two text integration conditions and across correct and incorrect test sentences. The materials included filler trials in which the sixth sentence was not ambiguous, analogous to the procedure in Experiment 1. There were 64 trials in total. Sample materials for Experiment 2 are in Fig. 1.

The paragraphs were presented one sentence at a time for a fixed period, with a 500 ms pause between sentences. The test sentence was marked with an asterisk on each side and was presented 500 ms after sentence six went off the screen. The dependent measures were the time taken to provide a correct "yes" response by pressing the yes button on the keyboard and the number of errors where the participant responded "no" to sentences consistent with the correct contextual interpretation of the ambiguity.

3.1. Results

Correct response times were analyzed by a two-Group (Hydrocephalus vs. Control) $\times$ 2 Integration Distance (Near vs. Far) ANOVA, which revealed a main effect of Group ($F(1,50) = 5.07$, $p < .05$) with longer response times for the hydrocephalus group, a main effect of Integration Distance ($F(1,50) = 15.14$, $p < .001$), and a Group by Integration Distance interaction ($F(1,50) = 6.426$, $p < .05$). The interaction reflects a larger effect of distance for the Hydrocephalus group than for the control group. A similar analysis on errors revealed no effects of group or integration distance. These results are in Table 5.

In sum, children with hydrocephalus and typically developing children were each faster at integrating information between sentences that were closer together in the text than those that were farther apart, although children with hydrocephalus were significantly more disadvantaged by textual distance than were typically developing children.

3.2. Discussion

Understanding what is read is a function of word decoding ability as well as skills related to the comprehension of words, sentences, and texts. Decoding and comprehension skills are separable components of reading comprehension, although they are often highly correlated throughout typical development (Lyon, Fletcher, & Barnes, 2003). Disorders such as early hydrocephalus that produce dissociations between

Table 5
Response times in milliseconds (SD) and % correct (SD) for Experiment 2

Group	Near distance	Far distance
Hydrocephalus		
Response time	5067 (2061)	5801 (2540)
% Correct	81 (14)	85 (16)
Controls		
Response time	4151 (1504)	4306 (1615)
% Correct	86 (14)	86 (14)

John and Eddie always get together on Saturdays.
(This Saturday John and Eddie were planting some bushes for John's mother).[1]
John especially likes Eddie for his sense of humor.
Eddie wants to be a stand-up comedian so he is always practicing new jokes on John.
The two have a great time together.
(This Saturday John and Eddie were planting some bushes for John's mother).[2]
John laughed as he picked up a spade.

Test Sentence: He began to dig.[3]

[1] Critical sentence appears as the second sentence of the paragraph in the Far Integration Condition or [2] as the fifth sentence of the paragraph in the Near Integration Condition
[3] Here the test sentence is consistent with the meaning of "spade" as specified by the critical sentence.

Fig. 1. Sample materials for Experiment 2.

decoding and comprehension provide the opportunity to investigate core processes involved in assembling meaning during reading. The experiments in this paper investigated meaning construction and integration processes in children with early hydrocephalus. The results are discussed in relation to what is known about comprehension deficits in children with hydrocephalus as well as in relation to cognitive and neurocognitive models of text comprehension.

Meaning assembly processes, including activation, suppression, and contextual enhancement, differ in some ways in children with hydrocephalus and age peers. During reading, children with hydrocephalus and typically developing children activated the same range of sentence meanings, suggesting that some meaning construction processes are similar in the two groups. Nevertheless, the hydrocephalus group was slower to activate meanings, and, more important, was deficient at suppressing contextually irrelevant meanings as sentence comprehension proceeded in time. Like controls, children with hydrocephalus were able to use context to select or enhance meaning, suggesting that they used context to keep contextually appropriate meanings active in memory.

Like children with hydrocephalus, children with no neurological disorder who are good decoders but poor comprehenders have deficits in inferential processing and text integration (Cain, Oakhill, Barnes, & Bryant, 2001; Cornoldi, DeBeni, & Pazzaglia, 1996; Stothard & Hulme, 1996). However, the integrity of comprehension processes such as suppression are not well understood in these groups. A specific deficit in meaning suppression has been found in adults with poor comprehension (Gernsbacher & Faust, 1991) and in adults with right hemisphere brain lesions (Tompkins, Baumgertner, Lehman, & Fassbinder, 2000), although interpretation of this result is complicated by the fact that the adults in some of these studies had word decoding deficits. Our results show that meaning suppression deficits do not stem from word decoding deficits because, even when decoding skills are adequate, suppression mechanisms may be selectively impaired. The results also provide additional support for the view that suppression, activation and enhancement mechanisms can operate independently in the course of comprehension.

The consequences of deficient suppression mechanisms are likely to be considerable. The inclusion of irrelevant semantic associations in the memory representation of the text as it unfolds over time is likely to produce coherence breaks and interfere with comprehension. For children with hydrocephalus who have difficulty in the integration phase of semantic processing, then, the representation of the situation described by the text (the situation model) contains information that is irrelevant.

Inadequate suppression means not only that the current text representation will contain irrelevant or interfering information, but also that subsequent modifications of the situation model are likely to lack coherence, with ongoing comprehension difficulties. Although children with hydrocephalus might be efficient at selecting meaning using context within the current processing cycle, the effects of poor suppression from previous and current processing cycles may begin to interfere with ongoing comprehension as they move into newer processing cycles that involve a modification of the situation model. Based on previous findings that children with hydrocephalus had difficulty using the discourse context to interpret metaphors (Barnes & Dennis, 1998), we had expected them to have difficulty selecting and enhancing activation of contextually appropriate meaning. One difference between the two studies is that metaphor interpretation was asked for at the end of reading or listening to a paragraph, whereas in the present experiment, meaning selection processes were tapped shortly after reading the sentence containing the ambiguous word. That the two comprehension situations produced different findings suggests that models of text comprehension require the inclusion of both on-line and off-line comprehension processes (van den Broek et al., 1999).

Texts extend over time, and the representation of the text is iteratively modified by reactivating old information and linking it with incoming information. Both working memory and memory reactivation are important components of comprehension models (Just & Carpenter, 1992; Kintsch, 1988; van den Broek et al., 1999). The role of working memory in text and discourse comprehension is to hold both the propositions from the current processing cycle and any reactivated propositions from previous processing cycles in memory at the same time (Graesser et al., 1997). Difficulties in reading comprehension have been linked to individual differences in working memory (Just & Carpenter, 1992; Oakhill, 1993).

Our approach in the current studies of individual differences in comprehension has been to understand how meaning activation, suppression, enhancement, and reactivation processes tune the contents of working memory as comprehension of a text unfolds over time. Deficits in any one or more of these processes will affect both the information that is available in working memory from one comprehension cycle to another, as well as the representation of the text in long-term memory, which changes as the text proceeds in time and which may continue to evolve long after the text has been read.

We investigated reactivation processes by comparing how quickly children could make an inference by integrating information between two propositions that were either close together or farther apart in the text.

Although all children took longer to reactivate information from a more distant comprehension cycle, the children with hydrocephalus had particular difficulty reactivating or reinstating prior text from long-term memory to understand a current text proposition. That they could integrate ideas when the distance between propositions was short suggests that these children experience no fundamental deficit in making an inference to integrate two propositions, and is consistent with their preserved immediate memory span (e.g., Backman, Beattie, & Bawden, 1999). They had difficulty when the inference draws on the ability to reactivate information from a previous processing cycle so it can be integrated in working memory with the contents of the current processing cycle, which is consistent with reports of poor delayed recall on memory tasks (Backman et al., 1999; Ewing-Cobbs, Barnes, & Fletcher, 2003; Yeates, Enrile, Loss, Blumenstein, & Delis, 1995). This interpretation of the data from on-line measures of text integration processes is consistent with explanations of the difficulties that children with hydrocephalus have in off-line comprehension tasks in which they have to answer inference questions after having read or listened to a story. They answer fewer inferential comprehension questions because they have problems in retrieving either text-based or knowledge-based information (Barnes & Dennis, 1996, 1998).

Children with hydrocephalus have many of the processes required for successful comprehension. Nevertheless, their slow activation of meaning and their failure to suppress irrelevant meanings have implications, not only for the understanding of the immediate text, but also downstream, for the ability to integrate and modify the situation model of the text over time. Situation models that continue to represent irrelevant meanings will be not only inaccurate, but also easily overloaded. The current studies do not distinguish whether deficient suppression mechanisms cause problems for text reactivation or whether the processes of suppression and reactivation make independent contributions to comprehension deficits in children with hydrocephalus.

Disorders such as hydrocephalus can be used to study the relationship of particular brain structures to cognitive functions. A growing body of evidence implicates the corpus callosum in integrating information during processing of lexical ambiguity and figurative language (Chiarello, 1991; Copland, Chenery, & Murdoch, 2002; Funnell, Corballis, & Gazzaniga, 2000; Huber-Okrainec & Dennis, 2002; Long & Baynes, 2002; Tompkins et al., 2000). In children with hydrocephalus and spina bifida, the degree of damage to corpus callosum is related to the learning of semantically non-decomposable idioms (e.g., talk a mile a minute), but not to the learning of semantically decomposable idioms (e.g., kick the bucket) (Huber-Okrainec & Dennis, 2002). This is relevant to the present results because decomposable idioms may be interpreted by using literal language comprehension processes primarily subserved by the left hemisphere even though the representations of such idioms once acquired may be more widespread (Papagano, 2001). In contrast, non-decomposable idioms require the integration of the idiom and context during acquisition, and perhaps, also, the suppression of literal meaning. Children with hydrocephalus and corpus callosum agenesis have particular problems in idiom comprehension (Huber-Okrainec, Blaser, & Dennis, 2003). Together, these results suggest that corpus callosum abnormalities may produce or exacerbate comprehension deficits in children with hydrocephalus, including those involved in meaning suppression and the use of context to specify meaning.

National educational testing suggests that many students, even those with adequate word decoding, are deficient in the reading comprehension skills needed to understand complex literary and informational texts (Snow, 2002). Yet, much less is known about the factors that contribute to reading comprehension ability and disability than those that are related to reading decoding (Fletcher et al., 2002). The findings from the current studies suggest that investigations of meaning assembly processes that are derived from cognitive models may be useful for studying individual differences in comprehension (Fletcher et al., 2002), particularly if such investigations were to include how a reader's knowledge, goals, and strategies interact with core cognitive processes such as suppression and reactivation to result in comprehension of text and discourse (Graesser et al., 1997; Schmalhofer et al., 2002; Snow, 2002). Children with hydrocephalus provide a model of how these processes may be decomposed, a model that may be pertinent to the larger population of children without brain insult but with poor comprehension skills.

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