Abstract
Narrative discourse performance of two groups with penetrating head injuries, left- and right-hemisphere damaged, was examined and compared to that of a non-injured control group. Discourse deficits were then associated with lesion size and brain regions (Brodmann areas) included within lesion boundaries. Findings indicated that discourse impairments involving the organization of language and maintenance of a narrative theme result from large or relatively small lesions to either hemisphere. Although specific frontal and temporal regions within both hemispheres were most commonly implicated, parietal and limbic areas also appear to play a role in the production of narrative discourse.

Full Text

Introduction

Numerous studies have documented the value of discourse analyses for delineating the subtle nature of cognitive-communicative deficits following closed head injuries (CHI) (e.g., Coelho, 2002; Glosser & Deser, 1990; Hartley & Jensen, 1991; McDonald, 1993). The treatment of discourse deficits following CHI has received far less attention, in part because it not clearly understood how discourse is organized in the brain. Data derived from CHI studies have not contributed a great deal toward that end because diffuse axonal injury, which characterizes CHI, is often difficult to localize.

Recently investigators have applied neuroimaging techniques to investigate discourse. For example, Gernsbacher and Kaschak (2003) observed that fMRI studies have implicated a variety of brain regions during discourse processing including the left and right inferior, middle, and superior frontal regions. In addition, the left temporal pole, and the left and right superior parietal regions were identified. Similarly, Postman and colleagues utilizing PET reported the following correlations: speech rate with left frontal, temporal and occipital areas; type-token ratio with left temporal and occipital areas; proper names with left frontal areas; mean length of utterance with left temporal areas; clauses with left frontal, temporal, and parietal areas; fundamental frequency range and narrative cohesion with medial limbic and right frontal areas; and fluency with bilateral activation in occipital, temporal, parietal, and medial limbic areas (Postman, Braun, Soloman, et al., 2005). It is apparent from these findings that discourse is a highly complex ability that may be disrupted by damage to any number of brain regions.

Based on the findings of discourse impairment following CHI there is substantial evidence to support inclusion of analyses of story grammar, and coherence when examining narrative discourse. Measures of story grammar reflect an individual's ability to develop and implement an organizational plan for language. Ratings of coherence reveal how well an individual is able to maintain and convey the overall theme of a narrative (Coelho, Ylvisaker, & Turkstra, 2005). Individuals with lesions of the prefrontal cortex have been reported to be severely impaired in the structural organization of script action knowledge (Zalla, Phipps, & Grafman, 2002) which may be involved in both story grammar and coherence.

The current paper presents preliminary results from a large ongoing investigation of the long-term consequences of penetrating head injuries (PHI). Brain lesion size and locale is presented along with various measures of discourse performance. Findings for three groups of participants-- left-hemisphere damaged, right-hemisphere damaged, and non-injured controls are reviewed.

Method

Participants

PHI. Sixteen participants with PHI, eight each with left-hemisphere damage (LHD) and right-hemisphere damage (RHD) were studied. These individuals were drawn from the Vietnam Head Injury Study (VHIS) a longitudinal investigation of the sequelae from head wounds incurred during the Vietnam War (see Mohr, Weiss, Caveness, et al., 1980). Each of these participants had been followed for over 30 years and received extensive cognitive evaluations on at least two occasions. Data for the present study were acquired during phase III of VHIS.

Controls. Eight non-injured individuals served as controls and were also drawn from the VHIS pool. All three groups were close in age (range= 55-62 years) and education (range= 12-19 years) but a broader range was evident for the pre-injury Armed Forces Qualification Test scores (13-97th percentile). In addition all three groups had comparable Boston Naming Test (range= 19-31) and Token Test (range= 91-100) scores, suggesting that any aphasia exhibited by the LHD group was mild (see Table1).

Quantification of Brain Lesions

Brain lesions were identified via CT scans which were digitized and analyzed with the software program Analysis of Brain Lesions (ABLe). This program quantifies brain lesion size as well as indentifying which Brodmann areas are contained within the boundaries of the lesion (Makale, Soloman, Patronas, et al., 2002).

Discourse Analysis Procedures.

Participants were shown a picture story without a sound track on a computer screen. Upon completion of the story participants were instructed to retell the story they had just watched. Each story was digitally video-recorded. The recordings were then transcribed verbatim, segmented into T-units and analyzed for story grammar as well as local and global coherence. Number of episodes was one measure of story grammar. The second story grammar measure was the proportion of T-units contained within episode structure (i.e., T-units in episode structure/total number of T-units in story narrative). Each transcript was also rated for global (i.e., the relationship of the meaning or content of an utterance to the general topic of the story) and local (i.e., the relationship of the meaning or content of an utterance to that of the preceding utterance) coherence. The first and second authors independently completed all story grammar analyses and the coherence ratings. Inter-judge reliability scores ranged from 82% to 94%.

Results

Quantification of Brain Lesions

In terms of overall severity, percentage loss of total brain volume ranged from less than one percent to 12 percent for the LHD group and from less than one percent to over 17 percent for the RHD group. A diverse array of lesion locales were represented within both groups, 15 of 16 participants had involvement in multiple Brodmann areas and more than one lobe. The most common sites of damage were frontal and temporal lobes. Five participants from each group had damage in the respective frontal lobes, and seven from each group had damage to the temporal lobes. Tables 2 and 3 summarize lesion data for the LHD and RHD participants.

Discourse Performance

Coherence ratings. Table 4 summarizes the findings for the coherence ratings of the LHD, RHD and control groups. The typical pattern for the control group, noted in seven of eight individuals, was for the local coherence rating to be equal to or slightly lower than that of global coherence. This same pattern was also noted for seven of eight participants in both the LHD and

RHD groups. Three controls (C1,2,3), three individuals with LHD (L1,4,5), and one individual with RHD had fair to poor ratings for local coherence with adequate global coherence. One participant from the LHD group (L6) had adequate local coherence and poor global coherence. Two participants with RHD (R2,8) had poor local and global coherence.

Story Grammar. Good performance on the story grammar measures was characterized by production of multiple episodes and 60% or more of all T-units within episode structure. This pattern was noted for five of eight of the controls and three of eight participants from each of the LHD and RHD groups. The three controls (C1,6,7) that did not follow this profile either did not retell the story completely (C1) or produced multiple asides unrelated to the story content (C6,7). Four participants from the LHD (L1,4,6,7) and five from the RHD group (R1,2,4,7,8) produced either a single episode or none at all.

Discourse Performance and Lesion Characteristics

Lesion data for those individuals who performed most poorly on the discourse measures (3 LHD, 4 RHD) and those who performed the best (3 LHD, 3 RHD) were compared. Brodmann areas contained within the lesions were summarized and those areas that were noted exclusively in the poorly performing participants were then identified (see Table 5). Frontal and temporal regions were implicated for both groups as well as parietal and limbic areas.

Discussion

The following issues will be discussed:

1) Discourse impairments involving the organization of language and maintenance of a narrative theme result from large or relatively small lesions to either hemisphere.
2) Findings are consistent with those of Gernsbacher and Kaschak (2003) and Postman and colleagues (2005). Specific frontal and temporal regions within both hemispheres were most commonly implicated however parietal and limbic areas also appear to play a role in the production of narrative discourse.
3) Production of narrative discourse is a complex multi-level process.   Damage to different cortical regions may result in deficits at various levels of this process.

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Table 1. Demographic information for the participants with left hemisphere damage (L1-8), right hemisphere damage (R1-8) participants, and the non-injured controls (C1-8) including: age at testing (Age), pre-injury Armed Forces Qualification Test score (AFQT), years of education (Education), Boston Naming Test score (BNT), and Token Test score(TT).

Participants	**Age**	**AFQT**	**Education**	**BNT**	**TT**
L1	58	74	13	56	100
L2	58	97	13	60	100
L3	57	76	14	57	98
L4	59	46	12	35	91
L5	57	46	14	52	96
L6	56	62	16	59	99
L7	56	70	12	56	94
L8	57	49	16	48	99
Range	**56-59**	**46-97**	**12-16**	**35-60**	**91-100**
R1	61	13	12	25	98
R2	62	60	16	60	97
R3	56	62	15	57	100
R4	55	78	17	52	97
R5	57	88	14	57	100
R6	59	97	19	58	96
R7	60	14	15	50	100
R8	56	83	12	56	99
Range	**55-62**	**13-97**	**12-19**	**25-60**	**96-100**
C1	58	82	14	57	100
C2	57		16	48	100
C3	56	21	12	51	96
C4	55	89	14	59	100
C5	56	65	12	60	100
C6	60	48	17	46	100
C7	62	65	13	52	99
C8	56	33	13	54	100
Range	**55-62**	**21-89**	**12-17**	**46-60**	**96-100**

Table 2. Lesion data for the participants with left-hemisphere-damage. Brodmann areas involved are specified as well as percentage loss of total brain volume.

Participant	Frontal	Temporal	Parietal	Occipital	Limbic	Percentage vol. loss
L1	10,11,25,32,47					2.4
L2		43				<1
L3		37		19		2
L4	4,6,8,9,10,11, 25,32,44	21,22,28,38,41, 42,43,	3,40		24	12
L5	6,9,11,44,45,46, 47	20,21,22,28,35, 36,37,38,43				4.3
L6	9,10,11,32,44, 45,46,47	22,41				2
L7		22	7,39,40	19	31	2.4
L8	10,11,25,32,47	20,21,28,34,35, 36,37,38				4.8

Table 3. Lesion data for the participants with right hemisphere damage. Brodmann areas involved are specified as well as percentage loss of total brain volume.

Participant	Frontal	Temporal	Parietal	Occipital	Limbic	Percentage vol. loss
R1	47	20,28,36,38				2
R2	4,6,8,9,10,44, 45,46,47	20,21,22,27,36, 37,38,39,41,42, 43	1,2,3,5,7, 39,40	18,19	24,30,31, 32	17.4
R3	9,10,32					<1
R4	45,47	20,21,22,28,34, 35,36,37,38				3.6
R5		22,37,39	2,5,7,40	17,18,19	31	5
R6	4,6	22,41,42,43	1,2,3,40			<1
R7		22,37,39,41		17,18,19	30	2.3
R8		22,39,41	2,40			<1

Table 4. Scores from analyses of story retell task including: local and global coherence, number of episodes and percentage of total T-units in episode structure for the participants with left hemisphere damage (L1-8), right hemisphere damage (R1-8), and the non-injured controls (C1-8).

	MACROSTRUCTURE (THEMATIC UNITY)		**SUPERSTRUCTURE (INFORMATION)**	
Participants	**Local coher.**	**Global coher.**	**Episodes**	**T-units in episodes**
L1	3.9	4.4	1	.15
L2	5.0	5.0	5	.91
L3	4.9	4.7	6	.94
L4	3.2	4.5	0	0
L5	3.4	4.0	1	.43
L6	4.3	3.4	0	0
L7	5.0	5.0	1	1.0
L8	5.0	5.0	3	.75
Range	**3.2-5.0**	**3.4-5.0**	**0-6**	**0-1.0**
R1	5.0	3.3	0	0
R2	2.0	2.3	1	.50
R3	4.8	4.8	3	.73
R4	5.0	5.0	1	.80
R5	4.8	4.8	5	.58
R6	4.6	4.9	4	.76
R7	3.5	4.2	1	.37
R8	1.0	3.0	0	0
Range	**1.0-5.0**	**2.3-5.0**	**0-5**	**0-.80**
C1	2.3	4.6	1	.50
C2	3.3	4.1	3	.91
C3	3.5	4.5	3	.75
C4	4.1	4.1	8	.87
C5	4.4	4.5	2	.86
C6	4.3	4.6	1	.33
C7	4.5	4.4	1	.24
C8	4.8	4.4	6	.63
Range	**2.3-4.8**	**4.1-4.6**	**1-8**	**.24-.91**

Table 5. Brodmann areas included in lesions noted exclusively for PHI participants with poor coherence and story grammar abilities.

Hemisphere	Frontal	Temporal	Parietal	Occipital	Limbic
Left	4,6,8,9,44,45,46	22,41,42	3,40		24
Right	8,44,45,46,47	20,21,27,28,36, 38,	39		24,30,32