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Language after hemispherectomy in childhood: Contributions from memory and intelligence

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ABSTRACT

After hemispherectomy (removal or disconnection of an entire cerebral hemisphere) in childhood for treatment of intractable epilepsy, gross speech and language functions are often rescued. Whether more complex functions, such as syntactic processing, are selectively impaired, remains controversial. Here we present a cross-sectional study of expressive and receptive language functions in 30 patients who have undergone hemispherectomy (17 left, 13 right). The patients had developed epilepsy-induced pathology either during the pre/perinatal period (19 cases), or after a period of normal development (11 cases; onset range = 20 months to 10 years). The patients were assessed at least 1 year post surgery on tests of receptive vocabulary, expressive and receptive grammar, instruction comprehension, and semantic association. Measures of verbal and nonverbal intelligence, short-term verbal memory, and working memory were also obtained. Principal component analysis revealed that two core components could be extracted from the five language measures, one reflecting receptive vocabulary abilities, and the other a composite of the other four measures. Regression analyses revealed that the best predictor of the composite language score was the short-term verbal memory score with some contribution from verbal intelligence, while the only predictor of receptive vocabulary was verbal intelligence. The results suggest that during childhood the lone left and right hemispheres have a similar potential for developing an adequate level of receptive vocabulary. However, congenital pathology affecting either hemisphere, and postnatal damage to the left hemisphere result in substantial language deficits that are reflected also in limitations in short-term verbal memory, and, to a lesser extent, in verbal intelligence.

1. Introduction

A growing body of evidence from functional imaging studies (e.g. Schapiro et al., 2004; Wood et al., 2004) and transcranial Doppler sonography (e.g. Lohmann, Drager, Muller-Ehrenberg, Deppe, & Knecht, 2005) suggests that speech and language functions are predominantly represented in the left hemisphere in normally developing children, just as in adults. Based on such findings, the expectation is that left hemisphere lesions sustained in childhood interfere with speech and language function just as they do in adults. Yet, compared to adult-onset left hemisphere lesions, injuries acquired early in life lead to remarkably good language outcome (Bates et al., 2001). It is widely assumed that this difference in outcome is due to increased cerebral plasticity and the capacity of the immature brain to reorganize.

The most striking instance of cerebral reorganization is seen in children who have undergone removal of the left hemisphere for the relief of intractable epilepsy (Vargha-Khadem et al., 1997; Vargha-Khadem, Isaacs, Papaleoudi, Polkey, & Wilson, 1991; Vargha-Khadem & Polkey, 1992; Vargha-Khadem & Mishkin, 1997), and whose everyday language functions are spared (Basser, 1962; Curtiss, de Bode, & Mathern, 2001; Dennis & Kohn, 1975; Devlin et al., 2003; Pulsifer et al., 2004; Stark, Bleile, Brandt, Freeman, & Vining, 1995; Vanlancker-Sidtis, 2004). Whether more complex language functions, such as syntactic processing, are selectively impaired (e.g. Dennis & Kohn, 1975), or whether their level is in keeping with the patients' lowered intelligence and memory capacities (Mariotti, Iuvone, Torrioli, & Silveri, 1998; Ogden, 1988; see also, Bishop, 1983), is still under debate.

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Studies of language outcome after hemispherectomy have raised several issues that need clarification. First, hemispherectomy being a rare surgical procedure, large group studies on language outcome have been rarely reported. The majority of patients described in the literature suffered from developmental or pre/perinatally acquired pathologies (e.g. Beardworth & Adams, 1988; Dennis & Kohn, 1975; Dennis & Whitaker, 1976; Verity et al., 1982) thus making it difficult to examine the effects of congenital vs. acquired onset of pathology (see Curtiss et al., 2001, for an exception). Specifically, studies of patients with pathology acquired after birth and later in childhood (for example as a result of infarct or Rasmussen's encephalitis) have involved small numbers (Vargha-Khadem et al., 1991), and the range of age at injury reported was limited (Boatman et al., 1999; Gott, 1973; Stark et al., 1995; Stark & McGregor, 1997). A relatively large study, directly comparing the language competencies of left and right hemispherectomy patients with postnatal and pre/perinatal pathology, is therefore required and serves as the primary goal of the present study.

A second issue is that despite different language measures being highly correlated, they have been traditionally examined independently. In most large-scale studies, one or two language functions have been studied (single word knowledge in Pulsifer et al., 2004; spoken grammar in Curtiss et al., 2001; Curtiss & de Bode, 2003; everyday communication in Devlin et al., 2003), preventing the investigation of inter-correlated deficits. The second goal of this report, therefore, was to extract core language components from several standardized measures of language function and use these as dependent variables. This data reduction step enabled us to identify the predictors of outcome for distinct core components of language functions.

Finally, in hemispherectomy patients both verbal intelligence and verbal memory can be severely impaired (as often seen preoperatively, Devlin et al., 2003; Pulsifer et al., 2004). Despite their potential intimate relationship to language abilities, the relationship between them has not been consistently taken into account in studies on language outcome (but see Ogden, 1988, and Mariotti et al., 1998, for exceptions). A final goal therefore was to examine the question of hemispheric differences in language abilities in relation to verbal intelligence and short-term verbal memory. Admittedly, these cognitive functions rely on similar processes. Yet, despite their interlinked nature, it is possible to assess the hypothesis of a selective language impairment over and above the restrictions in verbal intelligence and short-term verbal memory.

In the present study, standardized measures of expressive and receptive language (semantic association, receptive vocabulary, as well as sentence production and comprehension), were collected in 30 hemispherectomy patients (19 with pre/perinatal and 11 with postnatal pathology) and reduced to "core" language components using a principal component analysis (PCA). The effects of onset of pathology (Pre/perinatal vs. Postnatal) and hemispheric side of pathology (Left vs. Right) on the core language components were investigated, together with the roles played by memory and intellectual functions on language outcome.

2. Methods

2.1. Participants

The group was selected from a pool of children and adolescents who underwent hemispherectomy for relief from intractable epilepsy at Great Ormond Street Hospital for Children, or at King's College Hospitals, London, U.K. Patients were selected

Table 1
Patient details

Patient	Sex	Side of hemispherectomy	Pathology	Onset Of pathology	Age at onset of habitual seizures
L1	F	Left	Cortical dysplasia	Pre/perinatal	2;0
L2	M	Left	Sturge–Weber syndrome	Pre/perinatal	0;1
L3	F	Left	Sturge–Weber syndrome	Pre/perinatal	0;1
L4	M	Left	Epilepsy of unknown origin	Pre/perinatal	0;3
L5	M	Left	CVA	Pre/perinatal	0;1
L6	M	Left	CVA	Pre/perinatal	5;6
L7	M	Left	CVA	Pre/perinatal	0;1
L8	F	Left	CVA[a]	Pre/perinatal	0;7
L9	M	Left	CVA	Pre/perinatal	6;0
L10	M	Left	CVA	Pre/perinatal	0;1
L11	M	Left	CVA	Pre/perinatal	2;0
L12	F	Left	CVA	Pre/perinatal	7;0
L13	F	Left	CVA	Postnatal	1;8
L14	M	Left	Rasmussen's encephalitis	Postnatal	3;6
L15	F	Left	Rasmussen's encephalitis	Postnatal	6;6
L16	F	Left	Rasmussen's encephalitis	Postnatal	6;6
L17	M	Left	Rasmussen's encephalitis	Postnatal	10;0
R1	M	Right	Cyst	Pre/perinatal	4;6
R2	M	Right	HEMIMG	Pre/perinatal	0;1
R3	M	Right	Sturge–Weber syndrome	Pre/perinatal	0;3
R4	M	Right	Hemimegalencephaly	Pre/perinatal	0;7
R5	M	Right	Pachygyria	Pre/perinatal	2;9
R6		Right	CVA	Pre/perinatal	2;6
R7	M	Right	Hydrocephalus	Pre/perinatal	0;1
R8	M	Right	CVA[b]	Postnatal	7;0 (CVA at 0;6)
R9	M	Right	CVA	Postnatal	3;0
R10	M	Right	Rasmussen's encephalitis	Postnatal	4;6
R11	F	Right	Rasmussen's encephalitis	Postnatal	6;0
R12	M	Right	Rasmussen's encephalitis	Postnatal	7;0
R13	F	Right	Rasmussen's encephalitis	Postnatal	8;0

Note: Abbreviations—F, female; M, male; CVA, cerebro-vascular accident of the middle cerebral artery; Age in years; months. Note that only L17 and R13 were left-handed before onset of pathology. Cases L2 and L14 have previously been reported in Vargha-Khadem et al. (1997) and Jackson, Connelly, Gordon, and Gadian (1994), respectively. Cases L16 and L17 lost expressive communication as a consequence of the pathology but had regained fluent conversational skills at the time of assessment.

[a] Probably caused by multiple amniocenteses.

[b] Following meningitis.