Brain & Language 157–158 (2016) 25–34

Contents lists available at ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

Processing verbal morphology in patients with congenital left-hemispheric brain lesions

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ARTICLE INFO

Article history:
Received 8 April 2015
Revised 24 March 2016
Accepted 10 April 2016
Available online 5 May 2016

Keywords:
Congenital brain lesions
Language reorganization
Morphology
German past tense

ABSTRACT

The goal of this study was to test whether children, teenagers and adults with congenital left-hemispheric brain lesions master the regularities of German verbal inflectional morphology. Thirteen patients and 35 controls without brain damage participated in three experiments. A grammaticality judgment task, a participle inflection task and a nonce-verb inflection task revealed significant differences between patients and controls. In addition, a main effect of verb type could be observed as patients and controls made more mistakes with irregular than with regular verbs. The findings indicate that the congenitally damaged brain not only has difficulties with complex syntactic structures during language development, as reported by earlier studies, but also has persistent deficits on the morphological level. These observations suggest that the plasticity of the developing brain cannot fully compensate for congenital brain damage which affects regions associated with language functions.

1. Introduction

1.1. Early left-hemispheric brain injuries and reorganized language

This study analyzes the language skills of patients who acquired a unilateral brain injury either before or around birth. There is a large body of research that provides insights into the plasticity of the developing brain by studying the language skills of patients with pre- or perinatally acquired brain lesions (see Levine, Raja Beharelle, Demir, & Steven, 2015; Stiles, Reilly, Levine, Trauner, & Nass, 2012 for reviews). Early language development seems to be atypical or delayed in children with perinatal focal brain injury, regardless of lesion site or side (e.g. Avila et al., 2010; Bates et al., 1997; Chilosi et al., 2005; Thal, Reilly, Seibert, Jeffries, & Fenson, 2004; Trauner, Eshagh, Ballantyne, & Bates, 2013). Moreover, perinatal or childhood stroke results in overall slightly impaired cognitive and linguistic functioning, again, regardless of lesion site (Westmacott, Askalan, MacGregor, Anderson, & Deveber, 2010).

The influence of age at lesion on later language function is under debate. While children with perinatal stroke seem to reach an adequate language proficiency by school-age or adolescence (e.g. Bates & Roe, 2001; Reilly, Bates, & Marchman, 1998; Reilly, Losh, Bellugi, & Wulfeck, 2004), they may be more impaired in complex language tasks than those patients who have recovered from childhood stroke (Avila et al., 2010; Kolk, Ennok, Laugesaar, Kaldoja, & Talvik, 2011). In contrast to adult aphasic patients, however, the language skills of patients with pre- or perinatally acquired unilateral lesions are usually unremarkable in everyday communication. Moreover, children with congenital brain damage consistently show better language performance than children with specific language impairment (SLI) (e.g. Marchman, Saccuman, & Wulfeck, 2004; Reilly et al., 2004; Weckerly, Wulfeck, & Reilly, 2004). There are, however, some moderating variables, which are, due to usually small sample sizes, difficult to disentangle from age at lesion: while pre- and perinatal stroke exhibits a higher prevalence of large cortical and cortico-subcortical lesions most often affecting the frontal and temporal lobes, stroke suffered after the neonatal period more often results in smaller subcortical or infratentorial lesions, which do not commonly lead to aphasia (Gordon et al., 2015).

Secondly, interhemispheric language reorganization seems to play a much more prominent role in children with pre- and perinatal stroke than in children with later acquired brain lesions. It has for example been demonstrated that in children with pre- and perinatal stroke, even very small periventricular lesions may lead to interhemispheric language reorganization, if the lesion affects the facial motor tract (Staudt et al., 2001). In later acquired lesions,

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http://dx.doi.org/10.1016/j.bandl.2016.04.011
0093-934X/

interhemispheric reorganization is extremely rare, and perilesional reorganization is much more common (Chilosi et al., 2008). Thus, it has to be assumed that lesion site has differential effects on language representation, acquisition, and outcome in children with very early as compared to late left-hemispheric brain lesions. Thirdly, especially in children with perinatal stroke (Kolk et al., 2011; Pavlovic et al., 2006), post-stroke epilepsy is accepted as a prominent hazard for cognitive and linguistic development (Ballantyne, Spilkin, Hesselink, & Trauner, 2008; Kolk et al., 2011).

To conclude, pre- and perinatal lesions on the one hand and lesions acquired after the neonatal period on the other seem to represent different entities with respect to the relevance of these moderating factors for language development or outcome. We will therefore focus on data observed in children with congenital, i.e., pre- or perinatally acquired brain lesions. In contrast to large-scale studies on adult aphasics, sample sizes are usually too small to determine specific site effects (such as the affected lobes) on linguistic abilities. While there is a large body of evidence for a higher plastic potential of the developing as compared to the adolescent or adult brain, there are also studies that indicate that plasticity is limited.

Dick, Wulfeck, Krupa-Kwiatkowski, and Bates (2004) found in their study that children and adolescents with pre- or perinatally acquired unilateral focal brain lesions show deficits in processing passive structures and object clefts. Reilly, Wasserman, and Appelbaum (2013) found that especially children and adolescents with left-hemispheric brain damage produced more morphosyntactic errors in a narrative task than their age-matched controls. In addition, the language performance of patients with congenital brain damage shows a greater variability than the language performance of controls. Ballantyne, Spilkin, and Trauner (2007) note that school-age children with early focal lesions score below average on complex language tasks in standardized tests. This study found neither a relation between language performance and age nor between language performance and other cognitive abilities like IQ. Studies which compared the language skills of German children, teenagers and adults with and without left-hemispheric brain lesions found differences between patients and controls across age groups. These studies indicate that patients with pre- or perinatal lesions have difficulties with complex structures like topicalization and relative clauses (Lidzba, Konietzko, Schwilling, Krägeloh-Mann, & Winkler, 2013; Schwilling, Krägeloh-Mann, Konietzko, Winkler, & Lidzba, 2012). Therefore, non-canonical word order seems to be especially problematic for these patients.

The goal of the current study was to find out if deficits can only be observed on the complex syntactic level or if patients also show difficulties on the basal morphological level. The focus of our study lies on verbal inflectional morphology, more specifically on tense inflection. An example for an English inflectional morpheme is *-ed* which indicates past tense. Derivational morphology, which creates new words on the basis of existing words by adding derivational affixes (Meibauer et al., 2007), is not considered in this study (e.g. adding the derivational suffix *-ship* to the noun *friend* creates the new noun *friendship* and adding the suffix *-ly* to the noun *friend* creates the adjective *friendly*).

1.2. Morphological skills in patients with early brain damage

Reilly et al. (1998) and Reilly et al. (2004) asked children to tell a story from a picture series. In both studies, children with early focal lesions made more morphological errors than controls, but errors decreased with age. Older children performed within normal range. Morphological errors in these studies include errors in pronouns, auxiliaries, determiners, noun plurals, verb tense, number marking and prepositional errors. Reilly et al. (2013) conducted a similar study in which children and adolescents were asked to tell a personal story and found that children and adolescents with perinatal lesions made more morphological errors than the control group overall, but all groups improved with age. In all three of these studies, children with brain damage produced errors qualitatively similar to the errors which children with typical development produced. Reilly et al. (2004) note that English does not have a rich morphology and therefore the kinds of errors that can be produced are limited.

We are only aware of one study that explicitly looked at verbal morphology in children with focal lesions. Marchman et al. (2004) conducted an English past tense elicitation test with 14 children with early left-hemispheric focal lesions and eight children with early right-hemispheric focal lesions. Their results were compared to a group of children with SLI, who had no neurological abnormalities, and to children with typical language development. Children were shown pictures of everyday actions and heard a target sentence like "This boy is walking. He walks every day. Yesterday, he . . .?" The task was to complete the target sentence with the simple past form of the given verb. Items consisted of monosyllabic regular and irregular verbs. The study found no significant differences between children with early focal lesions and children with typical language development. Children with SLI, who had higher performance IQ scores than children with focal lesions, performed significantly worse than children with focal lesions and controls (see Reilly et al., 2004 for a similar observation). There was no significant difference between patients with right-hemispheric lesions and children with left-hemispheric lesions. Moreover, children with brain lesions and controls showed a similar error pattern. All three groups made more mistakes with irregular than with regular forms. The most common mistake for irregular verbs was to inflect them with an incorrect suffix.

Our study aims to find out whether differences in patients with congenital brain damage and controls can be observed when it comes to German inflectional verbal morphology. In contrast to English, German is a more inflected language (see Section 1.3 of this paper). For this reason, it might be possible to find more pronounced differences between patients and controls than in the English studies. Moreover, we compared the performance of children, teenagers and adults. While most studies report that children with early lesions reach adequate language performance by school-age, other studies have reported that patients still face deficits after childhood in complex linguistic tasks. Testing not only children but also teenagers and adults can offer a clearer picture of the plasticity of the developing brain. Our study may provide insight into a linguistic question regarding the mental representation of regular and irregular verbs. There is an ongoing debate about whether regular and irregular verbs are processed with the same mechanism (e.g. Baayen, Milin, Filipović Đurđević, Hendrix, & Marelli, 2011; Ramscar, 2002; Rumelhart & McClelland, 1986; Smolka, Zwitserlood, & Rösler, 2007) or with different mechanisms (e.g. Beretta et al., 2003; Pinker & Ullman, 2002).

We conducted three experiments on verbal morphology with children, teenagers and adults with pre- or perinatally acquired left-hemispheric lesions (n = 13) and age-matched controls (n = 35). Our study addresses the following research questions:

1. Do patients with congenital left hemispheric brain lesions master the regularities of German verbal morphology?
2. Can differences be observed between children, teenagers and adults in both the patient and the control group?
3. Do irregular verbs cause more problems than regular verbs?

Answers to these questions can contribute to our understanding of the brain's ability to recover from congenital lesions.