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Brain and Language 88 (2004) 180–189
Brain and Language
www.elsevier.com/locate/b&l

Mechanisms of verbal memory impairment in four neurodevelopmental disorders

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Accepted 2 April 2003

Abstract

Profiles of verbal learning and memory performance were compared for typically developing children and for four developmental disorders characterized by different patterns of language functioning: specific language impairment, early focal brain damage, Williams Syndrome, and Down Syndrome. A list-learning task was used that allowed a detailed examination of the process of verbal learning, recall, and recognition (California Verbal Learning Test—Children's Version). Distinct patterns of performance characterized the four disorders. These patterns were consistent with the language deficits typically seen in the disorders, with the exception of a dissociation seen in Williams Syndrome.

Keywords: Verbal learning; Verbal memory; Developmental disorders; Brain lesions; Specific language impairment; Williams Syndrome; Down Syndrome

1. Introduction

In recent years, the study of children with developmental disorders or early brain injury has contributed enormously to our understanding of brain–behavior relationships underlying language acquisition (cf. Bates, 1997). This line of investigation has underscored the differences between the developing and adult brain, as well as the potential for, and limitations of, neural plasticity. In particular, it has shown us that the long-term consequences for language of frank structural damage such as that occurring in early stroke can be far less devastating than the consequences of a disorder such as specific language impairment, which is not associated with obvious brain lesions. It has also demonstrated that language and other cognitive abilities can be dissociated by disorders of brain development.

The development of verbal learning and memory, both in typical children and in those with brain injury, has also seen a recent surge of scientific interest, made possible partly by innovations in assessment tools. Like language, verbal learning is an area with both theoretical and practical implications. The latter is particularly true for school-age children, who spend a huge proportion of their time engaged in tasks that are dependent on verbal learning and memory. For this reason, the assessment of verbal learning is an important part of any evaluation done following childhood traumatic brain injury or for the purpose of educational planning for children with learning or other developmental disabilities. Although a literature addressing these issues has begun to accumulate, the brain–behavior relationships underlying verbal learning and memory in children are

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doi:10.1016/S0093-934X(03)00097-X

still poorly understood, as is the relationship of verbal learning to language abilities. The purpose of this study was to compare verbal learning and memory in early, focal brain injury and three developmental disorders: specific language impairment (SLI), Williams Syndrome (WMS), and Down Syndrome (DS). Because these groups of children have different patterns of language impairment that are well characterized, we are able to examine the similarity of verbal learning ability to language characteristics in general. Furthermore, we are able to evaluate its plasticity, or potential for reorganization, following focal damage and compare it to brain dysfunction that is possibly, in the case of SLI, or certainly, in the case of WMS or DS, associated with more diffuse abnormalities in brain development.

In adults, brain–behavior relationships underlying verbal learning and memory appear to parallel other language functions in that deficits are most likely following damage to the left hemisphere. Evidence for this asymmetry exists both for the primary memory functions of the medial temporal lobes (but see Dobbins, Kroll, Tulving, Knight, & Gazzaniga, 1998, for a dissenting view) and for the organizational and other memory-related functions of the frontal lobes (Stuss et al., 1994). Damage to the right hemisphere can result in qualitative changes in verbal learning, such as decreased recency effects (Cappa, Papagno, & Vallar, 1990), but a preponderance of evidence supports an association between the left hemisphere and many aspects of verbal memory performance in adults. In the case of damage outside the medial temporal lobes, some investigators have suggested that deficits in verbal memory can be attributed to language dysfunction (Hermann, Seidenberg, Haltiner, & Wyler, 1992; Ween, Verfaellie, & Alexander, 1996), although it should be noted that some studies have found dissociations between aphasia and verbal memory deficits (Beeson, Bayles, Rubens, & Kaszniak, 1993). Given the complexity of memory processes in the brain (see Squire, 1987), it is reasonable to conclude that memory deficits can have multiple causes, aphasia being among them; however, the association between left hemisphere damage and verbal memory deficits remains fairly strong in adults.

Focal lesions occurring early in development produce a markedly different relationship between lesion localization and language functioning than that seen in adults. Although delays in early language acquisition are common, only subtle language problems typically remain by the time the children reach school age, unlike the frank aphasia that can occur in adults with focal left hemisphere damage (Reilly, Bates, & Marchman, 1998). Furthermore, early left and right hemisphere lesions produce comparable effects on language by school age (Bates et al., 2001). Less is known about learning and memory following early, focal lesions. Aram and Ekelman (1988) assessed children with unilateral focal lesions using the Woodcock–Johnson Psycho-Educational Battery and found that both left- and right-hemisphere lesions were associated with lowered performance on the memory cluster. Studies of verbal learning and memory in children with hippocampal pathology (Vargha-Khadem et al., 1997), closed head injury (Levin et al., 1996), and sickle cell disease (Watkins et al., 1998) have also begun to address the effects of lesion location; however, the latter two disorders are typically associated with widespread damage that complicates the interpretation of the findings.

The subtle language problems of children with early strokes provide an interesting contrast to the relatively severe language dysfunction seen in children with specific language impairment (SLI). Children with SLI have deficits in expressive and/or receptive language that are disproportionately greater than other cognitive problems. Although it could be assumed that their brains are in some manner different from those of children without SLI, obvious brain lesions have not been detected by neuroimaging procedures. However, it is possible that more subtle abnormalities exist that are able to exert a significant impact on brain systems associated with language, without allowing for reorganization, by virtue of their diffuse distribution or subcortical location (Bates, 1997). Differences between children with SLI and typically developing children have been described for a number of aspects of verbal memory, including free and cued retrieval (Kail, Hale, Leonard, & Nippold, 1984), memory scanning speed (Sininger, Klatzky, & Kirchner, 1989), phonological working memory (Montgomery, 1995, 2000), and verbal capacity (Kirchner & Klatzky, 1985; Weismer, Evans, & Hesketh, 1999). Studies comparing auditory short-term memory of children with SLI and language-matched controls, using such measures as digit span or word list tasks, have produced conflicting results (see Gathercole & Baddeley, 1995; van der Lely & Howard, 1993, 1995). However, tasks that look at the learning of supraspan lists over several trials and that assess delayed recall have found that children with SLI perform more poorly than chronological age controls. In a study of 12 children aged 8–9 with SLI, Shear, Tallal, and Delis (1992) found that, although the children had normal immediate memory span, they recalled fewer correct words over the learning trials of the California Verbal Learning Test—Children's Version (Delis, Kramer, Kaplan, & Ober, 1994), a list-learning task, and made more perseverative, but not intrusion, errors than control children. Although their free recall following a short delay was intact, they had difficulty recalling the list after a longer delay and failed to benefit from semantic cueing to the degree that controls did. Shear and colleagues suggested that the verbal learning and memory deficits of children with SLI might result from a limitation in information processing. The number of children in their study was relatively small, however, which may have precluded detecting some group differences.