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The impact of early unilateral brain injury on perceptual organization and visual memory

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Abstract

Studies of young children with early unilateral brain injury have suggested that while hemispheric differences in visuospatial processing appear to be present early in development, the young brain is better able to compensate for injury than when the injury occurs later, after networks have been established. The aim of this study was to determine if this pattern continues later in development when these children are given a challenging task: the Rey-Osterrieth Complex Figure. Experiment 1 included longitudinal data from ten children with early left hemisphere (LH) injury and nine children with early right hemisphere (RH) injury. Injury was presumed to be due to a prenatal or perinatal stroke. Compared with typically developing children, both groups were poorer in copying the figure. With development, these children produced reasonably accurate drawings but continued to use the most immature and piecemeal strategy. In Experiment 2, copy and immediate memory drawings from the 19 children with early unilateral brain injury were collected at a single age (11–14 years). Eight of the ten children with LH injury organized their memory reproductions around the core rectangle but included relatively few additional details. In contrast, only two of the nine children with RH injury organized their memory reproductions around the core rectangle and all but one produced the figure in a piecemeal manner. The results from both studies demonstrate the continuation of subtle deficits in visuospatial analysis with development but also the continued capacity for compensation.

Keywords: Brain development; Visuospatial; Memory; Early brain injury

The Rey-Osterrieth Complex Figure (ROCF) is widely used to assess visuospatial construction, planning, and memory skills in adults and children [15]. In a study of children between 6 and 12 years of age, Akshoomoff and Stiles [2] defined the normal developmental changes in children's ability to copy the ROCF. Age-related improvements in accuracy coincide with strategy changes that reflect the increased ability to extract larger units from the figure. Children also typically exhibit a more systematic approach in copying the figure as they mature. These findings extend data from more simple copying tasks with preschoolers [10,32]. Taken together, these results demonstrate that when children copy forms, starting with simple ones and going on to the more complex ROCF, there are systematic changes in both the types of parts that are identified and the integration of those parts throughout the developmental period.

Unilateral brain injury in adults leads to specific deficits that conform to important aspects of spatial pattern analysis [1,6,7,13,14,19–21]. At a very general level, adults with injury to right hemisphere brain regions have difficulty with spatial integration. They are able to identify, or segment, the parts of spatial forms but have difficulty organizing these parts into integrated spatial configurations. On the other hand, patients with injury to left hemisphere brain regions oversimplify spatial forms and fail to incorporate pat-

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tern detail. Recent functional imaging studies have also demonstrated that the posterior regions of the right hemisphere are more involved in global level processing and the posterior regions of the left hemisphere are more involved in local level processing [11,16]

Prenatal or perinatal injury to right and left hemisphere brain regions results in selective deficits of spatial analytic processing in children that are similar to those observed in adult patients [27,29,31]. The impairment observed among children appears to be less severe, thus children appear able to compensate for their deficits more readily than adults. Both task difficulty and task demand vary with developmental level and thus detection of deficits in this population often depends on specific task demands. Detailed assessments that document not only whether but how success is achieved on a given task are thus fundamental to our understanding of the process of cognitive development after early brain injury.

One study examined the performance of 4–6-year-old children with early unilateral brain injury on a highly structured spatial grouping task [28]. Performance accuracy among children with early left hemisphere (LH) injury did not deviate from typical children. However, children with early LH injury differed from typical children in the processes they used to produce accurate constructions. In contrast, children with early RH injury were significantly impaired on both simple and complex block constructions and created block patterns that were quite unlike those observed in children with early LH injury or typical children. When a second group of children with early unilateral brain injury was tested at 5–6 years of age, the accuracy of their performance was indistinguishable from typical 4-year-olds, but both children with early LH injury and children with early RH injury used different spatial processes than the typical children. These results were interpreted as evidence for persistent deficits in spatial processing in both groups. Similar results were found in a follow-up study of a larger sample of children of children with early unilateral brain injury [39].

In another study by Stiles and colleagues, the distinction between product and process was examined when children were asked to draw a house and then an impossible house [30]. By age 6, typical children readily draw elaborate and fanciful impossible drawings, which differ significantly in spatial structure from their free style house drawings [12]. While children with early RH injury made considerable progress in free style house drawing into the school age period, they were very reliant on the use of graphic formulas. In some cases, these children simply produced minor variants of their free drawings. In other cases, they combined elements of two graphic formulas. This strategy simplifies the task of generating a new spatial form in that the child can simply substitute a form from his or her existing graphic repertoire in response to the request to produce a novel figure. This strategy of formula substitution is not observed among typical children or children with early LH injury. These data suggest that early RH injury leads to persistent difficulty in reorganizing and reformulating the spatial structure of a graphic object.

Imposing a memory load also allows for the investigation of spatial deficits associated with unilateral brain injury. When an adult with unilateral brain injury is asked to copy or draw a complex stimulus, subtle deficits may not be apparent. However, when processing load is higher (such as after a delay has been imposed), the specific deficits associated with the site of injury may be more readily apparent. For example, when adults with unilateral brain injury were asked to draw hierarchical stimuli from memory after a brief exposure, the information that was recalled differed as a function of the hemisphere that was injured. That is, adults with LH injury were poorer in their recall of the local level elements while adults with RH injury were poorer in their recall of the global level elements [6,7]. In a study of memory for hierarchical stimuli in children, performance of children with early LH and RH injury mirrored that of adult patients. Compared with normal controls [8], children with either RH or LH injury were impaired in both global and local level processing. However, children with LH injury showed greater deficits in processing local level elements while children with RH injury showed greater impairment in global level processing. [29]. Interestingly, local processing for children in the RH group was selectively affected by the type of stimulus they were asked to recall. When the hierarchical stimuli were composed of letters their performance with local elements was comparable to normal controls, but when the stimuli were made of abstract forms their performance was significantly worse. This finding suggests that the children with RH injury were able to use a verbal mnemonic strategy to support local but not global processing. This strategy was apparently not available to children with LH injury. It is important to note that the differences between the groups with early unilateral brain injury were attenuated when the task involved only copying the hierarchical patterns rather than reproducing the patterns from memory.

In summary, studies from Stiles and her colleagues have demonstrated that when children with early unilateral brain injury are very young, their performance on visuospatial tasks is typically poor compared with same-age peers, but their performance on these tasks improve with age, regardless of site of injury. Analysis of the process used by the children or examination of performance under a processing load (i.e. memory) suggests that subtle deficits in spatial processing persist. Studies of early unilateral brain injury provide develop-