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CATEGORIZATION SKILLS AND RECALL IN BRAIN DAMAGED CHILDREN

A multiple case study

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Abstract – During development, children become capable of categorically associating stimuli and of using these relationships for memory recall. Brain damage in childhood can interfere with this development. This study investigated categorical association of stimuli and recall in four children with brain damages. The etiology, topography and timing of the lesions were diverse. Tasks included naming and immediate recall of 30 perceptually and semantically related figures, free sorting, delayed recall, and cued recall of the same material. Traditional neuropsychological tests were also employed. Two children with brain damage sustained in middle childhood relied on perceptual rather than on categorical associations in making associations between figures and showed deficits in delayed or cued recall, in contrast to those with perinatal lesions. One child exhibited normal performance in recall despite categorical association deficits. The present results suggest that brain damaged children show deficits in categorization and recall that are not usually identified in traditional neuropsychological tests.

KEY WORDS: developmental neuropsychology, brain damage, childhood, memory, categorization.

Habilidades de categorização e recordação em crianças com lesões cerebrais: um estudo de casos multiplos

Resumo – No desenvolvimento, as crianças tornam-se capazes de associar estímulos em categorias e de se beneficiar dessas associações para sua recordação posterior. Lesões cerebrais na infância podem interferir nesse desenvolvimento. Neste estudo, essas habilidades foram avaliadas em crianças com lesões cerebrais. A etiologia, topografia e época de instalação da lesão variaram. As tarefas incluíram: nomeação e recordação imediata de 30 figuras relacionadas perceptual e semanticamente; associação livre; recordação tardia e recordação com pistas. Testes neuropsicológicos tradicionais também foram usados. Duas crianças com lesões adquiridas na fase escolar associaram as figuras baseadas em relações perceptivas e não categóricas e apresentaram déficits de recordação tardia e com pistas, ao contrario das outras duas com lesões perinatais. Uma criança apresentou bom desempenho na recordação independentemente de associação categórica. Os resultados sugerem que crianças com lesões cerebrais podem apresentar déficits de categorização e recordação, que não são frequentemente evidenciados em testes tradicionais.

PALAVRAS-CHAVE: neuropsicologia do desenvolvimento, lesões cerebrais, infância, memória, categorização.

Developmentally-related differences in performance on memory tasks are influenced by acquisition of semantic knowledge[1]. During such acquisition, concepts in semantic memory become more complex and strongly associated. As a result, images or words which allow the identification of a greater number of semantic features are preferentially encoded, thus facilitating storage. There is evidence that following the development of such preferential encoding, semantic relations among stimuli are activated automatically, facilitating the retrieval of items represented in specific categories. Consequently, items which are more highly semantically related have a great-

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er chance of being stored and later recalled[2]. According to Vygotsky[3], concept formation initially relies on the child's concrete experience; during earliest development, only a few semantic properties involving concepts are available. With increasing age, children increase their ability to identify members of a given category, and in adolescence, a hierarchical organization of concepts is fully developed. Categorization tasks have been used to detect developmental changes in concept formation[4,5]. Before 7 years of age, children associate stimuli based on perceptual attributes of stimuli or with respect to their personal life experiences. In older children, associations may involve categorical dimensions. Later, category labels are fully employed in associating stimuli. When children identify categorical relations involving specific material to be recalled, they benefit from categorical relatedness to achieve a better recall, and are said to use categorical memory strategies[6].

As with concept formation, the use of categorical memory strategies increases with age[7,8]. In preschool children, the use of categorical memory skills is unusual. Emergence of these strategies takes place in a period of transition occurring in children aged 7-10 years. Following this period, children become able to identify categorical relations of the material to be remembered and to benefit from it for recall. Experimental evidence has been presented showing that changes from non-strategic to strategic behavior in memory performance occur between the ages of 9 and 10 years[9]. The adoption of memory strategies also depends on task-related factors, including the extent of elaboration-encoding possibilities for material, processing speed, and the level of complexity relative to the amount of mental effort required for conscious recollection[10].

Brain damage in childhood may interfere with the development of strategic memory skills. For instance, Levin et al.[11] showed that traumatic brain injury in children lead to deficits of performance in recognition memory tasks; when the subjects tested were teenagers, however, such deficits were no longer detected. The authors interpreted these results as reflecting the use of compensatory strategies to cope with performance demands. In younger children, these skills had not completely developed and were thus unavailable for mediating performance. At the time brain damage occurred, these children had fewer cognitive resources available for use in compensatory strategies; in addition, they had less accrued knowledge to draw upon in dealing with the task demands. Therefore, with knowledge acquisition and with the development of strategic skills, children may acquire the ability to use compensatory strategies to benefit from semantic components of information in order to deal with cognitive deficits. The spontaneous and efficient use of categorical memory strategies seems to be associated with frontal lobe function; maturation of frontal lobe function is not completed until adolescence[12,13].

The present study aimed to achieve a better understanding of categorization and memory dysfunctions which follow brain damage in childhood, taking into account the methods by which brain damaged children categorize stimuli and the extent to which they are capable of using categorical relations among stimuli for performance on recall tasks. The main interest was to explore differences in the development of categorization and verbal recall skills in children with various neurological characteristics and to determine the utility of a neuropsychological procedure for detecting performance differences.

METHOD

Subjects

Four boys with brain damage identified by magnetic resonance imaging (MRI) exams participated in the study. All of them belonged to families with equivalent socioeconomic status. Patient 1: 12-year-old, 6th school grade, exhibited periventricular damage following perinatal anoxia. Patient 2: 14-year-old, 8th school grade, exhibited right fronto-parietal damage related to extensive cortical dysplasia. Patient 3: 10-year-old, 1st school grade, was diagnosed as presenting a medulloblastoma in the cerebellar vermis at the age of 7 years, resected surgically soon after diagnosis. Complementary treatment with joint chemo- and radiotherapy in the neuraxis was applied. At the time of assessment, he had been out of treatment for about one year. Patient 4: 11-year-old, 4th school grade, suffered an ischemic stroke in the right middle cerebral artery when he was 9 years old, resulting in temporo-parieto-occipital damage. Complaints of poor academic outcome were reported by teachers and parents. These children were participating in a neuropsychological program of the Universidade Federal de São Paulo, Brazil; parents gave written informed consent for participation of their children in the study. A pediatric neurologist evaluated the children and the MRI exams; a neuropsychologist performed intellectual and neuropsychological testing. Patients exhibited no signs of epilepsy or psychiatric disorders and presented normal intellectual development as evaluated by the Raven's Colored Matrices Scale[14]. Experimental protocols were approved by the Ethics Committee of the Universidade Federal de São Paulo (UNIFESP), and comply with national and international rules and policies[5].

Testing material

Procedure involved a set of 30 figures, each representing six exemplars of five different categories, including fruits, animals, home appliances, school materials and vehicles, impressed on a white 7 × 7 cm card (examples: Fig 1). Figures were selected taking into account familiarity criteria[15]. In addition, figures were painted green, red or yellow; there were ten figures painted with each of these colors[5].

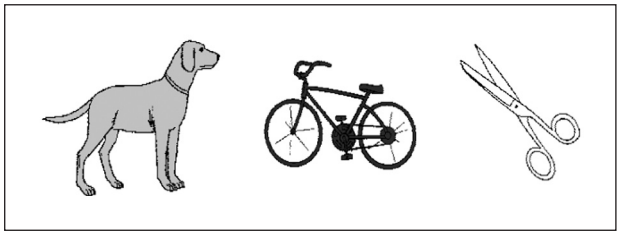

Fig 1. Examples of the stimuli used in the procedure.

Procedure

Figures were individually presented to the patient, who was asked to name them. Immediately after presentation, a free recall test was solicited (immediate recall). Then the subjects received all cards and were invited to perform a free classification task; the instruction was to "put together figures that matched". Twenty minutes after the classification, a delayed recall test was made, followed by a cued recall test. The latter involved a verbal presentation by the experimenter of the semantic categories to which the figures belonged. Note that in this procedure, performance could be affected by the explicit exposure of the stimuli categorical relations in prior tests. Traditional neuropsychological tests including Semantic Verbal Fluency (animals), digit span and Corsi Blocks Test (both backwards and forwards) were also made[16]. In Verbal Fluency, patients were asked to generate as many exemplars of the category as they could in 60 seconds. The digit span test involved the immediate repetition of sequences of 2 to 8 digits in forward order or sequences of 2 to 7 digits in backward order, presented orally by the examiner. The Corsi Blocks test involved the repetition of sequences of cubes disposed randomly in a wooden board, presented by the examiner.

Performance in the figure association task was evaluated taking into account the child's verbal comments about associations, following the guidelines of Vygotsky's theory on categorization[3], which includes the definitions that follow.

(A) Diffuse associations – grouped stimuli followed the child's subjective impressions (e.g., "the cat and the dog are together with the bed because they use to sleep on the bed"). (B) Functional associations – explanation included at least one categorical attribute actually shared by the associated stimuli, such as their function (e.g., "the book, the pencil and the scissors are used for homework"). (C) Taxonomic associations – when the child explicitly named the stimuli category (e.g. "animals, vehicles"). (D) Perceptual associations – explanation for classification referred to the color of figures.

Statistical analysis

A Z-score allowed comparison of each patient's performance to normative data[5]; a deficit was considered to occur when the patient's score was two standard deviations or more from the norm. Categorization skills were classified by the percentage of each type of association (diffuse, functional, taxonomic and perceptual). Performance in recall tests was evaluated by the number of items recalled; in addition, a clustering index[17] was calcu-

Table. Clinical data and tests results (Z-scores) of brain damaged patients.

Patients	1	2	3	4
Clinical data				
Age at injury	–	–	7 y 5 m	9 y 3 m
Age at assessment	12 y 4 m	14 y 4 m	10 y 3 m	11 y 2 m
Main regions of brain damage	Periventricular white-matter	Right fronto-parietal	Posterior fossa	Right temporo-parieto-occipital
Etiology	Perinatal hypoxic-ischemic event	Cortical dysplasia	Vermian medulloblastoma	Arterial ischemic stroke
Test's results				
SVF	–0.27	0.36	0.98	3.38
DS-F	–1.18	0.8	1.34	1.05
DS-B	–0.97	1.87	–1.84	–0.84
CB-F	–1	1,56	–0.71	1.42
CB-B	–0.63	0.72	–1.33	–0.51
IR	–1.41	–1.49	–0.55	–1.25
DR	–1.61	–0.31	–3.03	–1.95
CR	–1.17	–0.51	–3.4	–3.43
IR-C	–0.57	–6.26	0.85	1
DR-C	0.16	1.49	–3.05	0.64
TA	–1.34	0.78	–1.73	–2.19
FA	3.41	–0.71	–1.09	–1.34
DA	3.94	–0.32	–0.92	–1.09
PA	–0.35	–0.32	3.02	4.13

SVF: Semantic Verbal Fluency; DS-F: Digit Span Forwards, DS-B: Digit Span Backwards; CB-F: Corsi Blocs Forwards, CB-B: Corsi Blocs Backwards; IR: Immediate Recall; DR: Delayed Recall; CR: Cued Recall; IR-C: Clustering in Immediate Recall, DR-C: Clustering in Delayed Recall; TA: Taxonomic Associations, FA: Functional Associations, DA: Diffuse Associations; PA: Perceptual Associations. Test's results are shown considering the Z-scores obtained by patients in each test. Highlighted scores show deficits (–2 SD; except for FA, DA and PA, which increase means deficit).

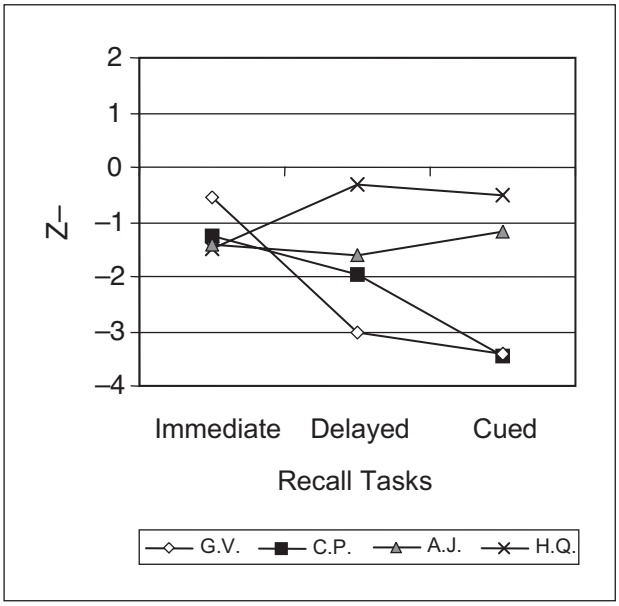

Fig 2. Differences of patients' performance in recall tasks.

lated taking into account the number of items belonging to each category recalled sequentially in relation to the total number of items recalled. This index can vary from 0 to 0.83, with 0.14 being the chance level for recalling items of the same category. Clustering index expresses the number of items of the same category recalled in a sequence and reflects the contribution of categorical information to recall. Performance in digit span and Corsi blocks tests was estimated by the number of items recalled in both forward and reverse sequential order. Performance in the semantic verbal fluency test was measured by the number of words generated.

RESULTS

Clinical information about the patients and their performance in each test are presented in the Table.

Patients' performance in traditional neuropsychological tests did not differ significantly from that reflected in normative data, except in the case of patient 4, who exhibited better performance in verbal fluency. This suggests that differences in the categorization and recall tasks could not be explained by episodic or working memory dysfunctions. Although those tests did not detect changes in patients' performance, a variety of significant differences relative to normative data were detected both in recall and classification tasks. In the latter, the percentage of perceptual associations exhibited by patients 3 and 4 were significantly greater than reflected in normative data; for patient 4, this effect was accompanied by a significant decrease in the percentage of taxonomic associations, for patient 3, a similar trend, that did not reach statistical difference, was seen. Another result observed with these patients relates to the fact that the number of items recalled by them did not increase throughout the recall tests; such an increase occurs with normally developing children (Fig 2).

Clustering in delayed recall was also relatively more impaired in patients 3 and 4 than in the other two patients. It seems that the former were unable to benefit either from exposure to categorical relations among stimuli during the association task or from categorical cueing. In immediate recall, categorical clustering was impaired only in patient 2. Also in this patient, the number of figures recalled in the delayed recall task was larger than the number recalled in immediate recall, despite low categorical clustering. Finally, none of the patients showed deficits in immediate recall. Their ability to immediately recall categorically related information seems preserved, regardless of clinical variables.

DISCUSSION

The procedures employed in this study were shown to possess sufficient sensitivity to identify subtle differences in performance which conventional tests could not detect. The results presented here suggest that the development of categorical and memory skills can be affected in different ways by brain damage in childhood. Results concerning greater percentage of perceptual associations in the categorization task and disruption of performance in delayed and cued recall exhibited by patients 3 and 4 suggest that their performance corresponds to that seen in younger children and is consistent with the possibility that their relative recent brain damage had interfered with the usual time course of development, resulting in a slower rate of maturation of the processes that underlie categorization skills. In other words, it is tempting to interpret these results in the way that development slowed after the morbid event, causing these patients to lag in development and thus exhibit performance scores comparable to those seen in younger children. However, since these patients did not exhibit disruption of performance in the immediate recall test, caution should be used in making this interpretation. Alternatively, these results may represent a memory retention deficit. This view receives support from the fact that patient 3 exhibited a smaller clustering index in delayed recall than in immediate recall. Additional studies will be required to evaluate these possibilities.

Other interesting result was that in patient 2 the number of figures recalled in the delayed recall task was larger than the number recalled in the immediate recall task, despite the lack of evidence of categorical clustering. Dissociation among the processes underlying recall of isolated stimuli and their recall in a categorically-related way is normal in the development of memory strategies, but in normal development, it occurs in an opposite pattern to

that observed in our patient[6]. At about 3th grade, children usually show an increase in clustering indices without a corresponding increase in the number of items recalled. An explanation that has been offered for this phenomenon is that young children dispend a disproportionately large amount of mental effort in organizational strategy, resulting in the availability of fewer resources for the recall of isolated stimuli. This pattern of performance is defined as a production deficiency in the use of memory strategies. Following this reasoning, our patient's performance cannot be interpreted as a typical immaturity in categorical memory skills. A better explanation would be that, in his case, memory performance was facilitated by other processes not determined by categorical relations of the material, such as processes related to visual memory. Moreover, this child was the only patient in our study with demonstrable frontal damage. It can therefore be considered that a failure in the processes underlying the recall of stimuli according to categorical membership, such as activation of semantic connections in long-term memory, may be caused by disorders in frontal lobe functioning.

The low clustering index in immediate recall seen in patient 2 suggests that integrity of the fronto-parietal regions is relevant for maintenance of neural activity in networks encoding categorical representation. Though it could possibly be argued that this interpretation conflicts with the lack of significant changes seen in the clustering index in the delayed recall test for this patient, it should be noted that while the immediate recall test was run after a single exposure to the material during the naming task, the delayed recall test occurred after that initial exposure plus an additional manipulation during the classification task. Therefore, an attentional deficit (which would be expected from the type of neural damage he holds) that contributed to the decrease in that index may have been circumvented by the additional exposure.

The data also indicate that the children in our study with acquired brain damage performed worse than the others on classification and recall tasks. We interpret this as reflecting limits on neuronal reorganization capacity following brain damage according to age at onset. Following acquired brain damage in childhood, mechanisms of neuroplasticity are superimposed on normal processes of maturation[18]. If the cognitive processes related to categorical memory skills are determined by frontal lobe functioning, our result would suggest that these processes were not totally consolidated at the time the children sustained brain damage and were subsequently impaired. In children with congenital brain damage, on the other hand, neuroplasticity may be more efficient and thus they may be spared this impairment.

The multiplicity of clinical variables related to brain damage in childhood (e.g. sites of injury and age at onset) renders definitive conclusions about categorical and memory disorders very difficult. Further studies utilizing larger datasets are required to conclusively answer the questions approached in this study. We consider that our results are useful in that they demonstrate that the development of categorical and memory skills can be differentially affected by different clinical conditions associated with brain damage. The investigation of these skills in neuropsychological assessment may provide relevant information for rehabilitation planning.

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