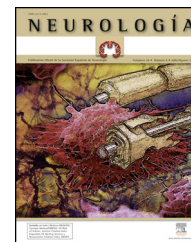




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ORIGINAL ARTICLE

The number processing and calculation system: evidence from cognitive neuropsychology[☆]



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Abstract

Introduction: Cognitive neuropsychology focuses on the concepts of dissociation and double dissociation. The performance of number processing and calculation tasks by patients with acquired brain injury can be used to characterise the way in which the healthy cognitive system manipulates numerical symbols and quantities. The objective of this study is to determine the components of the number processing and calculation system.

Methods: Participants consisted of 6 patients with acquired brain injuries in different cerebral localisations. We used *Batería de evaluación del procesamiento numérico y el cálculo*, a battery assessing number processing and calculation. Data were analysed using the difference in proportions test.

Results: Quantitative numerical knowledge is independent from number transcoding, qualitative numerical knowledge, and calculation. Recodification is independent from qualitative numerical knowledge and calculation. Quantitative numerical knowledge and calculation are also independent functions.

Conclusions: The number processing and calculation system comprises at least 4 components that operate independently: quantitative numerical knowledge, number transcoding, qualitative numerical knowledge, and calculation. Therefore, each one may be damaged selectively without affecting the functioning of another. According to the main models of number processing and calculation, each component has different characteristics and cerebral localisations.

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PALABRAS CLAVE

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Sistema de procesamiento numérico y cálculo: evidencias desde la neuropsicología cognitiva**Resumen**

Introducción: La neuropsicología cognitiva se centra en los conceptos de disociación y doble disociación. Mediante la descripción de las ejecuciones de pacientes con daño cerebral adquirido en tareas de procesamiento numérico y cálculo podemos caracterizar cómo el sistema cognitivo sano manipula los símbolos numéricos y/o las cantidades. Así, el objetivo de este trabajo es conocer y caracterizar los distintos componentes que forman el sistema de procesamiento numérico y cálculo.

Métodos: Los participantes en este trabajo son 6 pacientes con daño cerebral adquirido en diferentes localizaciones cerebrales. Como instrumento se ha empleado la *Batería de Evaluación del Procesamiento Numérico y el Cálculo*. Para el análisis de los datos se ha realizado una diferencia de proporciones.

Resultados: El conocimiento numérico cuantitativo es independiente de la recodificación numérica, el conocimiento numérico cualitativo y el cálculo. La recodificación es independiente del conocimiento numérico cualitativo y del cálculo. El conocimiento numérico cualitativo y el cálculo funcionan de manera independiente.

Conclusiones: El sistema de procesamiento numérico y cálculo parece estar formado por al menos 4 componentes que funcionarían de manera independiente, y estos son: conocimiento numérico cuantitativo, recodificación numérica, conocimiento numérico cualitativo y cálculo. De ahí que cada uno de ellos pueda dañarse de forma selectiva sin afectar al funcionamiento de los otros. Según los principales modelos de procesamiento numérico y cálculo, cada uno de ellos tiene características y localizaciones cerebrales diferentes.

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Introduction

Research in the field of cognitive neuropsychology is based on the concepts of dissociation and double dissociation. When a patient who is not able to perform task A effectively can perform task B without difficulties, we say that dissociation exists between the 2 tasks. However, this finding could simply be due to one of the tasks being easier to perform than the other.^{1,2} Therefore, double dissociation is a more conclusive finding. Double dissociation is demonstrated by the presence of another patient who is able to complete task A but unable to perform task B. This illustrates the functional specialisation of the cognitive system by providing proof of its modularity. Double dissociation can be used to demonstrate the functional independence of certain processing modules.³

Cognitive neuropsychology research includes recent descriptions of cases that contribute key information about the processes involved in number processing and calculation.⁴ Major dissociations described in the literature include those of word and number processing,^{5,6} number production and comprehension,^{7,8} number processing and calculation,⁸ rote verbal and quantitative knowledge,⁷ number retrieval and calculation processes,^{4,6} oral and written calculation,⁹ and lastly, independence between different arithmetic operations.^{7,10}

Different number processing-calculation models have been used to attempt to explain these dissociations. Each of these models presents a list of what processes, following which sequence and internal organisation scheme, occur during number processing and calculation. One of the

most influential models, proposed by McCloskey et al.,^{6,11} includes both number processing and calculation and is fundamentally semantic. This model has given rise to others including non-semantic processing, such as the Cipolotti,¹² Cipolotti and Butterworth,⁸ and Cuetos and Miera¹³ models. The latter does not include calculation processes. We should also highlight the anatomical and functional model^{7,14} developed after the triple-code model.¹⁵

Our study, which draws from the dissociations described in the literature and considers the contributions from various theoretical models, aims to understand the relationships between elements of the number processing and calculation system. The study used evidence obtained from the research on patients with acquired brain injury.

Patients and methods

This research was conducted at the University of Huelva over a 6-month period. Study participants consisted of 6 patients with acquired brain injury occurring in adulthood and at different cortex localisations.

Inclusion criteria

The study included consenting patients aged 38 to 65 years with a minimum of 8 years of basic education completed prior to injury. The disorder had to originate in the CNS and the injury had to have occurred at least 6 months before date of inclusion. Level of consciousness was optimal in all

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