NUMBER PROCESSING AND CALCULATION IN A CASE OF VISUAL AGNOSIA

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ABSTRACT

We describe the performance of a brain-damaged subject who suffered from visual agnosia leading to major difficulties in generating and exploiting visual representations from long-term memory. His performance in a physical judgement task in which he was required to answer questions about the visual shapes of Arabic numerals reflected his agnosic problems. However, he showed no impairment in usual number processing and calculation tasks. This case shows that, despite some commonalities in number and object processing, actual numerical processes are not affected by visual agnosia and can be preserved even when fine visual processes are impaired.

Key words: number processing, visual agnosia

INTRODUCTION

Arabic numerals[1] are rapidly and accurately processed by healthy adults. Despite this highly automatic processing, it is not easy to decide whether Arabic numeral reading should be considered as equivalent to word reading or to object (including drawings, ideograms, etc.) naming. Although their visual structure is close to alphabetical characters, their reading may be relatively spared in alexic patients (Anderson, Damasio and Damasio, 1990; Holender and Peereman, 1987). Cohen and Dehaene (1995) reported two such cases and conjectured that single digit reading might be similar to object naming because it requires the production of a single number word corresponding to the stimulus, whereas multi-digit numeral reading might be closer to word reading because it requires the parsing of a string of digits and the construction of a syntactically organised sequence of words. Cohen and Dehaene (1991) also reported the case of patient YM whose comprehension and calculation abilities were preserved whereas Arabic numeral reading was severely impaired. Errors consisted in digit substitutions and perseverations, and were affected by low-level visuo-spatial factors such as shape similarity and position of the digit in the string; when multi-digit Arabic numerals were presented vertically, the proportion of errors was equivalent for all positions. The authors suggested that a visual representation with visuo-spatial properties was accessed and used at several

[1] The term *numeral* refers to a symbol or string of symbols representing numbers (e.g., *6* is an Arabic numeral and *six* a written verbal numeral).

stages of the reading process (but see Seron and Noël, 1995). The relationship between Arabic numeral and word reading, and the potential link with object naming is thus a critical problem deserving careful investigation.

The present study aimed at investigating these relationships and focused on the way number processing and calculation may or may not be affected by visual agnosic deficits. We report the case of a brain-damaged patient suffering from visual agnosia leading to difficulties in processing mentally visual representations. We show that the agnosic problems extend to fine visual processes applied to Arabic numerals but that they do not affect numerical processing of the stimuli, thus documenting a dissociation between visual and numerical processing. We will first sketch out the basic assumptions of the two main number processing architectures concerning the nature of the underlying representations, and we will draw some implications from the study of agnosia and alexia for number processing. The dissociation observed in the present experimental investigation will be discussed in the light of current models of arithmetical cognition.

Architectures for Mental Representation and Processing of Numbers

How numerical information is coded, processed and stored in memory remains a matter of debate. McCloskey and his co-workers argued that number processing relies on a single abstract amodal representation and three functionally distinct modules (for a summary, see McCloskey, 1992). Comprehension mechanisms process and convert any numerical input into an abstract semantic representation; inversely, production mechanisms translate the abstract representation into the desired numerical output. Dedicated mechanisms exist for each type of notation (Arabic, spoken, or written verbal numerals). Finally, calculation mechanisms are applied to the abstract representation. Central to the model is the idea that the abstract representation underlies any numerical process because it is the mandatory link between the different modules. Since this representation is involved in different tasks and computed from different notations in different modalities (at least, visual and verbal modalities), it is assumed to be amodal and to express in a proposition-like language the basic quantities in a number and the associated powers of ten[2]. The Triple code model (Dehaene, 1992) has challenged this view and hypothesised three different representations with translation paths as well as exclusive links between each representation and some numerical tasks. Arabic visual representations (i.e., mental images of Arabic digits) are used in multi-digit operations and parity judgements. Verbal representations (i.e., auditory images of number names) are involved in counting and in retrieving from memory the solutions of simple additions and multiplications. Finally, analogue representations (i.e., distributions of activation on a mental continuum figuring numerical quantities) give rise to approximate calculation and number comparison.

[2] For example, the Arabic numeral *3425* and the verbal numeral *three thousand four hundred and twenty-five* both have the same mental abstract representation, formally expressed as {3}10EXP3, {4}10EXP2, {2}10EXP1, {5}10EXP0.