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Lack of awareness for spatial and verbal constructive apraxia

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ABSTRACT

It is still a matter of debate whether constructive apraxia (CA) should be considered a form of apraxia or, rather, the motor expression of a more pervasive impairment in visuo-spatial processing. Constructive disorders were linked to visuo-spatial disorders and to deficits in appreciating spatial relations among component sub-parts or problems in reproducing three-dimensionality. We screened a large population of brain-damaged patients for CA. Only patients with constructive disorders and no signs of neglect and/or aphasia were selected. Five apractic subjects were tested with both visuo-spatial and verbal tasks requiring constructive abilities. The former ones were tests such as design copying, while the latter were experimental tasks built to transpose into the linguistic domain the constructive process as phrasing by arranging paper scraps into a sentence. A first result showed a constructive impairment in both the visuo-spatial and the linguistic domain; this finding challenges the idea that CA is confined to the visuo-spatial domain. A second result showed a systematic association between CA and unawareness for constructive disorders. Third, lack of awareness was always associated with a lesion in the right dorsolateral prefrontal cortex, a region deemed as involved in managing a conflict between intentions and sensory feed-back. Anosognosia for constructive disorders and the potential role of the right prefrontal cortex in generating the impairment, are discussed in the light of current models of action control.

The core of CA could be the inability to detect any inconsistency between intended and executed action rather than a deficit in reproducing spatial relationship.

1. Introduction

Accurate performance on constructional tests, such as design copying or block construction, requires the ability to integrate complex spatial relations. Therefore, even in early studies a link was hypothesized between visuo-spatial disorders and constructional apraxia, at least to explain constructional disturbances in right brain-damaged patients (Trojano et al., 2004).

Kleist (1934) who originated the concept of constructive apraxia (CA), described the impairment as a disturbance "*in which the spatial form of the product proves to be unsuccessful, without there being an apraxia of single movements*" (in Benton, 1967) and placed it among the apractic syndromes, separately from basic visuo-perceptive deficits. Nevertheless, it is still a matter of debate whether CA should be considered a form of apraxia (as Mayer-Gross has pointed out since 1935) or, rather, the motor expression of a more pervasive impairment in spatial thinking (Grossi & Trojano, 2001; Guérin, Ska, & Belleville, 1999) or visuo-spatial processing.

In this paper, we discuss five right brain-damaged patients with moderate to severe CA and perturbed awareness of the inconsistency of their constructive performances. The patients were tested in a variety of constructive activities. These included linguistic tasks such as phrasing by arranging printed paper scraps into a sentence. The aim of the investigation was to verify the existence of combinatory and constructive impairments also on tasks where no implicit or explicit visuo-spatial processing is required.

First, we challenge the idea that the disorder is selectively confined to the visuo-spatial domain. If CA also disrupts performances on non-spatial tasks, the "executive" nature of the deficit would be supported rather than the spatio-agnosic interpretation (Duensing, 1953) and would allow us to postulate the supra-modal nature of the constructive disorder.

Then, we will discuss the impressive finding of limited awareness when an intended construction fails to be translated into the appropriate sequence of actions. The failure to register a mismatch between motor intention and sensory experience will be debated in the light of current models of action control.

The lack of awareness in these patients has been completely neglected in the literature and has never been taken into account to explain the syndrome. In fact, it is necessary to go back to Kleist (1934) to find a description of some traits of agnosia. The patient

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cannot self-correct, even if he recognizes differences between his performance and the model "*as he is agnosic for his own errors without any other signs of agnosia*" (Lange, 1938). Nevertheless, as a final step in the construction process, more recent accounts of constructive abilities (Grossi & Trojano, 2001; Roncato, Sartori, Masterson, & Rumiati, 1987) postulate a comparison between the final product and the given or internal model. A faulty evaluation of the consistency between the product and the model might lead to errors in construction.

In a goal-oriented action like construction, the congruence between motor outputs and current intentions is monitored by matching the expected and the realized sensory state, namely, by comparing the "constructive plan" (Feuchgtwanger, 1934; Grossi, 2001) to what has in fact, been assembled. We hypothesize that the core of CA is the impaired ability to take note of discrepancies between expectations derived from intended movements and what is actually seen. The patient can state that "there is something wrong" but cannot self-correct due to a failure in the integration of intention, action, and sensory feedback.

When the mismatch between intention and visual feedback is not perceived, then the patient may develop the false belief that there is nothing wrong with his reproduction and show profound or even complete anosognosia of his impairment.

According to current explanations of other forms of anosognosia for motor or sensory disorders, the lack of awareness of inconsistencies in reproducing a model is the consequence of abnormalities in the control of action (Frith, Blakemore, & Wolpert, 2000). To date, little is known about the neural substrate of the explicit monitoring of complex actions when an internal model of self-generated action is checked against an actual state and updated accordingly (Fink et al., 1999). In this study, we will try to shed light on the key anatomical structures of this "perception-action cycle" (Fuster, 1993).

2. Materials and methods

Based on their performance on the Copy Test of two-dimensional drawings (Spinnler & Tognoni, 1987), five patients with CA were selected (CA+) from a list of consecutively admitted brain-damaged patients who had been screened, over a 2-year period, for cognitive disorders at the Neuropsychological Unit of Santa Lucia Foundation in Rome. To eliminate potential confounding, we did not include patients with hemi-spatial neglect and/or aphasic impairments. Furthermore, no patient who scored below the cutoff on the standardized neglect battery used in our unit (pathological performances on two out of four tests: letter cancellation, barrage, sentence reading, and the Wundt–Jastrow Illusion test, Pizzamiglio, Judica, Razzano, & Zoccolotti, 1989) and no patient with aphasia or who scored below the cutoff on the Token test (Spinnler & Tognoni, 1987) was included. All patients showed a single focal lesion (CT or MRI see Fig. 1a) and had no previous history of psychiatric disorder. Five right brain-damaged (CA−) patients and five normal controls (N) were matched for age, sex, and education. MR or CT was available for four out of five CA− patients. Two patients had an ischemic fronto-parietal lesion extended to the temporal lobe in one subject (MN) and to the insula in the other (CAM); one patient (TU) had an ischemic thalamic lesion and another (CG) a right lesion confined to the internal capsula and corona radiata.

2.1. Neuropsychological tests

To fulfill the constructive apraxia definition, requiring neither signs of apractic disorders, nor elementary visuo-perceptual deficits, nor mental deterioration, apractic patients and brain-damaged controls were administered three groups of tests:

(1) Tests that assess the presence of constructive deficits.
(2) Neuropsychological tests that assess visuo-perceptual deficits, apractic disorders other than CA, intellectual level and verbal abilities, and a handedness questionnaire (the Italian version of the Edinburgh Inventory; Salmaso & Longoni, 1985). Two verbal and non-verbal short-term memory tests, as well as a verbal memory retention task, were included to rule out the potential effect of damage to the visuo-spatial working memory system on constructive performances or the influence of a retention deficit on linguistic experimental tasks.
(3) Experimental tasks aimed at evaluating the ability to assemble words and sentences into proper speech acts and to organize verbal and non-verbal sequences.

(A) Assessment of CA
  (A1) Copy of two-dimensional drawings (Spinnler & Tognoni, 1987).
  (A2) Immediate and delayed (10') reproduction of the Rey–Osterreith complex figure (1944), with scores adjusted for age (Carlesimo et al., 2002).
  (A3) Block Design subtest from the WAIS-r (Italian standardization for third and fourth age, Orsini & Laicardi, 1998).
  On the basis of these tests, four patients were classified as severe constructive apractic (see Table 1) and one as mild apractic (BM).
(B) Neuropsychological tests
  Detailed results of the neuropsychological assessment are reported in Appendix 1. They demonstrate that neither CA+ nor CA− patients showed any sign of VFD or visuo-perceptual deficits, as assessed by the Street Completion Test. No patient from either group was apractic (i.e. they always scored above the cutoff score for both ideomotor and ideational apraxia) and showed normal verbal and non-verbal reasoning abilities. Moreover, the patients' verbal intelligence quotient (verbal IQ) (measured by the Italian version of the WAIS-r) was in the normal range when adjusted for age. Although language and memory processing was normal in both groups, performance of both CA+ and CA− groups on a grammatical comprehension test (Miceli, Laudanna, Burani, & Capasso, 1994) was always below the mean error rate for healthy subjects for both the oral and the written presentation. As part of the assessment protocol we asked patients about their present state to test their knowledge of motor, sensory and/or cognitive deficits. Moreover, to gather information about awareness for constructive disorders, we specifically requested patients to evaluate their performances in the constructive assessment tests.
(C) Experimental tasks
  In order to transpose into the linguistic domain the visuo-spatial tasks commonly used to evaluate CA, which require the reproduction of an external model for copying and Block Design, and of an internal model for spontaneous drawing and free-construction (Mayer-Gross, 1935), we developed two sets of experimental tasks: (C1) this set is similar to Block Design or stick arranging, where a given model has to be reproduced by assemblage; (C2) this set is similar to free construction, where scattered items have to be assembled according to an internal mental representation of a plausible order.

(C1) Reproduction of an external linguistic model
  (a) copying a sentence by assembling unordered grammatical constituents printed on strips of paper and scattered on the table (20 sample sentences, mean length 10 utterances);
  (b) copying a paragraph by assembling unordered sentences printed on strips of paper (6 model paragraphs from 8 to 12 sentences in length, mean: 9.16 sentences);
(C2) Reproduction of an internal verbal or non-verbal model
  (a) subjects had to assemble grammatical constituents printed on strips of paper and scattered on the table into a syntactically plausible sentence, in two conditions: (1) with paper strips in sight; (2) paper strips removed as the subject ordered the sentence by pointing to each utterance.
  (b) patients had to assemble unordered sentences printed on strips of paper and scattered on the table into a coherent paragraph.
  (c) subjects had to arrange different actions, individually printed on strips of paper and jumbled on the table, to reconstruct the sequence of a well-known procedure (4 procedures from 8 to 20 actions, mean length: 13.5 actions);
  (d) patients were required to arrange three sets of humorous drawings to reproduce the humor (3 sequences: 4, 3, 2 drawings each, scattered on the table).
  (e) a different set of tasks assessed the patients' ability to reproduce an internal model built in a fixed order: subjects had to sequence into alphabetical, numerical and temporal order lists of first names (14), numbers (3 lists, 20 numbers each), months, and autobiographical events (previously collected from a family member); patients had to put five different hues in order by shade (4 jumbled samples).

2.2. Procedure

Before testing, every patient was adequately informed about the project and test to be conducted in it through the completion and signature of the special "informed consent". The research protocol and the informed consent have been approved by the Ethics Committee of S. Lucia Foundation.

Neuropsychological testing took place in a quiet room. Tests were administered and corrected according to standard procedures and sessions lasted no more than 1 h each. Instructions were consistent for all tasks ("*Use the strips on the table to assemble a sentence/paragraph/procedure according to Italian language rules* or *use them to replicate the sample sentence/paragraph/procedure. Be sure to use them all. Take your time, I'm not timing your performance*"). Patients and controls were allowed to correct themselves. No suggestions were given, just positive reinforcement. Whenever