Effects of frontal lesions on a selective attention task

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We set out to test the hypothesis that patients with frontal damage are specifically disabled in carrying out tasks requiring a high level of controlled attention. A group of patients with frontal lesions and another group of patients with retrorolandic lesions were tested for selective attention on a computerized task designed to produce a conflict situation between automatic and controlled processes. Frontal patients proved to be significantly more prone to errors of commission (false alarms) than retrorolandic patients.

Key Words: Frontal lobe — attention — neuropsychology.

Introduction

Cognitive disorders resulting from frontal lobe damage are among the hardest to categorize and are in some ways the most contradictory in clinical neuropsychology. Stuss and Benson [15] propose grouping the phenomena observed into six main categories, four of which refer directly to the strictly cognitive aspects:

1. Frontal patients exhibit a separation between action and verbal control: that is, they can understand what they are asked to do and describe it verbally but cannot carry it out correctly.
2. Frontal patients are disturbed in the execution of tasks calling for sequential behaviours and so their performances turn out to be repetitive.
3. The ability of frontal patients to establish a behavioural set or change an established one is disordered and so their actions become random or perseverative.
4. Frontal patients have difficulty in maintaining a set in the presence of interference.

It remains to be established, according to these workers, whether this complex of signs and symptoms is the expression of a single underlying disorder or of variously located autonomous functions (see also [4]).

A unitary interpretation of these frontal signs has been attempted from an explicitly cognitive angle by Norman and Shallice [10] and Shallice [13]. The model envisages decentralized units handling the routine control of schemes of action and thought (Contention Scheduling) and a central system of supervision (Supervisory Attention System), whose function is to integrate and modulate the activity of the lower control units in the face of new or nonroutine tasks. According to the model it is legitimate to expect frontal pathology to manifest electively in situations requiring a transition from highly automatic behaviors to conditions demanding accurate and/or prolonged moment-by-moment voluntary control.

Duncan [3] had emphasized the role of purpose in the optimization of behaviour as the element unifying and explaining disorders caused by frontal lobe damage. Most of the disorders commonly attributed to frontal damage, like those listed by Stuss and Benson, might be explained as the consequence of a specific deficit of "control through purpose" or of a tendency for action to be structured according to simple associative /repetitive patterns, which gives the behaviour of frontal patients the chaotic and incoherent character that emerges from most clinical reports (cf [14]).

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TABLE I. *Characteristics of the sample.*

	Frontal (n=23)	Nonfrontal (n=23)
Sex		
M	18	15
F	5	8
Age		
Mean	40,2	33,1
SD	18,2	13,7
Range	17-70	17-61
Etiology		
Vascular	2	7
Traumatic	11	14
Neoplastic	8	1
Congenital	2	—
Infective	—	1
Site		T O P T-P
Right	10	4 1 4 1
Left	13	8 — 3 2

T = Temporal
O = Occipital
P = Parietal
T-P = Temporo-parietal

The main aim of our study was to test the hypothesis that frontal patients have a specific disorder in the performance of a task calling for a high degree of voluntary attentional or goal-directed control by means of an experiment based on a specifically designed attentional task. We expected the behaviour of frontal patients to tend to escape voluntary control and to be structured according to automatic patterns activated by the context. This should be reflected in an increased number of false alarms and/or increased speed of response ("impulsiveness").

Method

Patients from the Arezzo Health Service Neurology Unit were screened for CT evidence of a single unilateral cerebral lesion of variable etiology confined to one lobe. A neurologist (Z.P.) and an external neuroradiological consultant of the Unit each made an independent assessment of the radiographic images and assigned them to one of two groups (frontal vs nonfrontal) according to the site of the lesion. Given the aim of the study, we included only patients presenting a single, unilateral, entirely pre- or post-rolandic lesion according to both of us. As the available neuroradiological material was not perfectly homogeneous, we could not go further to establish an intra-lobar site.
Patients with sensorimotor signs in the dominant upper limb and/or visual field defects (4 subjects) were later excluded, as were patients with a raw score of under 20/30 on the Cognitive Capacity Screening Examination [6] and/or a corrected score of under 29/36 on the Token Test [2], administered before the actual experiment (2 subjects).
The final sample was made up of 46 subjects, all righthanded, 23 with a frontal lobe lesion (10 right and 13 left) and 23 with a retrorolandic lesion (10 right and 13 left). The salient characteristics of the sample are listed in Table I. There was no significant difference between the two sub-groups in respect of sex ($\chi^2 = 3.2$; p 0.15) or age ($F = 2.2$; 1.44; p 0.111).

Experimental situation

Each patient was confronted in the course of a single 30-minute session with the following experimental situation: seated in front of an IBM-AT compatible personal computer at a distance of about 50 cm from the video, with the dominant hand resting on the button of a Logitech mouse, he had to carry out three visual attention tests, materially identical one to the other, while the verbal instructions were systematically varied from one test ot the next according to a prearranged order. The entire session was conducted with an examiner present but not participating. Each test was preceded by standardized verbal instructions and a number of trial runs sufficient to ensure that the task, which was extremely simple, was fully understood.
Each test consisted of a series of 60 elementary sequences, each of which was made up as follows:

— appearance of a simple visual warning signal (3 cm white square on a grey ground) in one of the two upper quadrants of the screen (7 cm above the horizonal midline), to the right or left of the vertical meridian of the screen at a lateral distance of 10 cm. Appearance to right or left was random. The subject had never to respond to this signal;
— blank interval lasting from 0.5 to 3 seconds varying randomly in 500 millisecond steps;
— appearance of a visual signal exactly like the warning signal except that it appeared in one of the two lower quadrants at the same distance from the midline axes of the screen. The side on which the signal appeared was randomized and so the probability of its appearing on the same (or opposite) side as the previous signal was 50%. To this signal the subject had to respond (or not) according to the instruction for each of the three tests;
— after the subject's response or after a 2-second noresponse gap, another interval of variable duration like the former started a new cycle.
The verbal instructions were manipulated as follows:
— In the first test the subject had to respond to all the visual stimuli appearing on the two lower quadrants of the screen regardless of side. He was asked to press the button once for every one of the 60 stimuli. This first test served only to set up a working stimulus-response association. Performances in this test were disregarded for the purposes of the subsequent assessment. Whenever the subject made a mistake, such as responding to the signal instead of to the stimulus, the program supplied a corrective acoustic feedback and replaced the incorrect sequence, in order to obtain a total of 60 correct responses.
— In the second and third tests the subject had to respond to all the stimuli appearing on the same side and only those (test 2: "valid" condition), or on the opposite side (test 3: "invalid" condition) to the immediately preceding warning signal. In these two tests, the only ones considered for subsequent processing, we had a situation in which only 50% of the stimuli called for an open response; the remainder had to be handled at the stage of perception but rejected at that of decision.

Results

In accordance with the general principles of signal detection theory each subject's performance was described by means of a nonparametric measure for *sensitivity* [P(Â)] and *criterion* (FPR = false positive rate) [11, 9, 12]. An increase in the P(Â) value denotes greater sensitivity in detecting the stimulus while an increase in FPR denotes a tendency to use a less strict decision criterion, that is, a tendency to respond randomly and repetitively. Any discrepancy between the two measures is to be seen as an indication of the possible level of interference: in the case of low sensitivity at the level of the information acquisition processes; in the case of lowering of the criterion, at the level of the decision processes.
The third parameter considered was the *mean reaction time* (TR), without distinction between correct responses and false alarms.
After appropriate transformations of the raw data (2 arcsin $\sqrt{x}$), a three-way variance analysis (site x side x valid vs invalid) was carried out separately for the three measures. The results obtained are summarized in Table II.
With regard to *sensitivity*, the results showed no significant effect either of site ($F = 2.132$; 1.42; p 0.152) or of side of the lesion ($F = 0.326$; 1.42; p 0.571). The majority of the patients, anterior and posterior, performed almost perfectly, as was to be expected in a task where the perceptive discrimination load is quantitatively and qualitatively reduced to the minimum.

TABLE II. *Results (SD in brackets).*

Group	Condition	Measure		
		P (Â)	FPR	TR (msec)
Frontal (n = 23)	Valid	0,961 (0,04)	0,129 (0,049)	442 (133)
	Invalid	0,952 (0,03)	0,167 (0,132) *	466 (155)
Nonfrontal (n = 23)	Valid	0,974 (0,02)	0,086 (0,06)	439 (162)
	Invalid	0,976 (0,02)	0,078 (0,07)	458 (178)
Right (n = 23)	Valid	0,943 (0,12)	0,083 (0,008)	467 (121)
	Invalid	0,935 (0,09)	0,064 (0,034)	485 (137)
Left	Valid	0,961 (0,13)	0,101 (0,06)	491 (187)
	Invalid	0,955 (0,16)	0,095 (0,083)	504 (191)

* $p < 0,05$ ($F = 4,649$; 1,42; p. 0,037).

With regard to the *criterion*, the performances of patients with an anterior lesion were significantly inferior to those of patients with a posterior lesion, especially in the invalid condition ($F=4.649$; 1.42; p 0.037) irrespective of lesion side ($F=0.148$; 1.42; p 0.670). Patients wih a frontal lesion tend to adopt a less and less rigorous criterion as the task becomes more complex.
As to the *speed of response*, no significant effect of site or side or condition was found, and no interaction.

Discussion

The main aim of the study was to detect any differences between subgroups on a goal-directed selective attention task simple enough to break down into the cognitive components probably involved in its performance.
Frontal patients proved to be significantly more disturbed in responding selectively to the targets, especially when they appeared on the side opposite to the warning signal.
This finding was in line with our expectations but was in partial disagreement with that of Knight et al [7] and of Salmaso and Denes [12], who found frontal patients not only less specific but also less sensitive in detecting stimuli. However, the latter authors used a rather exacting test of sustained attention, as shown by the absolute value of P(Â), and so the lower sensitivity of their frontal patients might have been due to a deficit of vigilance rather than to less competence in the actual perceptual treatment of the signals. This interpretation was later confirmed by Wilkins, Shallice and McCarthy [17], who demonstrated that frontal patients have a specific sustained attention disorder. The structure of the task we set is closer in some respects to that of Guitton et al. [5], whose patients had to identify visual stimuli appearing in the same position as a cue or in the diametrically opposite position. The frontal patients proved incapable of inhibiting the automatic cued response in favor of the voluntary response corresponding to the verbal instruction.
More recent studies [1, 16] have explored the ability of frontal patients to make correct use of an information cue to optimize their subsequent performance. In normal conditions an information cue acts as a mechanism of preselection/facilitation of the most appropriate behavioural pattern for achieving a given purpose. As expected, frontal patients proved much less able to benefit from this facilitation. Verfaellie also investigated one subject's ability to inhibit inappropriate motor responses. Actually, the results of our experiment, like those of Salmaso and Denes (cf [17], p 359), might find an alternative explanation in terms of motor "impulsiveness" [8]. Now, if impulsiveness means the tendency of responses to be structured according to simple automatic patterns, escaping higher-level selective control, this was precisely the aim of the exercise, and in this case the behavior of frontal patients can properly be called impulsive. But if impulsiveness is taken to mean a more "peripheral" characteristic, a sort of sensorimotor short-circuiting without strictly cognitive implications, then it would be reasonable to expect a generalized shortening of reaction times on the part of frontal patients. Neither our study nor that of Wilkins et al showed this.

Sommario

Il presente lavoro si propone di verificare l'ipotesi di una specifica perturbazione di soggetti con lesioni frontali nella esecuzione di compiti richiedenti un livello elevato di controllo attentivo volontario. Due gruppi di pazienti, rispettivamente con lesioni frontali e retrorolandiche, sono stati sottoposti ad un esperimento di attenzione selettiva assistito dal computer, costruito in modo da realizzare una situazione conflittuale tra processi di tipo automatico e volontario. I risultati hanno evidenziato una significativa tendenza dei soggetti con lesione frontale a commettere un maggiore numero di errori di commissione (falsi allarmi) rispetto ai soggetti con lesione retrorolandica.

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ORIGINAL ARTICLES

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