Cognitive Neuroscience
11/2/21

Executive Control Processes and Prefrontal Cortex

Most Complicated

1. Prefrontal patients in daily life:
   A mix of social-active and executive control impairments

2. Performance in open-ended tasks:
   Multiple Errands, Six Element

3. Performance in tasks requiring flexible rule-guidance:
   Wisconsin Card Sort, Brixton

4. Fluency:
   Word Fluency, Dynamic Aphasia, Proverbs

5. Susceptibility to environmental control:
   Hayling A and B, Stroop, Antisaccade

Least Complicated

Executive control: ability to plan & carry out plans

Phineas Gage → poster child for PFC damage

- was never the same to friends

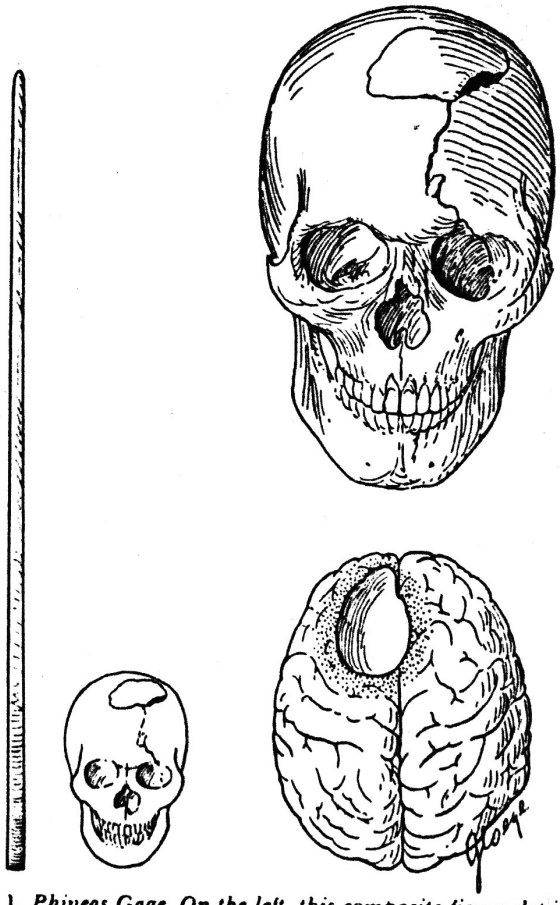

FIGURE 1. *Phineas Gage. On the left, this composite figure depicts the size and location of the frontal skull lesion in relation to the size of the iron tamping bar. On the right are an enlarged depiction of the skull defect and an artistic rendering of the probable location of brain destruction.*

out of control

socially inappropriate

His physical health is good, and I am inclined to say that he has recovered. . . . The equilibrium or balance, so to speak, between his intellectual faculty and animal propensities, seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operation, which are no sooner arranged than they are abandoned in turn for others appearing more feasible. A child in his intellectual capacity and manifestations, he has the animal passions of a strong man. Previous to his injury, though untrained in the schools, he possessed a well-balanced mind, and was looked upon by those who knew him as a shrewd, smart business man, very energetic and persistent in executing all his plans of operation. In this regard, his mind was radically changed, so decidedly that his friends and acquaintances said he was "no longer Gage." (pp. 339–340)

John Harlow, 1868

Pseudo-psychopathic

"no longer Gage"

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Executive dysfunction

Pseudo-depressive

CASE 1

A 45-year-old female physician felt markedly listless. Several years earlier, at a time of stress in her family life, she had required psychotherapy, and her current difficulty was initially considered a recurrent depressive reaction. When out-patient psychotherapy was unsuccessful, she was admitted to a psychiatric hospital. Three months later, the need for a pulmonary check-up prompted transfer to a general hospital where, somewhat fortuitously, a brain scan was ordered leading to the diagnosis of a large brain tumor. Her husband had noted an increasing listlessness about 1 year earlier when she had started to take refresher courses. She would often sleep in classes, would frequently stay in bed until noon, and generally experienced difficulty in getting going. She became slow in answering questions. About 6 months prior to hospitalization she became incontinent of urine and displayed a remarkable lack of concern. Her psychiatrist overlooked the fact that she never complained of depressed feelings, almost never cried, and lacked the morbid thoughts customary in the depressed. Her appetite had remained good, sleep was actually excessive, and she had stopped having dreams. She had remained affectionate toward her husband and was sexually responsive. She became extremely apathetic, never spoke on her own, was slow in response, and gave only brief answers when queried. She described her state of mind as a lack of enthusiasm and energy for almost anything. Electroencephalogram, brain scan, and preoperative ventriculography indicated a vascular tumor involving the anterior portion of the corpus callosum. The meningioma that was removed at right frontal lobectomy weighed almost 125 g.

Benson & Blumer (eds.)
Psychiatric Aspects of
Neurological Disease
(1975) Ch. 9, p. 151

Removal of PFC → Cognitive impairment

G. Rylander
Ch. 30, pp. 691-705
The Frontal Lobes
1948
Prefrontal lobotomy

Fig. 199. X-ray showing line of lobotomy incision.

The pattern of the original personality is not much altered, as an American psychologist recently asserted. But others—and I belong to that group—consider the changes rather grave.

Inspired by Jacobsen's (1935) report that prefrontal resections had a calming effect on chimpanzees, Egas Moniz had the idea of using a similar procedure to treat patients with intractable psychoses. The practice was picked up, popularized in the United States, and transformed into an outpatient procedure by Walter Freeman.

After a period when the procedure was used indiscriminately to treat a wide range of behavioral problems, it began to fall into disrepute, as reflected in Gösta Rylander's (1948) comment above. How much the abandonment of the technique owed to the introduction of antipsychotic drugs in the early 1950s is an interesting question.

The skilled mechanic, Case 2, before the operation was a rather intellectual type of man with many social and political interests, and with ardent feelings about the injustice of modern society. He had passed from one political group to another in his obsessive state, always feeling anxious and worried. He studied Marx, Buchariss, Upton Sinclair and similar authors. "Every week I bought a book." Since lobotomy he has not read a single book of the type mentioned. His social and political interests have entirely disappeared. He often changes employment—he gets tired of the environment or displeased with the boss or wants a better salary; sometimes he is fired because of heedless remarks.

Case 1 had been a conscientious and extremely efficient operating room nurse. She has lost much of her ambition, her interest in work and particularly her sympathy with the patients. Now she can perform only subordinate work. "I don't care if I make a mistake, it will turn out all right in the end." Like Patient 3, she was very fond of books and belonged to the nurses' literary circle. After the operation both of them lost most of their interest in books.

Patient 4 loved classical music. Now she cares only for dance tunes. Earlier she was religiously inclined, attending church now and then, especially when her brother preached. Now she thinks religion is humbug and often teases her brother because of his vocation. She had suffered from periods of anxiety with hysterical outbursts and had tried to commit suicide several times. She was a rather dangerous patient, smashing things and fighting the nurses in her temper tantrums. After lobotomy I engaged her as a cook in my household, thus getting excellent opportunities to study her at work and in daily life. She bought Christmas presents for me and my father, quite above her resources. Originally she was a clever cook, but now she had difficulty in using new recipes and made ridiculous mistakes. But her old cooking methods she usually applied faultlessly. Going out to buy food she might disappear for half a day. She had met a friend, had coffee with her, and chatted, forgetting time and duties. In her acts and reasoning she often had difficulties in seeing the possibility of more than one solution to a problem. I think she lacked the normal individual's fund of associations.

executive motor behavior

G. Rylander
Ch. 30, pp. 691-705
The Frontal Lobes

Transition from Case Descriptions to Clinical Studies

How can we make sense of the complex problems in everyday life that arise from damage to prefrontal cortex? To begin with, we can distinguish between **emotional/social** abnormalities (to be discussed later) and **executive control** impairments (to be discussed today).

Emotional/social abnormalities run the gamut from ones termed pseudodepressive to ones termed pseudopsychopathic.

Pseudodepressive (may be associated more with dorsolateral damage)

a. Apathy
b. Flat affect
c. Lack of drive

Pseudopsychopathic (may be associated more with orbitofrontal damage)

a. Social disinhibition
b. Impulsiveness
c. Inappropriate facetiousness (witzelsucht)

Impairments of executive control affect the ability to form and carry out plans (consider the case of the individual who set out on a shopping trip only to end up talking to a friend all afternoon). "Forming and carrying out plans" is a multifaceted process undoubtedly dependent on a widely distributed set of brain areas. What is the particular underlying ability that is lost after prefrontal damage? One way in which to answer this question is to examine how specific tests of executive control work and how prefrontal patients fail on them. In the clinical tests to be described in the remainder of today's lecture, patients exhibit:

a. Inefficiency (doing things in a suboptimal order) cooking, shopping
b. Rule-breaking (not following the stated rules of the task)
c. Perseveration (persisting in an approach although it is no longer working)
d. Capriciousness (abandoning an approach although it is working)
e. Vacancy (poverty or lack of fluency of thought or speech) drawing from within
f. Environmental dependence (behavior driven by habitual responses to objects)
g. Poor reflex suppression (inability to prevent automatic responses to stimuli)

Note that social/affective and executive control functions are closely intertwined in goal-directed behavior. We start out with felt needs and imagine goals that would satisfy them (using our capacity for emotion) then we achieve the imagined satisfactions by forming and carrying out plans (using our capacity for executive control).

MULTIPLE ERRANDS TEST
Complicated, done in a large area

Shallice & Burgess, Brain 114:727-741.

Multiple Errands Test (ME). The purpose of this test, which is undertaken in a pedestrian precinct near the hospital previously unknown to the patients, is for them to carry out a number of tasks in situations where minor unforeseen events can occur. The subtasks the patients had to carry out are basically very simple except for one, which has subcomponents designed to be reasonably demanding for someone of the IQ level and cultural background of the patients. While still inside the hospital the patient is given a card with 8 tasks written on it, 6 of which are simple (e.g., buy a brown loaf, buy a packet of throat pastilles). A seventh requires the subject to be at a certain place 15 min after starting. An eighth is more demanding, 4 sets of information have to be obtained and written on a postcard, namely: (1) the name of the shop in the street likely to have the most expensive item; (2) the price of a pound of tomatoes; (3) the name of the coldest place in Britain yesterday; and (4) the rate of the exchange of the French franc yesterday.

The card also contains the following instructions: 'You are to spend as little money as possible (within reason) and take as little time as possible (without rushing excessively). No shop should be entered other than to buy something. Please tell one or other of us when you leave a shop what you have bought. You are not to use anything not bought on the street (other than a watch) to assist you. You may do the tasks in any order.'

Scavenger hunt
1. Buy bread
2. Be here at 12pm
3. Write down this :

TABLE 5. ERRORS ON MULTIPLE ERRANDS

going into shop many times

	Cases			
	1	*2*	*3*	*Control*
Inefficiencies	6*	9*	5*	1.4 (1.1)
Rule breaks	5*	8*	8*	1.6 (1.3)
Interpretation failures	1	1	1	0.4 (0.7)
Task failures	0	5*	4*	1.1 (1.4)
Total errors	12*	23*	17*	4.6 (2.1)

entered wrong shop & got free stuff

* More than 2 SD worse than the control subjects.

(1) *inefficiencies*—where a more effective strategy could have been applied, e.g., entering the same shop more than once; (2) *rule breaks*—where a specific rule (either social or explicitly mentioned in the task) is broken, e.g., going outside the boundaries or leaving a shop with a newspaper without paying; (3) *interpretation failure*—where the requirements of a particular task are misunderstood, e.g., assuming that the information must be written on the birthday card rather than the postcard; (4) *task failure*—a task either not carried out or not completed satisfactorily.

Qualitatively the performance of the patients was even worse. They made types of error which were not produced by any control. Case 3 used a clearly irrelevant criterion inappropriately when she broke a rule (entering a shop without buying anything) because when in the shop (a chemist) she found it did not have a soap she especially liked; other cheap soap—which would have been at least as adequate for the task— was available. She also failed to note the time when starting. Cases 1 and 2 both became involved in social complications. Case 1 made the interpretative error of deciding he needed yesterday's newspaper (to find the coldest place in Britain on the previous day). He entered a newsagents and asked if they had the previous day's paper. They had, so he walked out with it, incidentally breaking the buying rule. He was pursued into the street by the shopkeeper who wanted to be paid for it. A.P. had just assumed that because a previous day's newspapers are generally worthless he could have one without paying. Case 2 produced a complex set of errors. Thus one series of actions began with his being the only subject to enter a shop simply to ask about the location of another type of shop (breaking buying rule). He was referred to a shop outside the allowed area, went to that shop (breaking the limit rule) and became involved in a heated argument with a shop assistant as he asked her to give him a birthday card free (which would have also broken the buying rule)!

Frontal patients failed along multiple dimensions in a multi-task test in a real-world setting.

SIX ELEMENT TASK INSTRUCTIONS

Done in one room

In the next 15 min we would like you to carry out 3 different tasks, each of which is in 2 parts. The tasks are:

1. To dictate* into the tape-recorder a *brief* account of two journeys. (a) Your journey to here; (b) your intended journey from here.

2. To write down the names of as many pictures as you can (in order). (a) Those in the left pile (set A); (b) those in the right pile (set B).

3. To solve 2 sets of arithmetic problems (as many as you can, in order). (a) Set I; (b) set II.

But you are not allowed to do the 2 subtasks (a) and (b) of the same type one after the other. Each of the 6 subtasks is given equal weight. Within subtasks 2 and 3, points will be given for correct answers. Earlier pictures/problems will be given more points than later ones in each subtask *and* errors/omissions will be penalized.

* The cassette recorder records throughout the 15 min so that the subject does not need to operate it.

1. Record brief account (journey here & home)
2. Write down names of pictures (left pile & right pile)
3. Solve arithmetic problems (2 sets)

- Don't do subtasks in same set one after the other

TABLE 4. PERFORMANCE ON THE SIX ELEMENT TASK

Case	No. of subtasks tackled	Max. time on any subtask (min, s)
1 (I)	2	7,30
1 (II)	4	6,19
2 (I)	5	10,11
2 (II)	3(+2 incorrect)	6,22
3 (I)	3	7,18
3 (II)	2	9,30
Controls	5.7 (±0.5)	5.35 (±0.53)

much less tasks

Behaved bizarrely (Δ'd 63 times)

Qualitatively the behaviour of the patients was also atypical. On his first attempt A.P. made notes for over 4 min to help with the dictation task, but in fact never dictated at all. He only attempted 2 subtasks, the second of these occupying the last 7.5 min. On his second attempt he tackled only 4 of the subtasks claiming that he did not dictate his journey back as he had not decided where he would go when he would leave the hospital! Case 2 succeeded in tackling 5 subtasks but spent much longer than any normal subject—over 10 min in 3 separate periods—on 1 of the subtasks (maths I) without ever trying its complementary task (maths II). On his second attempt he behaved bizarrely, changing task 63 times (mean task changes of controls 5.7, SD 2.19) and dictating the two sets of picture names—spending only 14 s and 20 s on them—instead of writing them down; no normal subject carried out a subtask incorrectly. Also on 6 occasions he carried out a subtask immediately after the complementary one, so breaking one of the rules. (One control also made this error. She said she had mistaken the rule as not doing a part I of a pair of subtasks after another part I; this she correctly applied.) Case 3, on her first attempt, only tackled 3 subtasks. On the second she wrote her journey instead of dictating it, attempted only 2 other subtasks and spent the last 9 min on just 1 of them. During this time she looked at the stopwatch on 7 occasions but did not switch tasks.

Frontal patients distributed their time less efficiently than controls in a situation where they had to alternate among several quite different subtasks.

WISCONSIN CARD SORT TEST

Rules Δ after 10 consecutive correct:

1. color
2. shapp
3. number

continues until 6 categories done or until through 128 cards

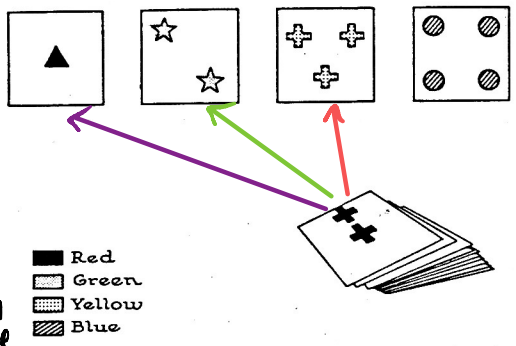


Fig 1.—Wisconsin Card Sorting Test, showing the material as presented to the subject.

B. Milner, Arch. Neurol. 9: 90-100 (1963)

The patient is arbitrarily required to sort first to color, all other responses being called "wrong"; then, once he has achieved ten consecutive correct responses to color, the required sorting principle shifts to form *without warning,* and color responses are therefore "wrong." After ten consecutive correct responses to form, the principle shifts to number, and then back to color once more. This procedure continues until the subject has successfully completed six sorting categories (color, form, number, color, form, number), or until all 128 cards have been placed. To succeed requires a readiness to abandon one method of approach when it ceases to work and also perhaps some interest in solving the problem.

This task was chosen because it provides some objective and quantitative measures of sorting behavior. In addition to yielding total error scores, this technique yields separate measures for perseverative and nonperseverative errors and for the number of sorting categories achieved. A perseverative response is defined as one which would have been correct on the immediately preceding stage of the test, or, in the first stage, as a continued response in terms of the patient's initial preference. All other errors are nonperseverative.

Still trying even though it isn't working

Locus of Excision	No. Cases	Categories Achieved, Max 6		Errors			
		Preop.	Postop.	Perseverative		Nonperseverative	
		Mean		Preop.	Postop.	Preop.	Postop.
Dorsolateral frontal	18	3.3	1.4	39.5	51.5	15.4	21.7
Control							
Temporal	33	4.3	4.6	21.5	13.5	18.0	16.7
Parietal	8	4.9	5.1	20.4	12.0	16.4	18.1
Parietotemporo-occipital	5	4.8	3.8	24.4	13.2	21.8	24.4
Orbitofrontal + temporal	7	5.3	4.9	9.3	12.0	15.4	15.6
Total control	53	4.6	4.7	20.0	12.8	17.7	17.8

PFC worse than control (even worse after operation)

In a task where they must infer the current correct strategy by trial and error, dorsolateral prefrontal patients tend to perseverate, using an old strategy long after it has ceased to work and even after they have verbalized that it's not working.

BRIXTON TEST

Expect perseverative errors

given current page, predict next page

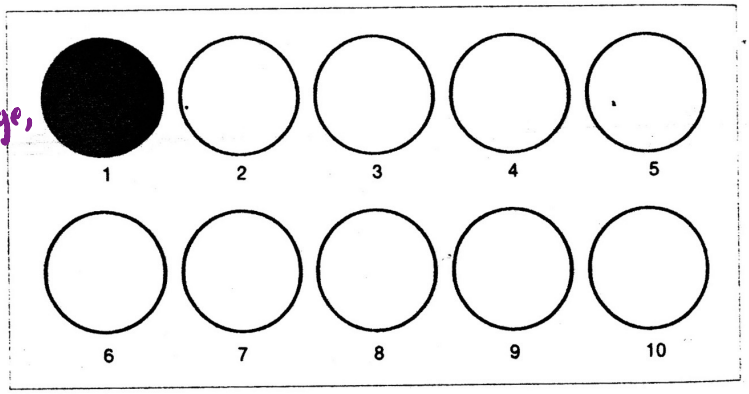


TABLE II

Rules Used in the Brixton Task

Section	Rule	Rules so far
1	+1 more filled	+1
2	−1 less filled	+1, −1
3	Alternate (5-10)	+1, −1, 5-10
4	+1	+1, −1, 5-10
5	−1	+1, −1, 5-10
6	+1	+1, −1, 5-10
7	Alternate (10-4)	+1, −1, 5-10, 10-4
8	Stay the same	+1, −1, 5-10, 10-4, stay
9	Alternate (8-9)	+1, −1, 5-10, 10-4, stay, 8-9

The Brixton test consists of 56 A4 pages each having a design similar to that shown in Figure 1. They are presented one at a time to the subject. Pages differ only in the position of the filled circle, which has a relation to its position on the proceeding page which obeys one of a number of rules. The number of consecutive pages where a particular rule applies changes in an unsystematic fashion from 3 to 8 so that changes in the rule cannot be anticipated. The rules are shown in Table II.

In a task requiring patients to infer by trial and error a rule that periodically changes, those with frontal injury (a) make many 'bizarre' (type 3) responses and (b) tend to abandon a good rule unnecessarily.

TABLE IV

Schematic Representation of Error Classification Procedure

	Error type
Correct	
Perseveration of single previously active rule (to last stimulus or last response)	1
Perseveration of subject's incorrect previously active rule (to last stimulus or response)	1
Perseveration of stimulus	1
Perseveration of response	1
Misapplication of current or previously active rule	2
Current response an application of a currently or previously active rule to an incorrect response	2
Response appearing in normal subjects' responses to that item?	2
If none of above criteria satisfied	3

TABLE V

Error Types across Groups (SD in brackets)

Error type	Anteriors (N = 40)	Posteriors (N = 24)
Absolute number	5.3 (3.7)	4.4 (4.2)
Type 1 as % of total errors	21.4 (12.2)	21.7 (13.6)
Absolute numbers	14.8 (4.3)	12.7 (4.4)
Type 2 as % of total errors	63.9 (16.7)	72.9 (15.5)
Absolute numbers	4.4 (6.2)	1.2 (1.8)
Type 3 as % of total errors	14.7 (15.2)	5.4 (6.6)

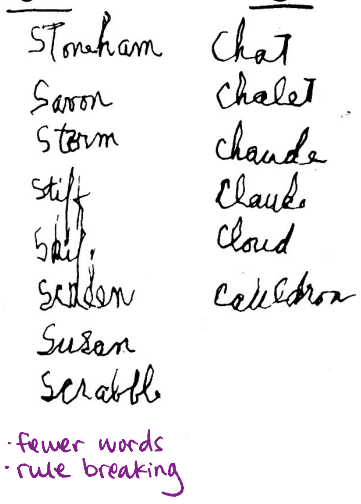
Capriciousness

Burgess & Shallice Cortex 32: 241-259 (1996)

WORD FLUENCY TEST

Simple rule:
over next 5 mins
write as many
words w rule

PFC



vacancy

A

Control

B

FIGURE 14.5. Word fluency. *A*. Mrs. P.'s lists. *B*. A normal control subject's lists. Both subjects were given 5 min to write as many English words as possible starting with the letter "s" and 4 min to write as many four-letter words as possible starting with the letter "c." Note Mrs. P.'s low output and her rule breaking in the four-letter "c" words. (Mrs. P. was multilingual, although English was her first language.)

Frontal patients performing an open-ended word-generation test (a) come up with fewer words than normals & (b) break rules.

Kolb & Whishaw
Human Neuropsychology
4th ed. 1996
P. 316

Patients start enumerating the words, then suddenly stop, complaining, "My brain becomes a blank, I run completely out of words. I can't think any more." The nurse when tested 20 months after the operation said, "This is the most difficult test you have. I have practiced it many times at home. I know there are masses of words but it is impossible to get at them."

G. Rylander
Ch. 30, pp. 691-705
The Frontal Lobes
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Vacancy

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Inefficiency
Rule-breaking
Perseveration
Capriciousness
Vacancy
Environmental dependence
Poor reflex supression

- not anomic
- Struggle coming up w words

Under which conditions?

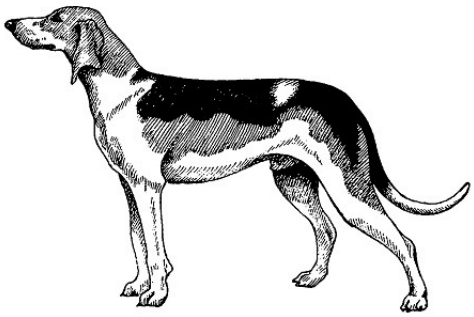
Dynamic Aphasia

immediately in front of Broca's on left side

Table 3 *Experimental Series 1: summary of scores on verbal generation tasks*

Test		Number correct	
Test 1	Generation of single words to complete a sentence	66/91*	
Test 2	Generation of a phrase to complete a sentence	3/20	
Test 3	Generation of a sentence from a single common word	2/15	
Test 4	Generation of a sentence from a given sentence context	3/20	
Test 5	Generation of a sentence from a single picture	0/6	Bad
Test 6	Generation of a sentence given a pictorial scene	34/34	Good
Test 7	Generation of sentences from a given pictorial scene	3/20	Bad
Test 8	Story generation from a pictorial context	0/5	
Test 9	Sentence construction task	14/15	

*All her correct responses were given in <2 s.



Vacancy

Fig. 2 An example of the pictorial scenes used in Test 7.

This frontal patient is poor at generating verbal responses in situations where the nature of the response is not fully determined by the stimulus

Test 5. Generation of a sentence from a single picture

A.N.G. was presented pictures of common objects (e.g. a man or a dog) and asked to produce a whole sentence incorporating the picture. Despite the instruction not to simply name the picture but to generate a sentence, she was only able to retrieve, after long pauses (mean response time ± SD = 15 ± 6 s), the picture names (e.g. '. . . it's a dog . . . all I can think . . .'; see Table 3). Her performance in this task was gravely impaired as was her performance in Test 3 requiring her to generate sentences from single common words. only subject

Test 6. Generation of a sentence given a pictorial scene

In this task, A.N.G. was asked to produce a sentence to describe simple pictorial scenes selected from the Psycholinguistic Assessment of Language Processing in Aphasia (Kay *et al.*, 1992) and the Test for the Reception Of Grammar (Bishop, 1989). She generated meaningful and grammatically correct sentences for all the pictures ('. . . a boy and a girl are riding an elephant . . .'; see Table 3). In contrast to her severe impairment in generating sentences from single words, single pictures and sentences she was remarkably unimpaired generating sentences from pictorial scene stimuli. subject + verb

Test 7. Generation of sentences from a pictorial scene: 'what might happen next?'

In this task, A.N.G. was presented with simple pictures and asked to generate a sentence describing what might happen next. She could only generate sentences for three out of 20 pictures (e.g. for Fig. 2 she correctly produced '. . . he will shoot a goal . . .'). For the remaining pictures she was completely unable to generate a sentence concerning what might happen next, although she was able to describe them (e.g. for Fig. 3 'She is skating on the ice and she is enjoying it.'). consequence

Robinson, Blair & Cipolotti
Brain 121: 77-89 (1998)

Proverb test

Concrete → abstract

The patient's capacity of abstract thinking was tested by several methods. I shall give only a few instances of their interpretations of proverbs and fables. After the lobotomy their interpretations acquired a more concrete character and their answers showed difficulties in generalizing.

"All is not gold that glitters" was interpreted, "One should not be taken in by any old thing; for instance, by fine talk." After the lobotomy, "Other substances also glitter."

"People in glass houses should not throw stones" was interpreted, "One should not criticize others. One can make the same mistake oneself." After the lobotomy, "Otherwise they will break the walls around them."

"Too many cooks spoil the broth" was interpreted, "If too many people are working with something it won't be good." After the lobotomy, "If too many people do the cooking, the food will not be so good."

The fables of the Stanford Revision were interpreted in the same concrete way. "The Farmer, His Son and The Donkey" was explained, "One should not act only on the advice of others." After the operation, "They should not both have ridden on the donkey."

G. Rylander
Ch. 30, pp. 691-705
The Frontal Lobes
1948

given sentence w/ final word omitted
A) fill in word that fits
B) fill in word that doesn't fit

Burgess & Shallice, Neuropsychologia 34: 263-273 (1996)

Hayling A and B tests

Subjects are presented with a sentence minus the final word with the completion word being strongly cued by the sentence frame. For instance, 99% of subjects completed the sentence frame 'He mailed the letter without a...' with the word 'stamp' (Bloom & Fischler 1980). In the first condition (A) the subject merely completed the sentence as quickly as possible. In the second condition (B) the subject had to complete the sentence with any word that made no sense given the sentence frame.

On Hayling A, frontal patients were slower. On Hayling B, they showed an excessive additional slowing.

Table 2. Response latencies across groups (sec; S.D. in brackets)

Group	Section A	Section B	B–A
Controls	12.6 (6.5)	26.4 (19.5)	13.8 (16.3)
Posteriors	17.4 (14.1)	40.6 (38.9)	23.2 (28.9)
Anteriors	28.6 (34.5)	83.1 (106.8)	54.4 (79.3)
Bifrontals	35.8 (23.1)	135.4 (119.3)	99.6 (118.9)
LH ($n=33$)	26.2 (22.3)	59.6 (68.2)	33.3 (56.0)
RH ($n=41$)	23.2 (33.9)	74.1 (105.1)	50.9 (74.5)

LH = all patients with (unilateral) left hemisphere lesions considered together.
RH = all patients with (unliateral) right hemisphere lesions.

Rating categories for Hayling B responses

Does the word reasonably complete the sentence (i.e. it's a word you might give yourself if asked to provide a word that would fit at the end).	C
Is the word an opposite of what you might expect as an answer?	SO
Is the word obviously semantically connected to the subject of the sentence?	SA
Is the word obviously semantically connected to the expected response?	SB
Does the word vaguely fit at the end of the sentence, but in a way that makes the sense of the sentence ludicrous – or is the word a slang semi-obsenity?	SC
If the word completely unconnected to the sentence:	
Is the word an item you might find in a hospital office?	UR
Is the word semantically connected to the subject's last response?	UL
Is the word both an item you might find in an office, and is also related to the last answer?	URL
Are none of the above true?	U

In addition, on Hayling B, they made many errors in the form of reasonable completions.

Table 5. Percentage responses in each category across groups

	C	SO	SA	SB	SC	UR	UL	URL	U*
Cont	4.2	2.7	2.5	1.5	5.8	31.5	5.0	1.7	45.2
Posts	4.7	3.7	2.7	3.7	9.6	27.2	8.9	1.7	37.5
Ants	16.9	8.2	3.4	3.1	10.9	24.8	2.7	1.1	27.7
BiFr	32.2	11.0	6.7	3.1	12.5	8.2	3.9	0.4	22.7

Responses on Hayling B

Bifrontals

more often filled in an appropriate word when they weren't supposed to

Controls

might use environment or pull from internally

Does the word reasonably complete the sentence (i.e. it's a word you might give yourself if asked to provide a word that would fit at the end).	C
Is the word an opposite of what you might expect as an answer?	SO
Is the word obviously semantically connected to the subject of the sentence?	SA
Inefficiency Rule-breaking Perseveration Capriciousness Vacancy Environmental dependence Poor reflex suppression	SB SC
Is the word an item you might find in a hospital office?	UR
Is the word semantically connected to the subject's last response?	UL
Is the word both an item you might find in an office, and is also related to the last answer?	URL
Are none of the above true?	U

STROOP TEST "Name the color"

Name colors of: D = dots

W = non-color words

C = noncongruent color words

PFC patients have trouble suppressing the reflexive reading response, so are slow to name the color

Table 3. Stroop-Test. Mean colour-naming time (sec) for each of the six patient groups with different cerebral lesions on the three parts of the test

Slow reaction times

Time (in seconds) to name 24 items

Group		Part D	Part W	Part C
Left	Frontal	26·4	48·6	110·7
	Temporal	21·1	26·7	44·3
	Posterior	26·2	34·2	61·8
Right	Frontal	16·9	22·9	41·7
	Temporal	15·5	21·1	33·8
	Posterior	24·4	31·8	53·3

Modified Stroop-Test. This consisted of three parts which were always presented in the same sequence. In *Part D* the patient had to name as quickly as possible the colour of 24 *dots*, 5 mm in diameter, arranged in a 6 rows by 4 columns array and printed in blue, green, red or yellow. Each colour was used six times, and the four colours were arranged in a pseudo-random order within the array, each colour appearing once in each row. Unlike the original Stroop-Test, *Part W* was similar to Part D, except that the dots were replaced by *words* (conjunctions and adverbs). The patients were required to name the colour in which the stimuli were printed, and to disregard their verbal content. *Part C*, finally, was again similar to Parts D and W, but here the coloured stimuli were the *colour-names* "blue", "green", "red" and "yellow" printed so that the print-colour never corresponded to the colour-name (e.g. "blue" was printed in either green, red or yellow, but never in blue). Part C, therefore, represented the greatest conflict between categories, with both the print-colour to be named and the verbal meaning to be disregarded belonging to the same category of "colour".

The time necessary to name the colour of the 24 stimuli was measured in seconds in each of the three parts of the tests. The rare errors in colour-naming were corrected immediately, and the patients were then told to go on as rapidly as possible.

The left frontal patients in this study showed an exaggerated slowing of reaction time when the irrelevant (semantic) content of the stimulus was incompatible with the relevant (ink-color) content.

Perret
Neuropsychologia
12: 323–330 (1974)

Poor reflex suppression

Environmental dependence

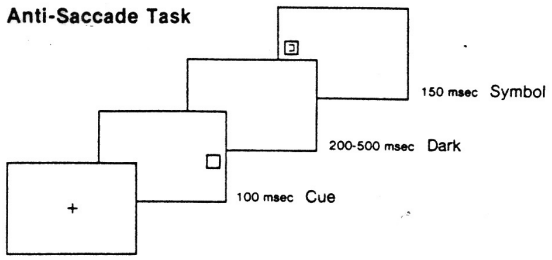


Fig. 1. Diagrammatic representation of the anti-saccade task. The subject faces a large screen cathode-ray oscilloscope on which there is a central fixation point (FP small cross in the rectangle in the bottom left). After a short random time the FP is extinguished and a stimulus cue appears for 100 ms randomly either 12° to the left or 12° to the right. The subject must not look in the direction of the cue but in the opposite direction, an equal distance from the FP, where a symbol (a square with a gap in it) will shortly appear. The task is to indicate with the thumb whether the gap is left, right, up or down. Task difficulty can be increased by decreasing the interval between cue and symbol

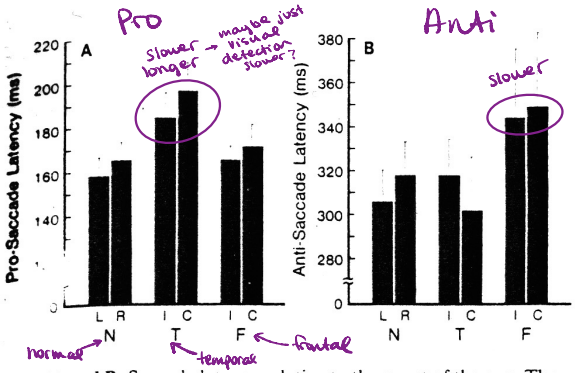


Fig. 3A and B. Saccade latency relative to the onset of the cue. The results in **A** and **B** are for the pro-saccade and anti-saccade tasks respectively. Only those anti-saccades that were not visually triggered and not preceded by a reflexive glance were included in the sample. The results for the normal, temporal and frontal groups are indicated by the letters N, T, and F. Columns labelled L, R refer to leftward and rightward saccades; I, C to the ipsilateral and contralateral sides relative to the lesion. Note the different scales on the ordinates of **A** and **B**. The line segment above each bar indicates the standard error of the mean.

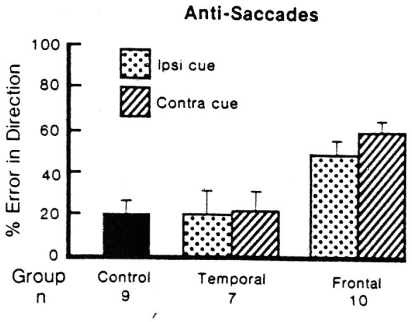


Fig. 10. Pooled data showing tendency of each group to make reflexive glances. The patients were studied two weeks post-operatively. The height of the dotted bars represents the mean percent error in direction when the cue was shown ipsilateral to the lesioned hemisphere. The hatched bars represent data obtained with a contralateral cue position. The data for the control gorup was obtained by first pooling together each subject's responses for left and right cue positions and then obtaining the average of these pooled values

Guitton et al., Exp. Brain Res. 58: 455-472 (1985)

Frontal patients make prosaccades (eye movements to flashed targets) at normal latency, but, in the antisaccade task, which requires looking away from the flashed target, they have long reaction times and make some prosaccadic errors.