

A STUDY OF VISUAL PROCESSES IN A CASE OF INTERHEMISPHERIC DISCONNEXION

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SUMMARY

A 75-year-old right-handed woman, after a probable cerebral infarct, developed an irregular constriction of the visual fields, a left-sided agraphia, and an anomia for objects in the left hand. Subsequent testing demonstrated an inability to name, though ability to recognize, letters and objects flashed in the homonymous left visual field. An inter-hemispheric disconnexion syndrome was inferred from these findings. The present publication concerns mainly the visual aspects of this disconnexion syndrome.

Tasks were devised to test the abilities of the major and minor hemisphere: (a) the left hemisphere demonstrated a complete dominance for language expression and an incomplete dominance for written language comprehension; (b) the right hemisphere appeared to be dominant for some visuo-spatial tasks including number comprehension; (c) when the hemispheres were given contradictory visual informations on a non-verbal task (chimeric stimuli) there was a predominance of the right hemisphere. The right hemisphere appeared able to process complex information. Specialization of functional activities in each hemisphere is briefly discussed.

INTRODUCTION

After complete section of the corpus callosum, sensory events occurring in one hemisphere are not available for processing in the other hemisphere (Sperry 1961). Therefore, human cases of interhemispheric disconnexion permit an independent study of the capacities of the major and minor hemispheres, notably of their verbal and visual capacities (Sperry, Gazzaniga and Bogen 1969). Our paper presents a study of visual processes in a case of interhemispheric disconnexion due to a probable cerebral infarct. We have employed methods developed in the testing of split-

brain patients as well as original tests. Our case confirms findings in cases of surgical commissurotomy and, moreover, indicates that the minor hemisphere is capable of processing complex information without language mediation.

CASE HISTORY

The clinical history has been reported in a previous publication (Barbizet, Duizabo, Degos and Chartier 1974).

The patient was a 75-year-old right-handed woman, without previous illness except arterial hypertension (170/110). She suddenly complained of headache and of an impression of "hazy vision" on 26 February 1971. Over the following few days she developed difficulty with her gait, impaired memory and spatial and temporal disorientation. In May 1971, she became suddenly somnolent and incontinent with a marked sensorimotor deficit of the right side. After several days she improved, at first rapidly then slowly, over the following months. In October 1971, her condition was stabilized and since then, particularly during the period of our observation (March 1972 to January 1974), no marked clinical change has occurred.

Neurological examination

In 1972 this disclosed: (1) a mild right-sided pyramidal syndrome; (2) a mild sensory deficit of the right side (hypoesthesia, impairment of two-point discrimination); (3) a constriction of the visual fields (see below). There was no sensory or motor deficit on the left side. However, objects placed in the left hand were named correctly in only 28% of cases (105 trials) while, on a tactile multiple choice, a correct response occurred in a proportion of 83% (84 trials). This "tactile anomia" led to the investigation and demonstration of an agraphia of the left hand (see Fig. 1). Gestures to command performed by the left hand were perturbed in the first few weeks of evolution. Later on, while symbolic movements were correctly carried out with either hand, sequences of gestures (such as "raise your arm, make a fist and extend your forefinger") were failed with the left hand and not with the right.

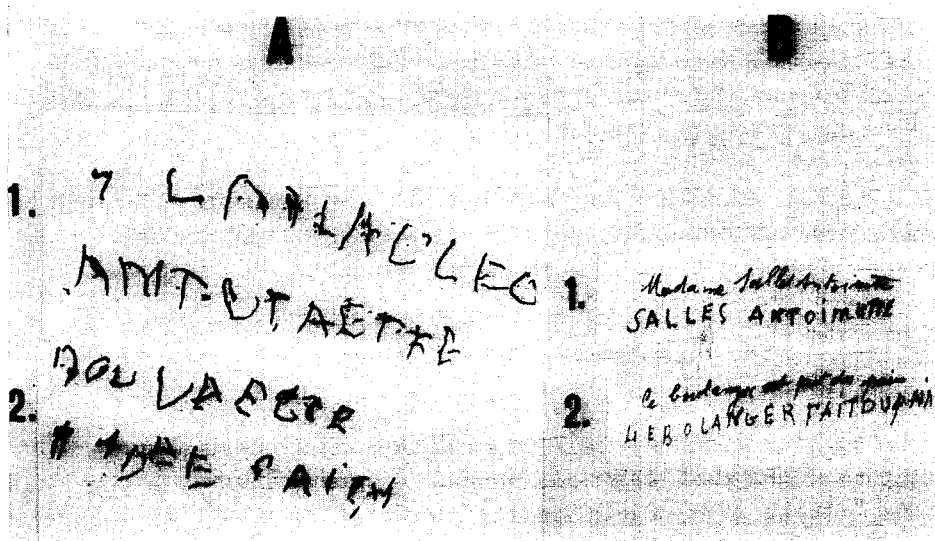


Fig. 1. Samples of the patient's handwriting *A*: with the left hand; *B*: with the right hand. 1. Patient's name; 2. Le boulanger fait du pain (the baker is making bread). (With kind permission from Prof. J. Barbizet and the publisher Masson, Paris, reproduced from J. Barbizet et al. (1974) Syndrome de déconnexion interhémisphérique, *Rev. neurol.*, 130: 127-141, Fig. 2).

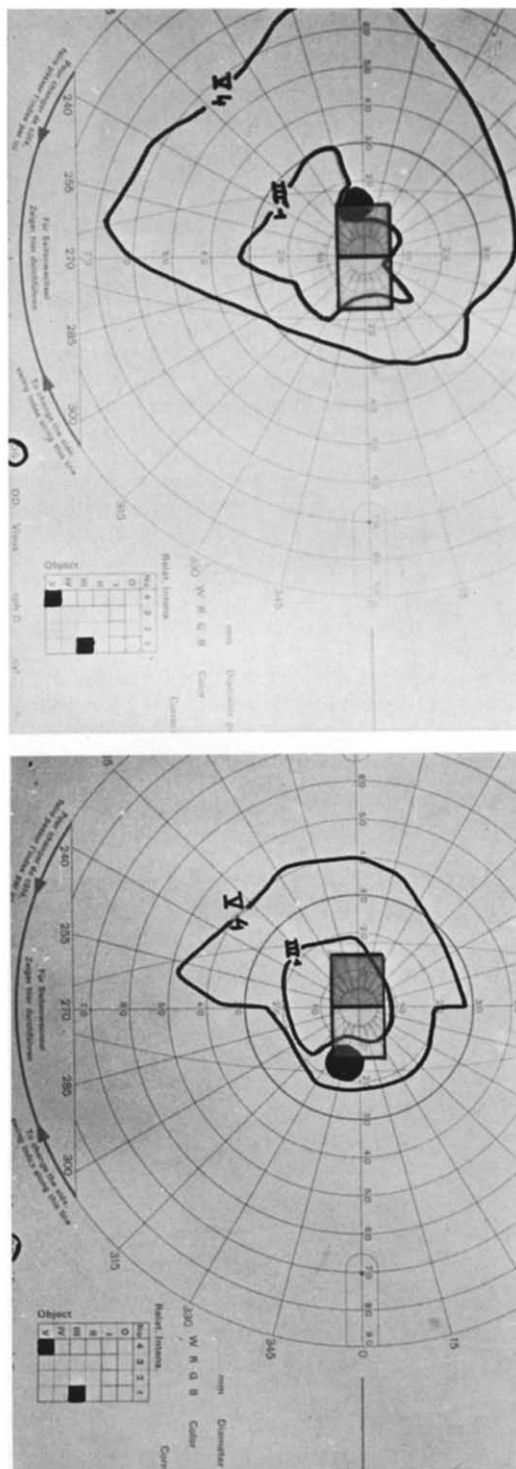


Fig. 2. Visual fields of the patient. Stimuli were presented tachistoscopically, on either side of the fixation point, in the square areas outlined ($15^{\circ} \times 15^{\circ}$).

WAIS full scale I.Q. was 96 (information: 10; comprehension: 11; arithmetic: 7; similarities: 10; digit span: 9; vocabulary: 12; digit symbol: 8; picture completion: 9; picture arrangement: 8; block design: 6; object assembly: 8). Spontaneous speech, repetition and naming were normal as was oral comprehension, as tested by simple and complex commands. Reading was slow but correct. Visual recognition of images and objects was normal. There was no disturbance of behaviour. The disorder of memory and disorientation noted at the onset had been completely resolved. The patient cooperated fully during the examination and subsequent testing.

An EEG obtained in 1971 showed bilateral slow polymorphic delta activity with a left hemisphere predominance. In June 1971 a brain scan (Ptc 99) showed two foci of uptake, one in the left temporo-occipital region and one in the right parieto-occipital area. A follow-up brain scan done in December 1973 was normal.

Ophthalmological examination (March 1972)

Uncorrected visual acuity was 6/10 in each eye. Fundal examination showed signs of hypertensive retinopathy. Opto-kinetic nystagmus was present and symmetrical. Goldmann perimetry showed irregularly contracted visual fields, the defect being greater in the right homonymous field than in the left (Fig. 2). Fusion threshold for flickering light (CFF) was tested for each visual field, first in the right, then in the left eye. For each eye, the left visual field was tested first. A flickering lamp was placed 10° from the point of fixation. The flicker frequency was increased, then decreased in a step-wise fashion. For each frequency the patient was requested to say whether or not she saw a flicker. In these conditions, the CFF was 31 for the left visual field and 26 for the right visual field. These figures were identical for the right and left eyes.

In summary, a 75-year-old woman, 8 months after the sudden onset of a transient neurological syndrome characterized by disorientation and disturbance of vision and gait, presented with a stable sensorimotor deficit of the right side, a constriction of the visual fields, and features of an inter-hemispheric disconnection syndrome (tactile anomia, agraphia and praxic difficulties) on the left side. The sudden onset, the progression of the clinical signs, and the clearing of the brain-scan foci suggested an ischaemic vascular accident. There were probably lesions of the pathways between the two hemispheres, in the corpus callosum and/or in the adjacent white matter.

TESTING METHODS

The patient was seated facing a screen with her head immobilized by an ophthalmological support. She was asked to fix her gaze on a red spot marking the centre of the screen and to try to

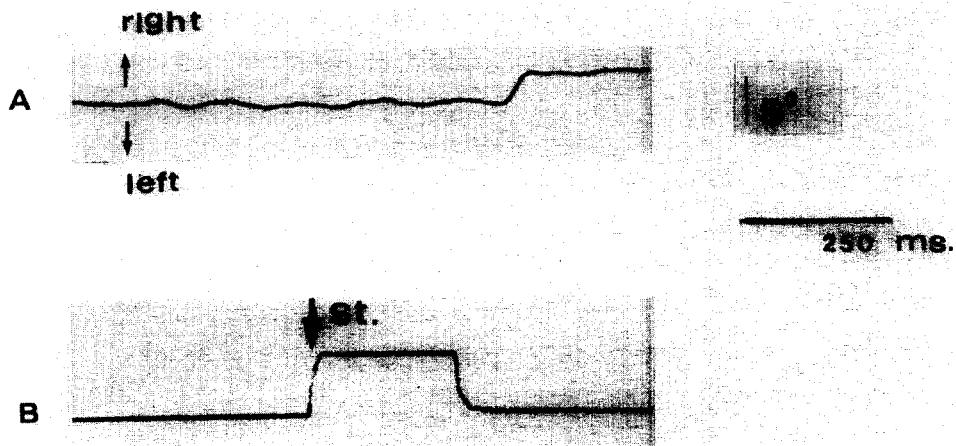


Fig. 3. Sample of EOG recording of eye movements. The upper tracing (A) represents the gaze displacement and the lower (B) the stimulus presentation. An arrow indicates the onset of the stimulus presentation on tracing (B). Note, on tracing (A), the small eye movement following stimulus presentation (300 ms).

recognize the items which were flashed on the screen. The pictures were presented tachistoscopically, laterally to the central red spot, either in the right (RVF) or in the left (LVF) homonymous half visual fields. Each tachistoscopic presentation lasted 250 msec. The immobility of gaze was checked by electro-oculographic recording of eye movements (Fig. 3). Although the gaze did not move during stimulus presentation, a gaze displacement was frequently observed immediately after the end of the presentation (300–350 msec after the onset of projection).

Based on previous studies of commissurotomy subjects, 3 series of tests having different objectives were used: (1) tests designed to demonstrate a visual hemispheric disconnection; (2) tests designed to study the perceptual capacities of each hemisphere tested separately; (3) simultaneous stimulation of the two hemispheres by chimeric figures.

I— Findings of visual disconnection

Naming and designation of pictures and letters. Twenty-four photographs of objects and 24 letters were serially presented in the LVF, then in the RVF. The patient was requested to "name what she saw". Then the test was repeated after she was requested to keep silent and to indicate the picture which she saw among a group of 6 pictures. For each test, the designation was effected serially by the two hands (first the left and then the right hand). The results are expressed as percentages of correct responses. In the tests of designation, the scores were compared to the chance level score (17%) by a chi-squared test.

Visuo-tactile matchings. Twenty-four photographs of objects and 24 letters were presented successively in the LVF and in the RVF. The patient had to choose tactually among 3 objects or 3 wooden letters the one corresponding to the visual stimulus. She was asked to palpate successively

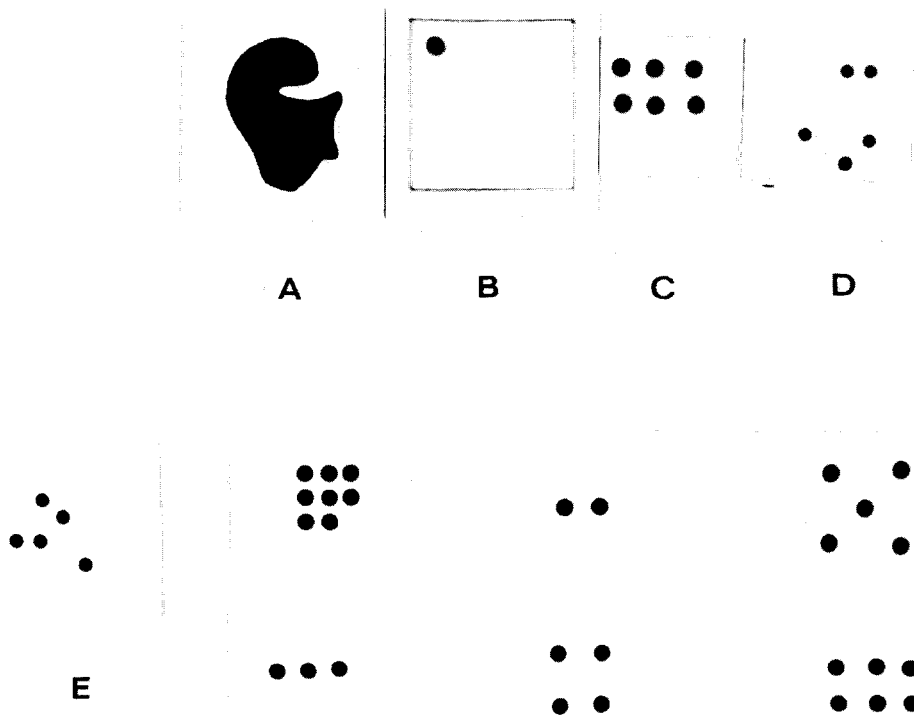


Fig. 4. Visuo-spatial tests: *A*: recognition of nonsense shapes; *B*: position of a dot in a square; *C*: number of dots from an identical spatial arrangement; *D*: variable disposition of 5 dots; *E*: number of dots from a different spatial arrangement (for this test, a multiple choice set is shown to the right of the stimulus). In test *C*, the patient had to match a certain number of dots (from 2 to 8) to the same number of dots disposed in an identical fashion. In test *E*, the patient had to match a certain number of dots (from 2 to 8) to the same number disposed differently.

the 3 objects or letters while blindfolded. For each presentation, the response was tested serially for either hand, first the hand contralateral to the presentation in the half-field, then the ipsilateral one. Finally the patient was asked to name the stimulus.

II — Perceptual capacities of each hemisphere

In each of the following tests the stimuli were presented to the LVF and then to the RVF.

Comprehension of written language. The stimulus word was printed. The response was a choice from 6 pictures of objects or from 6 words in cursive script (72 words were presented for the choice of pictures and 96 for the choice of words in cursive script). In another test, the response was by multiple choice among 3 palpated objects (12 different words were presented).

Visuo-spatial matching tests (Fig. 4). Different stimuli were used to test the visuo-spatial capacities of each hemisphere: (a) nonsense shapes; (b) position of a dot in a square; (c) the number of dots from an identical spatial disposition; (d) 5 dots variably disposed; (e) the number of dots from a different spatial arrangement (we will refer to this task as the "number comprehension" test). For each of these tests, 24 different stimuli were projected serially. As soon as a stimulus had been flashed, the patient was shown an array of 6 items belonging to the same category (e.g.: nonsense shapes) and she was requested to point to the one which matched the stimulus which had just been flashed.

III — Chimeric figures

In this last series of tests, composite right-left chimeric stimuli were presented centrally in the patient's visual fields (Levy, Trevarthen and Sperry 1972): (a) 16 pictures of asymmetrical objects; (b) 24 pictures of symmetrical objects; (c) 24 letters; (d) 24 pictures of objects belonging to the same

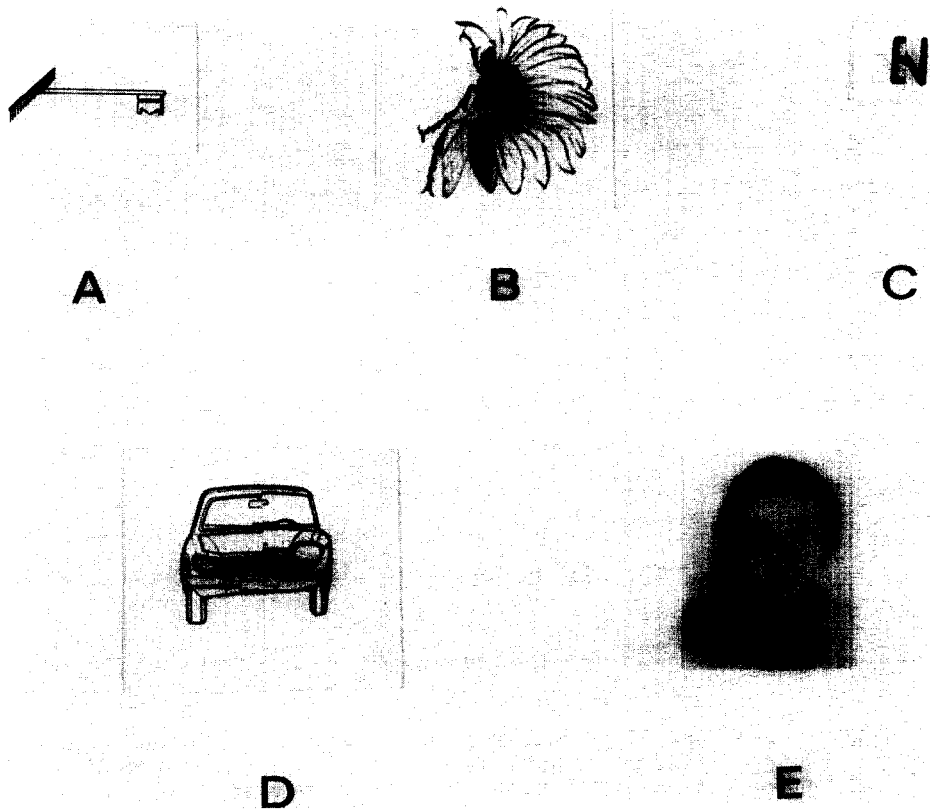


Fig. 5. Examples of chimeric stimuli used in the experiment. *A*: asymmetrical objects; *B*: symmetrical objects; *C*: letters; *D*: cars; *E*: faces.

category; cars were chosen to correlate with the findings of a previous study (Lhermitte, Chain, Escourrolle, Ducarne and Pillon 1972); and (e) 40 faces (Fig. 5). The right-left pattern chimeras were joined at the midline and projected on each side of the fixation point so that a different picture was presented in each hemifield. For each variety of stimulus, the patient was requested to respond initially by designation (left hand then right hand), and afterwards verbally (naming, or, for faces, description). For each test, the percentage of stimuli correctly recognized in the LVF (L) and the RVF (R) was recorded as well as the percentage of erroneous responses not corresponding to the two stimuli presented (E).

RESULTS

1— Findings of visual disconnection

Pictures of objects and letters (Table 1). Stimuli presented in the RVF were easily named. The only two errors concerned pictures which were slightly larger than the limits of the "seeing" visual field.

In 83% of cases, pictures of objects presented in the LVF could not be named correctly. The comments of the patient are interesting. She sometimes said: "I could not see . . . that goes to fast . . . I don't know . . ." or "I know I have recognized it but I can't remember the name of it" (17% of responses). Otherwise, she described the general form of the picture and eventually gave a name to it (49%). Thus, when presented with a comb, she said "that was a long object with teeth . . . it could be a rake" and, when presented with a car-key: "it is egg-shaped, with a tail, a kind of grater for cooking". On other occasions, her response had no relationship to the picture presented: a "food-mill" for a thimble (17%). Purely semantic associations between the response and the stimulus, as noted in some cases of visual agnosia (Lhermitte, Chedru and Chain 1973) and of optic aphasia (Lhermitte and Beauvois 1973), were not observed. In these tasks the patient was not told how many stimuli were to be presented but she was told whether the stimuli were going to be letters or pictures. When she was unaware of the nature of the stimulus, verbal responses were totally inaccurate; in particular, she was often unable to say whether she had been flashed a letter or a picture. When asked to point with either hand to the letter or to the picture which matched the stimulus, the patient promptly and correctly responded regardless of which homonymous field was stimulated.

Visuo-tactile matching (Table 2). On the "LVF/left-hand matchings", the scores were significantly better than chance level. During the task, the patient tended to verbalize the stimulus presented in her LVF, although she was asked not to speak. Quite often, the erroneous verbal identification did not prevent a correct matching. Thus, when presented the picture of an electric torch she said

TABLE 1
NAMING AND MULTIPLE CHOICE RECOGNITION OF PICTURES OF OBJECTS AND LETTERS

	Naming		Multiple choice				Chance level
	LVF	RVF	LVF		RVF		
			LH	RH	RH	LH	
Pictures of objects (24)	17%	92%	83% ^c	75% ^c	92%	92%	17%
Letters (24)	0%	100%	75% ^c	87% ^c	100%	96%	17%

The number of stimuli presented in each experimental condition is indicated in brackets. Scores are expressed as a percentage of correct responses. Each multiple choice score was compared to the chance level score by a χ^2 -test. Significance of the differences are schematized as follows: ^a $P < 0.05$; ^b $P < 0.02$; ^c $P < 0.01$.

For this table and the others, the following abbreviations were used: LVF: presentation in the left visual field; RVF: presentation in the right visual field; RH: pointing with the right hand; LH: pointing with the left hand; (RH) palpation with the right hand; (LH): palpation with the left hand; NS: not significant.

TABLE 2
VISUO-TACTILE MATCHING

	LVF		RVF		Chance level
	(RH)	(LH)	(RH)	(LH)	
Pictures of objects (24)	29%	62% ^c	100%	100%	33.3%
Letters (24)	35%	79% ^c	100%	100%	33.3%

See Table 1 for abbreviations and comments on statistical analysis.

TABLE 3
COMPREHENSION OF WRITTEN LANGUAGE

Multiple choice sets	LVF	RVF	Chance level
Pictures (72)	41% ^c	100%	17%
Words in cursive script (96)	33% ^c	100%	17%
Palpation of objects (12)	92% ^c	100%	33.3%

See Table 1 for abbreviations and comments on statistical analysis.

“it is a kind of double comb standing up”; a moment later, after palpating the 3 objects, she picked up without hesitation the electric torch and added “that’s it . . . it’s a comb”. Scores for the “LVF/right-hand matching” tests were not better than chance. When the stimuli were presented in the RVF, the patient could identify, by palpation with either hand, the corresponding object or wooden letter.

II — Perceptual capacities of each hemisphere

Comprehension of written language (Table 3). As expected, words projected in the RVF were correctly read aloud and matched with their corresponding images (or words in cursive script). When projected in the LVF, no stimulus words could be read aloud. By contrast, the scores obtained on the matching tasks were much better than chance. The rate of correct identification was higher for short words (3 letters) than for longer words. When asked prior to matching to say what she saw, the patient answered ‘I don’t know . . . that went too fast . . .’. On the other hand, after matching, she was sure she had previously been shown a *picture* and *not a word*.

TABLE 4
VISUO-SPATIAL TESTS

	LVF	RVF	Chance level	LVF/RVF comparisons (χ^2)
Test A (24)	67% ^c	30%	17%	^c
Test B (24)	46% ^c	37% ^b	17%	NS
Test C (24)	67% ^c	17%	17%	^c
Test D (24)	50% ^c	50% ^c	17%	NS
Test E (24)	57% ^c	27%	17%	^a

See Table 1 for abbreviations and comments on statistical analysis.

Matching a written word with a palpated object was possible provided the 2 stimuli were presented to the same hemisphere.

Visuo-spatial matching tests (Table 4). In tests B and D both hemispheres performed similarly. In tests A, C and E, the right hemisphere (i.e. the LVF) performed significantly better.

III — Chimeric stimuli

The patient was not surprised or uneasy when confronted with chimeric images. On the other hand, she did not realize that she was presented two different stimuli simultaneously. In these respects, she differed from normal subjects and behaved like the 4 split-brain patients studied by Levy et al. (1972).

The data pertaining to this part of the study are summarized in Fig. 6. When the response was verbal (naming or description), the RVF was clearly privileged whatever the type of the stimulus. When the response was non-verbal (designation): (a) the RVF remained markedly privileged in case of objects or letters; (b) the LVF was privileged in case of faces; (c) in case of cars, both visual fields were equivalent.

Of note was the large number of "E" responses, i.e. of responses leading to the designation of an item not belonging to the chimeric stimulus. In this respect, our patient appeared to differ from the split-brain subjects. Such a difference might be accounted for by the choice of stimuli: (a) the faces used could not be recognized by the presence or absence of a beard, a moustache or glasses; (b) half-cars and half-letters are difficult to identify on a tachistoscopic presentation even for normal subjects.

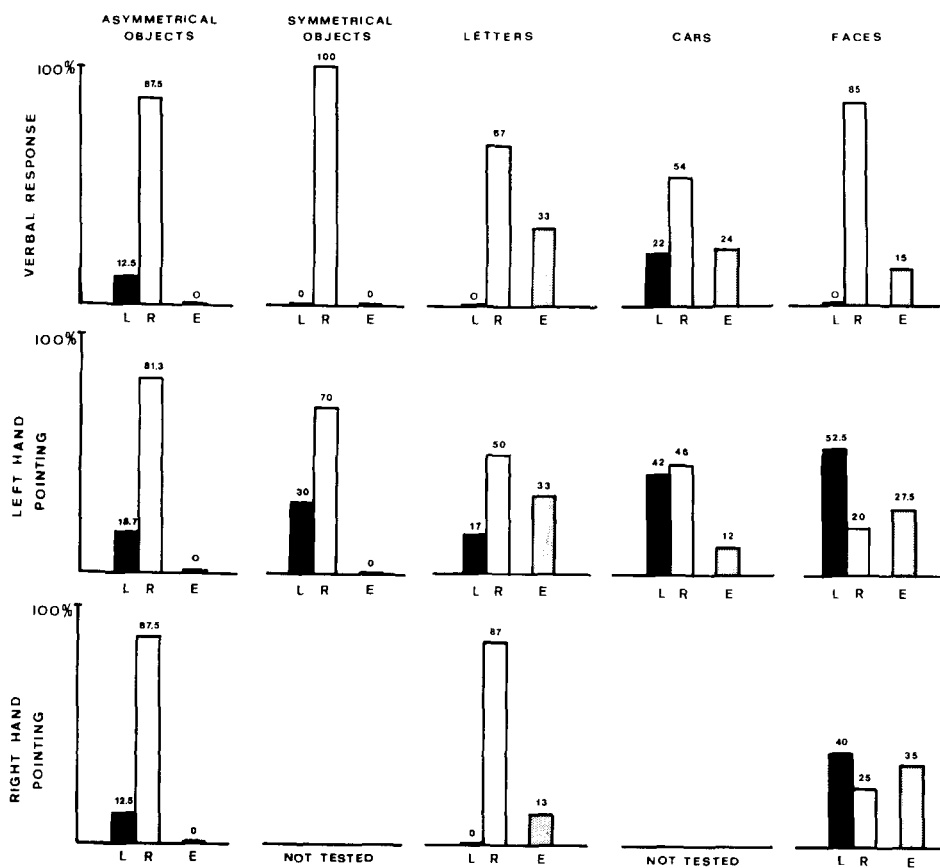


Fig. 6. Results of the tests with chimeric figures.

DISCUSSION

The existence of an agraphia and of a tactile anomia on the left side makes the present case similar to surgical and non-surgical cases of interhemispheric disconnexion (Geschwind and Kaplan 1962; Sperry et al. 1969; Schott, Michel and Dumas 1969; Brion and Jedynak 1972). The visual disorder also corresponds to cases of callosal sectioning, either limited to the splenium (Trescher and Ford 1937; Maspes 1948; Gazzaniga and Freedman 1973; Iwata, Sugishita, Toyokura, Yamada and Yoshioka 1974), or total division (Gazzaniga, Bogen and Sperry 1965). One could argue that the left visual field failed to recognize stimuli because of left field constriction and amblyopia. In fact, stimuli were flashed within the limits of the "seeing" visual fields as determined by perimetry. On the other hand, thresholds for flickering light were higher in the left than in the right visual field. Finally, recognition of highly contrasted letters (black block letters on a white background) was worse than that of lowly contrasted photographs of objects, a finding hardly consistent with an amblyopia but consistent with the hypothesis of disconnexion (*vide infra*). As for the failure of the right hand to recognize stimuli presented to the left visual field, it cannot be accounted for by sensory loss, since objects palpated by this hand could be normally named.

Interhemispheric disconnexion thus appears to be the most reasonable explanation for the patient's inability to name stimuli presented in her left visual field in spite of their recognition as determined by correct matching to corresponding pictures or objects. In this respect, a comment by the patient is of interest: "I know that I have recognized it but I can't remember the name of it".

Considering the clinical data and the initial brain-scan, it is probable that there were bilateral posterior ischaemic lesions involving commissural fibres at the level of the splenium and/or adjacent white matter. The lesions certainly extended rostral to the splenium since there were signs of sensory and motor disconnexion. The lesions did not lead, however, to a complete disconnexion since, as opposed to split-brain patients, some pictures presented in the left visual field could be described and occasionally named. Of note was the absence of a single correct oral response when written verbal material was projected. Such a dissociation between words and objects recalls cases of splenial section where, in spite of alexia in the left homonymous visual field, pictures were named correctly (Maspes 1948; Iwata et al. 1974). We may suppose that callosal transmission of information connected to written symbols requires a "coding" which is more accurate, less redundant and therefore more fragile, than that related to objects. Another feature indicating that the disconnexion was not complete was the patient's capacity to retrieve with her right hemisphere stimuli presented to her left hemisphere. Thus, by feeling a set of objects with her left hand, she was able to indicate the one which corresponded either to the picture previously projected in her right visual field, or to the object palpated by her right hand (Barbizet et al. 1974). On the other hand when the stimulus was presented to the right hemisphere and the multiple choice set was presented to the left hemisphere, matching was not possible. One can assume that, when presented a stimulus,

the left hemisphere informed the right hemisphere through (silent) verbalization; in the reverse condition (stimulus presented to the right hemisphere, multiple choice made by the left hemisphere) disturbing effects of incoherent (silent) verbalization would have prevented the same mechanism from occurring.

Control of the upper limbs. In matching tests, the patient performed correctly with either hand whichever visual field had been stimulated. Gazzaniga et al. (1965) have suggested that the proximal musculature of the upper limbs, which is involved in pointing movements, is controlled by the ipsilateral hemisphere almost as much as by the contralateral hemisphere. Another, and more likely explanation (Trevarthen 1974) is that the patient seeks the stimulus among a set of pictures with her maculae, i.e. with both hemispheres at the same time. The hemisphere "stimulated" by the tachistoscopic flash would then localize the picture and fix the gaze when a choice is made. Thereafter, either hand would be able to perform the pointing since both hemispheres would be aware of the choice.

Visuo-tactile matching. As anticipated from split-brain studies, the patient was able to match tactile to visual stimuli solely with the right hemisphere. These cross-modal matchings suggest that the right hemisphere, without verbal mediation, is able to elaborate "concepts", at least concepts of familiar objects. We will refer again to the significance of this fact and its relevance to the problem of the relationship between language and thought.

Comprehension of written language by the right hemisphere. Written words were "understood" by the right hemisphere: when words were flashed in the LVF, the patient retrieved, on visual or tactile multiple choice, the corresponding item at a frequency greater than chance. These performances cannot be explained by a partial disconnexion for, if linguistic information had reached the left hemisphere, it could have been at least partially expressed, something which did not occur in the patient. Similar observations have been made in split-brain patients (Gazzaniga and Sperry 1967) but their significance has been controversial: in view of the epileptogenic lesions in their cases, a reorganization of brain function might have occurred. In this respect our case provides evidence that, in an adult without previous neurological damage, the right hemisphere, although unable to formulate words, can understand some written language. This fact could account for the "paradoxical" performances of certain pure alexic patients, e.g., the patient of Albert, Yamadori, Gardner and Howes (1973) who, though unable to "read" could nevertheless group words according to their meanings and indicate a neologism in a series of English words. In such cases, the remnants of written comprehension may be performed by a right hemisphere which — because of the left lesion — receives and processes all the visual information.

Visuo-spatial tests. The right hemisphere appears equal or superior to the left one in the appreciation of the relative position of various visual patterns and in the recognition of meaningless shapes. These findings correspond to those of split-brain studies (Sperry et al. 1969; Nebes 1972), and fit with the now classical notion of minor hemisphere dominance for visuo-spatial performance (Milner 1971).

The results of the test of number comprehension (test E) deserve further comment. It has already been stated that in this test the left hemisphere was unresponsive

while the right hemisphere performed at a level very significantly superior to chance. While it appears surprising that the right hemisphere, though unable to verbalize, could perceive the equivalence of 2 series of dots having in common only their number, studies in experimental psychology have demonstrated that a normal individual can grasp immediately a small number of elements (less than 10) without verbal enumeration (Woodworth 1949). It is probably through such a direct "comprehension" that the task is performed by the right hemisphere. As for the inferiority of the left hemisphere in this regard, it is in agreement with that of normal subjects (Kimura 1966). It is suggested that, in normal subjects the immediate comprehension of numbers is performed by the right hemisphere, while other modes of number perception, requiring the intervention of language, are performed by the left hemisphere acting in cooperation with the right one. Whatever their significance in relation to normal performance, our data indicate that the right hemisphere is able to carry out complex intellectual operations without language mediation. Some animals comprehend numbers in a manner similar to that of the right hemisphere of our patient: "we are here so close to man that this ability (number comprehension) is shown by animals and man provided the stimuli be not verbally enumerated. In such situations, human performances are not better than performances of birds . . . It is putting thought into words that makes the difference (between man and animals) and not thought by itself . . ." (Chauvin 1969).

Chimeric figures. When chimeric figures are flashed to split-brain patients, the verbal response always corresponds to what appears in the right visual field while the non-verbal response (designation) generally corresponds to what appears in the left visual field (Levy et al. 1972). This does not depend on the nature of the chimeric figure. In the present case, the verbal response also corresponded to what appeared in the right visual field. However, the non-verbal response was not as expected; when the stimulus consisted of letters or pictures the right visual field was privileged, while when it consisted of faces, there was a predominance of the left visual field. This dissociation conforms to what is known of the role played by each hemisphere in visual recognition (Tzavaras, Hécaen and Le Bras 1970; Rizzolati, Ulmita and Berlucchi 1971). This difference in performance between our patient and the split-brain cases may, however, be due to the fact that our patient tended to verbalize everything presented to the right visual field. In fact, the right visual field was privileged with easily verbalized stimuli (letters and simple pictures of objects), while it was not with stimuli difficult to name or describe (faces or cars). This interpretation is supported by the following observation. When chimeric symmetrical objects were flashed to the patient for the initial 6 times, the patient pointed without saying anything to those pictures corresponding to the left field; it was only on the seventh trial that, while naming correctly the right-field picture, she hesitatingly pointed to both "right" and "left" pictures. Thereafter, she systematically pointed to the right-field pictures. Conceivably at a certain stage, the choice was facilitated by verbalizing the picture flashed, biasing performance to the right-half field.

In the present case, as in those of split-brain patients, the right hemisphere

was shown to be capable of processing complex nonverbal intellectual tasks, such as retrieving, by palpation, an object similar to another object visually perceived, matching a written word to a picture, pairing patterns of dots having in common only their number. It might seem astonishing that a "language-deprived" hemisphere could perform such tasks, since we are accustomed to think of language as a prerequisite for intellectual processes. In fact, studies of infants and children, of deaf-mute children, of aphasics and of animals have clearly demonstrated that high level intellectual activity (i.e., "thinking", "reasoning") may be present without, or with limited, language intervention. The data obtained in disconnexion patients are further evidence of this ability. The intellectual abilities of the right hemisphere appear to be different from those of the left. Experimental and clinical evidence suggests that the right hemisphere plays a role in tasks requiring holistic or immediate comprehension while the left hemisphere is concerned with serial analysis and language-bound activity. From an ontogenetic view-point one may speculate that, at birth, the potentialities of both hemispheres are equivalent. In the course of childhood, under the influences of genetically-induced cerebral dominance and of environment, language mechanisms of right-handed subjects develop in the left hemisphere. This leads one to ask whether the powerful urge for the acquisition of language does not result, in the left hemisphere, in a trend to process every piece of information in terms of language. On the other hand, the right hemisphere, being hardly involved in language activities, becomes able to develop and, later, to use other functional activities, more particularly those which are responsible, to a large extent, for visual processes giving rise to cognitive activities at a very elaborate level.

Whatever conclusions can be drawn from such hypotheses, interhemispheric disconnexion yields evidence that high level intellectual operations can take place without the support of language.

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