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The Recognition of Simple and Complex Realistic Figures in Patients with Unilateral Brain Lesion*

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Summary. Forty-one patients with unilateral retro-rolandic brain lesion were examined by means of three experimental tests requiring the recognition of complex realistic figures. In addition, all patients were given two tests for the recognition of common objects and simple realistic line drawings. A set of control variables included tests for elementary visual functions, non-verbal intelligence and aphasia. Furtheron, the influence of side and hemispheric locus as well as severity of brain lesion was examined.

By analyses of variance the following results were obtained: Aphasia did not play a significant role for test performance. In two of the experimental tests, the Street Test and the Hooper Test, the sub-group with right hemispheric lesion and visual field defect (VFD) was particularly impaired. It could be demonstrated, however, that this finding cannot be explained by VFD as a defect in visual function. Rather, the presence of VFD indicates a particular localization of brain lesion which is critical for the visuocognitive performances tested. For the Poppelreuter Test a significant hemispheric difference was found, right brain damaged patients performing poorer. The recognition of simple objects yielded no "agnosic" errors.

Key words: Pattern Recognition — Realistic Figures — Visual Object Agnosia — Unilateral Brain Lesion.

Zusammenfassung. 41 Patienten mit einseitiger retro-rolandischer Hirnschädigung wurden mit drei experimentellen Tests zur Prüfung des Erkennens komplexer realistischer Figuren untersucht. Außerdem wurde mit zwei Tests das Erkennen von gebräuchlichen Objekten und von einfachen realistischen Abbildungen geprüft. Als Kontrollvariablen dienten elementare visuelle Funktionen, nichtverbale Intelligenz und Aphasie. Außerdem wurde geprüft, ob die Seite der Läsion, der intrahemisphärische Ort und die Schwere der Hirnschädigung einen Einfluß auf die Testleistungen haben.

Varianzanalysen führten zu den folgenden Ergebnissen: Aphasie war nicht von entscheidender Bedeutung. In zwei der experimentellen Tests, dem Street Test und dem Hooper Test, hatten Patienten mit rechtsseitigen Hemisphärenläsionen mit Gesichtsfelddefekt die schlechtesten Leistungen. Der Gesichtsfeldausfall war dabei jedoch nicht als Beeinträchtigung der elementaren visuellen Leistungen wirksam. Es liegt vielmehr die Annahme nahe, daß der Gesichtsfelddefekt bei den rechts hirngeschädigten Patienten eine bestimmte Lokalisation anzeigt, die für

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die geprüften Testleistungen kritisch ist. Im Poppelreuter-Test waren generell die rechts hirngeschädigten Patienten am stärksten beeinträchtigt. Beim Erkennen einfacher Objekte und Abbildungen kamen keine „agnostischen" Fehler vor.

Schlüsselwörter: Bilderkennen — Realistische Figuren — Optische Agnosie — Einseitige Hemisphärenläsionen.

Introduction

In the study of higher visual functions most authors have abandoned the search for the global syndrome originally described as visual object agnosia (Lissauer, 1890). There are two reasons for this shift in interest: pertinent cases are extremely rare and the classical concept of visual agnosia in itself has become highly questionable (Critchley, 1964; Bender and Feldman, 1972). Obviously, the classical syndrome of visual agnosia is not unitary in nature. Bay (1950), for example, has stressed the role of elementary visual defects. Geschwind (1965) has pointed out that many of the disturbances assumed to be agnosic are in fact naming disorders which can probably be referred to disconnexion of the visual cortex from somesthetic and other association cortices and from the language area.

Objections of this kind are relevant at least for *marked* disturbances of visual cognition. There is reason, however, to assume that impairment in visual cognition can be found in various grades of severity. Therefore, recent studies have concentrated on visual performances which can be studied in large samples of brain-damaged patients by tests of graded complexity.

These studies, however, have not brought about a generally accepted view on the conditions leading to impaired performance in these tests. In the present study, comparable groups of patients with unilateral circumscribed brain lesions were examined by means of simple and complicated tasks for visual recognition of realistic figures. The aim was to assess the eventual influence of disturbance in elementary visual functions, severity of brain lesion, aphasia, side and hemispheric locus of lesion.

Subjects

This investigation is based on a series of 41 consecutive patients between 21 and 65 years of age having unequivocal unilateral brain damage restricted to the posterior hemispheric region, i.e. temporal, parietal or occipital lesions. The diagnosis of unilateral brain damage was assessed by neurological findings and the results of complementary examinations such as EEG, pneumo-encephalography, cerebral angiography and brain scan. As a rule, three different signs indicating a lesion of one hemisphere were required. Neuropsychological disturbances (e.g. aphasia) were intentionally not used for localization in order to avoid a bias towards one or the other hemisphere. The group consisted of 24 men and 17 women with a mean age of 48.5 years (s = 12.0 yrs).

We excluded subjects not sufficiently testable, e.g. bedridden, presenting with clouded consciousness or suffering from very severe aphasia. We also excluded patients with severe general intellectual deficit, i.e. having either a Verbal- or a Performance-Wechsler-IQ below 70. This alternative criterion was chosen to avoid a bias in favour of right- or left-sided brain damage, respectively. All subjects were tested for binocular visual acuity by means of a reliable screening instrument (Ortho-Rater). Patients with a score corresponding to a Snellen rating of 20/50 or less for far or near vision were excluded.

The patients were subdivided into two groups, one with parieto-temporal and one with occipital lesions, respectively. Some of the patients in the occipital group had lesions extending somewhat into the parietal and/or temporal region. The left hemispheric group consisted of 13 parieto-temporal (PT) and 7 occipital (O) cases, the right hemispheric group of 12 PT- and 9 O-patients.

The etiology of the brain lesion was vascular in 28 cases, neoplastic in 9 and traumatic in 3 cases. In one patient the etiology remained uncertain. About half of the subjects had their first symptoms only 1—3 weeks prior to admission. Among the left-sided group there were 11 patients suffering from aphasia, 7 patients presenting with marked language disturbances.

Methods

1. Poppelreuter's Overlapping Figures. This test requires the recognition of line drawings of common objects. On each of the 12 test cards there are 3, 4 or 5 overlapping objects. These were series of line drawings, standardized from Poppelreuter's (1917) original figure by Jung and Bender in 1943/44 (unpublished). An example is shown in Fig. 1. The subject was required only to give the number of the objects, which varied in a predetermined random order. The correct answer was expected within 20 sec, spontaneous corrections within this time limit were accepted. The score was the number of correct answers, the maximal total score being 12.

2. Street's Figure Completion Test (Street, 1931). This test consists of a series of 12 incomplete figures which the subject has to identify (Fig. 2). The pictures were projected tachistoscopically from the rear upon a translucent screen. Each item

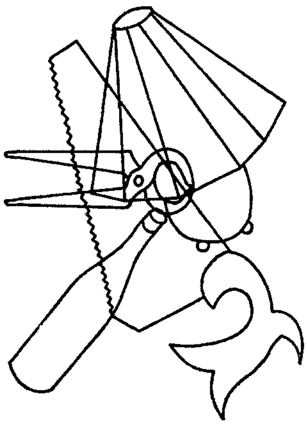

Fig. 1. Example from Poppelreuter's overlapping figures test

Fig. 2. Example from Street's figure completion test

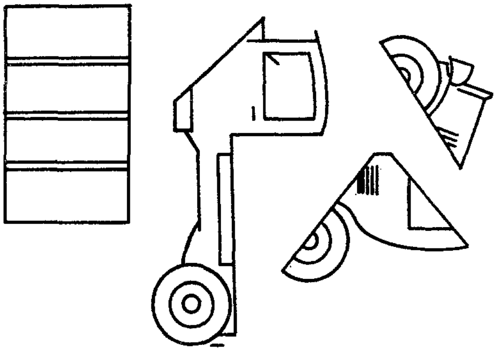

Fig. 3. Example from Hooper's visual organization test

was presented a maximum of 5 times with increasing length so that in case of total failure 60 presentations were given. Details of testing procedure are described elsewhere (Orgass *et al.*, 1972).

The score was defined as 60 minus the number of presentations necessary for recognition. No time limit was set for answering, appropriate descriptions instead of the name were accepted.

3. *Hooper's Visual Organization Test* (Hooper, 1958). This test presents the subject with drawings of simple objects, which in puzzle-like fashion are cut into several parts. For each item, these parts are printed on a single card in an apparently random arrangement (Fig. 3). The subject had to give the correct name of the objects recognized. No descriptions or circumlocutory answers were accepted. The test consisted of 30 items, given without time limit.

Several variables which could be assumed to influence performance in our experimental tests, i.e. elementary visual performances and overall intellectual level, were controlled:

1. Visual fields were examined by means of a tangent screen under standard conditions.
2. Binocular visual acuity for far and near vision was tested with the Master Ortho-Rater (Bausch and Lomb, Incorp.). Subjects usually wearing glasses were examined with their glasses in the corresponding acuity test; care was taken that these subjects also used their glasses during the experimental tests.
3. Tachistoscopic discrimination of two simple figures (cross and star) was used to determine the threshold for rapid visual discrimination. The test was given with decreasing presentation times from 10 msec to 2 msec. The score represented the minimal time necessary for correct recognition of at least 8 out of 10 items.
4. Simple Visual Reaction Time was determined by the method of "release reaction time" with variable foreperiod. Only the score for the hand ipsilateral to the brain lesion was taken into consideration. The total score consisted of the median for 48 reaction times for this hand.
5. The German version (HAWIE) of the Wechsler-Bellevue Adult Intelligence Scale was given in order to control for level of general intelligence.

For details of procedure see Orgass *et al.* (1972).

For statistical evaluation of the data mainly two-way analyses of variance for fixed effects were applied. Least-squares solutions were chosen in order to avoid an undue influence of unequal cell frequencies on the results (Winer, 1962). Normality of distributions and homogeneity of variances were checked by the Kolmogorov-Smirnov Test and Hartley's F_{max} Test respectively.

Results

All three tests called for verbal answers, although with different degrees of precision. Therefore, the influence of aphasia had to be checked first. We examined the effects of aphasia and localization within the left hemisphere by means of a two-way analysis of variance (Table 1). This analysis yielded neither significant main effects nor interaction effects for any of the three tests.

The next problem was to study the influence of hemispheric side and intrahemispheric locus of lesion on performance in the experimental tests (Table 2). There was only one significant result, a main effect due to hemispheric side of lesion in Poppelreuter's Test. Patients with right-sided brain damage performed worse than left brain-damaged patients.

A third analysis concerned the eventual influence of visual field defect within each hemispheric group (Table 3). In Poppelreuter's Test, in addition to the main effect for hemispheric side of lesion the main effect due to visual field defect (VFD) approaches the 5% level of significance ($F_{0.05} = 4.08$); patients with VFD tended to score lower. In the two other tests no significant main effect was observed. For both tests, however, a significant interaction was found. The nature of the interaction effects was analysed further by Scheffé's Test for multiple comparisons. For both, the Street Test and the Hooper Test, it was found that the means for left brain-damaged patients with and without VFD did not differ significantly from each other, nor from the mean of the right brain-damaged patients without VFD. It was only the sub-group of right brain-damaged patients with VFD which had significantly lower

Table 1. Analysis of variance: aphasia × localization ($N = 20$)

a) Cell frequencies and mean scores

	Number of Ss.		Mean scores					
			Poppelreuter		Street Test		Hooper Test	
	PT	O	PT	O	PT	O	PT	O
Aphas. −	5	4	10.00	10.00	32.60	38.25	20.40	22.75
Aphas. +	8	3	10.12	8.33	30.12	28.00	17.62	20.67

b) Analysis of variance summary

		Poppelreuter		Street Test		Hooper Test	
Source	d.f.	M.S.	F	M.S.	F	M.S.	F
Aphasia	1	1.28	0.54	132.40	1.26	30.61	1.80
Localization	1	3.47	1.48	14.24	0.14	31.93	1.87
Interaction	1	3.53	1.51	66.65	0.64	0.53	0.03
Error	16	2.35		104.68		17.03	

Table 2. Analysis of variance: hemisphere × localization ($N = 41$)

a) Cell frequencies and mean scores

	Number of Ss.		Mean scores					
			Poppelreuter		Street Test		Hooper Test	
	PT	O	PT	O	PT	O	PT	O
Left H.	13	7	10.08	9.29	31.08	33.86	18.69	21.86
Right H.	12	9	8.25	7.00	30.67	23.56	18.50	16.44

b) Analysis of variance summary

		Poppelreuter		Street Test		Hooper Test	
Source	d.f.	M.S.	F	M.S.	F	M.S.	F
Hemisphere	1	40.89	10.18**	182.71	1.80	49.80	1.84
Localization	1	10.38	2.58	59.04	0.58	1.51	0.06
Interaction	1	0.51	0.13	236.20	2.32	65.79	2.44
Error	37	4.02		101.64		27.00	

** $p \leq 0.01$.

Table 3. Analysis of variance: hemisphere × visual field defect ($N = 41$)
a) Cell frequencies and mean scores

	Number of Ss.		Mean scores					
			Poppelreuter		Street Test		Hooper Test	
	VFD−	VFD+	VFD−	VFD+	VFD−	VFD+	VFD−	VFD+
Left H.	16	4	9.94	9.25	30.19	39.50	18.69	24.25
Right H.	11	10	8.55	6.80	32.64	22.10	19.27	15.80

b) Analysis of variance summary

Source	d.f.	Poppelreuter		Street Test		Hooper Test	
		M.S.	F	M.S.	F	M.S.	F
Hemisphere	1	27.56	7.18*	121.51	1.41	44.08	1.80
V.F.D.	1	15.25	3.97	76.40	0.88	0.02	0.00
Interaction	1	2.22	0.58	782.61	9.06**	162.16	6.64*
Error	37	3.84		86.40		24.43	

** $p \leq 0.01$; * $p \leq 0.05$.

scores than all other sub-groups. The corresponding values of F' were 11.52 for the Street Test and 8.89 for the Hooper Test, both of which were significant at the 0.05 level.

The same kind of analyses of variance were computed for the control variables. With the exception of the Performance IQ no significant effects were found. The Performance IQ yielded a significant interaction between hemispheric side of lesion and VFD. By multiple comparisons it was found to be of the same type as for the Street Test and for the Hooper Test, i.e. right-sided patients with VFD showing the poorest performances (F' = 11.61), whereas all other sub-groups did not differ significantly from each other.

The observation that the sub-group with right-sided lesion plus VFD was impaired most severely in two of the experimental tests and also in the Performance IQ necessitated to check the possibility that performance might be affected by the severity of brain lesion. Based on the available neurological data, severity was rated in 3 classes. Of the right brain-damaged patients 6 were given grade I (mild) and 8 grade III (severe). Patients with and without VFD were represented with equal frequency in both groups. These two groups were then compared for performance in the experimental tests as well as for Performance IQ by means of the Mann-Whitney U Test. For the three experimental tests, U varied between 17 ($p = 0.21$) and 21 ($p = 0.38$). For the Performance IQ the value of U was 23.5 ($p = 0.45$). Conse-

Table 4. Spearman rank correlation (r_s) of the variables

		Left H. $n = 20$	RH, VFD– $n = 11$	RH, VFD+ $n = 10$
a) Correlation of control variables with the experimental tets				
Age	× Poppelreuter	– 0.08	– 0.28	– 0.09
	× Street Test	– 0.46*	– 0.40	– 0.33
	× Hooper Test	– 0.50*	– 0.35	– 0.34
Verbal IQ	× Poppelreuter	0.11	0.09	0.02
	× Street Test	0.14	0.30	– 0.09
	× Hooper Test	0.41*	0.17	– 0.10
Performance IQ	× Poppelreuter	0.28	0.42	0.89**
	× Street Test	0.30	0.38	0.80**
	× Hooper Test	0.67**	0.54*	0.74**
Visual Acuity [a]	× Poppelreuter	0.31	0.27	0.15
	× Street Test	0.23	0.43	0.37
	× Hooper Test	– 0.06	0.32	0.30
Tach. Figure Discrimination	× Poppelreuter	– 0.41*	– 0.24	– 0.27
	× Street Test	– 0.32	– 0.20	– 0.45
	× Hooper Test	– 0.31	– 0.28	– 0.50
Vis. Reaction Time	× Poppelreuter	0.03	– 0.50	– 0.48
	× Street Test	0.15	– 0.18	– 0.59*
	× Hooper Test	0.01	– 0.32	– 0.55
b) Intercorrelation of the experimental tests				
Poppelreuter	× Street Test	0.40*	0.84**	0.74**
Poppelreuter	× Hooper Test	0.09	0.81**	0.70*
Street test	× Hooper Test	0.52*	0.73**	0.97**

** $p \leq 0.01$; * $p \leq 0.05$.
[a] Street test: far acuity, other tests: near acuity.

quently, impairment in test performance could not be attributed to severity of brain lesion. Analyses of variance for the other control variables yielded no significant effects.

Finally, we analysed the correlations between the experimental tests and the control variables as well as the intercorrelations between the experimental tests (Table 4). Age, Visual Acuity, Tachistoscopic Figure Discrimination and Visual Reaction Time were not correlated systematically with the three experimental tests. Also, there was no significant correlation with the Verbal IQ, with the exception of a moderate correlation between Verbal IQ and the Hooper Test. For the Performance IQ we obtained different results in the three sub-groups: In patients with right-sided lesions and VFD all three experimental tests were highly correlated to Performance IQ. In the right-sided sub-group without VFD and in the left hemispheric group only Hooper's Test was significantly related to the Performance IQ. The intercorrelations of the experimental tests were highly significant for both right hemispheric sub-groups. In contrast, correlations within the left hemispheric group were moderate or absent.

Discussion

The common feature of the three experimental tests is that they require the recognition of realistic drawings under complicated perceptual conditions. All of the tests seem to call for some process of verbalization, at least implicit in the Poppelreuter Test (where the patient has to give the number of objects represented), explicit in the Street Test (where he has to name or to describe the object presented) and in Hooper's Test (where the exact name is required).

Therefore, it was necessary to consider whether aphasics were particularly impaired in these tests. Moreover, it seemed advisable to check the correlation with the Verbal IQ. We did not find a significant influence of aphasia on test performances. For the Verbal IQ, there was only one significant, if moderate, correlation which concerned the Hooper Test. The latter finding is explained by the high degree of verbal precision required in the Hooper Test. The generally negative results indicate that verbal processes, although implied in the solution, do not play a decisive role in failure in the experimental tasks.

The fact that recognition of the stimulus pictures involved decoding and processing of complex visual information suggested, on the other hand, the examination of the possible influence of hemispheric side and intrahemispheric locus of lesion. The pertinent analysis of variance yielded only one significant result, a main effect due to side of lesion for the Poppelreuter Test. In this test right brain-damaged patients had poorer performances than left-sided cases.

This finding is in agreement with the results of other investigators. De Renzi and Spinnler (1966) and De Renzi *et al.* (1969) found for the Poppelreuter Test a significant difference between right and left hemispheric groups. Hécaen and Angelergues (1963), in their comprehensive study, did not, however, find a consistent relationship between failure in the Poppelreuter Test and left-sided, right-sided, or bilateral locus of lesion.

For the Street Test and the Hooper Test we did not find a hemispheric difference. With regard to the Hooper Test there are no pertinent reports in the literature. However, our negative result concerning the Street Test is clearly at variance with the findings of other authors.

De Renzi and Spinnler (1966) observed a significant hemispheric difference, right brain-damaged patients having poorer performances. Warrington and James (1967) reported the same hemispheric difference for two similar tests. In both tests they found the sub-group with right parietal lesions most impaired. However, in a subsequent study which involved only one of the tests (Gollin Figures; Gollin, 1960) these findings could not be confirmed (Warrington and Rabin, 1970). Lansdell (1968) observed hemispheric differences in patients with temporal lobe ablations on a comparable test, the Mooney Test (Mooney, 1957) and hypothetically attributed performance in this test to the right temporo-parietal area. Newcombe (1969), also using Mooney's Test, found significantly inferior performance of right brain damaged patients, but did not find any critical intrahemispheric locus of lesion.

The discrepancy of our results and those reported in the literature was striking, particularly because all of our patients had retro-rolandic lesions. Therefore, we did a further analysis of variance subdividing our hemispheric groups in sub-groups with and without VFD. We now obtained significant results for each of the three tests: For the Poppelreuter Test the main effect due to hemispheric side of lesion persisted. For the Street Test and for Hooper's Test significant interaction between side of lesion and VFD was found. Whereas in the Poppelreuter Test both hemispheric sub-groups were impaired, in the other tests it was only the sub-group with right-sided brain damage plus VFD.

In the literature, the influence of VFD on performance in these tests has been examined only by a few authors. De Renzi and Spinnler (1966) applied both the Poppelreuter Test and the Street Test. They did not compare, however, patients with and without VFD for performance on each of the tests separately. Instead, they combined the scores of these two tests and of a recognition test for uncomplicated realistic figures into a total "agnosia score". For this score they compared patients with and without VFD, but did not consider hemispheric side of lesion. They found patients with VFD to be inferior to patients without VFD. This result is similar to our finding for the Poppelreuter Test where the main effect due to VFD approached significance. In another study with the Poppelreuter Test (De Renzi *et al.*, 1969), however, in which analysis of variance was applied and the influence of VFD was studied for both hemispheric groups separately, a significant interaction was found, due to very poor performance of the right brain damaged sub-group with VFD. Our result with the Poppelreuter Test is different, possibly because a different type of answer was required. In our version, the patient had to explore the overlapping figures and to give a verbal answer. De Renzi *et al.* presented the overlapping figures together with a multiple choice set of simple figures, which might have introduced a simple matching procedure.

For the Street Test there is only one comparable study. Newcombe (1969), in a supplementary analysis of her data, compared patients with right versus left retro-rolandic lesions, with and without VFD. She obtained neither a main effect of VFD nor an interaction between VFD and side of lesion. Again, a difference in procedure might account for our deviant result. In our study, the Street Test was given under strict speed conditions whereas Newcombe used a generous time limit of 30 sec per item.

For the Hooper Test, to our knowledge, no comparable study exists in the literature. Hooper's Visual Organization Test was introduced in this study, because it requires the recognition of objects under particularly difficult conditions. It is commonly used as a screening test for the identification of brain damaged patients. It has not been applied so far in studies especially investigating visuo-perceptive functions. Our result suggests that the Hooper Test, as a general screening test for brain damage, has a certain localizational bias. On the other hand, it is an interesting tool in the study of visual cognition.

The same result as for the Street Test and for Hooper's Test, right brain damaged patients with VFD being particularly impaired while all other sub-groups did not differ from each other, was also obtained for the Performance IQ. This coincidence could raise the question if these results can be explained by differences in severity of brain lesion. When severity of brain lesion in our sample was rated, however, it was found that this variable did not influence performance in the experimental tests or the Performance IQ, as demonstrated by non-significant results of Mann-Whitney's U Test. Moreover, there was no significant difference between right hemispheric patients with VFD and the remaining sub-groups in Visual Reaction Time which is considered as indicative of severity of brain damage by De Renzi and Faglioni (1964/65).

The outstanding position of the right hemispheric sub-group with VFD is emphasized by the especially high correlations between the three experimental tests and the Performance IQ for this sub-group. Only the Hooper Test was correlated to Performance IQ also in the remaining subgroups.

The latter finding is due, in our opinion, to the fact that the Hooper Test and the Wechsler subtests Block Design and Object Assembly call for a similar type of performance: In the first case, the subject has to imagine the composition of the whole design which requires the notion of the correct spatial relationship of the scattered fragments. In both Wechsler subtests the same ability is necessary to handle the test material successfully.

The inferior performance of patients with right-sided lesions plus VFD could be attributed neither to the loss of one visual halffield nor to poor visual acuity reduced by macular involvement: The presence of VFD did not decisively lower the performance of left brain damaged patients. Also, the degree of macular involvement was not significantly correlated to test performance. The same holds true for visual acuity and Tachistoscopic Figure Discrimination. Moreover, for these two control variables analyses of variance did not yield any significant result. It follows that the poor performance of right brain damaged patients with VFD cannot be explained by disturbance in elementary visual functions.

Consequently, the conclusion drawn in our previous study (Orgass *et al.*, 1972) that in right hemispheric patients VFD is indicative of a particular localization of lesion critical for impaired visual cognition is confirmed for the recognition of realistic figures under complicated perceptual conditions.

However, it is not justified to consider defective performance of certain brain damaged patients on these and similar tests as indicative of an agnosic disturbance in the classical sense. All our patients were given two additional tests, one requiring the recognition of 20 common objects, the other calling for the recognition of 20 realistic line drawings of objects. The task could be solved by naming, by any adequate circumlocution or by pantomimic indication of use. There were only 4 subjects among our sample of 41 who made any errors at all: Two aphasic patients were unable to identify in any way one object each; two patients of the right-sided sub-group with VFD made two errors each. We feel that these sporadic errors are negligible.

Therefore, it is evident that visual object agnosia in the traditional sense could not be demonstrated in our sample, not even in the sub-group most impaired in complex visuo-cognitive tasks. This is in accordance with the experience of Teuber *et al.* (1960), who examined patients with occipital gunshot wounds. Also, Bender and Feldman (1972) failed to disclose a single case of visual agnosia during 20 years of clinical experience. However, circumscribed lesions of a certain intrahemispheric localization result in more discrete disturbances of visual recognition, which can be demonstrated by adequate testing procedures, but are not evident in spontaneous behavior or routine clinical examination.

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