Brit. J. Psychiat. (1978), 132, 560–567

Depression and Hemispheric Functions: Changes Associated with Unilateral ECT

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SUMMARY **Nine depressed patients received ECT to the dominant (left) side along with nine matched depressed patients who received ECT to the non-dominant (right) side. Neuropsychological tests showed that the right hemispheric functions were more frequently abnormal as compared to left hemispheric (dominant) functions in the pre-ECT tests. ECTs delivered to either the right or left side improved right hemispheric functions when the depression was ameliorated. This study indicates that in depression right hemispheric functions are initially disturbed and ECT, instead of being deleterious to these functions, tends to improve them.**

Introduction

Unilateral electroconvulsive therapy to the non-dominant hemisphere (ND-ECT) has largely replaced the more conventional bilateral ECT for the treatment of depression. Compared with bilateral ECT, ND-ECT seems to cause less disruptive effects on verbal memory functions, with little or no change in antidepressant efficacy (d'Elia & Raotma, 1975; Levy, 1968l Bridder *et al*, 1970). Although verbal abilities may be spared by ND-ECT, some authors have suspected possible disruptive effects on non-verbal abilities, which are largely subserved by the non-dominant hemisphere. The issue, however, remains unsettled.

McAndrew *et al* (1967) were not able to find significant changes in performance on psychological tests of specific hemispheric functions following right-sided, left-sided and bilateral ECT. Their data, however, suggested a trend toward improvement on measures which bear a relationship to the proper functioning of the hemisphere stimulated. Annett *et al* (1974) administered tests of naming and visual discrimination before and after two ECT treatments to the left or right hemispheres. Whereas performance on naming tests was poorer after left-sided than after right-sided ECT, no systematic differences could be demonstrated for the visual discrimination tests. These data were similar to those obtained by Cronin *et al* (1970) following a series of six and eight ECTs. Berent *et al* (1975) administered Words and Forms before and after one ECT treatment to the right or left hemisphere, and showed a significant impairment on the Word Test following D-ECT, whereas a significant impairment on the Form Test followed ND-ECT. In a way, d'Elia *et al* (1976), using more elaborate psychological tests, reported that, whereas D-ECT had a more negative influence on verbal memory functions, ND-ECT had a more disruptive effect on complex non-verbal visual tests. Thus, the data are quite confusing and often contradictory. One possible source of confusion is the small number or lack of specificity of the psychological tests administered; another is the variation in the number of ECT treatments given.

We started this study with the view that the popularity of non-dominant or right-sided ECT might not be warranted if patients receiving such treatments were to suffer the consequence of disruption of cognitive functions subserved by the non-dominant hemisphere. In the present study we have attempted to evaluate the acute effects of a single ECT given to either one of the cerebral hemispheres and the cumulative effect of a series of eight ECTs on functions of each individual hemisphere. The psychological tests administered to the patients were specially

https://doi.org/10.1192/bjp.132.6.560 Published online by Cambridge University Press

chosen with relevance to the function of the single hemisphere and have been used in the past with a good degree of specificity in the assessment of organic brain deficit with lateralization to either one of the hemispheres. The unexpected finding was that some depressed patients initially performed badly on tests reflecting right hemisphere function and that the cumulative effects of ECT, which improved the depression, were also reflected in the improvement in performance on these tests.

Materials and Methods

1. Patients

The eighteen patients included in the study were all in-patients referred for ECT from the Psychiatric Hospital and the Veterans Administration Hospital in Iowa City. The decision in favour of ECT was made by both the resident and staff physician responsible for the patient. All patients included in the study were right-handed as assessed by an appropriate questionnaire (Benton *et al*, 1972; Varney and Benton, 1975), had no history of evidence of organic disease of the central nervous system and had signed a consent form to participate in the study. Selected patients were then randomly divided into two groups: one group receiving ECT to the dominant hemisphere (D-ECT), the other to the non-dominant hemisphere (ND-ECT). The descriptive characteristics of each group are summarized in Table I. As will be seen, the two groups are well-matched for age, sex, intellectual abilities, educational background and psychiatric diagnoses. The degree of depression in these patients was moderate to severe as assesed by clinical interview and the Zung Depression Scale (Zung, 1965).

TABLE I

Descriptive characteristics of the two groups

Variable	D-ECT	ND-ECT
Chronological age		
Mean	48.3	50.2
Standard deviation	17.8	18.5
Sex		
Male	6	6
Female	3	3
IQ*		
Mean	101.6	97.8
	11.2	16.7
Education†		
Mean	10.9	12.1
Standard deviation	2.6	2.3
Diagnosis		
Primary depression	8	8
Secondary depression	1	1
Number of patients	9	9

* Derived from Shipley-Hartford Scores (Paulson and Lin, 1970).
† Number of years in school.

2. General Procedure

All patients were tested on three different occasions: one day prior to the first ECT (pre-ECT), five hours following the first ECT (post-ECT #1) and five hours following the eighth ECT (post-ECT #8). On all three occasions, the following tests were given:

A. *Temporal Orientation (TO)*

(Benton *et al*, 1964, Levin & Benton, 1975): This is a simple test which consists of asking the patient to give the date (month, day of month, year, day of week) and the time of day. Performance is objectively scored and can be interpreted on the basis of emperical norms (Benton *et al*, 1964; Levin & Benton, 1975). Errors were subtracted from an arbitrary score of 10.

B. *Tests of Left Hemisphere Function*

1 *Digit Sequence Learning (DSL)* (Benton & Hamsher, 1976): This task consists of the presentation of a ten-digit number at a one-digit-per-second rate over a maximum of 12 trials. On each trial, the patient repeats what he can remember, with the goal of learning the entire number within a limit of 12 trials. The score is the number of correct repetitions. The test is particularly useful in assessing amnesic patients. (Drachman & Arbit, 1966) and memory impairment in the elderly (Drachman & Hughes, 1971). A different ten-digit number was used for each of the three testing sessions.

2 *Controlled Word Association (CWA)* (Benton & Hamsher, 1976): This subtest from the Multilingual Aphasia Examination (Benton, 1969) consists of presenting a letter and having the patient say all the words he can think of which begin with that letter within a one minute period. Three letters are used for each form of the test. This task has been shown to be a sensitive index of cerebral dysfunction (Borkowski *et al*, 1967), particularly disease of the left frontal lobe (Benton, 1968). One of the three alternative forms was used in each testing session. A score at or below the fourth percentile for hospital controls was considered defective.

3 *Sentence Repetition (SR)* (Benton & Hamsher, 1976): This subtest from the Multilingual Aphasia Examination consists of 14 sentences of increasing length which are read by the examiner for the patient

https://doi.org/10.1192/bjp.132.6.560 Published online by Cambridge University Press

to repeat. In the absence of an aphasic disorder this task is a measure of semantic short-term memory. One of three alternative forms of the test was used in each testing session. A score at or below the fourth percentile for hospital controls was considered defective.

4 *Token Test (TT)* (Benton & Hamsher, 1976): This substest from the Multilingual Aphasia Examination is a test of oral language comprehension. The test is a sensitive index of left-hemisphere brain damage even in the absence of a clinically evident dysphasia (DeRenzi & Vignolo, 1962; Boller & Vignolo, 1966). The test has two forms, which were given in an A-B-A order across the three testing sessions. A score at or below the third percentile for hospital controls was considered defective.

C. *Tests of Right Hemisphere Functioning:*

1 *Form Sequence Learning (FSL)* (Hamsher, 1975): This experimentaltaskwas devised as a non-verbal analogue to the DSL. The patient is shown six designs which appear as a row on a card. After a 20-second exposure a response card with 12 designs is shown and the stimulus card removed. The task is to point to the designs in the order they were presented. Twelve trials were allowed for learning this task. One of three alternative forms of the test (all designs being chosen from the same response-choice card) was used for each testing session.

2 *Judgement of Line Orientation (JLO)* (Benton *et al*, 1975): This test involves the matching of two stimulus lines with two lines having the same angle and direction in an 11-choice array. Defective performance on this task is associated with disease of the right hemisphere and appears to be little affected by brain disease in the left hemisphere, even in the presence of aphasia (Benton *et al*, 1975). Two alternative forms of the tests were given in an A-B/A order across the three testing sessions. A score at or below the third percentile for hospital controls was considered defective.

3 *Three-Dimensional Constructional Praxis-Photographic Stimuli (3DB)* (Benton, 1973): This task requires the patient to construct 3 three-dimensional block models from photographs. Performance on this test (Benton & Fogel, 1972; Benton & Ellis, 1970) has been shown to be related primarily to lesions of the right hemisphere (Benton, 1967; Benton, 1968), although patients with sensory aphasia associated with lesions in the left posterior temporo-patietal region may also show impairment on this task (Benton, 1973). The two alternative forms were presented in an A-B-A order across the three testing sessions. A score at or below the fourth percentile for hospital controls was considered defective.

4 *Facial Recognition Test (FRT),* Form SL (Benton *et al,* 1975): This task assesses the capacity to identify and discriminate photographs of unfamiliar faces. The original test (Benton & Van Allen, 1968) has been redeveloped to provide a shorter version (Levin *et al,* 1975) while preserving the original test (long form). Performance on this task is influenced primarily by lesions of the right hemisphere, although lesser impairment may be seen in some patients with ostensible left hemisphere lesions. The two forms of the test, short and long were administered in an A-B-A order across the three testing sessions. A score at or below the second percentile for hospital controls was considered defective.

D. *Self-Rating Depression Scale (SDS)* (Zung, 1965):

This scale was first devised by Zung for the quantitative assessment of depression (Zung, 1965). Subsequent studies have described its validity and reliability in the measurement of depression (Zung & Wonnacott, 1970; Zung, 1972). The SDS is comprised of a list of twenty items, each relating to a specific characteristic of depression. The patient is asked to check each item according to how it relates to him within a specified period. A score is then derived which reflects the severity of the depression.

The administration and interpretation of these tests were done on a double-blind basis, the psychologists handling the tests being unaware of the site of electrode placement.

3. ECT Procedure

All patients received 1.0 mg atropine I.M. 30 minutes before each treatment. Treatment medications included succinycholine (0.3–0.4 mg/kg body weight) for muscle relaxation and methohexital (dose titrated for each patient individually) to induce sleep, both given I.V. The electrodes were placed in the standard position on the designated hemisphere (the lower electrode placed midway between the lateral angle of the orbit and the external auditory meatus and one inch above this line, the upper electrode three inches higher and at an angle of 70° to the same line). When superficial narcosis and subtotal relaxation had been obtained, alternating current was delivered to the electrodes from a 396-C Electro-schock Unit set at a voltage of 160 volts for 0.6 seconds. A modified generalized convulsion was usually obtained. Oxygen was routinely administered following the seizure.

Results

1. *Left-sided ECT*

The mean score on each task in relation to ECT to the left hemisphere is presented in Table II. Following ECT #1, there was a decline on all

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TABLE II

Performance (mean score) on all tasks for patients receiving left-sided ECT

Test	Performance (mean score)		
	Pre-ECT	Post-ECT#1	Post-ECT#8
Temporal orientation	8.6	9.2	9.0
Tests of left-hemisphere functioning			
Digit sequence learning	2.3	1.0*	3.4
Token test	41.0	40.3	40.9
Controlled word association	37.9	37.0	30.6*
Sentence repetition	12.3	12.2	12.6
Tests of right-hemisphere functioning			
Form sequence learning	3.3	3.7	2.8
Judgement of line orientation	20.1	18.9	20.9
3-D constructional praxis	23.2	22.2	25.9
Facial recognition	43.3	39.4*	42.2
Self-rating depression scale	68.6	64.1	56.8*

* $P < 0.05$.

TABLE III

Performance (mean score) on all tasks for patients receiving right-sided ECT

Test	Performance (mean score)		
	Pre-ECT	Post-ECT#1	Post-ECT#8
Temporal orientation	8.9	9.7	9.0
Tests of left-hemisphere functioning			
Digit sequence learning	2.2	2.2	1.4
Token test	40.2	40.7	42.7
Controlled word association	32.8	28.7*	31.7
Sentence repetition	12.4	12.3	12.1
Tests of right-hemisphere functioning			
Form sequence learning	2.7	3.3	3.0
Judgement of line orientation	16.4	18.0	22.0*
3-D constructional praxis	23.7	21.9	24.8
Facial recognition	41.0	39.1	39.9
Self-rating depression scale	60.8	58.7	50.9

* $P < 0.05$.

tests of left hemisphere functioning, and all but one test of right hemisphere function (the exception being the FSL test). The decline was minimal on most tasks, but was statistically significant on the DSL test and FRT (P<.05). The depression scale revealed minimal improvement which was not statistically significant. Following ECT #8, there was improvement compared to pre-ECT performances on four tasks (DSL, SR, JLO and 3DB) amd decline on four (TT, CWA, FSL and FR), the only significant change being a decline on the CWA test (P<0.05). The data also reveal a significant improvement in mood, as indicated by a significant decline on the depression scale scores. (P<.05).

2. *Right-sided ECT*

Table III shows the mean score on the different tasks following the right-sided ECT as compared to pre-ECT scores. Following ECT #1 there was a decline on four tasks (CWA, Sr, 3DB and FRT) distributed evenly among left and right hemisphere tests. Three tasks improved (TT, FSL and JLO) and one task (DSL) remained unchanged. However, only the decline on the CWA task reached statistical significance (P<.05). Following ECT #8 improvement compared to pre-ECT scores was noted on four tasks, three of which (FSL, JLO and 3DB) are right hemisphere tests. Furthermore, the improvement on the JLO test was statistically significant (P<.01). Again there was a significant improvement in mood, with a drop on the depression scale score reaching statistical significance at the .05 level.

Discussion

Whereas the data are clear in indicating a significant improvement in mood following a series of ECTs to either hemisphere, the results with respect to cognitive functions are ambiguous. In spite of minimal chages on different tasks in either direction, the significant results indicate a decline in left-hemisphere function following left-sided ECT and an improvement in right-hemisphere functioning

https://doi.org/10.1192/bjp.132.6.560 Published online by Cambridge University Press

following right-sided ECT. These results are in agreement with many reports in the literature showing decline in left-hemisphere functioning following left-sided ECT (Cronin *et al,* 1970; d'Elia & Rootma, 1975; Berent *et al,* 1975). However, Berent *et al* (1975) and d'Elia and Rootma (1975) noted a decrease in right hemisphere function following a single right-sided ECT, and our findings also indicate a similar disruption of function with a single right-sided ECT. Whereas Cronin *et al* (1970) and Annett *et al* (1974) could find no significant decreases on tests of right-hemisphere function, our results, along with those of McAndres *et al* (1967), showed an improvement on right-hemisphere tests following 8 right-sided ECTs. Although comparing these studies is somewhat artificial because of differences in subjects and design, both in the study of McAndrew *et al* (1967) and in our own study the improvement on right-hemisphere function tests was evident after a course of at least six ECT. Thus in both the study of McAndrew *et al* (1967) and our own, the improvement on right-hemisphere function tests following right-sided ECT might have been related to the relief from depression.

TABLE IV

Incidence of defective performance among D-ECT and ND-ECT patients combined (N = 18)

Test	Pre-ECT	Post-ECT#1	Post-ECT#8
Left-hemisphere function tests			
Token test	2	4	1
Controlled word association	2	3	1
Sentence repetition	1	0	0
Total	5	7	2
Right-hemisphere function tests			
Judgement of line orientation	5	5	2
3-D constructional praxis	5	7	1
Facial recognition	3	3	3
Total	13	15	6
Total	18	22	8

DSL and FSL results were omitted because large-scale normative data are not yet available for these tests. Defective performance is defined in the text.

We propose that the acute effect of a single ECT is disruption of cognitive functions, both verbal and non-verbal, and that the disruption is probably more apparent on verbal functions. However, performance following a series of ECTs reflects the interactions of at least two opposing factors: the disruptive effect of the ECT procedure and the enhancing effect of the relief from depression. That depression hinders performance on cognitive function tests is evident in Table IV. Here, the number of defective performances (see General Procedure section above) was compared among the pre/ECT group (untreated depression), the post-ECT #1 group (depression treated with a single ECT) and the post-ECT #8 group (depression treated with a series of 8 ECTs). There were 18 defective performances among the pre-ECT group, suggesting that depression interfered with cognitive functioning in these patients. For the purposes of this study defective performance was defined as a score at or below the second or fourth percentile (depending upon the test) for patients in hospital for medical reasons and without either history or evidence of neurological disease, previous admission to a psychiatric hospital or mental deficiency. Where appropriate, scores were adjusted according to the patient's age, sex and educational level. That is, a defective score corresponds to a performance level exceeded by 96 to 98 % of hospital control patients whose Ns ranged from 100 (3db) to over 360 (for the Multilingual Aphasia Examination subtests)

Of particular interest was the finding that in pre-ECT patients the incidence of defective performance on right-hemisphere function tests 43 vs. 5 defective performances, (Table IV) was much higher than that for left-hemisphere function tests. This supports the theory that depression is associated with dysfunction of the right hemisphere (Flor-Henry, 1969; Flor-Henry, 1974). Following ECT #1, the disruption caused by ECT is added to that of depression, and performance is even worse (22 defective performances). However, in spite of the continued disruptive effects of ECT, performance following ECT #8 shows

https://doi.org/10.1192/bjp.132.6.560 Published online by Cambridge University Press

considerable improvement (8 defective performances as compared to 18). This could be explained more cogently on the basis of relief from depression and its underlying neurological disturbance.

In summary, our data suggest that although unilateral ECT is equally effective in treating depression regardless of the hemisphere stimulated, left-sided ECT has a disruptive effect on some left hemisphere functions, whereas right-sided ECT has an enhancing effect on some right hemisphere functions. In addition, we found that depression itself interferes with cognitive functions, mainly those subserved by the non-dominant hemisphere. Contrary to expectation, ECT did not impair brain functioning but instead brought about significant improvement in cognitive functions as well as in the depression.

Acknowledgements

We thank Dr Arthur Benton for his encouragement and for his comments on the manuscript. We also thank Dr George Winokur for his support and encouragement. This study was supported in part by the Iowa Mental Health Research Fund #66-225.43 and Research Grant NS-00616 from the National Institute of Neurological and Communicative Disorders and Stroke, U.S. Public Health Service.

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Appendix Table II

Individual test scores for D-ECT patients

		Left-hemisphere tasks				Right-hemisphere tasks				
	TO	DSL	TT	CWA	SR	FSL	JLD	3DB	FRT	SDS
Maximum score	10	12	44	None	14	12	30	29	54	
Pre-ECT										
Subject 1	10	1	40	24	10	0	21	29	36*	59
Subject 2	10	8	43	34	13	10	25	29	47	74
Subject 3	9	0	43	37	12	0	27	29*	41	73
Subject 4	8	5	43	38	15	8	23	28	47	56
Subject 5	10	0	41	44	12	0	27	26	39	81
Subject 6	10	3	41	46	12	3	14*	22	45	76
Subject 7	10	4	38	37	13	0	0*	6*	47	51
Subject 8	10	0	42	34	16	9	23	29	47	78
Subject 9	0*	0	38	47	8	0	21	21*	41	69
Post-ECT #1										
Subject 1	10	0	43	25	13	0	15*	23	39	39
Subject 2	10	6	44	44	12	12	25	29	39	70
Subject 3	8	0	38	30	10	0	26	18*	36	71
Subject 4	6*	0	43	39	14	10	21	29	47	55
Subject 5	10	0	35*	43	12	0	24	19*	36*	78
Subject 6	10	1	43	32	11	3	16*	25	35*	79
Subject 7	9	2	44	33	11	3	2*	13*	43	56
Subject 8	10	0	42	32	16	5	20	27	43	68
Subject 9	10	0	31*	55	11	0	21	17*	37	61
Post-ECT #8										
Subject 1	10	0	41	28	13	0	25	29	36*	60
Subject 2	10	7	42	32	13	8	27	29	45	48
Subject 3	7	0	39	34	11	0	15*	29	41	58
Subject 4	7	0	41	26	11	4	25	29	45	56
Subject 5	9	0	31*	24	11	0	22	24	37	60
Subject 6	10	6	43	22	13	3	21	27	45	44
Subject 7	10	5	44	29	14	0	9*	14*	45	43
Subject 8	8	10	44	30	14	9	21	29	50	83
Subject 9	10	3	43	50	13	1	24	23	36*	59

* Indicates defective performance by normative criteria after age, sex and education level are taken into account.

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Appendix Table III

Individual test scores for ND-ECT patients

		Left-hemisphere tasks				Right-hemisphere tasks				
	TO	DSL	TT	CWA	SR	FSL	JLD	3DB	FRT	SDS
Maximum score	10	12	44	None	14	12	30	29	54	
Pre-ECT										
Subject 1	10	7	44	31	14	0	36	22	43	78
Subject 2	10	0	44	20	12	0	5*	16*	43	48
Subject 3	2*	0	24*	11*	10	0	12*	19*	30*	64
Subject 4	10	5	40	43	14	10	24	29	47	43
Subject 5	10	0	44	27	12	0	20	28	41	63
Subject 6	10	8	44	44	12	8	26	29	50	61
Subject 7	10	0	43	40	11	6	12*	25	45	44
Subject 8	9	0	37*	41	12	0	13	29	34*	71
Subject 9	9	0	42	28	15	0	10*	16*	36	75
Post-ECT #1										
Subject 1	9	10	44	21	14	9	26	21*	43	75
Subject 2	9	0	44	18	12	0	14*	25	39	44
Subject 3	10	0	36*	13*	10	1	21	20*	35*	66
Subject 4	10	0	43	31	14	0	16*	29	38	50
Subject 5	10	0	42	31	13	8	22	27	40	56
Subject 6	10	10	42	38	12	8	26	28	46	65
Subject 7	9	0	42	35	13	3	20	27	37	45
Subject 8	10	0	30*	34	11	0	9*	18*	36	69
Subject 9	10	0	43	37	12	1	8*	2*	38	58
Post-ECT #8										
Subject 1	10	0	44	35	11	0	24	25	41	74
Subject 2	10	0	44	29	12	0	20	26	39	60
Subject 3	9	0	40	23	12	5	24	28	43	51
Subject 4	9	0	44	29	13	5	29	26	50	45
Subject 5	5*	7	42	26	11	0	21	28	37	51
Subject 6	8	5	44	38	10	9	29	29	47	46
Subject 7	10	0	44	32	14	7	21	24	45	30
Subject 8	10	1	38	38	13	1	14	24	25*	38
Subject 9	10	0	44	35	13	0	16	13*	32*	63

* Indicates defective performance by normative criteria after age, sex and education level are taken into account.

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https://doi.org/10.1192/bjp.132.6.560 Published online by Cambridge University Press