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Dichotic Perception and Memory Following Electroconvulsive Treatment for Depression

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Verbal and visuospatial memory and dichotic listening performance were examined in 15 acutely depressed patients with no history of ECT, 17 depressed patients currently in remission, 15 remitted depressed patients who had received ECT six months or more in the past, and 20 normal controls. The neuropsychological functioning of an additional group of 10 acutely depressed patients was also studied before and two weeks after ECT. The results revealed some evidence of logical and autobiographical memory impairment two weeks following ECT, but no evidence that ECT impaired dichotic listening ability. Rather, a normalisation of hemispheric laterality was apparent on the dichotic listening task following ECT and the concomitant relief from depression. There was also no evidence of cognitive dysfunction on any task in individuals who were tested six months or more following their last ECT treatment.

Although there have been a great many studies examining cognitive ability following electroconvulsive therapy (ECT), substantial variability in the quality, methodology, and outcome of these investigations has complicated their interpretation. Hence, it has not been possible to attain a consensus regarding possible deleterious effects of ECT. Several reports have suggested that no prolonged cognitive deficits exist after ECT (e.g. Cronholm & Molander, 1964; Brunschwig *et al*, 1971; Small, 1974; Squire & Chace, 1975; Squire *et al*, 1981; Weeks *et al*, 1980; Frith *et al*, 1983). However, most studies have either indicated that residual neuropsychological impairment follows ECT (e.g., Halliday *et al*, 1968; Bidder *et al*, 1970; Cronin *et al*, 1970; Goldman *et al*, 1972; Temper *et al*, 1973; Squire *et al*, 1976; Freeman *et al*, 1980; Steif *et al*, 1986), or they have yielded mixed or inconclusive data concerning protracted deficits after ECT (Cronholm & Ottoson, 1961, 1963; Bilikiewicz & Krzyzowski, 1964; Miller, 1970; Squire *et al*, 1979; Freeman & Kendell, 1980; Daniel *et al*, 1983). Our review of the literature indicated that of 43 studies that contained information on long-term (mean 26.5 months post-treatment) cognitive functioning after ECT, 19 studies included data indicative of protracted cognitive deficits. Although a wide variety of intelligence, mental status, and memory tests have been employed in previous ECT research, an alternative but seldom used approach to the investigation of ECT-related deficits involves examining information-processing capability directly, using, for example, dichotic listening tasks.

Dichotic listening (DL), introduced by Broadbent (1956), occurs when different auditory stimuli are presented simultaneously to the left and right ears. It has been found (e.g., Broadbent & Gregory, 1964; Kimura, 1961*a*, 1963) that in dichotic perception tasks normal individuals usually exhibit right-ear superiority in the detection of verbal material and left-ear superiority in the detection of non-verbal material. Trauma to the brain in the vicinity of the temporal lobe in the right hemisphere has been found to result in deficits in the perception of material presented to the left ear. This results in an exaggeration of the relative superiority of the right ear in tasks that involve dichotic perception of verbal material and diminishes the superiority of the left ear in the perception of non-verbal material. Lesions to the left hemisphere of the brain have a more variable effect upon dichotic perception. Left-sided injury has been found to result in bilateral impairment in the perception of verbal material and to exert varied effects upon the perception of non-verbal material (Kimura, 1961*b*; Schulhoff & Goodglass, 1969; Netley, 1972; Zurif & Ramier, 1972; Efron *et al*, 1977; Knellinger, 1981; Efron & Crandall, 1983).

Of particular relevance to ECT are the investigations that have used DL performance as an index of cerebral and especially temporal lobe dysfunction. This relevance is derived from the fact that although there is variability in the actual placement of the electrodes during the ECT procedure, the usual North American clinical application results in the discharge of electricity over or near the right temporoparietal area of the brain. The results of two previous studies which examined the dichotic perceptual ability of patients who had received unilateral ECT suggest that dichotic perception tasks may be sensitive to ECT-induced cognitive changes (Altman *et al*, 1979; Moscovitch *et al*, 1981).

The present study was conducted to help determine whether cognitive dysfunction follows ECT. Two

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TABLE I
Demographic characteristics of subjects

Group	No. of subjects		Age: years			Years of education	
	female	male	mean	s.d.	range	mean	s.d.
Current ECT	7	4	56.8	11.5	36–66	12.18	1.68
Depressed, non-ECT	11	4	40.8	13.0	24–68	12.53	2.72
Past ECT	9	6	48.3	12.0	31–65	12.47	2.72
Remitted, non-ECT	14	3	46.2	11.2	26–64	14.06	2.56
Normal	13	7	41.6	12.9	22–63	13.20	3.32

experimental groups, one consisting of patients evaluated before and after ECT and the other of individuals who had received ECT at least six months previously, were used. These groups were compared to currently depressed patients not receiving ECT and remitted depressives who had never received ECT. The latter two groups provided an opportunity to examine the dependent variables in individuals with a history of depression but not of convulsive treatment. Finally, a group of normal volunteers were included to assess task performance in persons with a history of neither depression nor ECT.

This study extended previous investigations of the neuropsychological performance of ECT-treated patients by using a standardised and reliable audiological test of dichotic perception. Various tests of memory were also included in the protocol because most studies of the cognitive effects of ECT have focused on possible memory dysfunction resulting from the procedure. It was hypothesised that any cognitive deficits present after ECT would be manifest by an abnormal exaggeration of the normal right-ear advantage on the DL test and by diminished performance on the tests of memory.

Method

Subjects

Fifty-eight patients in treatment at a major metropolitan hospital for a primary complaint of depression and twenty normal control subjects without history or symptoms of mental disorder gave informed consent to participate in this study. All subjects were right-handed, defined operationally as a score of at least 35, out of a possible 50, on the Edinburgh checklist criteria (Oldfield, 1971). On the basis of their clinical history, current status, and treatment, depressed patients were assigned to one of four groups: (a) depressed, non-ECT ($n = 15$); (b) remitted, non-ECT ($n = 17$); (c) current ECT (in treatment with right unilateral ECT, $n = 11$); (d) past ECT (received right unilateral ECT not less than six months prior to testing, $n = 15$). The normal control group consisted of individuals from local offices of the Unemployment Insurance Commission who were paid for their participation in the study.

Diagnoses were made independently by two clinicians, one of whom (RAR) conducted a clinical interview. The other (KMW) administered a modified version of the Diagnostic Interview Schedule (DIS; National Institute of Mental Health, 1981) and the Beck Depression Inventory (BDI; Beck *et al*, 1961) on the day the dichotic listening and memory tasks were given.

All patients, whether in remission or currently depressed, received a primary diagnosis of major affective disorder with depression according to the criteria specified in DSM–III (American Psychiatric Association, 1980). Thirty-nine of the patients had received a diagnosis of recurrent major depression (unipolar) and 19 of bipolar depression. Forty-six of the patients were receiving antidepressant medication or lithium carbonate when tested and 12 had not received medication for at least one month before testing. Subject characteristics are summarised in Tables I and II.

ECT characteristics

ECT was administered as sinusoidal current (Medcraft B-24 machine) for 0.5 to 1.0 seconds at 110 to 170 volts. A right non-dominant unilateral electrode placement as described by d'Elia (1970) was used. Standard anaesthesia (methohexital, succinolcholine) was administered before ECT. No preoperative atropine was given. In the majority of cases, treatments were given three times weekly. Seizure duration was monitored by the cuff method (Fink & Johnson, 1982) with all attempts to keep seizure duration between 25 and 40 seconds. Patients received between eight and 12 treatments in their course of ECT.

Audiometry

All subjects were tested audiometrically and for accuracy of dichotic perception in a Tracoustics RS257DS double-walled, sound-attenuating booth. Auditory stimuli were conveyed to the subject by means of Telephonics TDH-39 headphones in circumaural cushions. Audiometric readings of stimulus frequency and intensity level were made on a Madsen OB77 audiometer. Dichotic perception test instructions and stimuli were pre-recorded on cassette tape by Auditec of St Louis, Missouri (Katz, 1973, 1985). Dichotic perception was assessed by means of the staggered spondaic word (SSW) test, a standardised DL test that is commonly used in clinical audiometry and that has been the subject of much research with a variety of normal and

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TABLE II
Clinical characteristics of subjects

Group	*Medicated?*		*Diagnosis*		*Beck Depression Scale score*	
	yes	*no*	*UP*[1]	*BP*[2]	*mean*	*s.d.*
Current ECT						
pre-treatment	10	1	8	3	29.64	10.93
post-treatment	11	0	8	3	12.20	11.46
Depressed non-ECT	12	3	10	5	29.20	6.20
Past ECT	13	2	9	6	8.00	10.18
Remitted non-ECT	11	6	12	5	7.47	6.50
Normal	0	20	0	0	4.45	4.58

1. UP = Unipolar affective disorder (DSM-III criteria for recurrent depression).
2. BP = Bipolar affective disorder (DSM-III criteria).

clinical populations (e.g., Katz *et al*, 1963; Spitzer & Ventry, 1980; Arnst, 1981; Wetherby *et al*, 1981). The SSW test is a dichotic word perception task in which two spondaic words (e.g., upstairs; downtown) are presented, one to each ear. The words are staggered in time so that the second syllable of the first word occurs simultaneously with the first syllable of the second word. A series of 20 word pairs is presented in the test. The task of the subject is to repeat each of the pairs after it has been presented; the failure to do so correctly constitutes an error.

Administration and scoring of the SSW test followed the standard procedures employed routinely in clinical audiological evaluations (Arnst, 1982). To ensure correct administration of the SSW test, an audiometric examination (e.g. Hughson & Westlake, 1944) of the subject was undertaken before testing. This examination provided the following information for each subject: (1) pure-tone threshold; (2) three-frequency pure-tone average, defined as the mean intensity threshold for tones that were presented at frequencies of 500, 1000 and 2000 Hz; and (3) speech reception threshold, defined as the lowest intensity at which 50% of the spondees were repeated correctly. This information was then used to determine the speech discrimination score (SDS) of the subject. This score, expressed as a percentage error, indicated the accuracy with which the subject repeated a series of words presented 30 dB above his or her speech reception threshold. The SSW test stimuli were presented to the subject at a level of intensity that was 50 dB above the three-frequency pure tone average. The audiological examination and the SSW test were administered by a qualified clinical audiologist (PG) and scored (as specified by Arnst, 1981) such that the percentage of errors for each subject for the left and right ear was determined after correcting for the SDS. This was accomplished by subtracting the percentage SDS error for each ear from the raw percentage of errors for each ear. By correcting each participant's score in this fashion, subjects were not penalised for any hearing difficulties they may have had.

Memory

Memory was tested with a battery of tasks selected to provide an index of both anterograde and retrograde memory. Tests of anterograde functioning examined immediate and delayed recall of verbal and visuospatial material. Retrograde memory was evaluated with a test of autobiographical memory. All of the commercially available tests were administered and scored following the instructions outlined in the test manuals. Alternate forms of the tests (except recurring figures and autobiographical recall) were used for subjects who were tested twice. The memory tests employed were as follows.

(a) *Recurring figures test* (Kimura, 1963), a test that is sensitive to right temporal lobe dysfunction (Kimura, 1963; Rixecker & Hartje, 1980). Subjects are asked to recognise 40 figures that are embedded in a deck of 100 cards.

(b) *Digit span* (Wechsler, 1945, 1981), considered to be a test of short-term memory, or immediate auditory memory, concentration, attention, and the ability to shift thought patterns from digits forward to digits backward.

(c) *Benton visual retention test* (Benton, 1974) a test of the ability to recall and reproduce from memory geometric designs presented on ten cards. Forms D and E (administration D) were used.

(d) *Logical memory*, from the Wechsler Memory Scale (Wechsler, 1945), considered to be a test of the ability to recall logical verbal material. This test required subjects to recall details of two stories read to them after delays of five and three minutes respectively, during which time they completed questionnaires. Forms I and II were used.

(e) *Autobiographical memory*, a 32-item questionnaire designed specifically for the present research. The questionnaire was patterned after a scale used by Squire *et al* (1981) and was intended to assess the ability of the subject to recall material of an autobiographical nature. Subjects were required to recall both objective and subjective information either from their distant (over three years ago) or recent (within the last three years) past. The scoring indicated how many personal memories the subject could recall. It was not possible to verify the truth of the recalled memories. Sample questions were 'What did you do during your 1984 summer vacation?' and 'What was your favourite TV programme during the 1970's?'

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The above tests, in addition to the BDI, DIS and the Edinburgh Handedness Checklist, were administered on the same day that the audiometric assessment and the SSW test were conducted. All subjects except those in the current-ECT group were tested once. The current-ECT patients were tested twice, once a few days before starting ECT and again approximately two weeks after the conclusion of the ECT series.

Results

Applications of analysis of variance (ANOVA) and the χ^2 statistic revealed no differences among groups in educational attainment, proportion of bipolar depressives, or sex composition. However, an ANOVA based on age indicated that the groups differed in age ($F(4,73)=3.61$, $P<0.01$). *Post hoc* comparisions revealed that the differences were attributable to the fact that the subjects in the current-ECT group were significantly older than those in the depressed non-ECT and normal groups, although the past-ECT group did not differ in age from the other groups. Accordingly, in the among-group analyses of the neuropsychological data that follow, age was used as a covariate.

As expected, the groups differed in level of depression on the BDI, both before and after the subjects in the current-ECT group had undergone treatment ($F(4,73)=39.61$, $P<0.001$ and $F(4,72)=26.10$, $P<0.001$, respectively). Multiple comparisons revealed that before commencing treatment, the subjects in the current-ECT and depressed non-ECT groups did not differ from one another in level of depression, but both groups of patients were significantly more depressed than those in all of the other groups. After treatment the depressed non-ECT group was significantly more depressed than all the other groups, including the current-ECT group which showed a level of depression similar to that in the other groups (see Table II).

Dichotic listening

ECT patients before and after treatment

The dichotic listening performance of the current-ECT patients was evaluated by conducting a 2(ears)×2(times) repeated measures ANOVA. Neither the main effect for ears nor time was significant. The interaction effect, however, was significant ($F(1,9)=5.21$, $P<0.05$), and indicated that right-ear performance improved significantly ($F(1,9)=8.96$, $P<0.5$) while left ear performance was unchanged ($F(1,9)=0.52$).

Group comparisons

Table III shows the results of the SSW test for all groups. It was hypothesised that comparison of right- and left-ear performance on the SSW task would differentiate those who had received ECT in the past from the various control subjects who had not. To test this prediction, the right- and left-ear dichotic perceptual scores were compared for the subjects in all but the current-ECT group by calculating a 2(ears)×4(groups) ANCOVA with repeated measures on the first factor. The main effect for ears was significant ($F(1,62)=18.46$, $P<0.001$), but the main effect for groups ($F(3,62)=1.15$) and the ear by group interaction ($F(3,62)=1.35$) were not. Paired t-tests comparing left- and right-ear performance for each group were calculated; all four tests confirmed that right ear errors were less frequent than left ear errors. The results confirmed that all of the groups performed in a similar fashion and demonstrated right-ear superiority; indeed, all generated mean scores that fall within normal limits (Katz, 1973).

Memory

ECT patients before and after treatment

To test the hypothesis that the current-ECT patients would show a decrement in performance following ECT, the memory performance of the current-ECT patients was contrasted before and after they had received ECT by

TABLE III
Mean values (s.d.) of memory and dichotic performance by group

Test	*Current ECT*		*Depressed non-ECT*	*Past ECT*	*Remitted non-ECT*	*Normal*
	Pre-ECT	*Post-ECT*				
SSW left[1]	5.91 (8.14)	5.70 (10.46)	4.27 (5.42)	4.27 (3.95)	1.50 (2.37)	3.40 (3.35)
SSW right[1]	5.82 (9.38)	2.10 (5.92)	1.40 (2.75)	0.00 (5.13)	0.62 (2.75)	1.20 (1.76)
Autobiographical memory[2]	26.09 (3.11)	23.60 (5.02)	28.73 (3.45)	28.87 (2.44)	29.82 (2.00)	29.85 (2.75)
Recurring figures[3]	19.18 (9.32)	20.50 (9.37)	24.87 (6.85)	22.07 (7.78)	26.12 (7.02)	26.70 (8.26)
Digits backward[4]	4.36 (1.12)	4.50 (1.35)	4.53 (1.12)	4.53 (0.92)	5.18 (1.47)	4.70 (0.73)
Logical memory[5]	7.36 (3.29)	5.60 (3.78)	9.00 (3.25)	8.87 (4.08)	10.65 (3.69)	12.75 (2.77)
Benton visual retention[6]	3.00 (2.57)	3.78 (2.82)	6.87 (2.55)	5.93 (2.66)	7.06 (2.77)	7.95 (1.82)

1. Percent error corrected for each subject's hearing ability. Unlike the memory tasks, a high score on this test reflects poor performance.
2. Number of memories recalled.
3. Number of correct identifications minus the number incorrectly identified as having been seen before.
4. Number of digits repeated.
5. Number of ideas recalled from two memory passages.
6. Number of correct reproductions.

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conducting a series of correlated *t*-tests. These tests were based on 10 subjects because one patient in this group was unavailable after treatment. As can be seen in Table III, test performance actually improved slightly across occasions for the digit span, recurring figures, and Benton tasks, but autobiographical memory ($t(9) = -2.01$, $P < 0.05$) and logical memory ($t(9) = -1.92$, $P < 0.05$) performance were significantly worse following treatment.

Group comparisons

A multivariate analysis of covariance (MANCOVA) was conducted to compare the memory capability of the groups after the current-ECT patients had finished treatment. The significant multivariate effect ($F(24,228) = 1.93$, $P < 0.01$) was further evaluated by conducting univariate ANCOVAs which indicated that the groups differed significantly on logical ($F(4,72) = 5.05$, $P < 0.01$) and autobiographical ($F(4,72) = 5.97$, $P < 0.001$) memory. *Post hoc* comparisons revealed that these results were attributable to the patients in the current-ECT group, after treatment, having the least number of autobiographical and logical memories.

Medication effects

There were no significant differences between medicated and unmedicated depressive subjects in their performance on the memory and dichotic listening tasks.

Discussion

Dichotic listening

A major innovation of the present study involved the use of a standardised dichotic listening task commonly employed in clinical audiometry that is sensitive to various types of brain dysfunction (see Arnst & Katz, 1982). It was hypothesised that ECT would lead to an exaggeration of normal right-ear superiority, perhaps manifest by an increase in left-ear errors. The results, however, revealed a slight drop in left-ear error and a significant drop in right-ear error in the current-ECT subjects. Before ECT, there was no difference in error rate between ears, a result that is consistent with other reports that found dichotic listening deficits in acutely ill patients with major affective disorder (Bruder *et al*, 1981; Johnson & Crockett, 1982; Lisman *et al*, 1978; Moscovitch *et al*, 1981; Yozawitz *et al*, 1979). The significant improvement in the right-ear dichotic listening performance of the current-ECT subjects after treatment suggests a normalisation of hemispheric functioning after ECT, rather than a change in functioning attributable to right-hemisphere dysfunction. Following conclusion of treatment and clinical improvement, the right-ear error rate for the ECT subjects was within the normal range and consistent with that of the other subjects (see Table III). This pattern of results is similar to that reported by Moscovitch *et al* (1981) who concluded that the alleviation of depression following ECT may have had a normalising effect on dichotic listening in a small group of seven depressed patients.

The dichotic listening findings from the past-ECT group support the above conclusion that ECT does not lead to a DL performance deficit. The past-ECT subjects showed a normal pattern of listening performance, thereby indicating that there is no significant residual effect of ECT on dichotic performance six or more months following treatment.

Memory tasks

Five univariate statistics were calculated to determine if a decrement in memory performance existed following ECT. Two of these tests generated significant results despite the small sample size of the current-ECT group and associated lack of power to detect significant effects. Indeed, a possible concern with these analyses is that clinically meaningful performance decrements may exist following ECT, but that they were not statistically significant because only a small group of patients was studied. This possibility is not supported by the data, however, which shows that for the three memory tests that failed to yield significance, memory performance actually improved slightly following ECT.

Do patients who have recently completed ECT show a memory deficit relative to other subjects who have not? Our analyses showed that the current-ECT group performed more poorly after ECT than the other subjects on two of the five memory tests, autobiographical memory and logical memory. The two memory test-analyses complement and reinforce one another because in both cases, memory deficits were identified in these same two tests, but were not found in the other three memory tasks. These findings, that recent administration of ECT leads to impaired performance on these two tests, and that patients recently administered ECT are impaired on the same two tests compared with other groups of depressives and normal subjects, provide compelling evidence that autobiographical and logical memory are impaired during the two weeks following ECT.

The deficits observed in the current-ECT group following treatment existed despite the fact that for one of the tests (autobiographical memory), the identical scale was administered on both occasions. This observation of post-ECT deficits in autobiographical memory is consistent with that of previous work in this area (e.g. Squire *et al*, 1981). In addition, the poor performance of these subjects cannot be attributed to depressed mood. The clinically depressed non-ECT patients did not show a similar deficit, and

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the current-ECT subjects were substantially less depressed following ECT. The average level of depression of the subjects in the current-ECT group, as reflected by BDI scores, was 29.64 before treatment and only 12.20 after treatment.

Although all the memory tests require the retrieval of memories, the logical and autobiographical memory tasks place great demand on retrieval processes. The only other test that emphasises memory retrieval, the Benton, did not show significant impairment. However, subjects were asked to draw the Benton figures after only a 15-second delay during which there was no interference from other tasks. By contrast, the two logical memory passages were presented with delays of five and three minutes, and during the delay interval, subjects were required to complete questionnaires. The recurring figures test, on which current-ECT patients performed well, also involves a delay between stimulus presentation and the memory test. However, this is a recognition test. The fact that patients performed well on this test indicates that they were able to acquire new information because they could recognise it later. Another difference between the recurring figures and Benton tests and the autobiographical and logical memory tests is that the former involve visuospatial memory while the latter are concerned with verbal material. Hence, the nature of the information subjects were asked to remember could account for the different performance. Nevertheless, overall this pattern of results suggests that there is a problem with long-term memory retrieval of verbal material two weeks following ECT.

By including the past-ECT group it was possible to determine if ECT was associated with residual or protracted memory dysfunction. Since performance deficits were observed in the past-ECT patients, such problems may not persist six months or more after treatment. This failure to detect evidence of prolonged cognitive deficit is consistent with a number of reports from other investigators (see introduction).

Conclusion

Dichotic listening performance following ECT was not indicative of right hemisphere dysfunction, but there was some evidence of abnormal lateralisation on this task in the group of acutely depressed patients scheduled for ECT. The results of the present investigation support the notion that the retrieval of verbal material from long-term memory is impaired two weeks following right unilateral ECT. Memory deficits were not detected in visuospatial performance based on tasks that required recognition of figures or reproduction of designs after a short delay. Immediate auditory memory and attention, as indexed by the digit span test, were also normal two weeks post-ECT. The results of the present study provided no evidence of long-term (that is, six months or more after treatment) deficits in cognitive functioning associated with ECT.

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