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The Experience of Memory Function after Electroconvulsive Therapy

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Ever since E.C.T. was introduced it has been observed that complaints of impaired memory are very common after this form of treatment, but also that the complaints vary considerably in different patients. That memory performances—as they may be measured by means of tests—are disturbed to a varying degree after E.C.T. has been established by several authors. It is thus reasonable to assume that the varying complaints of impaired memory, at least in part, reflect true disturbances of memory abilities. It is a common impression, however, that patients who have gained an obvious release from emotional distress comparatively seldom complain of memory disturbances after E.C.T. Thus, the complaints of memory impairment seem to be determined also by another factor, acting in the opposite direction, *viz.*, improvement of disease. No investigation of the extent to which various factors have influenced the complaints of memory disturbances after E.C.T. seems to have been made.

The present investigation, which concerns E.C.T. in endogenous depression, is an attempt to determine whether there is a relationship between the report of memory change after E.C.T. ("subjective memory change") and (*i*) the improvement of the depressive state which is a result of the therapy and (*ii*) the change of various memory functions as measured by a memory test battery ("objective memory change").

Material and Methods

General procedure

35 patients who had been referred for E.C.T. owing to endogenous depression were examined before the therapy and one week after four (in five patients three) treatments. On both occasions ratings of the severity of the depressive state and memory testing were made; on the second occasion, in addition, a self-rating of the memory change.

Material.

The 35 patients, 21 women and 14 men, belong to a material which has been described earlier (Cronholm & Ottosson 1960, 1961a). Out of the original material the present sample represents a selection, for those who were too disturbed to be able to co-operate in the initial memory testing had to be excluded. Age range was 36-69 years, mean age 51·3 years. 18 patients had been subjected to 1-4 previous courses of E.C.T., none of them during the actual period of illness and none more recently than half a year.

E.C.T. technique.

The treatments were given at intervals of 3-4 days with a Konvulsator III (v. Braunmühl 1951), which delivers volleys of unidirectional pulses of 5 msec duration at a frequency of 50 per sec. All treatments were given in intravenous narcosis, under total muscular relaxation (seizures recorded electroencephalographically) and with supply of oxygen keeping arterial oxygen saturation above 90 per cent. (Ottosson 1960a). Three different treatment modifications were used: supraliminal electrical stimulation (14 patients), liminal stimulation (8 patients) and liminal stimulation together with reduction of seizure activity by lidocaine (13 patients). All types of therapy result in improvement of the depressive state and some memory disturbance, the effects only differing in degree (Cronholm and Ottosson 1960; Ottosson 1960b). For the present analysis we have felt at liberty to take

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all patients together and treat them as a single group.

Self-rating of memory change.

At the end of the post-treatment memory testing the patients were given a questionnaire comprising 5 questions, all aimed at making the patients compare their memory on the actual day of examination with that before the therapy. The questions were if they experienced a difference (*i*) of their memory (without specification), (*ii*) in remembering names of people, (*iii*) in remembering what they read in books, newspapers and magazines, (*iv*) in remembering incidents occurring some months previously and (*v*) in their performances in the memory tests on the second occasion as compared with the first. For each of the questions the patients had to choose between 5 possible responses: much better, better, about the same, worse, much worse. We scored these degrees as +2, +1, 0, −1 and −2 respectively and formed a composite score for each patient by adding the single self-rating scores. The third question was omitted by 5 patients, evidently because they had had no opportunity of examining this function, and therefore we formed the composite score for all patients from questions *i*, *ii*, *iv* and *v* only. It is apparent from our scoring procedure that a positive composite score implies that the memory was experienced as improved, a negative score as impaired and score 0 as comparatively unchanged. It need scarcely be pointed out that the selection of questions in the self-rating scale is relatively arbitrary. It was dictated by the desirability of making easily understandable questions which all patients could answer from their own experience. In the present investigation, "subjective memory change" is operationally defined as this composite score. It is, of course, a rough estimate of the individual experience of memory change and we do not claim it to be more than a measure useful for the present purpose.

Memory test procedure.

Three memory tests were used, "the 20 figure test", "the 30 word pair test" and "the 30 personal data test" all constructed by Cronholm and Molander (see Cronholm & Molander 1957; Ottosson 1960b; Cronholm & Ottosson 1961a, b). The tests are characterized by a comparatively high internal-consistency reliability and by giving measures of reproduction both immediately after learning (a single combined auditory and visual presentation of the material) and after a longer interval. For each of the tests three scores are obtained on each test occasion: "immediate reproduction" (number of items reproduced immediately after learning), "delayed reproduction" (number of items reproduced three hours later) and "forgetting" (difference between immediate and delayed reproduction). The tests are available in two equivalent forms (Ottosson 1960b) to be used alternately before and after the therapy. The "objective memory change" is operationally defined as the difference between the scores before and after E.C.T.

Rating of clinical improvement

Before and after the therapy the severity of 8 depressive symptoms was rated, comprising depression of mood, anxiety, depressive ideas, suicidal tendencies, sleep disturbance, psychomotor retardation, patient's experience of intellectual and conative retardation and patient's experience of emotional retardation. Rating scales with 4 categories were used (3 in the case of sleep disturbance), score 3 (2) meaning a maximally pronounced symptom, score 0 the "normal" state. The total sum of the 8 separate scores was taken as a measure of the severity of the depressive state and the difference between the total scores on the two rating occasions as a measure of improvement of the disease. Besides, the improvement was globally rated from 0 (no improvement) to 3 (recovery). For details of rating procedure, see Cronholm & Ottosson (1960).

Statistical methods.

Since it may be assumed that the subjective experience of memory change (Y) depends partly on the objective memory change (X_1) and partly on the improvement of the depressive state (X_2) for its value, the principles of multiple regression have been applied (see

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Snedecor 1956). By these we segregate in a single equation the independent contributions of X_1 and X_2 to Y. The analysis is undertaken with the assumption that our sample is from a normal multivariate population, Y, X_1 and X_2 being three random variables. On the assumption that the regression surface is a plane its equation may be written

$$\hat{Y}=\bar{y}+b_{Y1\cdot2}\,(X_1-\bar{x}_1)+b_{Y2\cdot1}\,(X_2-\bar{x}_2).$$

$\hat{Y}$ is the point on the regression plane corresponding to X_1 and X_2, $\bar{y}$, $\bar{x}_1$ and $\bar{x}_2$ are mean values and $b_{Y1\cdot2}$ and $b_{Y2\cdot1}$ are partial regression coefficients; $b_{Y1\cdot2}$ is the regression of Y on X_1 independent of X_2, *i.e.* it tells how many units Y increases for every unit increase in X_1, when the effects of X_2 are held constant. Analogously, $b_{Y2\cdot1}$ is the regression of Y on X_2 when the effects of X_1 are removed from consideration. The partial regression coefficients and their standard deviations, s_b, are computed according to current formulas (Snedecor 1956) and the significance of the regression coefficients is tested by t-tests ($t=b/s_b$; degrees of freedom: $n-3$). In this way it has been examined whether there are significant relationships between Y and the two independent variables X_1 and X_2.

It has also been calculated how much of the variation of Y can be accounted for by the regressions studied here. The sum of squares of the dependent variable, Σy^2, can be divided into a part attributable to regression ($\Sigma\hat{y}_{12}^2$), and a part due to deviation from the regression. The former fraction is calculated according to the formula

$$\Sigma\hat{y}_{12}^2=b_{Y1\cdot2}\,\Sigma x_1y+b_{Y2\cdot1}\,\Sigma x_2y,$$

where x_1, x_2 and y refer to deviations from the means. The two terms of the right member may be used as measures of the contributions of X_1 and X_2 respectively to the regression. By dividing all the terms of the equation by Σy^2 the contributions may be obtained in terms of fractions of the total variation of Y.

Results

Effects of E.C.T.

The effects of the therapy on the three experimental variables are summarized in Table 1. As will be seen from the table there is, on an average, practically no change of the experience of the memory function as measured by the self-rating scale. In fact, 16 patients considered their memory as improved, 6 as relatively unchanged and 13 as impaired. Simultaneously, judging from the performance in the total memory tests, there is an average non-significant improvement of immediate reproduction (19 improved, 4 unchanged and 12 impaired), an average also non-significant impairment of delayed reproduction (14 improved, 2 unchanged and 19 impaired) and an average significant ($p<0\cdot001$) increase of forgetting (5 improved, 3 unchanged, 27 impaired). The depressive state in the group has undergone a considerable, significant ($p<0\cdot001$) improvement as measured by each of the two rating scores (10 patients recovered, 15 considerably improved, 7 moderately improved, and 3 unimproved according to global scores).

The results concerning memory performances and the clinical improvement in this material agree with those described earlier (Cronholm & Ottosson 1961a). These results were interpreted to mean that E.C.T. has an adverse influence mainly on the hypothetical memory variable "retention" whereas another hypothetical variable "learning" shows improvement parallel with the amelioration of the depressive state.

Table I

Effect of E.C.T. on the three experimental variables. (n = 35)

Variable	Score M	s	range
Self-rated memory function (Y)	+0·2	1·8	— 3 — + 4
Performance in memory tests (X_1)			
Immediate reproduction			
20 figures	+1·3	2·9	— 5 — + 8
30 word pairs	+0·0	4·7	—10 — +11
30 personal data	+1·1	5·2	— 8 — +10
Total test	+2·4	9·5	—16 — +18
Delayed reproduction			
20 figures	+0·9	3·5	— 6 — + 8
30 word pairs	—3·1	5·1	—12 — + 6
30 personal data	+0·1	5·0	—10 — + 8
Total test	—2·1	10·5	—23 — +19
Forgetting			
20 figures	—0·4	2·7	— 6 — + 5
30 word pairs	—3·0	4·1	—14 — + 6
30 personal data	—1·0	2·6	— 7 — + 4
Total test	—4·5	5·7	—21 — + 3
Rated severity of depression (X_2)			
Total score	+6·8	3·4	0 — +14
Global score	+1·9	0·9	0 — + 3

M stands for mean value, s for standard deviation. Positive signs denote improvement, negative signs impairment.

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Analyses of regression.

Table II presents how the experienced change of memory function (Y) is determined by the objective memory change (X_1) and the improvement of the depressive state (X_2). By combining the score for subjective memory change with each of the memory test scores and with each of the two measures of clinical improvement, we obtain several combinations of Y, X_1 and X_2, and for each combination the two partial regression coefficients $b_{Y1\cdot2}$ and $b_{Y2\cdot1}$ may be computed. The table gives the t-values for the regression coefficients and the degrees of significance which fall below 0·05. Positive and negative t-values denote positive and negative coefficients of regression respectively. It follows from preceding definitions (Table I) that a positive regression implies that subjective improvement of memory function is associated with improvement of memory test performance or of the depressive state.

As may be seen from the table, the regression of Y on X_2 independent of X_1 is positive throughout, although a high degree of statistical significance is not reached. The result indicates that there is a tendency towards a positive relationship between the experienced memory function and the improvement of the depressive state, *i.e.* a more improved patient tends to judge his own memory more favourably and *vice versa*. In the profound alteration of experience which occurs in a successfully treated depressed patient memory is apparently experienced as improved, independent of its factual change.

It may be seen from the table that higher t-values are always obtained when calculating with global scores of improvement than with differences between total scores. A possible explanation is that the total scores are based on several variables, some of which may be determined by such abilities as are not much related to the experienced memory function. Another explanation may be different implications in the two measures; the global score being

TABLE II

Significance of regressions.

Regression	Y on X_1 independent of X_2 ($b_{Y1\cdot2}$)		Y on X_2 independent of X_1 ($b_{Y2\cdot1}$)	
Variable X_2	Change in severity of depression			
	total score	global score	total score	global score
Variable X_1				
Change in memory test performance:				
Immediate reproduction				
20 figures	+0·70	+0·71	+0·65	+1·50
30 word paris	+2·48 p <0·02	+2·50 p <0·02	+0·25	+1·38
30 personal data	—0·12	+0·43	+0·73	+1·59
Total test	+1·38	+1·19	+0·21	+1·16
Delayed reproduction				
20 figures	+0·69	+0·32	+0·45	+1·27
30 word pairs	—0·22	—0·14	+0·74	+1·54
30 personal data	—0·27	—0·62	+0·79	+1·67
Total test	+0·05	—0·26	+0·66	+1·52
Forgetting				
20 figures	+0·11	—0·43	+0·66	+1·56
30 word pairs	—2·96 p <0·01	—3·12 p <0·01	+0·88	+1·85
30 personal data	—0·28	—0·28	+0·71	+1·52
Total test	—2·16 p <0·05	—2·62 p <0·02	+1·05	+2·24 p <0·05

The table gives the t-values ($t = \frac{b}{s_b}$; df=32) of the partial regression coefficients $b_{Y1\cdot2}$ and $b_{Y2\cdot1}$. Y denotes the experienced change of memory function.

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based on an intra-individual comparison but the scores of the separate variables included in the total score on inter-individual comparisons. On the other hand, it does not seem probable that the relative error of measurement is greater in the difference between two total scores than in a global score. The discriminating power between the two measures of improvement has proved to be equally good (Cronholm & Ottosson 1960).

The regression of Y on X_1 independent of X_2 displays more complicated conditions. Firstly, it is evident that the experienced memory function has a significant relationship only to performances in the word pair test, while the relationship to the total test is mainly determined by the word pair test. Secondly, the change of immediate reproduction in the word pair test has a significant positive relationship to the patient's experience of memory change. Consequently, a patient who reproduces an increased number of items after the therapy usually also experiences his memory as improved, even when the effect of the improvement of the depressive state is kept constant. Thirdly, there is a *negative* relationship between changes in the experienced memory functions and in forgetting in the word pair test. This relationship implies that a higher degree of forgetting is associated with a more favourable verdict of the memory function.

A possible explanation of this astonishing negative relationship may be that a high score of immediate reproduction is associated with a high score of forgetting and that a patient to the greatest extent judges a memory function determining immediate reproduction, and not at all, or to a smaller extent, a function determining forgetting in the word pair test. In fact, there is correlation between the changes of immediate reproduction and forgetting after E.C.T. in this material ($r=0\cdot34$, $p<0\cdot05$, $df=33$), implying that a higher gain of immediate reproduction after E.C.T. is associated with a greater forgetting (reasonably owing to the fact that there is more to forget). In the regression of subjective memory change on forgetting in the word pair test the regression coefficient b is $-0\cdot20$ (standard error — $0\cdot07$, t — $2\cdot95$ at 33 df, $p<0\cdot01$). If the effect of immediate reproduction is eliminated by forming a partial regression coefficient this amounts to $-0\cdot15$ (standard error — $0\cdot07$, t — $2\cdot24$ at 32 df, $p<0\cdot05$). Part of the negative relationship between experienced memory function and forgetting may thus be explained as an effect of different levels of immediate reproduction. The negative relationship that still exists after nullifying the influence of different levels of immediate reproduction may be random. This explanation seems to be most reasonable since it is somewhat odd if a patient gets the impression that his memory is the more improved the more he forgets.

It should finally be pointed out that on the whole the tendency is uniform if we calculate with each single self-rating memory score (*i-v*) instead of the composite score. The degrees of significance of the regression coefficients will be somewhat lower throughout, but single t-values are higher than for the composite score. Furthermore, if the computations are performed separately for each of the three modifications of treatment, the groups agree well in all respects.

Contributions of independent variables to variance of dependent variable.

In Table III the contributions of X_1 and X_2 to the variance in Y are given. The values are given in per cent of the total variance of Y.

As may be seen from the table it is only for the word-pair test that a more notable part of the variance is attributable to the regression. However, even here most of the variation in Y is unexplained. The remaining variation, not explained by the regression, may be due to several factors. Firstly, to a certain extent, it may be explained by random errors of the methods used. Secondly, the error variance will be increased if the regressions are curvilinear instead of linear as assumed in our computations. Thirdly, our methods of studying the underlying variables "experience of memory functions", "memory abilities" and "depressive disease" may have too low a validity to make it possible to obtain correct measures of even rather strong associations between these variables. Fourthly, the remaining variation may be partly attributable to other independent variables not considered in our analysis, *e.g.* the age of the patients and also various personality traits which determine the way of experiencing disturbances in

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TABLE III

Contributions of independent variables to variance of dependent variable.

Variance in Y due to:	X_1	X_2	$X_1 + X_2$	X_1	X_2	$X_1 + X_2$
	Variable X_2			Change in severity of depression		
Variable X_1				total score		
					global score	
Change in memory test performance:						
Immediate reproduction						
20 figures	1·7	1·5	3·2	1·7	6·7	8·4
30 word pairs	17·1	0·5	17·6	16·4	5·7	22·1
30 personal data	—0·1	1·8	1·7	0·3	7·7	7·9
Total test	6·7	0·5	7·2	5·5	5·3	10·8
Delayed reproduction						
20 figures	2·0	1·1	3·1	0·9	6·2	7·2
30 word pairs	0·0	1·7	1·7	0·0	7·0	6·9
30 personal data	0·0	1·9	1·9	0·0	8·0	8·0
Total test	0·1	1·6	1·7	—0·3	7·4	7·1
Forgetting						
20 figures	0·1	1·6	1·7	—0·5	7·9	7·4
30 word pairs	21·0	1·8	22·8	21·3	7·3	28·6
30 personal data	0·3	1·6	1·9	0·3	6·8	7·1
Total test	12·0	2·2	14·2	13·9	9·3	23·2

The table gives the contributions in per cent of the total variance in Y.

memory functions and the way of formulating these experiences.

The question may also be raised whether or not it is possible from the results in table III to judge the relative contribution of clinical improvement and objective memory change to the experience of memory function (see statistical discussion in Guildford (1956), p. 397). An inspection of the figures in table III might seem to indicate that the objective memory change has a more decisive influence than the amelioration of the depressive state on the subjective experience of memory function. However, all conclusions on this problem are strictly bound to the methods used, a fact which is evident *e.g.* from the circumstance that the contribution of clinical improvement seems to be more pronounced when it is scored globally than by differences between total scores. Since we have no possibility of measuring our variables with scales of constant units and absolute zero points, generalized statements concerning the relative contributions of the two independent variables are not justified.

DISCUSSION

Sources of error

Sources of error of the rating scale for depressive symptoms and of the memory tests have been discussed earlier (see Cronholm & Molander, 1957; Cronholm & Ottosson, 1960; Ottosson, 1960b). Concerning the self-rating scale for memory functions it is not possible to give a measure of its reliability on the basis of its use in the present material. The composite score has probably a higher reliability and a higher validity relative to an underlying variable than every single score (Ekman 1950; Guildford, 1954; Cronholm & Ottosson 1962). It is reasonable to assume that the errors of methods have rendered it more difficult to demonstrate relationships between the variables studied and the relationships established may then be regarded as fairly safe.

We have only worked with two independent variables in the analysis of regression. It is obvious that the introduction of other variables in addition may give increased information and even necessitate a modification of the conclusions drawn.

Comments on the results

In the present analysis of factors influencing the reported experience of memory change ("subjective memory change") after E.C.T. the following brief observations will be made:

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