THE EFFECTS OF Bi and Uni ECT ON NON-VERBAL MEMORY

PhD PSYCHOLOGY

THE EFFECTS OF BILATERAL AND UNILATERAL ELECTROCONVULSIVE THERAPY (ECT) ON NON-VERBAL MEMORY IN DEPRESSED PSYCHIATRIC PATIENTS

Barbara Miller

Abstract

The differential effects of unilateral and bilateral ECT on non-verbal memory were studied in a group of 40 patients diagnosed as depressives. A Latin Square design was employed and each subject received one bilateral (Bi), one non-dominant (ND), one dominant (D), and one pseudo (Ps) ECT. Testing was done with parallel forms of a specially developed non-verbal memory test. Other features of the design included testing for laterality, random assignment of patients to treatment groups, a double-blind procedure, and keeping the parameters of electric shock constant.

The results indicate: (a) Bi and ND ECT impair non-verbal memory to a significantly greater degree than do D or Ps ECT, and this is discernable after the first treatment, (b) both retroactive and proactive impairment of non-verbal memory occur, (c) Bi and ND ECT affect retention, the production of false positive responses, and learning to a significantly greater degree than do D or Ps ECT, and (d) some recovery from proactive impairment occurs within 3 hours after treatment.

Ph.D. PSYCHOLOGY

THERAPIE BILATERALE ET UNILATERALE PAR ELECTROCHOCS (ECT): SES EFFETS SUR LA MEMOIRE NON-VERABLE CHEZ DES PATIENTS PSYCHIATRIQUES EN ETAT DE DEPRESSION

Barbara Miller

Résumé

Les effets différentiels du ECT unilatéral et bilatéral sur la mémoire non-verbale furent étudiés chez un groupe de 40 patients jugés dépressifs. Chaque sujet étudié a reçu un ECT bilatéral (Bi) , un non-dominant (ND), un dominant (D) et un ECT pseudo (PS); un format expérimental de type Carré Latin était employé. Un test de mémoire non-verbale spécialement développé en vue de la présente étude et comprenant deux versions parallèles fut utilisé lors de l'évaluation. Parmi les autres caractéristiques du format expérimental on retrouvait: l'analyse de la latéralité, la distribution au hazard des patients dans les divers groupes expérimentaux, une procédure où expérimentateur et patient étaient tenus naifs et l'invariabilité des divers paramètres du choc électrique pour tous les patients.

Les résultats indiquent ce qui suit: (a) les électrochocs de nature Bi et ND provoquent une détérioration de la mémoire non-verbale a un degré significativement supérieur lorsque comparés aux électrochocs de types D ou PS; on constate ces différences dès après le premier traitement; (b) des détériorations de type rétroactif et proactif de la mémoire non-verbale sont toutes deux présentes; (c) les électrochocs Bi et ND affectent la rétention, la production de fausses réponses positives, et l'apprentissage à un degré significativement supérieur que ne le font les électrochocs D ou PS et (d) on observe la dissipation de la détérioration proactive en dedans des 3 heures qui suivent le traitement.

THE EFFECTS OF BILATERAL AND UNILATERAL ELECTROCONVULSIVE THERAPY (ECT) ON NON-VERBAL MEMORY IN DEPRESSED PSYCHIATRIC PATIENTS

by

Barbara Miller

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Department of Psychology
McGill University
Montreal, Canada

April, 1973

ACKNOWLEDGEMENTS

I wish to thank Dr. A. E. Schwartzman for his advice and encouragement throughout the course of my research. I also thank the staff of the Out-Patient Department of the Allan Memorial Institute, Montreal, Canada, and particularly Dr. H. Azim and Dr. T. Kolivakis, without whose help and cooperation this study could not have been done. In addition, Dr. M. Corballis and Laurel Ward are thanked for their helpful assistance on the statistics, and Shirley Utstein is gratefully acknowledged for the typing of the thesis.

Above all, I wish to thank my husband, Murray, who has been a constant source of support, understanding, and encouragement. His interest and pride in my academic endeavours have been inspiring.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

INTRODUCTION

Electroconvulsive therapy (ECT), a treatment for certain psychiatric disorders, was first used in 1938 by Cerletti and Bini as a technical modification of chemical convulsive therapy, introduced by von Meduna in 1929. The aim of both methods was to induce convulsive seizures. ECT became particularly popular as a psychiatric treatment with the introduction of muscle relaxants and general anaesthetics, which greatly reduced the risk of bone fractures frequently accompanying shock therapy, as well as the anxiety patients experienced with this form of treatment.

The usual method of administering ECT is described in most psychiatric textbooks (Kalinowsky & Hoch, 1961; Mayer-Gross, Slater, & Roth, 1960; Sargant & Slater, 1963). Briefly, a generalized convulsion is produced by the passage of a 70 to 120 volt current for from .3 to .6 seconds through two electrodes, one placed on each side of the head in the temporal region. The aim is to produce a clinical seizure with the minimum amount of electric current. The treatment at present usually consists of a series of two or three ECTs per week for an average of 2 to 4 weeks.

Since the incepti on of electroconvulsive therapy, a large literature has accumulated on this form of psychiatric treatment. To date, however, no predominant or convincing rationale for the use of ECT has emerged, and it remains an empirically-based form of treatment. Reviews by Kalinowsky and Hoch (1961) and by Miller (1967) highlight the theoretical confusion surrounding ECT.

The therapeutic efficacy of ECT is fairly well established. Clinical impression, and experimental studies (Greenblatt, Grosser, & Wechsler, 1964; Kalinowsky, 1968; Kalinowsky & Hoch, 1961; Kiloh, Child, & Latner, 1960; Ottosson, 1960, 1962; Shapiro, Campbell, Harris, & Dewsberry, 1958; Thomas, 1954) have indicated that depression, in particular, can be successfully treated with ECT. Also, ECT tends to produce better recovery rates for endogenous than for exogenous depression (Carney, Roth, & Garside, 1965; Mendels, 1965; Rose, 1963).

The present investigation is concerned with the effects of bilateral and unilateral ECT on non-verbal memory in depressed psychiatric patients. Early ECT studies, using the standard procedure of bilateral electrode placement, demonstrated impairment of memory for events experienced both prior to, and after ECT. Electroconvulsive shock (ECS) research with animals has generated hypotheses concerning the processes underlying the ECS-induced memory disturbance, as have studies with human subjects.

More recently, a modification of the original bilateral ECT technique has been introduced in which the two electrodes have been placed on the non-dominant side of the head. This procedure has been found to produce significantly less memory loss than bilateral ECT.

Whether or not unilateral non-dominant ECT results in virtually no memory loss remains to be determined. Neuropsychological research has demonstrated specialization of function in the left and right cerebral hemispheres of man. The

dominant hemisphere is associated with verbal memory and the non-dominant hemisphere relates to non-verbal memory functioning. Since the usual unilateral ECT procedure involves the administration of shock to the non-dominant hemisphere only, and because most of the studies on the effects of non-dominant ECT on memory have only used verbal memory measures, it is possible that non-verbal memory impairment does exist but has not been tested for appropriately. Although bilateral ECT, which implicates both the dominant and non-dominant hemispheres, produces greater verbal memory impairment than does non-dominant ECT, the effects of the two procedures on non-verbal memory require further investigation.

Not only has research in the area of ECT concentrated on verbal memory function, but, to date, methodological variability of investigations has made it difficult to compare and to interpret the variable and contradictory results obtained from the ECT research in general and from the unilateral ECT research in particular. The aim of the present study, therefore, is to overcome earlier methodological weaknesses and to attempt to demonstrate localization of non-verbal memory in the non-dominant hemisphere, under well controlled and defined experimental conditions. Another aim of this study is to determine whether the characteristics of ECT-induced non-verbal memory disturbance are similar to those suggested by animal research, neuropsychological investigations, and the ECT research which has employed verbal measures of memory.

The Effects of ECT on Memory

Almost all authorities have noted that an adverse effect on memory is an almost invariable sequel to bilateral ECT. Consequently, research has not been limited to the question of the therapeutic efficacy of bilateral ECT. Studies have been concerned with both the nature of the ECT-induced memory impairment and the specific parameters of ECT administration responsible for the memory disturbance.

Bilateral ECT-induced Memory Impairment

In addition to the amnesia for the period of treatment itself, memory disturbances associated with ECT may be classified into two categories: retrograde amnesia, i.e. difficulty in remembering events experienced before treatment; and anterograde amnesia, i.e. difficulty in remembering events experienced after treatment.

Retrograde effects. In the recovery of personal memories following ECT, there is usually a considerable "shrinkage" with the passage of time. Patients may be unable at first to remember a large part of their lives, but the gaps gradually close as normal mental functions are restored (Williams, 1966). Ebtinger (1958) considers that the pattern of shrinkage is not always from past to present, but consists rather of a filling in between islands of memory. However, several experimental studies have revealed that the events forgotten are closely related to the onset of the seizure, those last experienced being most readily forgotten (Cronholm & Lagergren, 1959; Maher, McIntire, & House, 1962; Mayer-Gross,

1943; Zubin & Barrera, 1941).

Patients almost invariably regain personal orientation (knowledge of name, occupation, home address) before orientation for place or time (Lancaster, Steinert, & Frost, 1958). Those habits most firmly established and most often practised are the first to be regained. Rochford and Williams (1962) found this principle to apply even to the recovery of vocabulary. Thus, words with a high frequency of usage are remembered earlier after ECT than difficult or rare words.

The longer one waits to test patients after ECT the more likely it is that a stimulus presented prior to ECT will be recalled (Cronholm, 1969; Mayer-Gross, 1943; Williams, 1969). This indicates a diminishing anterograde postictal effect of ECT which is distinct from the retrograde amnesia effect. Thus, temporary memory defects, so commonly reported, could be attributed to postictal confusional impairment of retrieval, as suggested by Jarvik (1972). Indeed, immediately following ECT, patients are disoriented, confused, and unable to respond to questions in a coherent manner. Stimuli presented to them at this time are forgotten almost immediately, and after final recovery of orientation, patients claim total amnesia for events occurring at this time.

Nevertheless, it is a generally accepted fact that the immediate post-ECT memory defects associated with a confusional state are independent of ECT-produced retrograde amnesia. For some time after return of full consciousness and orientation, patients often continue to experience memory gaps for pre-treatment events. Cronholm and Molander (1957) isolated the two effects that ECT

has in retrograde amnesia. These authors interpreted their data as indicating: (a) a memory trace is weakened more when the learning-shock interval is short; (b) recovery takes place at the same rate independent of this interval; and (c) the memory trace reaches a lower final level when the learning-shock interval is short than when it is long. The implication of these findings is that one effect of ECT is the partial destruction of the memory trace, and the other is temporary disruption of the mechanisms of recall. The latter process dissipates with time, so that recall eventually becomes possible up to the limits permitted by the partial destruction of the trace by ECT.

Anterograde effects. There is evidence that ECT produces impaired ability to acquire and retain information after treatment. Brengelmann (1959) reported impairment in visual learning when five or more shocks had been administered. Stone (1947) reported that the effect of a series of ECTs was to produce a gradual decline in intellectual efficiency, as measured by scores on a standard memory scale.

The results of studies dealing with memory effects in general, and with anterograde effects in particular, are difficult to compare because different tests have been used and different hypothetical constructs of memory have been adopted.

Cronholm and his associates have utilized highly controlled investigative techniques and have operationally defined their terms in a precise manner. The memory tests used were constructed by Cronholm and Molander (1957). The basic procedure consists of a single combined visual and auditory presentation, and

testing for recall at different time intervals after presentation. The series comprises three sub-tests, each with 30 items. In the 30-Figure Test, the subject is shown a picture with 30 common objects, which are pointed out and named. On a new picture, where the 30 objects are mixed with 30 others, the subject is asked to point out those which he recognizes. In the 30-Word-Pair Test, word pairs are shown and read 10 at a time, and the subject is then asked to complete the pairs after being presented with the first words in a new order. In the third sub-test, the 30-Personal-Data Test, the subject is told five facts about six persons shown to him in pictures. He is then asked to relate the facts he remembers when the pictures are presented in a new order.

Three scores are obtained: immediate reproduction (IR), i.e. the score obtained immediately after presentation; delayed reproduction (DR), i.e. the score obtained after 3 hours; and forgetting, which is the difference IR - DR. IR is said to be determined by one hypothetical variable, denoted learning, and forgetting by another theoretical variable, denoted retention. Delayed reproduction is said to be determined both by learning and retention.

The results on the anterograde effects produced by ECT obtained by these investigators, reveal a certain dissociation of memory functions. Immediate memory span and learning capacity return to pre-treatment levels fairly quickly. The ability to learn new material, furthermore, is positively correlated with the lifting of depressive symptoms. The main consistent defect resides in the mechanism described as retention. Specifically, this consists of a quick fall-off of

information with the lapse of time or with interpolated tasks.

Recovery of memory. The duration of memory defects depends on the individual subject, the time intervals between ECTs, the shock intensity, and the memory measure used. Estimates range from 1 week after termination of a series of bi-weekly ECTs (Cronholm & Bloomquist, 1959; Hetherington, 1956) to 3 weeks after termination of a course of ECT (Zubin & Barrera, 1941). Cronholm and Molander (1964) found complete restitution of all memory functions, including retention, in a group of 28 patients, 1 month after the last ECT of a series. The series had constituted a mean number of 5.3 ECTs and had extended over a mean time period of 17.9 days.

Kalinowsky (1961) cites several studies (Huston & Strother, 1948; Rabin, 1948; Sherman, Mergener, & Levitin, 1941; Stone, 1947; Wilcox, 1953; Zubin & Barrera, 1941) to support his conclusion that no evidence has been brought forward to indicate that permanent memory losses are caused by ECT. Perlson's (1945) psychological testing of a patient who had the unusual number of 248 convulsions, and Rabin's (1948) analysis of Rorschach tests given to patients who had received 100 or more treatments, revealed no evidence of intellectual impairment nor signs of persisting neurological dysfunction.

In the case of residual retrograde amnesia, this is thought to cover a period of only a brief few seconds prior to ECT, but investigation has shown that the cut-off point for amnesic effect is neither sharp nor sudden (Williams, 1966).

In general then, while reports of permanent amnesia are rare, memory

impairment has frequently been found to last for weeks and even months (e.g. Brody, 1944; Levy, Serota, & Grinker, 1942).

Variables Which Affect Memory

Much of the research in the area of ECT has addressed itself to specific factors which might affect post-ECT memory functioning. Commonly studied variables have been the parameters of ECT, such as the number of shocks administered; the time interval between shocks; and the intensity of the electrical stimulation. Other variables which have been investigated have included medication, age, and clinical diagnosis. Still other variables influencing post-shock memory impairment have been identified by animal research.

Number and interval of shocks. It is generally believed that even if ECTs are spaced at 2- or 3-day intervals, the return of memory functions becomes progressively slower as the number of shocks increases. This belief is partly based on the evidence that the convulsive threshold tends to rise with successive treatments (Kalinowsky & Hoch, 1961), making it necessary to increase the stimulus intensity in order to produce a seizure. However, experimental evidence does not support the impression that memory impairment increases with the number of treatments given.

Cronholm and Lagergren (1959) found that there was a trend towards more complete and more rapid recall of single numbers presented to patients just before ECT, from the first to the fourth treatment. Thorpe (1959) inspected the learning graphs of patients who were required to learn 10 three-letter nonsense syllables 4 hours after every treatment for 20 successive ECTs. The graphs showed some

fluctuations for the first 10 days but then showed a steady improvement up to the twentieth day. Perlson (1945) found no residual memory impairment in one patient who received 248 individual shocks.

These studies measured either learning or the retention of events or material acquired before treatment. It is interesting to note that no study has investigated retention deficits for events presented after ECT in relation to the number and frequency of treatments.

Despite the foregoing experimental findings, there is a lack of agreement among investigators on the relationship of number and frequency of shocks to memory defects. This is illustrated by the conclusions of Barbizet (1970), which are contrary to those just presented. Barbizet summarizes the issue as follows:

> Memory recovery, which is almost total after a single shock, becomes less and less satisfactory as the series is prolonged, until the patient may be unable to remember even important personal events, such as the death of the husband or wife that had provoked the actual depressive episode. After a series of ECTs, the patient will take from one to four weeks to recover his personal memories entirely. Nevertheless, he will be left with a partial or total lacuna concerning the period of his treatment. Later, some patients may complain of small memory troubles in everyday life, but these become attenuated in a few months. When massive memory disorders persist after an ECT series, it is in most cases considered to be due to a hysterical amnesia [p. 21].

The effects of very frequent or "intensive" ECT were first described by Milligan (1946). This method involves the application of ECT two or three times per day for up to 34 treatments. By the end of such treatment patients usually show complete regression consisting of incontinence, muteness, rigidity, and increased reflexes. Individual differences have been found with respect to the number of

treatments required to produce this state. Emergence from this state takes an average of from 7 to 10 days, but the author reports no lasting damage to memory functions.

Russell, Page, and Jillet (1953), using a modified form of intensive ECT, found individual differences in the degree of amnesia and confusion following treatment, and claimed that amnesia and confusion were no greater than that following a comparable number of ordinary, conventional ECTs. Stengel (1951) studied the effects on 10 patients of intensive therapy consisting of two to four shocks on successive days for 1 to 2 weeks. He found a highly abnormal residual retrograde amnesia for personal events in four patients, all diagnosed as hysterics. Schwartzman and Termansen (1967) found no test evidence of persisting intellectual or memory impairment in 28 patients who had received intensive ECT, but reported significantly high evidence of persisting memory complaints among these patients.

Alexander (1953) reported that a non-convulsive stimulus applied right after a regular ECT causes memory impairment to clear up more rapidly than a routine ECT. The results obtained with this technique, called countershock, were confirmed by Russell, Page, and Jillet (1953). Cronholm and Ottosson (1961), however, found an increase in immediate retrograde amnesia with this procedure.

Intensity of electrical stimulation. Whether the adverse effect of ECT on memory function is mainly dependent on the electrical stimulation or on seizure activity is a controversial issue in the ECT literature.

On the assumption that memory disturbance is at least partially an effect of the electrical energy administered, several modifications of the ECT stimulus have been proposed. The energy required to elicit a generalized seizure has been greatly reduced by substituting the original alternating sinusoidal current with a unidirectional pulsating current (Beek & Stuart, 1953; Friedman & Wilcox, 1942; Liberson, 1944, 1948; Offner, 1946; von Braunmuhl, 1951). However, whether or not the altered method retains its therapeutic effect and causes less memory disturbance is a debatable issue.

From general clinical assessments, several authors found less confusion and memory defect with the undirectional pulsating current (Bayles, Busse, & Ebaugh, 1950; Epstein & Wender, 1956; Gayle & Josephs, 1948). On the other hand, Proctor and Goodwin (1945) did not observe any differences between the two procedures in their effect on memory.

Several investigators, working with memory tests, have found smaller adverse effects on memory with lower energy stimuli (Liberson & Wilcox, 1945; Lindner & Brouschek, 1953; Mendlicott, 1948) but statistical significance was attained only in the study of Kendall, Mills, and Thale (1956). Cronholm and Ottosson (1963) found retrograde amnesia to be shorter with ultra-brief ECT compared with routine treatment, having pulses of longer duration.

Brengelman (1959) and Mayer-Gross, Slater, and Roth (1960) claim that there is little convincing evidence that modifications of wave-form, pulse-strength, duration and interval between pulses, and polarity, have different effects on post-

ECT confusion and memory impairment.

Comparative investigations into the effect on memory performance of electrically induced seizures and those evoked by pharmacological agents, which might elucidate the topic under discussion, are scarce. The general clinical impression seems to be that ECT causes memory impairment more frequently than does pharmacological convulsive treatment (Ewald & Haddenbrock, 1942; Levy et al., 1942; Lewis, 1945; Silfverskiold & Dencker, 1957).

Experimental variation of seizure discharge for systematically studying the mechanism of memory impairment was initiated by Ottosson (1960). Ottosson compared four methods of treatment in four experimental groups.

Group 1: A seizure discharge was evoked by a stimulus considerably above threshold for a grand mal seizure.

Group 2: A seizure discharge was evoked by a stimulus only moderately above the threshold. This procedure corresponds to routine ECT.

Group 3: A seizure discharge was evoked by a stimulus moderately above threshold and under the influence of lidocaine, a local anesthetic which acts as an anti-convulsant and which reduces the seizure discharge.

Group 4: Only the premedication-anesthetic, muscle relaxant, and lidocaine, without the shock, were administered.

The memory tests devised by Cronholm and Molander (1957) were administered to the patient 1 to 5 days before treatment, and after a single experimental procedure. The results obtained by Ottosson were summarized as

follows. The adverse influence on memory performance was significantly greater in Group 1 than in Group 2. Further, the adverse influence in Group 2 was greater, though not with the same degree of significance, than in Group 3. Finally, Group 3 displayed considerably and significantly greater adverse influence than Group 4, the control group. Since Groups 1 and 2 did not differ significantly with respect to seizure duration or seizure pattern, despite the different stimulus energies, the greater adverse influence in Group 1 was ascribed to an effect of the increased electrical stimulation. The difference between Groups 2 and 3 was attributed to the reduced seizure activity in Group 3.

Thus, the results pointed to an adverse influence on memory performance being determined both by stimulus intensity and by seizure discharge. However, Ottosson found that the reduction of seizure discharge had a less pronounced effect than the increase of stimulus intensity. Also, whereas the increase in stimulus intensity between Groups 1 and 2 was not exceptionally high, the reduction of seizure activity between Groups 2 and 3 was marked. The conclusion of this important study was that the major adverse influence on memory performance can be accounted for by effects of electrical stimulation other than seizure activity.

It is interesting to note that the memory disturbance found in this study was mainly seen in the variable "retention", as defined by Cronholm, as opposed to the variables "learning" and "recall".

Medication. Memory disorders reported since the introduction of anaesthetics and relaxants are very similar to those reported earlier. Brengelman

(1959) concludes that the anaesthetic has no effect on memory impairment following ECT. Cronholm and Molander (1957) carefully tested the effect of Evipan on retention. Using the same test battery as had been used to measure post-ECT memory disorders, the authors found no memory loss in these patients, in contrast with the obvious memory impairment seen in a comparable group who received both Evipan and ECT. Ottosson (1960) found no significant memory changes associated with the anaesthetic and the muscle relaxant which accompany ECT.

Age and clinical diagnosis. It is well known that some aspects of memory functions alter with age. However, whether retention deficits following ECT increase with age has not been established.

Kalinowsky and Hoch (1961) reported that older subjects take longer than younger ones to regain orientation after treatment. Cronholm and Lagergren (1959) found no effect of age on the ability to recall a single number presented shortly before the shock. In general, those older patients who show persistent and severe memory loss after ECT, are usually presumed to have already sustained some intellectual deterioration due to factors other than ECT (Feldman, Susselman, Lipetz, & Barrera, 1946).

ECT-produced retention impairment seems to be independent of behavioral disturbance. Although different diagnostic groups show many characteristically different patterns on pre-treatment performance, pre- and post-ECT memory functions show the same quantitative and qualitative differences in all diagnostic

groups. The situation is different, however, with respect to immediate memory span and learning. While improvement on these measures usually follows relief of depression, it does not necessarily follow the alleviation of other symptoms of mental disorders (Cronholm & Lagergren, 1959).

Sargant and Slater (1963) and Stengel (1951) observed prolonged retrograde amnesia following ECT in patients with marked hysterical symptoms. On the other hand, Milligan (1946) achieved greatest success with those patients who showed hysterical conversion symptoms.

Animal research. Animal research has, to a great degree, concerned itself with the processes by which ECS impairs memory. The variable results obtained from the different research designs have been interpreted as supporting one or another theory. Although these theories and the research to support each are presented in a later section, some general conclusions from the animal studies are relevant here.

The kinds of results one obtains with animal research are related to the training situation, which includes the apparatus, the behavior tested (e.g. passive avoidance versus active avoidance), the time intervals between training and ECS and between ECS and testing, and the number of ECSs administered. The results are also a function of the criterion of learning.

Jarvik (1972) has reviewed the recent animal ECS literature and brings to light still more relevant information. Events occurring during the conditioning-ECS interval modify the amnesic effects of ECS. For example, detaining the animal in

the test apparatus markedly potentiates the amnesic actions of ECS (Davis, 1968; Robustelli, Geller, & Jarvik, 1968). Any procedure that tends to weaken the trace appears to make it more susceptible to further weakening by ECS. Thus, a flashing light during the interval potentiates the action of ECS (Miller, Mesanin, & Lewis, 1969). Incidents occurring at any time during the retention interval might be expected to produce an interfering effect of the same type.

The permanence of ECS-induced amnesia is a subject of recurring debate. Again, the nature of the training procedure employed seems to be responsible for the differences. Most investigators have found relatively long-lasting amnesia varying from days to weeks. Under the same training conditions, amnesia can be temporary if conditioning is strong and permanent if conditioning is weak. Also, the strength of the ECS can influence permanence. Thus, high intensity ECS may produce a permanent amnesia while low intensity ECS can cause a temporary amnesia (Pagano, Bush, Martin, & Hunt, 1969). Geller and Jarvik (1968), Hughes, Barrett, and Ray (1970), and McGaugh and Landfield (1970) have demonstrated an apparent growth of amnesia with time--the surprising fact that there is sometimes a tendency for the memory loss to increase after the cessation of the amnesic treatment. Finally, ECS-induced amnesia is never complete even when it appears to be so because amnesic animals show marked savings upon relearning when compared with controls (Geller & Jarvik, 1968).

Unilateral ECT

A major aim of research with bilateral ECT, as seen in the study of factors

which affect memory, has been the development of procedural modifications which would lessen subsequent memory impairment and yet remain therapeutically effective. The introduction of unilateral ECT was an outgrowth of this search.

Table 1 summarizes the studies which have investigated the effects of unilateral non-dominant ECT on memory.

The therapeutic efficacy of non-dominant ECT as compared to the standard bilateral stimulation is a controversial issue. The two procedures have, by and large, been found to be equally effective for depression (Studies 1, 3, 5, 10, 11, 13, 14, 15, 16, 17, 18, 19, 22, Cannicott, 1962; Cannicott & Armin, 1968), although some investigators suggest that bilateral ECT may be superior (Studies 1, 5, 11, 12, 22; Kalinowsky & Hippius, 1969).

Non-dominant ECT has repeatedly been found to produce less memory impairment than bilateral ECT (Studies 1, 3, 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22). Similarly, duration of post-treatment confusion is reported to be considerably shorter after unilateral than after bilateral ECT (Studies 1, 3, 5, 10, 11, 13, 15, 18, 19, 22; Cannicott, 1962; Man & Bolin, 1969; Thenon, 1956).

A plausible explanation offered for the diminished memory impairment with unilateral ECT in the earlier studies which compared bilateral and non-dominant ECT (Studies 1 and 3) was that a smaller portion of the brain was being affected by unilateral ECT. However, when Zamora and Kaelbling (1965) compared non-dominant ECT with unilateral ECT to the dominant hemisphere and found non-dominant ECT to produce less memory loss, a functional difference between the two

Table 1

Studies on Memory Effects of Bilateral and Unilateral ECT

Study	Tests		Type of Task					
	Verbal	Non-Verbal	Verbal			Non-Verbal		
			Total Recall	Recognition	Learning	Total Recall	Recognition	Learning
1. Lancaster, Steinert, & Frost (1958)	Short sentence		x					
2. Gottlieb & Wilson (1965)	Personal information		x					
	Digit span		x					
	Proverbs							
3. Martin, Ford, McDanald, & Towler (1965)	Wechsler Memory Scale		x		x			
4. Zamora & Kaelbling (1965)	Wechsler Memory Scale		x		x			
5. Impastato & Karliner (1966)	Several simple questions		x					

Table 1 (Continued)

Study	Tests		Type of Task					
			Verbal			Non-Verbal		
	Verbal	Non-Verbal	Total Recall	Recognition	Learning	Total Recall	Recognition	Learning
6. Cannicott & Waggoner (1967)	Memorization of nouns Similarities	Block Design (Wechsler Bellevue)	x					
7. McAndrew, Berkey, & Matthews (1967)	Battery of neuro-psychological tests	Battery of neuro-psychological tests						
8. Wilson & Gottlieb (1967)	(see 2)							
9. Cohen, Noblin, Silverman, & Pennick (1968)	Paired associates	Forms Test	x		x			x
10. Halliday, Davison, Browne, & Kreeger (1968)	Digit span Learning the meaning of unfamiliar words	Rey Davis Boards	x		x			x

Table 1 (Continued)

Study	Tests: Verbal	Tests: Non-Verbal	Type of Task: Verbal: Total Recall	Verbal: Recognition	Verbal: Learning	Non-Verbal: Total Recall	Non-Verbal: Recognition	Non-Verbal: Learning
11. Levy (1968)	Paired associates		x		x			
	Wechsler Memory Scale		x		x			
	Gresham Test Battery		x					
12. Strain, Brunschwig, Duffy, Agle, Rosenbaum, & Bidder (1968)	Paired associates	Benton Visual Retention Test	x		x	x		
	Personal data sheet		x					
13. Valentine, Keddie, & Dunne (1968)	Paired associates		x		x			
14. Zinkin & Birtchnell (1968)	Pictures of common objects			x				

Table 1 (Continued)

Study	Tests: Verbal	Tests: Non-Verbal	Type of Task: Verbal: Total Recall	Verbal: Recognition	Verbal: Learning	Non-Verbal: Total Recall	Non-Verbal: Recognition	Non-Verbal: Learning
15. Sutherland, Oliver, & Knight (1969)	Wechsler Memory Scale Sentence	Visual sub-test (Wechsler Memory Scale)	x x		x	x		
16. Bidder, Strain, & Brunschwig (1970)	(See 12)	(See 12)						
17. Costello (1970)	Paired associates		x	x	x			
18. Cronin, Bodley, Potts, Mather, Gardner, & Tobin (1970)	Modified word learning test Digit span Wechsler Memory Scale (Pts. 1 & 2)	Graham Kendall Memory for Designs Benton Visual Retention Test	x x		x	x x		
19. d'Elia (1970)	Cronholm-Molander battery		x	x	x			

Table 1 (Continued)

Study	Tests		Type of Task					
	Verbal	Non-Verbal	Verbal			Non-Verbal		
			Total Recall	Recognition	Learning	Total Recall	Recognition	Learning
20. Fleminger, Horne, Nair, & Nott (1970)	Paired associates		x		x			
21. Dornbush, Abrams, & Fink (1971)	Paired associates	Visual short term memory test	x		x	x		
	Consonant trigrams		x					
22. Abrams, Fink, Dornbush, Feldstein, Volavka, & Roubicek (1972)	(See 21)	(See 21)						

hemispheres was indicated.

On the whole, the results reported in the unilateral ECT research have been difficult to compare and to interpret. Studies with unilateral ECT have differed along a number of dimensions. While all of the studies have used verbal memory tests, only a few have also included non-verbal memory tests. Studies which looked at verbal memory have differed with respect to the tests used, the types of memory function investigated (i.e. recall, recognition, learning) and whether or not recovery of memory was also investigated. Studies of non-verbal memory have likewise differed from each other in these respects. Finally, regardless of whether verbal or non-verbal measures were employed, across all of the studies which investigated the differential memory effects of bilateral and unilateral ECT are a number of methodological variables, the variation of which may well have contributed to some of the contradictory results reported.

The Effects of Non-Dominant ECT on Verbal Memory

Some investigators conclude that while both bilateral and non-dominant ECT impair memory, non-dominant ECT does so to a lesser degree (Studies 5, 9, 11, 13, 14, 18, 19, 21). Other studies have shown either improvement in memory function following non-dominant ECT (Studies 3, 4, 6) or virtually no adverse effect (Study 19). Study 15 found bilateral, non-dominant, and dominant ECT each to improve memory, with the non-dominant group showing the most marked improvement.

As can be seen in Table 1, studies have differed greatly with respect to the

verbal tests used and the type of memory function investigated. While most studies have investigated either learning or some form of recall, others (e.g. Studies 6, 7) have been concerned with verbal cognitive functions which do not fall directly into either of these categories (e.g. concept formation and abstraction ability).

In general, such terms as learning, recent and remote memory, immediate and delayed memory, have been used but have not been consistently defined. Nor have the processes underlying these terms been clearly conceptualized. In addition, one finds no consensus among investigators as to the time intervals associated with so-called "short term" or "long term" memory.

Investigators have frequently reported their findings without specifying their intention to investigate retroactive or proactive effects of ECT. It is apparent, however, that retroactive effects were investigated in Studies 1, 6, 10, 11, 12, 13, 14, 15, 17, and 19, and proactive effects were investigated in all of the studies except Studies 1 and 13.

d'Elia (1970) carried out an intensive investigation in which both proactive and retroactive effects were assessed. In addition, he looked at both immediate and delayed recall, and at the hypothetical variables proposed by Cronholm (described earlier). d'Elia found that retrograde amnesia was significantly higher after bilateral than after non-dominant or dominant ECT, and that dominant ECT was more adverse than non-dominant ECT. Anterograde amnesia was impaired by bilateral ECT but not by non-dominant ECT (a dominant ECT condition was not

included here).

Few investigators have explicitly recognized the importance of the difference between a test which requires total recall and one which involves recognition. Recognition tests are more sensitive to the effects of ECT while tests of total recall tend to produce many false negative results (Williams, 1966). Only three studies (14, 17, and 19) employed recognition tests. A third approach in testing recall, the savings method, has not been systematically used even though experimental paradigms have been suggested by the animal research on ECS and memory.

Recovery of Verbal Memory

Only a few studies have investigated recovery of verbal memory function. Bidder et al. (1970) and Strain et al. (1968) found no difference in memory performance between patients treated with bilateral ECT and those treated with non-dominant ECT, 10 days, 30 days, and 1 year after the last treatment. Halliday et al. (1968) found that 3 months after treatment, patients treated with bilateral ECT were significantly more impaired than those treated with either dominant or non-dominant ECT, and dominant ECT continued to show a more adverse effect than non-dominant ECT. Cronin et al. (1970) found that memory functioning was better after non-dominant than after dominant or bilateral ECT, 4 to 6 weeks after eight treatments. Zinkin and Birtchnell (1968) found the acute anterograde effects of ECT to have diminished greatly 2 hours after treatment for both bilaterally and non-dominantly treated patients; however, the bilateral group was still somewhat more impaired

than the non-dominant group.

The Effects of Non-Dominant ECT on Non-Verbal Memory

No study has concentrated solely on the effects of the various modes of ECT on non-verbal memory. Those studies which have included non-verbal measures also employed verbal memory tests (see Table 1).

No significant differences in the effects on non-verbal memory between bilateral and non-dominant ECT were found by Dornbush et al. (1971) and Strain et al. (1968), or between dominant, non-dominant and bilateral ECT, by Cronin et al. (1970). These studies found non-verbal memory function to be virtually unchanged after treatment. Halliday et al. (1968) found non-dominant ECT to produce greater memory impairment than dominant ECT, while the effects of bilateral ECT were not significantly different from either non-dominant or dominant ECT. Cohen et al. (1968) concluded that bilateral and non-dominant ECT caused significantly greater memory decrement than dominant ECT.

There are studies, however, which suggest improved memory following ECT. Sutherland et al. (1969) found that non-dominant ECT significantly improved performance on the Wechsler Memory scale when the visual subtest was excluded, while both non-dominant and dominant ECT significantly improved performance when the visual subtest was included. In both instances, bilateral ECT also improved performance but not significantly. Cannicott and Waggoner (1967) showed that bilateral and non-dominant ECT were each responsible for improved performance on the Block-Design sub-test of the Wechsler-Bellevue. McAndrew et al. (1967) found

that non-dominant ECT improved memory for tests said to be associated with right hemisphere functioning, dominant ECT improved memory for tests said to be associated with left hemisphere functioning, and bilateral ECT improved performance on both kinds of tests. Clearly, lack of agreement among investigators is frequent.

Recovery of Non-Verbal Memory

The research on recovery of non-verbal memory has been understandably scanty since only a few studies have been concerned with the effects of ECT on non-verbal memory. Of these, most have failed to discover any non-verbal memory deficits.

Bidder et al. (1970) and Strain et al. (1968) found no adverse effect from either non-dominant or bilateral ECT 36 hours, 10 days, 1 month, and 1 year after treatment. Cronin et al. (1970) found no significant differences among the effects of dominant, non-dominant,and bilateral ECT 4 to 6 weeks after eight treatments. Halliday et al. (1968) found that 3 months after treatment a bilaterally treated group continued to show impairment while a non-dominantly treated group was unimpaired.

Table 1 illustrates that a variety of non-verbal tests have been used. Most of these tests require a considerable amount of motor response on the part of the subject, and insofar as motor output is frequently retarded in depressed patients, the value of such tests with depressed subjects is questionable. In addition, some of the tests are not clear cut measures of memory (e.g. Studies 6 and 7).

All of the studies investigated proactive effects of ECT. Retroactive effects

of ECT on non-verbal memory have not as yet been investigated. Another common feature of the non-verbal tests used to date is that all have involved either total recall or learning. No study has employed a non-verbal recognition task.

Other Methodological Variables

As described earlier, research with bilateral ECT, and the animal ECS research have assessed the influence of a number of variables on the degree of memory impairment obtained, e.g. shock intensity, frequency, etc. Investigators who compare the effects on memory of bilateral and unilateral ECT should take these findings into account in designing their research. They should also incorporate such features as a double blind procedure and a test for laterality.

Bidder et al. (1970) and Strain et al. (1968), in reviews of the recent unilateral ECT literature, have shown that almost all studies have failed to meet one or more of the following procedural requirements.

Assignment of patients to treatment groups in a random manner. The criteria of patient selection for a study should be specified in advance, and subsequent placement of patients in one of various treatment groups should be via random assignment so as to avoid subtle selection bias.

Double-blind technique. As in drug studies, maintenance of the double-blind technique is crucial in studies which compare the different types of ECT and which allow for various a priori hypotheses.

Specification of the electrical parameters. Since the parameters of the electrical stimulus have been shown to be an important determinant of the degree of

memory loss associated with ECT, it is necessary that the intensity of the shock applied not only be specified by the author, but also be kept constant across the various ECT procedures.

Diagnostic homogeneity of the groups studied. Many studies have either included patient populations heterogeneous in diagnosis or have not specified the diagnoses of the patients studied. In general, even aside from the lack of diagnostic homogeneity, the equivalence of groups is often questionable. Probably the best solution to the problem of group heterogeneity is the research design in which each subject serves as his own control. Few studies, however, have adopted this design.

Demonstration of cerebral dominance. The complex inter-relationship of cerebral dominance and handedness has received considerable study and is lucidly reviewed by Brain (1965), Piercy (1967), and Zangwill (1960). It appears that in most right-handed individuals the dominant cerebral hemisphere, that is, the hemisphere associated with language and other verbal functions, is on the left side of the brain. Branch, Milner, and Rasmussen (1964) found that 10% of their right-handed patients had right-sided speech dominance. For left-handed individuals, calculated to be about 5 to 10% of the general population (Brain, 1965), the dominant speech area tends to be right-sided, or else speech tends to have bilateral representation.

Studies which investigate the differential effects on memory of different electrode placements must demonstrate, a priori, the assumed site of dominance of

the patients studied if the results are to be meaningful. Although tests of handedness and other aspects of laterality are only indirect measures of cerebral dominance, they do identify cerebral dominance reasonably well beyond chance.

Time intervals. Another methodological variable, although not a procedural requirement, is the comparability of time intervals at which memory is tested. Studies have differed with respect to the time intervals associated with both the presentation of material before ECT and the testing of memory after treatment. The interval from test presentation to ECT has varied from just prior to ECT (Lancaster et al., 1958) to 19 hours before ECT (Costello et al., 1970). The interval between treatment and recall has varied from immediately after ECT (Lancaster et al., 1958) to 2 days after ECT (Halliday et al., 1968).

Virtually all studies tested for ECT-induced memory impairment after the administration of a series of ECT. The number of treatments comprising a series has varied not only between studies but also frequently within a study. Only d'Elia (1970) and Zinkin and Birtchnell (1968) investigated memory loss after a single treatment. Testing patients after an ECT series permits the confounding of ECT effects on memory with those resulting from the alleviation of depressive symptoms.

The Role of the Temporal Lobes in Memory Function

Studies of memory function in patients following temporal lobectomy are of relevance to ECT research for two major reasons. First, there are similarities between the memory defects seen after temporal lobe excisions and those seen after bilateral ECT. Both procedures affect retention as opposed to immediate memory;

and both seem to produce an interfering effect on new material to be retained. Of course, memory impairment is far more transient following ECT than following temporal lobectomy.

Second, as will be seen, the neuropsychological studies have provided much evidence to suggest an association between the dominant cerebral hemisphere and verbal memory, and between the non-dominant cerebral hemisphere and non-verbal memory. These studies have not only revealed the importance of the non-dominant temporal lobes for non-verbal memory but have also suggested the kinds of tests which are sensitive to non-verbal memory dysfunction.

One of the outstanding features of studies which have compared the effects of bilateral and non-dominant ECT on memory has been the failure to systematically investigate non-verbal memory. Few investigators have ignored the evidence suggesting a specialization of function of the cerebral hemispheres. Indeed, many researchers attributed the lack of memory loss after non-dominant ECT to the fact that the dominant hemisphere had been spared the electrical impact. However, only a few investigators have attempted to demonstrate non-verbal memory loss with non-dominant ECT and no one has demonstrated such a loss using the non-verbal tasks suggested by Milner (1970). Where attempts have been made to relate non-dominant ECT to non-verbal memory impairment, either the measures used have been questionable or other methodological short-comings (as described earlier) have prevailed.

Amnesia Associated with Bilateral Temporal Lobe Lesions

Terzian and Dalle Ore (1955) reported that after the removal of both temporal lobes, a patient showed severe retrograde amnesia extending back to his childhood, and marked anterograde amnesia.

Numerous case studies have suggested a relationship between memory disorder and hippocampal damage (Bekhterev, 1900; Glees & Griffith, 1952; Hegglin, 1953; Ule, 1958; Victor, Angevine, Mancall, & Fisher, 1961). However, the most convincing evidence for the role of the temporal lobes in memory probably comes from the observations of memory loss following the removal of parts of the temporal lobes.

The reports of Petit-Dutaillis, Christophe, Pertuiset, Dreyfus-Brisac, and Blanc (1954), Sawa, Ueki, Arita, and Harada (1954), and Terzian (1958) suggest that bilateral excisions limited to the amygdala and the area of the temporal pole can be made without causing any interference with memory, but that more extensive bilateral excisions are likely to produce memory impairment, affecting primarily the recall of recent events. Scoville and Milner (1957) described a severe impairment of recent memory, both anterograde and retrograde, after bilateral removal of the mesial parts of both temporal lobes in an epileptic patient. The operation spared the temporal neocortex entirely, but parts of the hippocampus were destroyed bilaterally, as were the uncus and the amygdala. Subsequent observation of eight more patients who had undergone this operation revealed memory loss in all patients with removals extending far enough to damage the

hippocampus and the hippocampal gyrus. Also, there seemed to be a positive correlation between the size of the removal and the degree of memory impairment. No residual memory deficit was seen after removals limited to the uncus and the amygdala.

Milner (1958, 1966, 1970) has shown fairly conclusively that bilateral lesions of the hippocampus and parahippocampal gyrus, on the medial side of the temporal lobe in man, cause a severe and lasting memory disorder of a generalized nature, but without other intellectual changes. These lesions do not produce a loss of previously acquired knowledge and skills; nor are they responsible for significant perceptual difficulties. Patients will remember new information normally, as long as the information does not exceed the immediate memory span. Thus, registration of new information appears normal. The outstanding feature of these patients is that they are unable to add new information to the long-term store.

Bilateral medial temporal lobe resection produces some retrograde amnesia for a period of time before the operation, but memory for events preceding the retrograde amnesia is normal. The gross impairment of memory is for events subsequent to the operation. This retention difficulty is not specific to any kind of material and it cuts across any distinction between verbal and perceptual material or between sense modalities. The defect is not primarily one of attention, concentration, or reasoning ability and there is no aphasia. Basically, patients are unable to recall test material after a few minutes or less if their attention has been diverted to another topic in the meantime. In the absence of distraction, a three-

figure number or a word-pair, for example, can be retained for many minutes, but only with continuous verbal rehearsal on the part of the patient (Milner, 1959).

Amnesia Associated with Unilateral Temporal Lobectomy

Unilateral temporal lobectomy involves the ablation of one temporal lobe, including the lateral neocortex and the underlying uncus, amygdala, hippocampus, and hippocampal gyrus. The procedure is a reliable method of treatment for well-lateralized temporal-lobe epilepsy. Following this operation, generalized memory disorders are rare but testing does reveal mild memory deficits which vary with the side of the lesion.

A comparison of the effects on memory of left and right temporal lobectomy reveals that the most significant variable is the verbal or non-verbal character of the material to be retained. Thus, there is evidence for specialized functional differences between the so-called major and minor cerebral hemispheres in man.

Left temporal lobectomy (anterior to the speech zone) selectively impairs verbal memory (Meyer & Yates, 1955; Milner, 1958), regardless of whether the material to be retained is heard or read (Blakemore & Falconer, 1967; Milner, 1967), and regardless of whether retention is measured by recognition, free recall, or rate of associative learning (Milner, 1958, 1967; Milner & Kimura, 1964; Milner & Teuber, 1968). Although these patients show verbal perceptual difficulty (Milner, 1967) this is trivial in comparison to the verbal memory deficit. Individual words, clearly enunciated, are easily understood and written sentences are easily read. The prime difficulty relates to learning verbal material in excess

of the immediate memory span. The latter is disproportionate to any verbal discrimination defect. The poor verbal memory performance has been demonstrated on a variety of tasks, which are described elsewhere (Milner, 1958, 1967; Milner & Kimura, 1964; Milner & Teuber, 1968). There is evidence to suggest that the degree of verbal memory impairment is dependent upon the amount of removal of the left hippocampus (Corsi, 1969). On non-verbal tasks, patients with left temporal lobectomies are indistinguishable from normal controls.

Right non-dominant temporal lobectomies leave verbal memory intact but affect performance on certain non-verbal tasks, and these defects are not limited to a particular sense modality. In audition, patients with right temporal lobectomy show impaired discrimination of tonal patterns and of timbre, although they can discriminate pitch (Chase, 1967; Milner, 1962). They also find it difficult to recognize snatches of instrumental music and familiar tunes (Shankweiler, 1966a, 1966b). The auditory impairment is not contingent upon the removal of the transverse gyri of Heschel, the main auditory perception area (Milner, 1967). In vision, defects have been found on such tasks as the interpretation of cartoon drawings (Meier & French, 1966; Milner, 1958), the estimation of the number of dots flashed on a screen (Kimura, 1963), and the recognition of irregular nonsense patterns (Kimura, 1963). Right temporal lobectomy also impairs maze learning, whether tactually or visually guided (Corkin, 1965; Milner, 1965). Performance on the mazes does not suggest spatial discrimination but rather difficulty in retaining the correct sequence of turns from one trial to the next (Milner, 1967).

The visual disorders associated with right temporal-lobe lesions affect both memory and perception. The essentially perceptual changes are so slight, however, that they have to be elicited via special techniques, e.g. with a tachistoscope (Kimura, 1963), by requiring the discrimination of small contour differences of complex patterns such as fragmented concentric circles (Meier & French, 1965), or by eliminating the normal contour lines (Lansdell, 1968; Mooney, 1956). In general, the perceptual tasks which these patients find difficult are ones in which the normal redundancy of the stimuli has been reduced. On the other hand, clearly visible stimuli exposed for sufficient time to allow normal viewing are readily identified by patients with right temporal lobectomy. Thus, for example, no impairment is seen on card-sorting tasks in which the essential cues, though visual, are distinct and fall into well-established categories (Milner, 1964).

The most pronounced defect suffered by these patients becomes manifest on visual memory tests. Patients with right temporal-lobe lesions have marked difficulty in learning to distinguish recurrent from non-recurrent nonsense patterns (Kimura, 1963). They also perform poorly on face recognition tasks (De Renzi & Spinnler, 1966; Milner, 1958, 1968; Warrington & James, 1967). The common feature underlying all the memory tasks which patients with right temporal-lobe lesions find difficult is the fact that the material cannot be accurately described in words.

With right temporal lobectomy, the postoperative deficit in maze learning is contingent upon removal of the hippocampus (Corkin, 1965; Milner, 1965). There is

also some evidence to suggest that the same is true for the deficit in recognition of unfamiliar photographed faces (Milner, 1968), although not for the recall or recognition of nonsense figures or complex geometric designs (Milner, 1970).

In general, the mild, specific memory changes seen after unilateral temporal lobe lesions interfere little with the daily life of the patient (Milner, 1970). Indeed, an instance of grave amnesia after unilateral temporal lobectomy in a patient was explained by an unsuspected lesion in the hippocampal region of the opposite hemisphere (Penfield & Milner, 1958).

Finally, it should be pointed out that performance decrements associated with left or right temporal lobectomy differ quantitatively or qualitatively from performance as affected by lesions in other parts of the brain, for example the frontal or parietal lobes (Corkin, 1965; Milner, 1964, 1967, 1968; Milner & Rasmussen, 1970).

ECT Effects on Memory:
Theoretical Considerations

The major interest in ECT has been of a practical nature--its therapeutic effects and its impact on memory function. Nevertheless, many theories have been put forth in an attempt to explain the underlying processes by which ECT produces therapeutic and amnesic changes.

Whether the effects of ECT on memory and on depression are independent phenomena, or whether, for example, lifting of depression is a function of memory loss, are unresolved theoretical issues.

The study to be described was concerned with memory and no attempt was made to systematically investigate therapeutic outcome. In addition, although the research was not designed to test any theory of the process by which ECT impairs memory, the possibility of some further light being shed on this question was, of course, present. Consequently, it is of interest to review the contributions derived from both animal research findings with ECS and from human research with ECT concerning the possible ways in which ECT affects memory.

Animal Research

Most of the experimental studies on the amnesic effects of ECS have involved animals. The distinct disadvantages in using animals as subjects are the absence of a highly developed language, the frequent requirement of elaborate training programs, and the much more restricted behavior repertoire. Furthermore, the validity of generalizing from the findings of lower species to man is often questionable. Nevertheless, the animal research, which has the main advantage of far greater control, has addressed itself to various theoretical considerations in an attempt to discover the process by which ECS impairs memory. Hence, the results of this line of research might illucidate the amnesic phenomenon seen in man.

A complete review of the animal work is beyond the scope of this paper. What follows, however, is a review of the main theories which have been generated by the research, and the problem areas which remain.

Neural consolidation theory. This is the most prominent theory in ECS research with animals, and other theories were often outgrowths of presumed

inadequacies in this theory.

Duncan (1949) trained rats to make an avoidance response in a two-compartment shuttle box and administered ECS at intervals of 20 seconds, 40 seconds, 4 minutes, 15 minutes, 1 hour, 4 hours, and 14 hours. He noted that when the interval was 20 seconds, there was no sign of learning, while with intervals of 1 hour or more there was no loss. The intervening intervals showed progressive loss from 15 minutes to 40 seconds. Similar findings were reported by Gerard (1955), Heriot and Coleman (1962), and Thompson and Dean (1955). In general, it appeared that intervals of less than 1 hour between learning trial and ECS would produce some loss while intervals of over 1 hour produced little or no loss.

The interpretation of such data have usually been in terms of the neural consolidation theory of memory. The theory states, in essence, that any stimulus event produces activity in the central nervous system of the subject, activity which must endure for some minimum period of time before it can be stored permanently, or consolidated (Gerard, 1955; Hebb, 1949; Muller & Pilzecker, 1900). Disruption of the central nervous system during this period disrupts the storage of the event and eradicates it from the recall repertoire of the subject. ECS, then, presumably has the necessary intensity to disrupt the consolidation process. Since retention was shown to be a negatively accelerated function of the interval between learning and ECS, the early studies were accepted as demonstrating the validity of this theory.

These early studies were criticized because they used several learning trials, thus giving the early trials time to consolidate before the later ones occurred (Pearlman, Sharpless, & Jarvik, 1961). More satisfactory experiments using one learning trial followed quickly by a single ECS (King, 1965; Madsen & McGaugh, 1961) have, nevertheless, upheld the consolidation theory. Chevalier (1965), using a single learning trial and a single ECS design, has shown that the retrograde amnesia remains undiminished over 30 days.

Other experiments, using the same initial design but going on to give further learning trials and ECSs, have concluded that other factors come into operation when several ECSs are given (Chorover & Schiller, 1965; Hudspeth, McGaugh, & Thomson, 1964).

Difficulties for the consolidation notion have been generated by other experimental evidence. Adams and Lewis (1962) and Poschel (1957) showed that ECS has a detrimental effect upon learning even when given before training. Brady, Hunt, and Geller (1954) showed that a series of ECSs given a few days after learning and thus long after what would normally be considered as the consolidation period, can also disrupt retention. Yet another problem for the theory is that retrograde amnesic results with animals seem to disappear with time.

Conflict theory. Coons and Miller (1960) replicated some of the features of Duncan's experiment and obtained results which they interpreted as showing that fear was induced by ECS. However, the experiment did not control for the effect of ECS alone, thus the effect of ECS was confused with other variables.

Studies which have used one aversive learning trial rapidly followed by a single ECS, in a direct test of this theory, have shown that the amnesic effect of ECS is stronger than any induced fear (King, 1965; Madsen & McGaugh, 1961). Other experiments, however, have found that after a series of ECS has been administered aversive effects of ECS do appear (Chorover & Schiller, 1965; Duncan, 1949).

The conflict theory cannot account for the results of experiments using the one learning trial and single ECS paradigm and so cannot displace the consolidation theory. Furthermore, while experiments using several ECSs found effects attributable to fear, these effects could be explained in other ways.

Competing response theory. This theory was first proposed by Adams and Lewis (1962a) and assumes that some aspect of the response to ECS becomes conditioned to stimuli in the surroundings. Lewis and Maher (1965) suggest that the coma following the seizure is due to "protective inhibition" and that components of this inhibition become conditioned to surrounding stimuli in the experimental apparatus.

This theory, if correct, would predict that ECS given in the same location as learning took place would disrupt learning far more than when given in a dissimilar situation. Confirmatory results were obtained by Adams and Lewis (1962b), but Quartermain, Paulino, and Miller (1965) found the location in which ECS was given to be irrelevant, as would be predicted by the consolidation theory. The two experiments did differ, however, in the timing and number of ECSs, with

Quartermain et al. using a single ECS and a short learning-ECS interval, and Adams and Lewis using several ECSs and a longer learning-ECS interval.

Once again, the study which used the single ECS and short learning-ECS interval supports the consolidation theory. When the longer learning-ECS interval and a series of ECSs are used other factors come into play which could be attributed to competing responses, as suggested, or explained in other ways.

Conditioned emotional responses. Hunt and Brady (1951) studied the effects of ECS upon an established conditioned emotional response (CER) which was defined as the suppression of a bar-pressing response in the presence of a conditioned stimulus previously paired with unavoidable shock. ECS was given 3 to 4 days after the CER had first appeared and when it was still quite strong. Twenty-one shocks at the rate of three per day were given and following this the CER was eliminated. Under some circumstances there was evidence that the CER reappeared after a 30-day rest interval. The general tenor of this and other studies employing the CER is that ECS reliably attenuates responses based upon fear.

In general, at least part of ECS-induced amnesia can be explained by a neural consolidation idea. Jarvik (1972) concludes that whether ECS-induced amnesia is due to impaired consolidation of long-term memory or to increased sensitivity to interference are unanswered questions of great importance. Further questions raised, and as yet essentially unanswered, concern the generality of the phenomenon of retrograde amnesia and whether retention, rather than registration or retrieval, is primarily affected by ECS. Finally, insofar as recovery from

amnesia occurs, this indicates either recovery from the impairment of a retrieval ability or some capacity of spontaneous restrengthening of a weakened trace.

Human Research

As in the animal research, the most prominent theory to explain how ECS affects memory is the neural consolidation theory. A theory of consolidation which conceptualizes the process of memory impairment as operating on an all or none principle, or as operating only retroactively, does not account for all of the observed post-ECT memory impairment. As already described, there is gradual recovery of memory loss even after patients are fully conscious and totally oriented. Furthermore, it has been demonstrated that even when patients deny any recollection of stimuli presented shortly before the onset of a seizure, such stimuli can frequently be picked up on a recognition task (Mayer-Gross, 1944) or can be recalled with prompting (Williams, 1950). Finally, as described earlier, numerous investigators have shown an anterograde effect of ECT.

Williams (1966) notes that test material presented in the confusional state following ECT is recollected in very much the same way as similar material presented just before ECT and now subject to partial retrograde amnesia. Since material presented before the shock was received in "clear consciousness," the state of awareness, at the time of perception itself, cannot be the only factor responsible for forgetting. Consequently, Williams concludes that the memory defect is due not so much to failure to register events as to defect in "consolidation" of recent memory, which has both retroactive and proactive significance. The rule

cited by Williams is that there is no retrograde amnesia without anterograde amnesia. The implication of these statements is that disruption of neural consolidation is not to be conceptualized simply as the total obliteration or erasure of the memory trace but rather interference with its complete establishment, whatever that might mean physiologically.

In the final analysis, the basic issue appears to be whether or not the effects of ECT on memory can be explained by a single theory. In other words, how is one to conceptualize the disruption of neural consolidation by ECT? Conceptualized as the obliteration of a trace, the theory has limited explanatory value for the observed phenomena and a second theory must be advanced to explain the events unaccounted for by the first. The alternative is not to conceptualize the disruption of neural consolidation as necessarily total obliteration or erasure of a memory trace. Instead, it might also involve interference with the complete establishment of memory traces, thus allowing for some recovery.

Insofar as memory impairment may or may not be reversible, the question arises as to how one is to define amnesia in the first place. Weiskrantz (1966) suggests that although strictly speaking, amnesia ought to mean absence of retention, it is more convenient and realistic to speak of degrees of amnesia. The demonstration of impaired retention leaves open the question whether the impairment is due, on the one hand, to an erasure of a trace, failure of consolidation or any other failure of storage, or, on the other hand, to interference or some other failure of retrieval of an adequately stored trace. Weiskrantz

demonstrates that it is always impossible to prove conclusively that a retention impairment is not solely a failure of retrieval. Retention failure can never be shown to depend conclusively on the destruction of a trace because it is always possible that some circumstances would be found in which retention would be unimpaired. Thus, little is gained practically by restricting the term amnesia so as to exclude certain types of retrieval failures, as has been implied in the usage of several writers (e.g. McGaugh & Madsen, 1964). Indeed, Weiskrantz offers a theoretical model of how ECS affects memory, based upon what he calls the noise level values associated with ECS, and their interaction with short-term and long-term memory traces. The aim of the model is to explain retrieval difficulty associated with retrograde and anterograde amnesia. However, in order to adequately account for all the observed phenomena, Weiskrantz's model involves two processes. Irreversible memory loss is explained by the effect of ECT on neural consolidation and the reversible memory loss is explained by the "noise" level effects of ECT.

The Present Study

The various sources of research which have been described suggest important guidelines for research in ECT. The investigation now to be reported was designed with the evidence from the human ECT, the animal ECS, and other neuropsychological studies in mind. The aims of the present study were:

1. To determine differential effects of bilateral, dominant, non-dominant, and pseudo ECT on non-verbal memory. It was hypothesized that bilateral and non-

dominant ECT each impair non-verbal memory to a greater degree than do either dominant or pseudo ECT.

2. To determine the effect of a single ECT on non-verbal memory. The use of a single treatment permits the investigation of acute effects of ECT and, more importantly, avoids contamination of memory effects by other variables such as the therapeutic effect of the treatment.

3. To determine whether non-verbal memory is affected retroactively, proactively, or both.

4. To determine whether any recovery of non-verbal memory occurs over a relatively short period of time.

5. To determine whether non-verbal retention, in particular, is affected or whether, for example, learning is affected.

6. To consider possible mechanisms by which ECT impairs non-verbal memory. For example, does the evidence support the consolidation theory?

METHOD

The Instrument

The first step in the study was the construction of an appropriate test of non-verbal memory. Since the subjects of the study were depressed patients, often fearful of ECT, it was essential that the test be brief, involve minimal effort, and produce as little frustration and anxiety as possible, in order to gain and retain the cooperation of patients.

The test devised was a modification of the Recurring Figures test developed by Kimura (1963). In Kimura's test, a subject is presented with 20 cards, each card containing a line drawing of either a regular geometric figure or an irregular nonsense figure. Eight of the designs on these cards (4 nonsense, 4 geometric) appear again later; the other 12 do not. The subject is subsequently presented with 7 more trials of 20 cards each. The 8 recurring designs appear randomly in each series along with 12 new designs (half of them nonsense, half geometric). Responses to the test reflect recognition as opposed to spontaneous recall. To each of the 140 cards the subject is required to say "yes" if he thinks he has seen it before or "no" if he thinks he has not seen it before. Of the 140 figures, 56 are recurring; they consist of the 8 drawings of the first trial presented 7 times each.

The Recurring Figures test is highly sensitive to the effects of right temporal-lobe resections (Kimura, 1963; Milner, 1967; Milner & Kimura, 1964). Milner (1968) states that the Recurring Figures task tests "memory for highly idiosyncratic patterns that are too rich in detail to be rapidly and unambiguously

described in words. Hence . . . the task [cannot] be solved by verbal mediation, but requires the persistence of a detailed visual impression [p. 205]."

The modified test consists of a deck of 76 cards on each of which appears a drawing of a geometric or nonsense figure. The subject is first shown 16 cards consecutively, half of the series containing geometric, and the other half, nonsense figures. He is then tested for recognition in the following manner: Three sets of 20 cards are presented in succession. Each set contains 4 of the original 16 stimulus cards, and these never reappear in subsequent sets (non-recurring stimuli); another 4 of the original 16 cards recur in each set (recurring stimuli); in each set 12 of the 20 cards are always new stimulus figures (new stimuli). Figure 1 illustrates the test.

Within each set of the deck, the cards are randomly distributed. Each category of stimuli--non-recurring, recurring, and new--is divided equally into nonsense and geometric forms; and the test for recognition requires simply that the subject say "yes" if he thinks he has seen the card before and "no" if he thinks he has not seen it before.

The introduction of non-recurring (NR), recurring (R), and new (N) stimuli across the three sets of cards was done with the aim of assessing a number of factors associated with recall. Responses to the NR stimuli can serve as an indication of how the passage of time affects memory. Responses to the R stimuli can demonstrate whether recall is facilitated by re-exposure to the stimulus material over trials. Responses to the N stimuli can reveal the influence of items

Figure 1

Representation of Non-Verbal Memory Test

Original 16 Stimuli	Recognition Test		
	Set 1	Set 2	Set 3
A B C D E F G H I J K L M N O P	A B C D E F G H 12 New	A B C D I J K L 12 New	A B C D M N O P 12 New

that are both unfamiliar and distracting.

Patients with right temporal-lobe excisions demonstrate memory impairment for both nonsense and geometric designs (Kimura, 1963). Kimura's findings indicate that recall of geometric designs does not involve significantly more verbal mediation than does recall of nonsense figures. Both stimulus forms were included in the modified test in order to determine whether recall of nonsense and geometric figures are also equally sensitive to the effects of ECT.

The modified test, as described above, appeared to be a suitable instrument in terms of the aims of the study and the kind of patients to be used. It is non-verbal; response effort involves a mere "yes" or "no"; it is a single test as opposed to a battery of tests; the total number of stimulus cards is only 76, as compared, for example, to the 160 cards of Kimura's Recurring Figures test; and finally, because the subject receives no information from the tester as to whether his responses are correct or incorrect, and because there is no reinforcement (either positive or negative) contingent upon appropriate responding, the testing procedure is not likely to be experienced as frustrating or anxiety-producing by the subject.

A total of 20 categories of error scores can be obtained from the test. For each of the three sets the following error scores can be calculated:

1. The number of "no" responses to the R stimuli.
2. The number of "no" responses to the NR stimuli.
3. The number of "yes" responses to the N stimuli. This is a false

positive (F+) score.

4. The sum of "no" responses to the R and NR stimuli. This is a false negative (F-) score.

5. The sum of incorrect responses to the R, NR, and N stimuli. This is a Total error score for the set.

These same scores can also be summed across the three sets, yielding a Full Test error score for each of the five measures (R, NR, F+, F-, and Total error), and, hence, a total of 20 scores.

In each instance, an erroneous response is given the score of 1 point. Thus, for example, the best Full Test Total error score attainable is 0, and the worst, 60 points.

A sample of the stimuli comprising the memory test appears in Appendix A; a sample score sheet appears in Appendix B.

Because patients were to be tested repeatedly, nine parallel forms of the test were developed, using college students as subjects, in order to assure equivalence of forms in difficulty and to preclude the possibility of practice effect. A Latin Square for nine test forms and nine orders was constructed according to the method described by Winer (1962). Ten subjects were assigned randomly to each order and each subject received all nine forms of the test. Subjects were tested twice daily, receiving two different forms each day. On the fifth day, subjects received only the ninth form. Testing was done on consecutive days in all cases, and the procedure was as follows: Subjects were shown the original 16 stimulus

cards in succession. Inspection time for each card was 5 seconds. Following a 3-minute unfilled delay period, subjects were tested for recognition on the three sets of cards presented in succession, with a 3-second exposure period for each stimulus. Fifteen minutes after the completion of the recognition test, the second form of the test was introduced. The method of stimulus presentation and recognition testing was identical for all test forms.

A two-way analysis of variance performed on the data indicated that the nine test forms were of equal difficulty and that subjects tested repeatedly showed no carry-over of practice effect from one form to another. The results of this analysis are presented in Appendix C.

Subjects

The subjects were 40 patients (20 patients for each of two studies) ranging in age from 19 to 60 years, referred for ECT because of depression at the Allan Memorial Institute in Montreal, Quebec. Both in-patients and out-patients, males and females, served as subjects (see Table 2). All were English-speaking, with no history or evidence of neurological dysfunction. Only those patients who had not received ECT for a minimum period of 6 months were acceptable, so as to minimize any possible effects of previous treatments. The latter criterion was adopted for several reasons. The results of studies concerned with the duration of ECT effect on memory have been variable. A review of the relevant literature has revealed that many studies have not required a pre-experimental ECT-free period. Those studies which have adopted this condition have required that the time interval

be anywhere from 1 to 6 months, with most research designs having incorporated a 3-month period.

Table 2

Patient Characteristics

Study	Age		Sex		Inpatients	Outpatients
	Mean	Range	M	F		
Retroactive (N = 20)	36.9	21-60	10	10	8	12
Proactive (N = 20)	35.1	19-51	8	12	7	13

Since it is generally accepted that the left cerebral hemisphere is dominant for speech in most strongly right-handed individuals (Brain, 1965; Piercy, 1967; Zangwill, 1960) subjects were selected who exhibited strong right laterality (see Procedure).

Subjects were required to have good vision with or without the aid of eye-glasses. Only those patients who agreed to cooperate and appeared motivated were included in the sample.

A baseline measure of non-verbal memory was obtained for each subject the day before the first treatment of the ECT series. This procedure permitted each subject to serve as his own control. It precluded the need for matching subjects on specific type of depression and medication, and on the usual variables of sex, age, intelligence, and socio-economic status.

A sample of 20 subjects (per study) with repeated measures on each is

acceptable in terms of statistical analysis requirements. A number of factors limit the availability of appropriate subjects in this type of study. Several criteria governing subject suitability have already been described in this section; other restrictive selection criteria will be outlined in the section on Procedure which follows. In addition, sample size is trimmed down still further by clinical circumstances. For example, patients scheduled for ECT at the last moment or patients treated on an emergency basis were not included in the study because time did not permit the acquisition of baseline memory measures. Several out-patients were lost because they did not return to complete the experimental treatment series. Several in-patients were lost because part way through the ECT series their physicians changed the treatment plan from ECT to another form of therapy. A number of subjects were unsuitable because twice-daily ECTs had been prescribed. A few patients rejected testing, either at the beginning of, or part way through the procedure.

Considering the stringent criteria built into the study; the occurrence of unpredictable and unavoidable events so often associated with clinical research; and the fact that ECT is not always the treatment of choice for depressed patients; the sample size acquired was respectable. A period of 14 months was required to obtain complete data on 40 subjects.

Procedure

Testing for lateral dominance. Subjects were tested for laterality on a dominance test battery developed by Zamora and Kaelbling (1965) and a handedness

questionnaire developed at the Montreal Neurological Institute.

The first part of the laterality test is concerned with the performance of certain tasks during which the tester notes hand, foot, and eye preference. The instructions are phrased without revealing that laterality is being investigated. In the second part of the test the subject is asked to report the hand preference of various members of his family. The final portion of the test investigates possible conversion of handedness during the subject's lifetime.

Although the Sodium Amytal technique would have provided fairly conclusive information about cerebral dominance, it is a rather drastic procedure used as a preoperative screening device in cases of temporal-lobe epilepsy (Milner, 1968). The Dichotic Listening test is another method of testing for dominance (Kimura, 1961a, b). It was not selected, however, because its administration is less practical than the procedure adopted in the present study.

The laterality test and scoring criteria appear in Appendix D.

Administration of ECT. Each subject received four ECT conditions spaced at 2- to 3-day intervals--one bilateral (Bi), one unilateral to the non-dominant hemisphere (ND), one unilateral to the dominant hemisphere (D), and one pseudo (Ps). The Ps condition involved pre-treatment medication and electrode placement (either bilateral or unilateral), but subjects never received shock.

A balanced Latin Square for four treatments and four treatment orders was designed as follows (Winer, 1962):

	CONDITION			
ORDER	D	ND	Bi	Ps
	Bi	D	Ps	ND
	Ps	Bi	ND	D
	ND	Ps	D	Bi

Prior to treatment, each subject received atropine (.6 mg.), to depress salivation and inhibit the effect of the vagus on the heart; brietal (100 mg.), a general anaesthetic; and anectine (25-30 mg.), a muscle relaxant.

Electrode placement for bilateral ECT was as follows: each electrode was lubricated with electrode jelly and then placed bitemporally. Electrode placement for the unilateral ECT was done in the manner described by Lancaster et al. (1958):

> After application of electrode jelly, the lower electrode was placed midway between the lateral angle of the orbit and the external auditory meatus and 1 1/2" above this line. The upper electrode was placed 3" higher than the lower electrode and at an angle of 70° to this line [p. 223].

ECT was administered through a Medcraft model B-24 unit, manufactured by the Medcraft Electronic Corporation, Skippack, Pennsylvania. The machine was set at 130 volts and .5 seconds for all patients. Thus, the total bipolar electrical current introduced was equivalent for the three true ECT conditions. Only those subjects who achieved bilateral convulsions were included in the study. Subjects who failed to convulse or who achieved only contra-lateral convulsions (following unilateral ECT) on this amount of shock, were treated again for therapeutic reasons with a higher shock dosage and were therefore excluded from the research sample.

Muscle relaxants reduce the magnitude of the convulsions but do not eliminate them. Muscular twitches remain discernable on various parts of the body and it is therefore possible to establish whether or not patients have convulsed.

The investigation was double-blind. Neither the tester nor the patient knew which ECT condition the patient had experienced and in the Ps condition, patients were not aware that they had not received shock. Nurses kept the information until the data were complete and ready for statistical analysis.

The foregoing research design was approved by the hospital Ethics Committee, which noted that regardless of electrode placement, the attainment of convulsions was the important factor in this method of treatment for clinical depression. Certain precautions were rigorously observed. When a patient required ECT on a day scheduled for the Ps condition, he was treated and removed from the research sample (this occurred in five cases). High suicide risk patients, those acutely depressed, and patients requiring special treatment procedures because of particular health problems were not included in the study. Finally, following the four ECT conditions which comprised the research design, patients continued to receive ECT for therapeutic reasons, as determined and prescribed by their physicians.

Retroactive study. The retroactive study was designed to investigate the effect of ECT on a recognition task for non-verbal material presented to subjects prior to treatment. The design of the study permitted comparisons among the effects of the different types of electrode placement on non-verbal memory.

Approximately 5 minutes before ECT 20 subjects were shown the original 16 stimulus cards of the test, one at a time. Ten seconds of inspection time were permitted for each stimulus card. After the 16 cards had been seen once through, a second inspection was given, allowing 2 seconds per card. This amount of inspection time was given to make sure that each stimulus card was attended to and adequately perceived rather than overlooked because of a drift in attention, concentration difficulty, or anxiety about the forthcoming treatment.

At no time was there any indication that subjects were anxious about this task. They were simply told that the tester was doing a study on memory.

Forty-five minutes after ECT, recognition testing began. There is evidence to suggest that patients are fully oriented by this time (Fleminger et al., 1970; Halliday et al., 1968; Lancaster et al., 1958). A number of studies have shown that patients treated with unilateral ECT are fully oriented significantly sooner than those treated bilaterally (Lancaster et al., 1957; Valentine et al., 1968). Consequently, in order to avoid any clues about the treatment received, the tester did not see the subjects until the nurses delivered them to the testing room 45 minutes after treatment. At the time of testing, there were no overt signs of confusion or disorientation in any of the subjects. The patients responded appropriately to questions of orientation (e.g. person, place, time, occupation), they recognized the experimenter and remembered her purpose, and they were able to repeat sequences of digits.

Prior to testing, subjects were reminded of the stimuli they had seen

earlier. They were assured that their performance on the task would not determine the number of treatments that they would require (a concern occasionally voiced) and further reassured that their participation would not influence any other negative personal consequences. Finally, subjects were encouraged to guess at any stimulus card when they were uncertain. Inspection time for each stimulus was 3 seconds.

Milner (1968), using a non-verbal face recognition test, found that patients with right anterior temporal lobe lesions were consistently impaired whether or not there was a delay interposed between the first and second exposure to the faces, and whether or not, in the delay condition, the interval was filled with an irrelevant visual task. Normal subjects and those with left temporal lobe lesions were found to be impaired only when there was no delay between the two exposures. Neither unfilled nor filled intra-test delay affected the performance of these subjects significantly.

With these findings in mind, it was decided to interpose a 5 minute interval between the three sets of stimulus cards of the recognition test. Such a delay also permitted an investigation into the effect of this particular time variable on memory. The decision to use 5 minutes as the interval time was based upon the fact that this time period was short enough to prevent any possible boredom and loss of interest on the part of the patient.

Milner's findings also imply that there is no need for stringent rules about what subjects can or cannot do during intra-test intervals. As it happened, these

subjects usually drank coffee or juice and either sat quietly, dosed, or occasionally made conversation.

Figure 2 illustrates the testing procedure for the retroactive study.

Figure 2

Testing Procedure: Retroactive Study

5 mins. Present 16 stimuli	ECT	45 mins.	Recognition task Set 1	5 mins.	Recognition task Set 2
5 mins.		Recognition task Set 3			

Since every patient received one of each of the four types of ECT conditions, this testing procedure was followed on each treatment day, with parallel forms of the test. The same procedure and time span were used to procure baseline data. As noted previously, treatments were separated by 2 or 3 days.

All subjects received the same five parallel forms of the test and the same order of the five tests.

Nurses randomly assigned five subjects to each of the four treatment orders in a double blind method.

Proactive study. The proactive study was designed to investigate the manner in which D, ND, Bi, and Ps ECT affect performance on a recognition task for non-verbal material presented to subjects after treatment. A second goal was

the determination of recovery effect over time, should impairment in performance be found.

The memory task was the same as that employed in the retroactive study. The design, too, was the same in that each subject received one D, one ND, one Bi, and one Ps ECT, and was pretested for baseline memory measures. In this study, however, the subjects were not shown any stimuli prior to ECT. Forty-five minutes after treatment, 20 subjects were shown the original 16 stimulus cards and 45 minutes later recognition testing began. The method for presentation of stimuli and testing for recognition was identical to that of the retroactive study. Upon completion of the memory testing, and following a 15-minute break, the procedure was repeated with a parallel form of the test. Thus, each subject was tested twice following each of the four treatment conditions. Repeated testing afforded the opportunity to investigate recovery effects.

As in the previous study, five subjects were assigned randomly to each of the four treatment orders by the nurses in a double-blind fashion. Also, all of the subjects received the parallel forms of the test in the same order.

Figure 3 presents the testing procedure for the proactive study.

Figure 3

Testing Procedure: Proactive Study

ECT	45 mins.	Present 16 Stimuli	45 mins.	Recognition test Set 1	5 mins.	Recognition test Set 2
5 mins.	Recognition test Set 3	15 mins. rest	Present 16 Stimuli	45 mins.	Recognition test Set 1	
5 mins.	Recognition test Set 2	5 mins.	Recognition test Set 3			

RESULTS: RETROACTIVE STUDY

Comparison of Baseline and Pseudo Scores

An analysis of variance was performed on the Full Test Total error score of the memory task to determine whether baseline scores differed from scores obtained following the pseudo condition. Neither between the groups nor within the groups were the baseline scores found to differ significantly from scores obtained after pseudo ECT. The results of the analysis of variance are presented in Appendix E. Table 3 presents the two condition means and the four group means, as well as the F ratio values.

Table 3

Baseline vs. Pseudo Scores

	Baseline	Pseudo	df (3, 16)	F
Condition Means (Across Groups)	10.80	10.15		2.347

	1	2	3	4	df (1, 16)	F
Group Means (Across Conditions)	9.50	10.20	11.60	10.60		.412

Since patients were medicated for the pseudo condition in the same way as they were for true ECT, these results suggest that the brietal, anectine, and atropine were in no way affecting non-verbal memory.

Comparison of Baseline Scores

An analysis of variance was performed on the baseline scores to determine

the comparability of the four groups of subjects. The groups were found not to differ significantly (Full Test Total error $\underline{F}$ = .1204, $\underline{df}$ = 3, 16). The results of the analysis appear in Appendix F.

Since the four groups did not differ significantly in performance on the memory task under non-ECT conditions, and since the baseline scores were found not to differ significantly from the pseudo scores, the groups appeared to be very well matched and group equivalance could be assumed in further analyses. Consequently, the analyses were performed on the raw scores derived from the Latin Square rather than on difference scores (i.e. baseline minus post-ECT scores). Thus, it was possible to avoid the statistical difficulties frequently attributed to difference scores (e.g. Ferguson, 1966) and to select the analysis of variance (performed on the raw data) as the proper statistical manipulation.

Overall Analysis

An analysis of variance was performed on the data derived from the Latin Square design of the retroactive study in order to investigate three main effects.

Of prime interest was the Condition effect, that is, the differential effects of the four ECT conditions--bilateral (Bi), non-dominant (ND), dominant (D), and pseudo (Ps) ECT.

Of interest also were the Order effect--the differential effects of the four treatment orders, and the Treatment effect--the differential effects of the first, second, third, and fourth treatments, regardless of the actual type of ECT administered in each instance.

The analysis was performed on each of 20 dependent variables. It will be recalled from the section on Method that the recognition task consists of three sets of 20 stimulus cards and that within each set are four recurring (R), four non-recurring (NR), and 12 new (N) stimuli. The R and NR drawings comprise the original 16 stimuli presented to the subjects prior to ECT.

Within Sets 1, 2, and 3 of the test, error scores were obtained for:

1. The R stimuli.
2. The NR stimuli.
3. The sum of the R and NR stimuli.
4. The N stimuli.
5. The sum of the R, NR, and N stimuli.

The five types of error calculated within each set (yielding 15 scores) were also calculated across the three sets yielding five Full Test error scores and hence a total of 20 scores for the test.

The results of the analyses of variance are presented in Appendix G. Since the Condition and Treatment variables represented repeated measures on subjects, a conservative number of degrees of freedom were used to calculate the significance levels of the F ratios. The degrees of freedom associated with the numerator and denominator of the F ratios were divided by N - 1, N being the number of repeated measures. Through this conservative procedure, the possibility of a lack of homogeneity of covariance among the repeated measures is more than compensated for (Davidson, 1972).

Condition Effect

A significant Condition effect was obtained for each of the 20 measures. Table 4 presents the Condition means and F ratio values. The Newman-Keuls statistic (Winer, 1971) was used for the purpose of multiple means comparisons* and the following results were obtained. On each measure Ss performed significantly more poorly when treated with Bi or ND ECT than when treated with D or Ps ECT. On none of the 20 measures were the ND and Bi conditions significantly different from each other with respect to degree of memory impairment. Subjects consistently produced more errors in the D as compared to the Ps condition and statistical significance was attained on 10 of the 20 variables and of these, 7 were on global scores (i.e., Full Test score or Total error within set score): Full Test F-

Full Test R

Full Test F+

Full Test Total error

Set 1 Total error

Set 2 Total error

Set 3 Total error

R Set 1

F- Set 1

F+ Set 3

---

*Statistical significance for these comparisons and for all comparisons to be mentioned hereafter refers to the .05 or .01 probability levels.

Table 4

Condition Means and F Ratio Values

Measure	Condition D	ND	Bi	Ps	F
R Set 1	.95	3.05	2.85	.25	86.139*
NR Set 1	.85	2.70	2.50	.50	38,348*
F+ Set 1	2.25	4.65	4.45	1.60	41.587*
F- Set 1	1.80	5.75	5.35	.75	122.722*
Total error Set 1	4.05	10.40	9.80	2.35	158.026*
R Set 2	.20	1.80	1.95	0.00	31.329*
NR Set 2	1.20	2.90	3.15	1.05	47.129*
F+ Set 2	3.50	5.80	5.75	2.85	31.603*
F- Set 2	1.40	4.70	5.10	1.05	108.903*
Total error Set 2	4.90	10.50	10.85	3.90	156.042*
R Set 3	.05	1.45	1.75	.05	42.797*
NR Set 3	1.70	3.55	3.35	1.40	41.263*
F+ Set 3	3.80	5.85	5.80	2.45	19.356*
F- Set 3	1.75	5.00	5.10	1.40	97.135*
Total error Set 3	5.55	10.85	10.90	3.85	96.089*
Full Test R	1.20	6.30	6.55	.30	184.222*
Full Test NR	3.70	9.10	9.00	2.95	105.376*
Full Test F+	9.55	16.30	16.00	6.90	68.063*
Full Test F-	4.95	15.45	15.55	3.25	252.408*
Full Test Total error	14.50	31.75	31.55	10.15	315.499*

Note. - Conservative df = 1, 16.

*p < .001.

The comparisons of means appear in Appendix H.

Order Effect

The purpose of this aspect of the analysis was to determine whether a significant effect on retroactive memory was produced by a particular ordering of the four ECT conditions. In essence, the four groups of subjects were compared on test scores summed across the four conditions.

The four treatment orders, with five Ss assigned to each order, were as follows:

Order 1 - D, ND, Bi, Ps

Order 2 - Bi, D, Ps, ND

Order 3 - Ps, Bi, ND, D

Order 4 - ND, Ps, D, Bi

Table 5 presents the Order means and F ratio values. Significant F ratios were found for 7 of the 20 measures. A comparison of the Order means for each of the 7 measures with a significant F ratio showed that in each case Order 2 produced significantly less impairment than Order 3. Scores for Order 2 were also significantly better than scores for Order 4 on 3 of these measures: R Set 3, F+ Set 3, and Total error Set 3. The comparisons of means appear in Appendix I.

Treatment Effect

A significant Treatment effect was obtained for 3 of the 20 measures. Table 6 presents the Treatment means and F ratios. The Newman-Keuls statistic was applied to the means associated with the significant measures, and indicated that,

Table 5

Order Means and F Ratio Values

Measure	Order 1	2	3	4	F
R Set 1	1.70	1.90	1.70	1.80	.173
NR Set 1	1.50	1.75	1.75	1.55	.419
F+ Set 1	3.60	2.60	3.70	3.05	2.098
F- Set 1	3.20	3.65	3.45	3.35	.288
Total error Set 1	6.80	6.25	7.15	6.40	.496
R Set 2	.90	1.20	.80	1.05	.823
NR Set 2	1.85	2.05	2.35	2.05	1.330
F+ Set 2	4.35	3.35	5.55	4.65	3.265*
F- Set 2	2.75	3.25	3.15	3.10	.457
Total error Set 2	7.10	6.60	8.70	7.75	1.518
R Set 3	.70	.45	1.00	1.15	5.473**
NR Set 3	2.50	2.30	2.95	2.25	3.286*
F+ Set 3	4.15	3.00	5.50	5.25	3.927*
F- Set 3	3.20	2.75	3.95	3.35	5.171*
Total error Set 3	7.35	5.75	9.45	8.60	4.712*
Full Test R	3.30	3.55	3.50	4.00	.651
Full Test NR	5.75	6.10	7.05	5.85	1.548
Full Test F+	12.10	8.95	14.75	12.95	3.680*
Full Test F-	9.15	9.65	10.55	9.85	.617
Full Test Total error	21.25	18.60	25.30	22.80	2.329

Note. - $df = 3, 16$.
*$p < .05$
**$p < .01$

Table 6

Treatment Means and F Ratio Values

Measure	Treatment 1	2	3	4	F
R Set 1	1.85	1.75	1.65	1.85	.409
NR Set 1	1.35	1.45	1.95	1.80	2.449
F+ Set 1	2.70	3.55	3.40	3.30	2.434
F- Set 1	3.20	3.20	3.60	3.65	1.180
Total error Set 1	5.90	6.75	7.00	6.95	2.519
R Set 2	.95	.95	.75	1.30	1.554
NR Set 2	1.85	2.15	2.00	2.30	1.451
F+ Set 2	4.05	4.25	5.30	4.30	4.271
F- Set 2	2.80	3.10	2.75	3.60	3.645
Total error Set 2	6.85	7.35	8.05	7.90	3.523
R Set 3	.65	.85	.85	.95	.830
NR Set 3	2.30	2.25	2.60	2.85	2.638
F+ Set 3	3.75	4.85	4.65	4.65	1.716
F- Set 3	2.95	3.05	3.45	3.80	3.655
Total error Set 3	6.70	7.90	8.10	8.45	4.204
Full Test R	3.45	3.55	3.25	4.10	2.239
Full Test NR	5.45	5.80	6.55	6.95	4.484
Full Test F+	10.50	12.65	13.35	12.25	4.530*
Full Test F-	8.95	9.40	9.80	11.05	4.696*
Full Test Total error	19.45	22.05	23.15	23.30	7.840*

Note. - Conservative df = 1, 16.

*$p < .05$.

while in no instance were the six possible comparisons of the four Treatment means all significantly different from each other, subjects performed best after the first treatment or worst after the fourth (see Appendix J).

On the measure of Full Test Total error, the lowest error score was obtained after Treatment 1 and the highest after Treatment 4. While Treatments 2, 3, and 4 were each significantly different from Treatment 1, they were not significantly different from each other. Hence, all that can be said in this instance is that the first treatment was the least disruptive.

On the Full Test F+ measure, performance after Treatment 1 was significantly better than performance after Treatments 2, 3, or 4.

On the Full Test F- measure, scores were best after the first treatment and worst after the fourth. Scores obtained after the fourth treatment were significantly worse than those obtained after the first, second, or third treatment.

These results indicate that there is an accumulative effect of treatments on non-verbal retroactive memory, even when the treatments consist of different types of ECT.

Comparison of Measures Across Sets 1, 2, and 3

Each of the five measures derived from the memory test (R, NR, F+, F-, Total error) was compared across the three sets in order to determine the effects of such variables as the passage of time and re-exposure to the stimulus material on these measures. Appendix K provides the results of these analyses of variance and Appendix L contains the results of the multiple means comparisons.

Table 7 presents the means and F ratios for the five measures compared across sets. Responses to the R stimuli were found to improve across the three sets. It appears then that Ss were making positive use of the re-exposure to these stimuli. R responses in Set 2 and in Set 3 showed significantly fewer errors than those in Set 1. Although there was an improvement in performance between Sets 2 and 3, it was not significant. These same results were found whether the ECT condition was Bi, ND, D, or Ps.

Table 7

Comparison of Measures Across Sets

Measure	Set 1	Set 2	Set 3	F
R	1.775	.987	.825	32.719**
NR	1.637	2.075	2.500	41.164**
F+	3.237	4.475	4.475	22.926**
F-	3.412	3.062	3.312	2.888
Total error	6.650	7.537	7.787	10.082*

Note. - Conservative df = 1, 16.

*p < .01.
**p < .001.

Error Scores on NR stimuli increased significantly across the three sets. That is, the longer the time interval between the first exposure to the NR stimulus cards and the test for recognition, the greater the memory loss. Besides the time

intervals, however, it is probable that the interference produced by the N stimuli also contributed to the erroneous responses. Sets 1, 2, and 3 were all significantly different from each other on this measure, and these findings held for all four ECT conditions.

The comparison of F+ responses across the three sets also revealed a consistent increase in error scores. Sets 1 and 3 and Sets 1 and 2 were significantly different from each other on this measure, but the difference between Sets 2 and 3 did not reach significance. Thus, as testing progressed, Ss tended to respond more inaccurately to the N stimuli. The longer the time interval between the presentation of the original 16 stimuli and the recognition task, the more difficult it was for Ss to discriminate the original stimuli adequately from the N stimuli. Once again, these results were found for all ECT conditions.

When F- scores (R + NR) were compared across the three sets, no significant differences were found.

On the Total error score, Ss were found to make an increasing number of errors across the three sets. The best scores, which were obtained in Set 1, were significantly different from both the worst scores, obtained in Set 3, and the scores obtained in Set 2. Set 2 scores were not significantly different from Set 3 scores. These results were found for all ECT conditions.

Table 8 presents the three Set means for each ECT condition on each of the five measures.

A significant Condition effect was found to exist for each of the five measures

Table 8

Set Means for ECT Conditions on Each Measure

Measure	Condition	Set 1	Set 2	Set 3
R	D	.95	.20	.05
	ND	3.05	1.80	1.45
	Bi	2.85	1.95	1.75
	Ps	.25	.00	.05
NR	D	.85	1.20	1.70
	ND	2.70	2.90	3.55
	Bi	2.50	3.15	3.35
	Ps	.50	1.05	1.40
F+	D	2.25	3.50	3.80
	ND	4.65	5.80	5.85
	Bi	4.45	5.75	5.80
	Ps	1.60	2.85	2.45
F-	D	1.80	1.40	1.75
	ND	5.75	4.70	5.00
	Bi	5.35	5.10	5.10
	Ps	.75	1.05	1.40
Total error	D	4.05	4.90	5.55
	ND	10.40	10.50	10.85
	Bi	9.80	10.85	10.90
	Ps	2.35	3.90	3.85

compared across the three sets. Table 9 presents the Condition means and F ratios. Bi and ND ECT were significantly more detrimental to performance than were D or Ps ECT, regardless of whether or not the scores on the five measures changed across the sets. Scores obtained after Bi and ND treatment were in no instance significantly different from each other. Scores associated with the D condition were always worse than those associated with the Ps condition and significant differences between these two conditions were found on four of the five measures: R, F+, F-, and Total error.

Table 9

Condition Means and F Ratios for Measures Compared Across Sets

Measure	Condition				F
	D	ND	Bi	Ps	
R	.400	2.100	2.183	.100	184.222*
NR	1.250	3.050	3.000	.983	104.068*
F+	3.183	5.433	5.333	2.300	68.063*
F-	1.650	5.150	5.183	1.066	254.893*
Total error	4.833	10.583	10.516	3.366	322.115*

Note. - Conservative df = 1, 16.

*p < .001.

Effect of a Single Treatment

The results of analyses of variance to determine the effects of a single

treatment, whether ND, D, Bi, or Ps, are presented in Appendix M.

Each analysis compared the four groups of Ss on memory scores obtained after the first treatment (the groups having been defined by which ECT procedure patients received first). It will be recalled that the first treatment was D ECT in Order 1, Bi ECT in Crder 2, Ps ECT in Order 3, and ND ECT in Order 4. Since the research design was such that each S only received one of each of the four types of ECT, what is meant here by a single treatment is the first treatment, uncontaminated by the potential effects of the other three.

Except for the F+ scores in Set 1 and Set 2 of the recognition task, a significant Condition effect was found to exist. The Newman-Keuls test to compare means revealed that in most error score categories ND and Bi ECT impaired performance significantly more than did D or Ps ECT. The scores obtained following the D and Ps conditions were not significantly different from each other on any of the dependent variables. The Bi and ND conditions were significantly different from each other on four of the variables, with the ND condition producing the greater impairment: R Set 3; Total error Set 3; Full Test F+; and Full Test Total error. Except for the F+ score in Set 3, ND ECT produced significantly greater impairment than did D ECT. The Bi condition was significantly more deleterious than the D or Ps conditions on all measures except: NR Set 3, F+ Set 3, Total error Set 3, and Full Test F+. The ND condition impaired performance significantly more than did the Ps condition on all measures except NR Set 3.

Table 10 presents the Condition means and F ratios for the 20 measures. In

Table 10

Condition Means and F Ratios After Single Treatment

Measure	Condition D	ND	Bi	Ps	F
R Set 1	.60	3.20	3.00	.60	12.666***
NR Set 1	.40	2.00	2.20	.80	7.121**
F+ Set 1	3.00	3.40	2.60	1.80	1.761
F- Set 1	1.00	5.20	5.20	1.40	17.290***
Total error Set 1	4.00	8.60	7.80	3.20	11.010***
R Set 2	.00	1.60	2.20	.00	10.106***
NR Set 2	.60	2.60	2.80	1.40	8.282**
F+ Set 2	4.20	5.40	3.20	3.40	2.847
F- Set 2	.60	4.20	5.00	1.40	18.888***
Total error Set 2	4.80	9.60	8.20	4.80	7.959**
R Set 3	.00	1.80	.80	.00	16.222***
NR Set 3	1.40	3.00	2.80	2.00	3.644*
F+ Set 3	3.60	6.60	3.00	1.80	3.739*
F- Set 3	1.40	4.80	3.60	2.00	14.444***
Total error Set 3	5.00	11.40	6.60	3.80	9.163***
Full Test R	.60	6.60	6.00	.60	27.569***
Full Test NR	2.40	7.60	7.80	4.20	9.964***
Full Test F+	10.80	15.40	8.80	7.00	5.986**
Full Test F-	3.00	14.20	13.80	4.80	29.930***
Full Test Total error	13.80	29.60	22.60	11.80	16.843***

Note. - df = 3, 16.
*$p < .05$.
**$p < .01$.
***$p < .001$.

general, the effect of a single treatment on retroactive non-verbal memory appears to depend on the nature of the treatment. These results indicate that a single Bi ECT or a single ND ECT tended to impair performance on the present task to a greater degree than did a single D or a single Ps ECT. The comparisons of means are presented in Appendix N.

Nonsense vs. Geometric Figures

It will be recalled that the memory test designed for this research consisted of both nonsense and geometric figures which were equally distributed amongst the R, NR, and N stimulus cards. Two analyses of variance (the results of which are presented in Appendix O) were performed to determine whether a Condition effect would continue to exist when one looked at the responses to the geometric and nonsense figures separately. The Full Test total error score was analyzed in this fashion.

Table 11 illustrates that a significant Condition effect was found for responses to both the nonsense and the geometric figures. Multiple means comparisons (Appendix P) revealed that for both types of stimuli the Bi and ND conditions produced significantly more erroneous responses than did the Ps or D Conditions. D ECT impaired performance significantly more than did Ps ECT on both the nonsense and geometric stimuli. Finally, on neither type of stimulus material were the Bi and ND conditions significantly different from each other.

Table 11

Comparison of Nonsense and Geometric Figures

Figure	Condition				df	F
	D	ND	Bi	Ps	1, 16	
Nonsense	7.35	16.45	16.25	5.80		215.798*
Geometric	7.15	15.30	15.80	4.35		206.095*

*$p < .001$.

RESULTS: PROACTIVE STUDY

Comparison of Baseline and Pseudo Scores

As in the retroactive study, the Full Test Total error baseline scores were compared with scores obtained following the pseudo condition by means of an analysis of variance. The scores were found not to differ significantly. Table 12 presents the two Condition means and the four Group means as well as the F ratio values. The results of the complete analysis of variance appear in Appendix Q.

Table 12

Baseline vs. Pseudo Scores

	Baseline	Pseudo	df (3, 16)	F
Condition Means (Across Groups)	9.80	9.25		2.390

	1	2	3	4	df (1, 16)	F
Group Means (Across Conditions)	8.90	9.70	9.50	10.00		.356

Comparison of Baseline Scores

As in the retroactive study, the four groups of subjects were compared on baseline scores. The analysis of variance revealed no significant Groups effect (Full Test Total error $F = .7855$, $df = 3, 16$).

The equivalence of groups on the non-verbal memory task prior to ECT having been demonstrated, the rationale adopted for further analyses was the same as that described in the previous section dealing with the retroactive study. The

results of the analysis are presented in Appendix R.

Overall Analysis

An analysis of variance was performed on the data derived from the Latin Square design of the proactive study to determine the following main effects:

Condition--differential effects of D, ND, Bi, and Ps ECT.

Order--differential effects of the four treatment orders.

Treatment--differential effects of the first, second, third,and fourth treatments, regardless of the particular type of ECT administered.

Recovery--differential performance on the first and second tests presented after ECT.

As in the retroactive study, the analysis was done on each of 20 variables. The results of the analyses appear in Appendix S.

Condition Effect

Table 13 presents the Condition means and F ratio values obtained for each of the 20 measures. A significant Condition effect was found in each instance.

The Newman-Keuls statistic was used to compare Condition means. With the exception of two instances (the D and ND conditions were not significantly different from each other on the NR Set 3 measure and the ND condition was not significantly different from either the D or Ps conditions on the R Set 1 measure), Bi and ND ECT produced significantly greater impairment than did D or Ps ECT.

On all 20 measures, the rank order of Condition means from best to worst was: Ps, D, ND, Bi. The four means were all found to be significantly different

Table 13

Condition Means and F Ratio Values

Measure	Condition D	ND	Bi	Ps	F
R Set 1	.200	.375	.475	.150	5.269*
NR Set 1	.325	.975	1.050	.200	30.950**
F+ Set 1	2.750	3.550	4.525	1.425	87.060**
F- Set 1	.525	1.350	1.525	.350	28.740**
Total error Set 1	3.275	4.900	6.050	1.775	62.099**
R Set 2	.000	.475	.775	.000	50.690**
NR Set 2	.775	1.300	1.575	.500	17.890**
F+ Set 2	3.400	4.575	5.525	2.775	79.740**
F- Set 2	.775	1.775	2.350	.500	62.020**
Total error Set 2	4.175	6.350	7.875	3.275	210.260**
R Set 3	.000	.450	.725	.000	36.507**
NR Set 3	1.700	1.800	2.225	1.150	16.950**
F+ Set 3	3.100	4.700	4.850	2.825	36.045**
F- Set 3	1.700	2.250	2.950	1.150	32.770**
Total error Set 3	4.800	6.950	7.800	3.975	97.870**
Full Test R	.200	1.300	2.000	.150	48.210**
Full Test NR	2.800	4.075	4.850	1.850	58.450**
Full Test F+	9.250	12.825	14.900	7.050	189.430**
Full Test F-	3.000	5.375	6.850	1.975	109.287**
Full Test Total error	12.250	18.200	21.750	9.025	397.870**

Note. - Conservative df = 1, 16.

*p < .05.
**p < .001.

from each other on the following measures: F+ Set 1, Total error Set 1, F+ Set 2, Total error Set 2, F- Set 3, Total error Set 3, Full Test NR, Full Test F+, Full Test F-, and Full Test Total error.

Those measures on which the effects of Bi and ND ECT did not differ significantly from each other were: R Set 1, NR Set 1, F- Set 1, NR Set 2, F+ Set 3.

The D and Ps conditions did not produce significantly different effects on the following measures: R Set 1, NR Set 1, F- Set 1, R Set 2, NR Set 2, F- Set 2, R Set 3, F+ Set 3, and Full Test R.

The multiple means comparisons appear in Appendix T.

Recovery Effect

It will be recalled from the section on Method that Ss were tested twice, following ECT, in the proactive study. A comparison of scores for the two tests revealed that on all of the measures except NR Set 1, Ss improved on the second test. This improvement was significant for 10 scores, as can be seen in Table 14, which presents the two test means and F ratios for each of the 20 measures.

Order Effect

A significant Order effect was obtained for only three of the measures: R Set 1, R Set 2, and Full Test R. Table 15 presents the Order means and F ratio values. Multiple means comparisons revealed that for R Set 1 Order 4 was significantly better than Orders 1 and 2; for Full Test R Order 4 was significantly better than Orders 1, 2,and 3, and Order 3 was significantly better than Order 1;

Table 14

Comparison of Test Means: Recovery Effect

Measure	Means		F
	Test 1	Test 2	
R Set 1	.3375	.2625	1.530
NR Set 1	.6000	.6750	1.600
F+ Set 1	3.4125	2.7125	82.520***
F- Set 1	.9375	.9375	0.000
Total error Set 1	4.3500	3.6500	62.099***
R Set 2	.3875	.2375	4.965*
NR Set 2	1.0500	1.0250	.056
F+ Set 2	4.2125	3.9250	3.860
F- Set 2	1.4375	1.2625	2.214
Total error Set 2	5.6500	5.1875	14.880**
R Set 3	.3250	.2750	.727
NR Set 3	1.7750	1.6625	1.317
F+ Set 3	4.1375	3.6000	14.670**
F- Set 3	2.1000	1.9250	3.110
Total error Set 3	6.2375	5.5250	26.096***
Full Test R	1.0500	.7750	14.890**
Full Test NR	3.4250	3.3625	.205
Full Test F+	11.7625	10.2500	56.748***
Full Test F-	4.4750	4.1250	6.877*
Full Test Total error	16.2375	14.3750	76.420***

Note. - df = 1, 16.

*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 15

Order Means and F Ratio Values

Measure	Order 1	2	3	4	F
R Set 1	.450	.450	.200	.100	5.004*
NR Set 1	.550	.625	.575	.800	1.170
F+ Set 1	2.950	2.975	2.975	3.350	.579
F- Set 1	1.000	1.075	.775	.900	.640
Total error Set 1	3.950	4.050	3.750	4.250	.404
R Set 2	.475	.300	.300	.175	7.487**
NR Set 2	.900	.925	1.225	1.100	2.092
F+ Set 2	3.800	4.025	4.050	4.400	.994
F- Set 2	1.375	1.225	1.525	1.275	1.483
Total error Set 2	5.175	5.250	5.575	5.675	.605
R Set 3	.425	.325	.300	.150	2.505
NR Set 3	1.550	1.750	1.800	1.775	.571
F+ Set 3	3.850	3.450	4.050	4.125	1.095
F- Set 3	1.975	2.075	2.100	1.900	.264
Total error Set 3	5.825	5.525	6.150	6.025	.531
Full Test R	1.350	1.075	.800	.425	11.035***
Full Test NR	3.000	3.300	3.600	3.675	1.065
Full Test F+	10.600	10.450	11.100	11.875	1.118
Full Test F-	4.350	4.375	4.375	4.100	.127
Full Test Total error	14.950	14.825	15.475	15.975	.360

Note. - df = 3, 16.

*$p < .05$.
**$p < .01$.
***$p < .001$.

and for R Set 2 Order 1 was significantly worse than Orders 2, 3,and 4. The results show a consistent trend specific to the recognition of non-verbal material. Order 4 produced the least impairment and Order 1 produced the most. The comparisons of means appear in Appendix U.

Treatment Effect

On none of the 20 measures was a significant Treatment effect found to exist. Table 16 presents the Treatment means and F ratios.

There does not appear to be an accumulative effect of treatments on the recognition of material presented to Ss after ECT when the four treatments consist of four different types of ECT.

Comparison of Measures Across Sets 1, 2,and 3

Each of the five measures derived from the memory test (R, NR, F+, F-, Total error) was compared across the three sets in order to determine the effects of such variables as the passage of time and re-exposure to the stimulus material on these measures. Analyses of variance were performed on the two tests independently. The results of the analyses on the first test are presented in Appendix V, and Appendix W provides the multiple means comparisons.

Test 1. Table 17 presents the three Set means and F ratios for each of the measures.

Scores on the R stimuli were not found to change significantly across the three sets.

Error scores for the NR stimuli were found to increase across the three sets.

Table 16

Treatment Means and F Ratio Values

Measure	Treatment 1	2	3	4	F
R Set 1	.225	.400	.300	.275	1.245
NR Set 1	.750	.650	.550	.600	1.181
F+ Set 1	2.925	3.100	3.000	3.225	.854
F- Set 1	.975	1.050	.850	.875	.714
Total error Set 1	3.900	4.150	3.850	4.100	.984
R Set 2	.250	.375	.400	.225	2.690
NR Set 2	.875	.950	1.100	1.225	1.828
F+ Set 2	4.350	3.950	4.025	3.950	1.936
F- Set 2	1.125	1.305	1.500	1.450	2.325
Total error Set 2	5.475	5.275	5.525	5.400	.571
R Set 3	.150	.425	.300	.325	3.492
NR Set 3	1.775	1.675	1.725	1.700	.158
F+ Set 3	3.725	3.875	4.000	3.875	.410
F- Set 3	1.925	2.100	2.025	2.000	.288
Total error Set 3	5.650	5.975	6.025	5.875	.843
Full Test R	.625	1.200	1.000	.825	3.595
Full Test NR	3.400	3.275	3.375	3.525	.348
Full Test F+	11.025	10.925	11.025	11.050	.046
Full Test F-	4.000	4.475	4.375	4.350	.953
Full Test Total error	15.025	15.400	15.400	15.400	.425

Note. - Conservative df = 1, 16.

Scores were best in Set 1 and worst in Set 3. The three sets were all found to differ significantly from each other. This pattern was found for all conditions.

Table 17

Comparison of Measures Across Sets: Test 1

Measure	Set 1	2	3	F
R	.3375	.3875	.3250	.7434
NR	.6000	1.0500	1.7750	75.3966*
F+	3.4125	4.2125	4.1375	16.4206*
F-	.9375	1.4375	2.1000	72.7465*
Total error	4.3500	5.6500	6.2375	63.6341*

Note. - Conservative df = 1, 16.

*p <.001.

Scores on the F+ measure were found to change significantly across the sets. The best scores, obtained in Set 1, were significantly different from both the worst scores, obtained in Set 3, and the scores obtained in Set 2. Scores in Sets 2 and 3 did not differ significantly from each other. These findings pertained to all conditions.

For all conditions, F- scores were found to increase steadily across the three sets. The three scores all differed significantly from each other.

For all conditions, Total error scores were also found to grow steadily

worse across the three sets. In this instance, however, significant differences occurred only between Sets 3 and 2 and Sets 3 and 1.

Table 18 presents the three Set means on each of the five measures for each ECT condition.

A significant Condition effect was obtained for each of the five measures compared across the sets. Table 19 presents the Condition means and F ratios. In all cases, Bi ECT produced significantly greater impairment than did ND, D or Ps ECT, while ND ECT produced greater impairment than did D or Ps ECT. D ECT was more damaging than Ps ECT on all measures except R.

Table 19

Condition Means and F Ratios for Measures Compared Across Sets: Test 1

Measure	Condition				F
	D	ND	Bi	Ps	
R	.066	.516	.766	.050	36.2847*
NR	.950	1.316	1.650	.650	47.1009*
F+	3.350	4.616	5.300	2.416	180.2138*
F-	1.016	1.833	2.416	.700	75.8326*
Total error	4.366	6.456	7.716	3.116	425.0068*

Note. - Conservative df = 1, 16.

*p < .001.

Table 18

Set Means for ECT Conditions on Each Measure

Measure	Condition	Set 1	Set 2	Set 3
R	D	.20	.00	.00
	ND	.45	.60	.50
	Bi	.55	.95	.80
	Ps	.15	.00	.00
NR	D	.35	.70	1.80
	ND	.80	1.30	1.85
	Bi	1.05	1.70	2.20
	Ps	.20	.50	1.25
F+	D	2.95	3.75	3.35
	ND	3.95	4.90	5.00
	Bi	5.05	5.35	5.50
	Ps	1.70	2.85	2.70
F-	D	.55	.70	1.80
	ND	1.25	1.90	2.35
	Bi	1.60	2.65	3.00
	Ps	.35	.50	1.25
Total error	D	3.50	4.45	5.15
	ND	5.20	6.80	7.35
	Bi	6.65	8.00	8.50
	Ps	2.05	3.35	3.95

Test 2. The results of the analyses of variance for Test 2 appear in Appendix X and the comparisons of means appear in Appendix Y.

The results for Test 2 were much like those for Test 1. Table 20 presents the means and F ratio values for the five measures compared across the three sets.

Table 20

Comparison of Measures Across Sets: Test 2

Measure	Set 1	2	3	F
R	.2625	.2375	.2750	.1134
NR	.6750	1.0250	1.6625	69.2517*
F+	2.7125	3.6000	3.9500	21.5770*
F-	.9375	1.2625	1.9250	36.4270*
Total error	3.6500	5.1875	5.5250	69.0513*

Note. - Conservative df = 1, 16.

*$p < .001$.

R scores were found not to change significantly across the three sets for any of the conditions.

For all conditions, scores on the NR measure changed significantly across the sets. Ss performed best in Set 1 and worst in Set 3. Sets 1, 2, and 3 all differed significantly from each other.

A significant effect was found for the F+ measure. The best scores,

obtained in Set 1, were significantly different from both the worst scores, obtained in Set 2, and the scores in Set 3. Sets 2 and 3 did not differ significantly.

The investigation of a significant Condition by Set interaction for the F+ measure ($\underline{F} = 4.55$, $\underline{df} = 1, 16$, $\underline{p} < .05$) revealed the following: F+ scores associated with D ECT did not change significantly across the three sets. The pattern for ND and Ps ECT was the same as that for the main effect, Set 1 being significantly better than both Sets 2 and 3, and Sets 2 and 3 not differing significantly from each other. Following Bi ECT, the error score was highest in Set 2 and this score was significantly worse than the scores of both Set 1 and Set 3. Sets 1 and 3 did not differ significantly. In general, then, except for the D condition, performance on this measure was found to deteriorate beyond the first set of the recognition test. A significant reversal towards improvement beyond Set 2 occurred only following Bi ECT.

For all conditions, erroneous responses on the F- measure were found to increase across sets. The best scores were obtained in Set 1 and these differed significantly from both the worst scores, obtained in Set 3, and the scores obtained in Set 2. Sets 2 and 3 were also found to differ significantly from each other.

The Total error score increased across sets. Scores in Set 1 were significantly better than scores in Set 2 and scores in Set 3. Sets 2 and 3 did not differ significantly.

Table 21 presents the three Set means on each of the five measures for each ECT condition.

Table 21

Set Means for ECT Conditions on Each Measure: Test 2

Measure	Condition	Set 1	Set 2	Set 3
R	D	.20	.00	.00
	ND	.30	.35	.40
	Bi	.40	.60	.70
	Ps	.15	.00	.00
NR	D	.30	.85	1.60
	ND	1.15	1.30	1.75
	Bi	1.05	1.45	2.25
	Ps	.20	.50	1.05
F+	D	2.55	3.05	2.85
	ND	3.15	4.25	4.40
	Bi	4.00	5.70	4.20
	Ps	1.15	2.70	2.95
F-	D	.50	.85	1.60
	ND	1.45	1.65	2.15
	Bi	1.45	2.05	2.90
	Ps	.35	.50	1.05
Total error	D	3.05	3.90	4.45
	ND	4.60	5.90	6.55
	Bi	5.45	7.75	7.10
	Ps	1.50	3.20	4.00

A significant Condition effect was found for each of the measures compared across the sets. Table 22 presents the Condition means and F ratios. Multiple means comparisons revealed that on all of the measures the ND and Bi conditions produced significantly higher error scores than did the D or Ps conditions. D ECT was responsible for higher error scores than was Ps ECT on all measures except R. Bi ECT produced significantly worse scores than ND ECT on all measures except NR.

Table 22

Condition Means and F Ratios for Measures Compared Across Sets: Test 2

Measure	Condition				F
	D	ND	Bi	Ps	
R	.066	.350	.566	.050	22.9900*
NR	.916	1.400	1.583	.513	27.4939*
F+	2.816	3.933	4.633	2.266	88.7457*
F-	.983	1.750	2.133	.633	68.1200*
Total error	3.800	5.683	6.766	2.900	229.2468*

Note. - Conservative df = 1, 16.

*p < .001.

Effect of a Single Treatment

An analysis of variance was performed on the scores obtained on the first

test of the proactive study to determine whether a Condition effect occurs after the first treatment. In effect, this analysis determined the effect of a single treatment (whether D, ND, Bi or Ps) uncontaminated by the potential accumulative effects of a series of treatments. Thus, the four groups of subjects were compared on scores obtained after the first treatment, which was D ECT for Group 1, Bi ECT for Group 2, Ps ECT for Group 3, and ND ECT for Group 4. The results of this analysis are presented in Appendix Z.

Table 23 provides a summary of Condition means and F ratio values obtained after a single treatment. A significant Condition effect occurred for 18 out of the 20 measures. Significance was not obtained for the NR Set 2 and NR Set 3 measures.

Application of the Newman-Keuls statistic for multiple means comparisons to the significant measures revealed the following:

The D and Ps conditions were significantly different from each other, with the D condition producing greater impairment, on four of the measures:

F+ Set 1

Total error Set 1

Full Test F+

Full Test Total error

Bi ECT produced significantly worse scores than ND ECT on the following measures:

R Set 1

Table 23

Condition Means and F Ratios After Single Treatment

Measure	Condition D	ND	Bi	Ps	F
R Set 1	0.00	0.00	0.80	0.20	7.1667**
NR Set 1	0.40	1.20	1.60	0.20	8.7330**
F+ Set 1	3.00	4.20	4.80	1.00	29.5789***
F- Set 1	0.40	1.20	2.40	0.40	11.1667***
Total error Set 1	3.40	5.40	7.20	1.40	30.6179***
R Set 2	0.00	0.80	1.00	0.00	7.9048**
NR Set 2	0.60	0.80	1.20	0.20	1.4400
F+ Set 2	4.00	6.20	5.60	3.40	9.1228***
F- Set 2	0.60	1.60	2.20	0.20	5.5778**
Total error Set 2	4.60	7.80	7.80	3.60	13.5143***
R Set 3	0.00	0.00	0.60	0.00	6.0000**
NR Set 3	1.60	2.00	2.40	1.40	2.8095
F+ Set 3	3.60	4.80	4.40	2.80	4.4952*
F- Set 3	1.60	2.00	3.00	1.40	4.8250*
Total error Set 3	5.20	6.80	7.40	4.20	9.7576***
Full Test R	0.00	0.80	2.40	0.20	19.7220***
Full Test NR	2.60	4.00	5.20	1.80	9.6450***
Full Test F+	10.60	15.20	14.80	7.20	30.5461***
Full Test F-	2.60	4.80	7.60	2.00	16.5043***
Full Test Total error	13.20	20.00	22.40	9.20	35.7101***

Note. - df = 3, 16.

*$p < .05$.
**$p < .01$.
***$p < .001$.

R Set 3

Full Test R

F- Set 3

Full Test F-

Total error Set 1

The Bi condition was significantly worse than the Ps condition on all measures. Bi ECT was worse than D ECT on all measures except F+ Set 3.

The ND condition impaired performance significantly more than did the D condition on 10 measures:

NR Set 1

F+ Set 1

Total error Set 1

R Set 2

F+ Set 2

Total error Set 2

Total error Set 3

Full Test F+

Full Test F-

Full Test Total error

ND ECT was significantly worse than Ps ECT for 13 measures. Significance was not attained for:

R Set 1

F- Set 1

R Set 3

F- Set 3

Full Test R

The comparisons of means appear in Appendix AA.

In general these results suggest that D ECT as a single treatment impaired performance more than did Ps ECT; ND ECT produced greater impairment than did D or Ps ECT; and Bi ECT produced greater impairment than did Ps, D, or ND ECT. Bi ECT as a single treatment was the condition which produced greatest response impairment.

DISCUSSION

The results of the present investigation revealed that ECT effects on memory are clearly different when electrodes are placed on the dominant as compared to the non-dominant temporal lobe area. This suggests that the areas of the cortex most proximal to electrode placement receive the major impact of ECT and determine the type of memory impairment which occurs after treatment. More specifically, in this study, stimulation of the non-dominant hemisphere, whether with unilateral non-dominant ECT or with bilateral ECT, produced greater non-verbal memory disturbance than did unilateral stimulation of the dominant hemisphere. Non-dominant and bilateral ECT also produced greater non-verbal memory disturbance than did a pseudo ECT condition in which patients received the routine pre-treatment anaesthetic and muscle-relaxant without actual ECT.

All patients, whether treated with bilateral or unilateral ECT, experienced generalized seizures for therapeutic purposes. It is clear, therefore, that neither side of the brain was ever completely spared the impact of the shock. Nevertheless, it seems that with unilateral ECT (dominant or non-dominant) the side of the cortex stimulated is affected to a greater degree than the contralateral side. The findings of several investigations that non-dominant ECT produced less verbal memory loss than bilateral ECT were explained by the fact that the dominant hemisphere, which is associated with verbal memory, was, to a great degree, spared the major impact of the shock (Cannicott, 1962; Lancaster et al., 1958; Martin et al., 1964). As further evidence of relatively circumscribed cortical effects associated with

electrode placement, other studies have shown that while both bilateral and unilateral ECT produce bilateral electroencephalographic dysrhythmia, unilateral ECT elicits a greater amount of dysrhythmia on the side of the head ipsilateral to that of electrode placement (Abrams et al., 1972; Martin et al., 1965; Sutherland et al., 1969; Zamora & Kaelbling, 1965). The finding in the present study that dominant ECT occasionally produced greater non-verbal memory loss than did pseudo ECT probably relates to the fact that the non-dominant hemisphere was affected to some degree by this procedure because of the spreading of the shock from the dominant to the non-dominant side. It was this non-dominant cerebral involvement which was responsible for the non-verbal memory impairment following dominant ECT.

The results of the present study support the neuropsychological research which suggests a specialization of function of the cerebral hemispheres, with the dominant hemisphere responsible for verbal memory functioning and the non-dominant hemisphere responsible for non-verbal memory functioning. Earlier ECT studies found an association between left temporal lobe involvement and verbal memory (e.g. Zamora & Kaelbling, 1965). The present study has revealed that non-dominant temporal lobe involvement is responsible for non-verbal memory impairment following ECT.

The design of the investigation permitted comparisons to be made between bilateral, dominant, non-dominant, and pseudo ECT, and it was revealed that whether one investigates retroactive memory or proactive memory, bilateral and

non-dominant ECT produce greater non-verbal memory impairment than do dominant or pseudo ECT. The effects of the different types of ECT on retroactive memory were clear cut. On each measure of the memory test employed, the bilateral procedure and the non-dominant procedure produced significantly more memory impairment than did the dominant or pseudo procedures, but the effects of bilateral and non-dominant ECT were not significantly different from each other in any instance.

The effects of the four ECT conditions on proactive memory were somewhat different from those seen on retroactive memory measures. Here, bilateral ECT was more disruptive to non-verbal memory than non-dominant ECT on almost all measures. The data suggest that the only instances in which the effects of bilateral and non-dominant ECT did not differ significantly from each other were on measures of retention, early in the test session, and on false positive scores, late in the testing sequence.

The results of the retroactive and proactive studies viewed in combination highlight the need for study of both these aspects of memory in ECT research. While the effects of bilateral and non-dominant ECT did not differ with respect to retroactive memory, non-dominant ECT appeared to be the less disruptive of the two for proactive memory. This issue will be taken up again at a later point.

Following ECT, patients are usually aware of some memory loss and frequently expect this to recur on the next treatment day. In order to measure this possible expectancy effect the pseudo ECT condition was necessary. In both the

retroactive and proactive studies, the baseline non-verbal memory scores obtained prior to ECT were not significantly different from the non-verbal memory scores obtained after the pseudo ECT condition. It may be concluded, then, that factors such as expectancy or suggestibility were not producing non-verbal memory impairment in the pseudo condition.

In the pseudo condition, patients received a muscle relaxant and an anaesthetic in the manner administered for routine ECT. Since the baseline memory scores and the pseudo ECT memory scores were not significantly different from each other, it also appears that pre-treatment medication does not contribute to non-verbal memory impairment.

There is an accumulative (although not necessarily linear) effect of ECT on retroactive non-verbal memory with additional ECT administrations, even when the consecutive treatments vary in electrode placement. Although this effect was operative on only three measures, with a trend found on a fourth measure, the fact that these were global Full Test scores, and that highly conservative degrees of freedom were adopted in the data analysis strengthen the validity of these findings. These results support the clinical impression that patients tend to show progressively more memory impairment with repeated ECTs.

An accumulative effect of ECT was not found on measures of proactive non-verbal memory. It appears, then, that with respect to non-verbal material, retroactive memory is more sensitive to the accumulative effects of repeated ECT than is proactive memory. The ECT literature presents contradictory evidence on

the question of increased memory impairment with repeated ECT. The present results suggest that such contradictions may be due at least in part to the fact that investigators have not carefully distinguished retroactive and proactive memory effects with repeated ECT.

The order in which the four types of ECT were administered was found to exert some influence on non-verbal recall in both the retroactive and proactive studies. It will be recalled that the four orders were (a) dominant, non-dominant, bilateral, pseudo; (b) bilateral, dominant, pseudo, non-dominant; (c) pseudo, bilateral, non-dominant, dominant; (d) non-dominant, pseudo, dominant, bilateral. Statistical significance was attained on 7 of the 20 measures in the retroactive study and on 3 of the 20 measures in the proactive study. The Full Test Total error score, which summarizes all sub-response measure scores, was not affected differentially by the four orders. For this reason, the conclusiveness or importance of those results which did reach statistical significance cannot be clearly assessed. Nevertheless, the findings suggest that non-verbal memory disturbance was more severe when bilateral and non-dominant ECT were given consecutively to each other than when dominant and pseudo ECT were interposed between the bilateral ECT and the non-dominant ECT. It may be argued that because dominant and pseudo ECT are each less disruptive to non-verbal memory than bilateral or non-dominant ECT, the insertion of the dominant and pseudo procedures between the bilateral and non-dominant procedures served to minimize a compounding negative effect of these more damaging treatments. This explanation,

however, does not account for the few instances in which the bilateral and non-dominant procedures were in fact separated by dominant and pseudo ECT, yet an order effect continued to exist. A multifactorial design, involving all of the possible permutations of the four ECT conditions, would be required to investigate thoroughly the order effect.

One of the aims of the present study was to investigate the effects of bilateral, non-dominant, dominant, and pseudo ECT on learning and retention. It has been demonstrated, with the use of verbal measures, that bilateral ECT primarily affects retention rather than learning (Williams, 1966). The present study was concerned with the learning and retention of non-verbal stimulus material. These variables were studied in relation to stimuli which had originally been presented to subjects prior to treatment (i.e. the retroactive study) as well as in relation to critical stimuli which had originally been presented to subjects after treatment (i.e. the proactive study).

There are difficulties with the concepts of learning and retention because the demonstration of one requires the involvement of the other. In the present study, learning and retention were operationally differentiated in the following way: Learning was said to occur when the subject was seen to make positive use of re-exposure to the recurring stimuli, that is, when fewer erroneous responses were made to the recurring stimuli as testing proceeded. Retention was measured by the degree to which the subject was able to recognize, with the passage of time, stimuli seen only once before.

In the retroactive study, all subjects demonstrated a significant improvement in performance with re-exposure to the stimuli as testing progressed. Thus, they were capable of learning, despite the more detrimental impact on learning of bilateral and non-dominant ECT than of dominant or pseudo ECT. In the proactive study, subjects did not improve significantly in their responses to the recurring stimuli. However, number of errors for all the ECT conditions was very low to start with and remained low throughout testing, leaving little room for improvement. The high accuracy of response is the notable finding rather than the apparent inability of these subjects to learn.

By contrast, the effects of the different types of ECT on retention were dramatic. One would expect that under normal circumstances it would become progressively more difficult to recognize a stimulus, seen only once before, due to both the passage of time and the accumulative interference of intervening stimuli. This was seen to occur in the pseudo condition. The effect of non-dominant or bilateral ECT was to magnify this phenomenon. Thus, non-dominant or bilateral ECT made it far more difficult for subjects to retain the stimuli than did dominant or pseudo ECT. The manner in which retention was affected was the same for retroactive and proactive memory. In the proactive study, however, bilateral ECT was significantly more disruptive than non-dominant ECT while in the retroactive study the two procedures were equivalent in their effects.

Kimura (1963) found that patients with right temporal lobe excisions characteristically produced a disproportionately high number of false positive

responses to new stimuli, interspersed with familiar stimuli, on a Recurring Nonsense Figures test. In the present study, while all subjects showed an increase in false positive responses to the new stimuli as testing proceeded, subjects gave significantly more false positive responses when treated with bilateral or non-dominant ECT than when treated with dominant or pseudo ECT. This occurred whether retroactive or proactive memory was considered. Bilateral and non-dominant ECT appear to render subjects less efficient at retaining the differences between, or discriminating between, non-verbal stimuli which they have seen before and new stimuli. Once again, bilateral ECT was significantly more detrimental than non-dominant ECT in the proactive study while in the retroactive study the two procedures produced identical effects.

In both the retroactive and proactive studies, there were two variables, in addition to the type of ECT procedure, which potentially affected both learning and retention. One was the passage of time between the presentation of the original 16 stimuli and the recognition test sessions, and the other was the interference produced by the introduction of new stimuli. The study did not aim to determine the degree to which one or the other of these factors was significantly more disruptive to non-verbal memory. However, insofar as recovery of newly learned material has been shown to occur with time after ECT (Mayer-Gross, 1943; Williams, 1969), one would expect that it was interference rather than the time variable which mainly contributed to a decline in efficiency of non-verbal memory observed in the present study.

The memory impairment produced by ECT is usually found to be temporary and there is evidence that some recovery from verbal memory loss can be seen within a few hours after ECT (Zinkin & Birtchnell, 1968). In the present study, recovery of proactive non-verbal memory was measured by retesting subjects with a parallel form of the test. A comparison of scores between the two tests administered after ECT revealed that some recovery from non-verbal memory impairment occurred within 3 hours after ECT. Although performance on the second test was still worse after bilateral or non-dominant ECT as compared to dominant and pseudo ECT, the bilateral and non-dominant conditions showed some improvement over scores obtained in the first test. It is unlikely that this recovery was actually a practice effect because preliminary studies provided nine test forms of equal difficulty. It was demonstrated that performance on one of these forms did not result in score gains on another due to practice.

Although recovery was by no means complete within the relatively short time span that subjects were tested, the data suggest that the proactive effects of ECT on non-verbal memory are reversible. The time period required for complete proactive non-verbal memory recovery is an interesting question for future research.

The present research design did not include an independent measure of recovery of retroactive memory as was the case in proactive memory. Cronholm (1969) noted that the demonstration of recovery of memory for verbal stimuli presented prior to ECT is related to the length of time one waits after ECT before

beginning to test. It is possible, therefore, to look at performance on the non-recurring stimuli in the present study as a measure of recovery of retroactive memory. According to Cronholm's position, one would have predicted an improvement in the recognition of these stimuli as testing progressed. As has already been shown, just the opposite result occurred--performance deteriorated as testing went on. Nevertheless, the conclusion that recovery of non-verbal retroactive memory does not occur would be unwarranted for several reasons. First, the memory test employed in the present study included an interference factor, produced by the new stimuli, which might have masked recovery. Second, the present study, unlike Cronholm's, did not test independent groups of subjects at particular time intervals after ECT. Instead, all subjects were tested at each brief time interval and thus were subject to accumulative interference effects. Finally, because all testing of retroactive memory was complete within 1 hour after ECT, it is possible that recovery had not yet taken place to any demonstrable degree. This possibility is supported by an interpretation of the data which is presented later in this section.

Another aim of the present investigation was to determine the differential effects on non-verbal memory of the first administration of bilateral, non-dominant, dominant, and pseudo ECT. In general, bilateral and non-dominant ECT proved to be more deleterious than dominant or pseudo ECT in their effects both on retroactive and on proactive memory. Of note were the significant differences between bilateral and non-dominant ECT effects which occurred on a number of

retroactive recall measures. It was the non-dominant procedure which was more disruptive.

The question arises as to why a single non-dominant ECT should lead to more disturbance in retroactive memory than a single bilateral ECT, especially since one of the significant differences between these two procedures was seen on the Full Test Total error score. One can postulate that the non-dominant hemisphere, which is critical for performance on the non-verbal memory test employed, bears the brunt of the shock with unilateral non-dominant ECT whereas there is a greater distribution of the same amount of shock with bilateral ECT. However, this postulated effect requires further scrutiny in relation to the finding that a single bilateral ECT was either as disruptive as a single non-dominant ECT or even more so on several measures in the proactive memory study.

Clearly, the results obtained from the statistical analysis performed on all the data of the Latin Square design, reported earlier, which compared subjects with themselves across the four experimental conditions, and these results, obtained from the analysis which compared the four groups of subjects with one another after their first treatment, are not entirely congruent. The differences in results may relate to the possibility that some of the effects observed after a single treatment were idiosyncratic since the groups were each comprised of only five subjects. Furthermore, the reliability of any single sub-test measure of the memory test employed is possibly less than any combination of scores. Finally, some of the differences were no doubt due to cumulative and order effects. Nevertheless, since

there is an essential over-all similarity between the two sets of results, the real possibility still remains that (a) bilateral and non-dominant ECT are more disruptive to non-verbal memory than dominant or pseudo ECT, (b) the effects of non-dominant ECT are more potent for retroactive as compared to proactive memory, and (c) the effects of bilateral ECT are more potent for proactive as compared to retroactive memory.

Taken at face value, then, the data suggest that the neurophysiological processes underlying retroactive and proactive memory are differentially susceptible to the effects of bilateral and non-dominant ECT. Non-dominant ECT either weakens the trace established prior to treatment, or impairs the retrieval of this trace, to at least the same degree as does bilateral ECT. On the other hand, bilateral ECT appears to be more disruptive than non-dominant ECT either to the registration of material presented after treatment or to the retrieval of this information.

An alternative explanation of the results would be as follows: It will be recalled that in the retroactive study recognition testing was begun 45 minutes after ECT. In the proactive study the 16 test stimuli were presented 45 minutes after treatment and recognition testing was begun 90 minutes after treatment. It is possible that at 90 minutes post-ECT, recovery from non-dominant ECT had begun and the differential effects of non-dominant and bilateral ECT became manifest. One would predict that testing at an earlier time period would have revealed no significant proactive differences between bilateral and non-dominant ECT. As

regards the retroactive study, one would predict that had testing been undertaken at a later point in time, once recovery from non-dominant ECT had begun, significant differences between the bilateral and non-dominant procedures would have occurred.

There is reason to believe that one should expect the effects of bilateral ECT to be longer lasting than the effects of unilateral ECT. Halliday et al. (1968) found that half a week after four treatments, the disruptive effects of bilateral and non-dominant ECT on non-verbal memory were equivalent; 3 months later, the effects of bilateral ECT persisted while the impairment shown by patients treated with non-dominant ECT had virtually disappeared. At this point in time, bilateral ECT was seen to be significantly more disruptive to non-verbal memory than non-dominant ECT.

The foregoing interpretation of the data, which suggests that recovery from non-dominant ECT occurs sooner than recovery from bilateral ECT, accounts for the results of the overall analysis of the Latin Square data. However, since this interpretation assumes that the effects of bilateral and non-dominant ECT are not significantly different from each other when memory testing is begun relatively soon after ECT, what still remains to be explained is the finding that after a single ECT, non-dominant ECT is significantly more disruptive than bilateral ECT for retroactive memory. If this finding is not statistical artefact, it suggests that non-dominant ECT may initially be more disruptive both to retroactive and proactive non-verbal memory than bilateral ECT, but still permits earlier recovery than bilateral ECT.

The non-verbal memory test which was employed in the present study was a modification of the Recurring Nonsense Figures test--a test which has been shown to be sensitive to the effects of right (non-dominant) temporal lobe excisions (Kimura, 1963). The importance of selecting an appropriate non-verbal memory test is reflected in the fact that the present study demonstrated a relationship between non-verbal memory impairment and non-dominant ECT, while most other studies addressed to this issue obtained negative results (Cannicott & Waggoner, 1967; Cronin et al., 1970; Dornbush et al., 1971; Strain et al., 1968). An interesting finding in the present study was that independent analyses of the responses to the geometric and nonsense figures, the two stimulus forms comprising the memory test, revealed similar differential effects of bilateral, non-dominant, dominant, and pseudo ECT. While one might intuitively have guessed that the geometric forms would be more susceptible to verbal mediation than were the nonsense figures, they were, in fact, responded to in the same manner as were the nonsense figures.

There is a great discrepancy in opinion among researchers with respect to the appropriate time interval after ECT at which testing should be done (Bidder et al., 1970; Zinkin & Birtchnell, 1968). It has been suggested that if one tests too early, when the effects of a confusional state are operative, confusion rather than memory is measured. In the present study, all subjects were found to be ostensibly fully oriented, and showed no signs of confusion, 45 minutes after ECT. At this time, subjects were able to recall personal information (name, address, occupation,

etc.), they were able to repeat sequences of digits, and they recognized the experimenter and remembered her purpose.

Because the subjects did not appear to be confused and because it was hoped to study the acute non-verbal memory effects of ECT as measured by a very specific memory test, testing for retroactive effects of ECT was begun 45 minutes after treatment. For the same reasons, in the investigation of proactive effects of ECT, the stimuli were presented to the subjects 45 minutes after treatment.

Insofar as it has been shown that disorientation and confusion are most intense and longest-lasting after bilateral ECT, least intense and shortest lasting after non-dominant ECT, and of an intermediate degree after dominant ECT, although still significantly worse than non-dominant ECT (Halliday et al., 1968; d'Elia, 1970) the results of the present study suggest that it was not the confusional state that was measured. Patients were always significantly more impaired following non-dominant ECT than following dominant ECT and the effects of non-dominant ECT were far too similar to the effects of bilateral ECT for a confusional state hypothesis to explain adequately. Unless it can be shown that a difference exists between verbal confusion and non-verbal confusion, the present study can be said to have investigated the effects of bilateral, non-dominant, dominant, and pseudo ECT on non-verbal memory and not on confusion.

There exist two views of the significance of the memory impairment produced by ECT, for depression. A unitary view considers the memory disturbance and the therapeutic effect of ECT as two unseparable aspects of an

unspecific ECT-induced process. Some authors have even suggested that the therapeutic effect derives from the memory disturbance. A dualistic view considers the amnesic and antidepressive effects of ECT as essentially independent processes.

To date, evidence tends to favor a dualistic view. It has been demonstrated that the memory disturbance and the antidepressive outcome arise at least partly via different mechanisms: the therapeutic effect being associated with the seizure and the memory impairment being determined by the amount of electrical current as well as the seizure (Ottosson, 1960). Furthermore, a greater memory disturbance does not give a better antidepressive effect as might be expected from a unitary view (Cronholm & Ottosson, 1961).

With the introduction of unilateral non-dominant ECT came still more support in favor of a dualistic viewpoint as it was revealed that depression could be lifted under circumstances of virtually no memory loss. The studies of unilateral ECT employed verbal memory measures, however, and the results of the present study indicate that unilateral non-dominant ECT does in fact produce memory disturbance but this can only be revealed with specifically non-verbal measures. At a theoretical level, then, the independence of the amnesic and therapeutic effects of ECT has not been proven.

The neuro-anatomical substrates responsible for ECT-produced phenomena have not yet been clearly delineated. It has been suggested, however, that the brain stem has a central position in the causation of affective disorders and is a target for antidepressive treatments, while the hippocampal-mammilary system plays a

significant role for retention. It has also been suggested that the pathway of propogation of cerebral discharge seems to be different in bilateral and unilateral ECT such that with bilateral ECT the seizure is driven from the brain stem structures right from the start, while with unilateral ECT the primary epileptogenic focus is probably situated cortically or closer to the cortex and the centrencephalic pace-maker is possibly not activated until later (d'Elia, 1970). Because non-dominant ECT was found to be significantly more disruptive to non-verbal memory than dominant ECT in the present study, it seems that further investigation into the anatomical structures associated with ECT-produced phenomena should not be simply for those associated with memory, defined globally, and those associated with depression. Instead, there is reason to believe that verbal and non-verbal memory disturbances are the result of the effects of ECT on distinct anatomical structures, namely, the left and right temporal lobes of the brain.

An important theoretical issue in the ECT literature is the process by which ECT affects memory. Neither retroactive nor proactive memory effects of ECT can be fully explained as an interference with the registration of information via disruption of neural consolidation because immediate memory remains intact and because recovery from amnesia occurs. The question arises as to whether (a) the retroactive and proactive effects of ECT on memory are qualitatively different from each other, with the retroactive effects reflecting mainly an interference with consolidation and the proactive effects reflecting mainly an interference with

retrieval; or whether (b) insofar as the effects of ECT on memory can be categorized as reversible and irreversible, the important variable is not the retroactive-proactive dichotomy but rather the time interval between the establishment of a memory trace (either before or after treatment) and ECT.

Weiskrantz (1966) has suggested that the main effect of ECT on memory is a non-specific interference with retrieval, which he refers to as "noise" (without considering its neurophysiological properties). He has proposed an interpretation of ECT-induced memory disturbance based upon the following assumptions: (a) An input establishes a short term trace (STT) which rapidly decays (Broadbent, 1957; Brown, 1964) and to which Weiskrantz assigns a half-life of about 20 seconds. (b) STT can initiate a long term trace (LTT) which is based on structural changes in the nervous system. (c) LTT requires some minimal degree of "priming" by STT before it can survive autonomously, and Weiskrantz postulates that such priming normally takes about 5 seconds. (d) Once LTT has been primed, it begins to increase autonomously and continues to do so more or less indefinitely. (e) The strength of LTT may also be increased by repetition of the events leading to its initiation. (f) LTT must be above the noise level before it can be retrieved. (g) ECT has two types of effects: it abolishes or alters the course of STT; it alters the noise level. (h) Any treatment which produces retrograde amnesia of more than a few seconds should also produce anterograde amnesia, since it is postulated that such a treatment has an effect upon noise level.

Given these assumptions, Weiskrantz makes the following predictions about

the retroactive effects of ECT: (a) The maximum time interval covered by the retrograde amnesia depends upon the noise-inducing properties of the treatment. Indeed, there is evidence to suggest that the amount of energy applied in ECT can directly effect the severity of retrograde amnesia (Cronholm and Ottosson, 1963). (b) There ought to be gradual shrinkage of the duration of amnesia to some irreducible minimum corresponding to the minimum required for LTT to become viable. Such shrinkage ought to occur both because those LTTs that are already established are gradually increasing in strength and therefore are more likely to exceed the noise level, and also because the specific increase in noise induced by a time-specific treatment such as ECT ought itself gradually to decline. Consequently, the events ought to be retrieved in decreasing order of their age.

Clinical reports support the predicted direction of shrinkage from old to new, and it has been reported that true residual retrograde amnesia in humans exists only for events which occurred seconds before ECT (Barbizet, 1970; Williams, 1967). When the residue of retrograde amnesia is reported to extend well beyond the few seconds predicted by his scheme, Weiskrantz suggests that clinical methods are insufficiently sensitive to reveal retention of more recent materials, and also that such material sometimes will have had considerable time to be affected by intervening stimuli.

Weiskrantz makes similar predictions about the proactive effects of ECT: (a) The degree of defect ought to be a function of the parameters of the treatment. Ottosson (1960) did find that an increase in the stimulus intensity of ECT results in a

significantly increased proactive memory disturbance. (b) Holding constant the interval between ECT and subsequent perceptual experience, the longer the interval between perception and retest, the better the retention. That is, anterograde amnesia, like retrograde amnesia, ought to shrink with time, the older events returning before the more recent ones. (c) Holding constant the interval between perception and retest, the closer the treatment to the perceptual experience, the poorer the retention. (d) Finally, the after-effects of a treatment such as ECT might persist sufficiently long enough to disrupt a newly established STT occurring some time afterwards. In this case, no LTT could become viable. In other words, shrinkage of anterograde amnesia would only be expected where perceptual material is shown to be normally retained for several seconds after its reception.

In light of the foregoing, whether the demonstrated retroactive effects of ECT in the present study reflected an interference with consolidation cannot be established for several reasons. The research design did not include a specific, uncontaminated measure of recovery from retroactive effects. The demonstration of recovery would have provided evidence to suggest that ECT did not in fact prevent the registration of non-verbal stimuli. Furthermore, the question of whether or not the effects of ECT on consolidation can extend backwards in time beyond a 5-minute interval remains unresolved. Finally, to prove that a memory has been irreversibly obliterated is an extremely difficult endeavour because the possibility always exists that this memory would be retrieved under different testing methods or conditions. This is particularly the case for the effects of routine ECT because

much recovery of "lost" memories occurs.

The opinion of the investigator is that retroactively ECT did not interrupt consolidation but rather that the effects of ECT both retroactively and proactively reflected an interference with retrieval. The subjects inspected the material for a relatively long period of time and, in the retroactive study, it was several minutes later that ECT was administered. It is unlikely, therefore, that ECT affected a short term trace. Also, the effects of ECT (bilateral or non-dominant) on retroactive as compared to proactive memory were not qualitatively different with respect to such variables as retention or the production of false positive responses. The direction of change in these variables was the same whether in relation to stimuli perceived prior to ECT or post-ECT.

It could be argued that similar results were, in fact, produced by qualitatively different retroactive and proactive effects of ECT; or that in the present study the effect of ECT proactively, as well as retroactively, was an interference with the registration of stimulus material. The latter possibility is highly unlikely considering the mental status and learning capabilities of the subjects at the time of stimulus presentation and recognition testing.

Finally, the observation that responses given by subjects after ECT were quantitatively but not qualitatively different from responses given under non-ECT conditions, suggests that interference from irrelevant stimuli, compounded with the interfering noise created by ECT, made retrieval particularly difficult for subjects after treatment.

SUMMARY

The results of the present investigation permit the following conclusions:

1. Bilateral and non-dominant ECT impair non-verbal memory to a significantly greater degree than do dominant ECT or a pseudo ECT condition.

2. The differential effects of dominant, non-dominant, bilateral, and pseudo ECT are manifest after the first treatment.

3. ECT affects non-verbal memory both retroactively and proactively.

4. There is recovery from the proactive effects of ECT on non-verbal memory.

5. Non-verbal variables impaired by ECT include retention, the production of false positive responses, and to a lesser degree, learning. In each instance, bilateral and non-dominant ECT are more disruptive than dominant or pseudo ECT.

In the present study, bilateral ECT was found to be more disruptive than non-dominant ECT in its proactive effects while the two procedures were equivalent in their retroactive effects. Whether the retroactive-proactive differences were due to the different time intervals in the two studies between ECT and testing requires further investigation. Another issue which requires further investigation concerns the cumulative effects of ECT on retroactive and proactive memory.

Verbal memory is impaired when the dominant cerebral hemisphere is

affected by ECT. The present investigation has demonstrated that non-verbal memory is significantly impaired when the non-dominant cerebral hemisphere receives ECT.

REFERENCES

Abrams, R., Fink, M., Dornbush, R. L., Feldstein, S., Volavka, J., & Roubicek, J. Unilateral and bilateral electroconvulsive therapy. Effects on depression, memory, and the electroencephalogram. Archives of General Psychiatry, 1972, 27, 88-91.

Adams, H. E., & Lewis, D. J. Electroconvulsive shock, retrograde amnesia and competing responses. Journal of Comparative and Physiological Psychology, 1962, 55, 299-301. (a)

Adams, H. E., & Lewis, D. J. Retrograde amnesia and competing responses. Journal of Comparative and Physiological Psychology, 1962, 55, 302-305. (b)

Alexander, L. Treatment of mental disorders. Philadelphia: Saunders, 1953.

Barbizet, J. Human memory and its pathology. San Francisco: W. H. Freeman, 1970.

Bayles, S., Busse, E. W., and Ebaugh, F. G. Square waves (BST) versus sine waves in electroconvulsive therapy. American Journal of Psychiatry, 1950, 107, 34-41.

Beek, H., & Stuart, K. C. The electroshock technique. Folia psychiatrica, neurologica et neurochirurgica neerlandica, 1953, 56, 196-209.

Bekhterev, V. M. Demonstration eines gehirns mit zerstorung der vorderen und inneren theile der hirnrinde beider schlafenlappen. Neurologisches Zentralblatt, 1900, 19, 990-991.

Bidder, T. G., Strain, J. J., & Brunschwig, L. Bilateral and unilateral ECT. Follow-up study and critique. American Journal of Psychiatry, 1970, 127, 737-745.

Blakemore, C. B., & Falconer, M. A. Long-term effects of anterior temporal lobectomy on certain cognitive functions. Journal of Neurology, Neurosurgery and Psychiatry, 1967, 30, 364-367.

Brady, J. V., Hunt, H. F., & Geller, L. The effect of electroconvulsive shock on a conditioned emotional response as a function of the temporal distribution of the treatment. Journal of Comparative and Physiological Psychology, 1954, 47, 454-457.

Brain, L. Speech disorders. London: Butterworths, 1965.

Branch, C., Milner, B., & Rasmussen, T. Intracarotid sodium amytal for the lateralization of cerebral speech dominance. Observations in 123 patients. Journal of Neurosurgery, 1964, 21, 399-405.

Brengelman, J. C. The effect of repeated electrical shocks on learning. Berlin: Springer, 1959.

Broadbent, D. E. Immediate memory and simultaneous stimuli. Quarterly Journal of Experimental Psychology, 1957, 9, 1-11.

Brody, M. B. Prolonged memory defects following electrotherapy. Journal of Mental Science, 1944, 380, 777-779.

Brown, J. Short-term memory. British Medical Bulletin, 1964, 20, 8-11.

Cannicott, S. M. Unilateral electroconvulsive therapy. Post Graduate Medical Journal, 1962, 38, 451-459.

Cannicott, S. M., & Armin, R. H. Unilateral electroconvulsive-therapy. British Journal of Psychiatry, 1968, 114, 1483.

Cannicott, S. M., & Waggoner, R. W. Unilateral and bilateral electroconvulsive therapy: a comparative study. Archives of General Psychiatry, 1967, 16, 229-232.

Carney, M. W. P., Roth, M., & Garside, R. F. The diagnosis of depressive syndromes and the prediction of ECT responses. British Journal of Psychiatry, 1965, 3, 659-674.

Cerletti, U., & Bini, L. L'elettroshock. Archivio generale di neurologia e psichiatria, 1938, 19, 266-268.

Chase, R. A. Discussion. In F. L. Darley (Ed.), Brain mechanisms underlying speech and language. New York: Grune & Stratton, 1967.

Chevalier, J. A. Permanence of amnesia after a single post trial electroconvulsive seizure. Journal of Comparative and Physiological Psychology, 1965, 59, 125-127.

Chorover, S. L., & Schiller, P. H. Short-term retrograde amnesia in rats. Journal of Comparative and Physiological Psychology, 1965, 59, 73-78.

Cohen, B. D., Noblin, C. D., Silverman, A. J., & Pennick, S. B. On the functional assymetry of the human brain. Science, 1968, 162, 475-477.

Coons, E. E., & Miller, N. E. Conflict versus consolidation of memory traces to explain "retrograde amnesia" produced by ECS. Journal of Comparative and Physiological Psychology, 1960, 53, 524-531.

Corkin, S. Tactually-guided maze learning in man: Effects of unilateral cortical excisions and bilateral hippocampal lesions. Neuropsychologia, 1965, 3, 339-351.

Corkin, S., Milner, B., & Rasmussen, T. Somatosensory thresholds: Contrasting effects of postcentral-gyrus and posterior parietal-lobe excisions. Archives of Neurology, 1970, 23, 41-58.

Corsi, P. M. Verbal memory impairment after unilateral hippocampal excisions. Paper presented at the 40th Annual Meeting of the Eastern Psychological Association, Philadelphia, April, 1969.

Costello, C. G., Belton, G. P., Abra, J. C., & Dunn, B. E. The amnesic and therapeutic effects of bilateral and unilateral ECT. British Journal of Psychiatry, 1970, 116, 69-78.

Cronholm, B. Post-ECT amnesias. In G. A. Talland & N. C. Waugh (Eds.), The pathology of memory. New York: Academic Press, 1969.

Cronholm, B., & Bloomquist, C. Memory disturbances after electroconvulsive therapy. 2. Conditions one week after a series of treatments. Acta Psychiatrica et Neurologica Scandinavica, 1959, 34, 18-25.

Cronholm, B., & Lagergren, A. Memory disturbances after electroconvulsive therapy: 3. An experimental study of retrograde amnesia after electroconvulsive shock. Acta Psychiatrica et Neurologica Scandinavica, 1959, 34, 283-310.

Cronholm, B., & Molander, L. Memory disturbances after electroconvulsive therapy. 1. Condition 6 hours after electroshock treatment. Acta Psychiatrica et Neurologica Scandinavica, 1957, 32, 280-306.

Cronholm, B., & Molander, L. Memory disturbances after electroconvulsive therapy. 5. Conditions one month after a series of treatments. Acta Psychiatrica Scandinavica, 1964, 40, 212-216.

Cronholm, B., & Ottosson, J. O. Countershock in electroconvulsive therapy. Archives of General Psychology, 1961, 4, 254-259.

Cronholm, B., & Ottosson, J. O. Ultrabrief stimulus technique in electroconvulsive therapy. II: Comparative studies of therapeutic effects and memory disturbances in treatment of endogenous depression with Elther ES electroshock apparatus and Siemens Konvulsator III. Journal of Nervous and Mental Disease, 1963, 137, 268-276.

Cronin, D., Bodley, P., Potts, L., Mather, M. D., Gardner, R. K., & Tobin, J. C. Unilateral and bilateral ECT: a study of memory disturbance and relief from depression. Journal of Neurology, Neurosurgery and Psychiatry, 1970, 33, 705-713.

Davidson, M. L. Univariate versus multivariate tests in repeated-measures experiments. Psychological Bulletin, 1972, 77, 446-452.

Davis, R. E. Environmental control of memory fixation in goldfish. Journal of Comparative and Physiological Psychology, 1968, 65, 72-78.

d'Elia, G. Comparison of electroconvulsive therapy with unilateral and bilateral stimulation. 2. Therapeutic efficiency in endogenous depression. Acta Psychiatrica Saandinavica, 1970, 46, (Supplement 215), 30-43.

d' Elia, G. Comparison of electronconvulsive therapy with unilateral and bilateral stimulation. 3. Anterograde amnesia. Acta Psychiatrica Scandinavica, 1970, 46, (Supplement 215), 44-60.

d'Elia, G. Comparison of electroconvulsive therapy with unilateral and bilateral stimulation. 4. Retrograde amnesia. Acta Psychiatrica Scandinavica, 1970, 46, (Supplement 215), 61-75.

d'Elia, G. Comparison of electroconvulsive therapy with unilateral and bilateral stimulation. 5. Confusion and other side-effects. Acta Psychiatrica Scandinavica, 1970, 46, (Supplement 215), 77-89.

De Renzi, E., & Spinnler, H. Facial recognition in brain-damaged patients. Neurology, 1966, 16, 145-152. (a)

De Renzi, E., & Spinnler, H. Visual recognition in patients with unilateral cerebral disease. Journal of Nervous and Mental Disease, 1966, 142, 515-525. (b)

Dornbush, R., Abrams, R., & Fink, M. Memory changes after unilateral and bilateral convulsive therapy (ECT). British Journal of Psychiatry, 1971, 119, 75-78.

Duncan, C. P. The retroactive effect of electroshock on learning. Journal of Comparative and Physiological Psychology, 1949, 42, 32-44.

Ebtinger, R. Aspects psychopathologiques du post-electrochoc. Colmar: Imprimerie Asatie, 1958.

Epstein, J., & Wender, L. Alternating current vs. undirectional current for electroconvulsive therapy--comparative studies. Confina Neurologica (Basel), 1956, 16, 137-146.

Ewald, G., & Haddenbrock, S. Die elektrokrampftherapie. Ihre grundlagen und ihre erfolge. Ein beitrag zur pathogenese der psychosen. Zeitschrift fur die gesamte Neurologie, 1942, 174, 635-669.

Feldman, F., Susselman, S., Lipetz, B., & Barrera, S. E. ECT in elderly patients. Archives of Neurology and Psychiatry, 1946, 56, 158-161.

Ferguson, G. A. Statistical analysis in psychology and education. (2nd ed.) New York: McGraw-Hill, 1966.

Fleminger, J. J., Horne, D. J. de L., Nair, N. P. V., & Nott, P. N. Differential effect of unilateral and bilateral ECT. American Journal of Psychiatry, 1970, 127, 430-437.

Fleminger, J. J., Horne, D. J. de L., Nott, P. N. Unilateral electroconvulsive therapy and cerebral dominance: effect of right- and left-sided electrode placement on verbal memory. Journal of Neurology, Neurosurgery and Psychiatry, 1970, 33, 408-411.

Friedman, E., & Wilcox, P. H. Electrostimulated convulsive doses in intact humans by means of unidirectional currents. Journal of Nervous and Mental Disease, 1942, 96, 56-63.

Gayle, R. F., & Josephs, D. Brief stimulus therapy. Southern Medical Journal (Bgham, Ala.), 1948, 41, 245-251.

Geller, A., & Jarvik, M. E. The time relations of ECS induced amnesia. Psychonomic Science, 1968, 12, 169-170.

Gerard, R. W. Biological roots of psychiatry. Science, 1955, 122, 225-230.

Glees, P., & Griffith, H. B. Bilateral destruction of the hippocampus (Cornu Ammonis) in a case of dementia. Monatsschrift fur Psychiatrie und Neurologie, 1952, 129, 193-204.

Gottlieb, G., & Wilson, I. Cerebral dominance: temporary disruption of verbal memory by unilateral electroconvulsive shock treatment. Journal of Comparative and Physiological Psychology, 1965, 60, 368-372.

Greenblatt, M., Grosser, G. H., & Wechsler, H. Differential responses of hospitalized depressed patients to somatic therapy. American Journal of Psychiatry, 1964, 120, 935-943.

Halliday, A. M., Davison, K., Browne, M. W., & Kreeger, L. C. A comparison of the effects on depression and memory of bilateral ECT and unilateral ECT to the dominant and non-dominant hemispheres. British Journal of Psychiatry, 1968, 114, 997-1012.

Hebb, D. O. The organization of behavior. New York: Wiley, 1949.

Hegglin, K. Uber einen fall von isolierter linkseitiger ammonshorner-weichung bei praseniler demenz. Monatsschrift fur Psychiatrie und Neurologie, 1953, 125, 170-186.

Heriot, J. T., & Coleman, P. D. The effects of electroconvulsive shock on retention of a modified "one-trial" conditioned avoidance. Journal of Comparative and Physiological Psychology, 1962, 55, 1082-1084.

Hetherington, R. The effects of ECT on efficiency and retentivity. British Journal of Medical Psychology, 1956, 29, 258-269.

Hudspeth, W. J., McGaugh, J. L., & Thomson, C. W. Aversive and amnesic effects of electroconvulsive shock. Journal of Comparative and Physiological Psychology, 1964, 57, 61-64.

Hughes, R. A., Barrett, R. J., & Ray, O. S. Training to test interval as a determinant of a temporally graded ECS-produced response decrement in rats. Journal of Comparative and Physiological Psychology, 1970, 71, 318-324.

Hunt, H. F., & Brady, J. W. Some effects of electroconvulsive shock on a conditioned response ("anxiety"). Journal of Comparative and Physiological Psychology, 1951, 44, 88-98.

Huston, P. E., & Strother, C. R. The effect of electric shock on mental efficiency. American Journal of Psychiatry, 1948, 104, 707-712.

Impastato, D. J., & Karliner, W. Control of memory impairment in EST by unilateral stimulation of the non-dominant hemisphere. Diseases of the Nervous System, 1966, 27, 182-188.

Jarvik, M. E. Effects of chemical and physical treatments on learning and memory. Annual Review of Psychology, 1972, 23, 457-486.

Kalinowsky, L. B. Thirty years of empiricism. International Journal of Psychiatry, 1968, 5, 169-170.

Kalinowsky, L., & Hippius, H. Pharmacological, convulsive and other somatic treatments in psychiatry. New York: Grune and Stratton, 1969.

Kalinowsky, L. B., & Hoch, P. H. Somatic treatments in psychiatry. (Rev. ed.) New York: Grune and Stratton, 1961.

Kendall, B. S., Mills, W. B., & Thale, T. Comparison of two methods of electroshock in their effect on cognitive functions. Journal of Consulting Psychology, 1956, 20, 423-429.

Kiloh, L. G., Child, J. P., & Latner, G. Endogenous depression treated with Iproniazid: a follow-up study. Journal of Mental Science, 1960, 106, 1425-1428.

Kimura, D. Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 1961, 15, 166-171. (a)

Kimura, D. Some effects of temporal-lobe damage on auditory perception. Canadian Journal of Psychology, 1961, 15, 156-165. (b)

Kimura, D. Right temporal lobe damage. Archives of Neurology, 1963, 8, 264-271.

King, R. A. Consolidation of the neural trace in memory: investigation with one trial avoidance conditioning and ECS. Journal of Comparative and Physiological Psychology, 1965, 59, 283-284.

Lancaster, N. P., Steinert, R. R., & Frost, I. Unilateral electroconvulsive therapy. Journal of Mental Science, 1958, 104, 221-227.

Lansdell, H. C. Effect of extent of temporal lobe ablations on two lateralized deficits. Physiology and Behavior, 1968, 3, 271-273.

Levy, N. A., Serota, H. M., & Grinker, R. R. Disturbances in brain function following convulsive shock therapy. Archives of Neurology and Psychiatry, 1942, 47, 1009-1029.

Levy, R. The clinical evaluation of unilateral electroconvulsive therapy. British Journal of Psychiatry, 1968, 114, 459-463.

Lewis, D. J., & Maher, B. A. Neural consolidation and electroconvulsive shock. Psychological Review, 1965, 72, 225-240.

Lewis, N. D. C. Shock therapy, evidences for and against damage. Digest of Neurology and Psychiatry, 1945, 13, 159-169.

Liberson, W. T. New possibilities in electric convulsive therapy: "Brief stimuli" technique. Preliminary report. Digest of Neurology and Psychiatry, 1944, 12, 368-369.

Liberson, W. T. Brief stimulus therapy. American Journal of Psychiatry, 1948, 105, 28-39.

Liberson, W. T., and Wilcox, P. H. Electric convulsive therapy: comparison of "Brief stimuli technique" with Friedman-Wilcox-Reiter technique. Digest of Neurology and Psychiatry, 1945, 13, 292-302.

Lindner, M., & Brouschek, R. Klinische erfahrungenmit der kurzreiz-methode in der elektrokrampftherapie. Nervenarzt, 1953, 24, 163-164.

Madsen, M. G., & McGaugh, J. L. The effect of ECS on one-trial avoidance learning. Journal of Comparative and Physiological Psychology, 1961, 54, 522-523.

Maher, B. A., McIntire, R. W.,& House, C. Retrograde amnesia following ECT. Paper presented to Southeast Psychological Association, Miami Beach, 1962.

Man, P. L., & Bolin, B. J. Further exploration of unilateral electroshock treatment. Diseases of the Nervous System, 1964, 30 (8), 547-551.

Martin, W. L., Ford, H. F., McDanald, E. C., & Towler, M. L. Clinical evaluation of unilateral EST. American Journal of Psychiatry, 1965, 121, 1087-1090.

Mayer-Gross, W. Retrograde amnesia. Some experiments. Lancet, 1943, 2, 603-605.

Mayer-Gross, W., Slater, E., & Roth, M. Clinical psychiatry. London: Cassell, 1960.

McAndrew, J., Berkey, B., & Matthews, C. The effects of dominant and non-dominant unilateral ECT as compared to bilateral ECT. American Journal of Psychiatry, 1967, 124, 483-490.

McGaugh, J. L., & Landfield, P. W. Delayed development of amnesia following electroconvulsive shock. Physiology and Behavior, 1970, 5, 1109-1113.

McGaugh, J. L., & Madsen, M. C. Amnesic and punishing effects of electro-convulsive shock. Science, 1964, 144, 182-183.

Meier, M. J., & French, L. A. Lateralized deficits in complex visual discrimination and bilateral transfer of reminiscence following unilateral temporal lobectomy. Neuropsychologia, 1965, 3, 261-272.

Meier, M. J., & French, L. A. Longitudinal assessment of intellectual functioning following unilateral temporal lobectomy. Journal of Clinical Psychology, 1966, 22, 22-27.

Mendels, J. Electroconvulsive therapy and depression. II. Significance of endogenous and reactive syndromes. British Journal of Psychiatry, 1965, 3, 682-686.

Mendlicott, R. W. Brief stimuli electroconvulsive therapy. New Zealand Medical Journal, 1948, 47, 29-37.

Meyer, V., & Yates, H. J. Intellectual changes following temporal lobectomy for psychomotor epilepsy. Journal of Neurology, Neurosurgery and Psychiatry, 1955, 18, 44-52.

Miller, E. Psychological theories of ECT: a review. British Journal of Psychiatry, 1967, 113, 301-311.

Miller, R. R., Mesanin, J. R., & Lewis, D. J. Amnesia as a function of events during the learning-ECS interval. Journal of Comparative and Physiological Psychology, 1969, 67, 145-148.

Milligan, W. L. Psychoneuroses treated with ECT. Lancet, 1946, 2, 516.

Milner, B. Psychological defects produced by temporal lobe excision. Research Publications. Association for Research in Nervous and Mental Diseases, 1958, 36, 244-257.

Milner, B. The memory defect in bilateral hippocampal lesions. Psychiatric Research Reports, 1959, 11, 43-58.

Milner, B. Laterality effects in audition. In V. B. Mountcastle (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: The Johns Hopkins Press, 1962.

Milner, B. Some effects of frontal lobectomy in man. In J. M. Warren & K. Akert (Eds.), The frontal granular cortex and behavior. New York: McGraw-Hill, 1964.

Milner, B. Visually-guided maze learning in man: effects of bilateral hippocampal, bilateral frontal, and unilateral cerebral lesions. Neuropsychologia, 1965, 3, 317-338.

Milner, B. Amnesia following operation on the temporal lobes. In C. W. M. Whitty & O. L. Zangwill (Eds.), Amnesia. London: Butterworths, 1966.

Milner, B. Brain mechanisms suggested by studies of temporal lobes. In F. L. Darley (Ed.), Brain mechanisms underlying speech and language. New York: Grune & Stratton, 1967.

Milner, B. Visual recognition and recall after right temporal-lobe excision in man. Neuropsychologia, 1968, 6, 191-209.

Milner, B. Memory and the medial temporal regions of the brain. In K. H. Pribram & D. E. Broadbent (Eds.), Biology of memory. New York: Academic Press, 1970.

Milner, B., & Kimura, D. Dissociable visual learning defects after unilateral temporal lobectomy in man. Paper presented at 35th Annual Meeting of the Eastern Psychological Association, Philadelphia, April, 1964.

Milner, B., & Teuber, H. L. Alteration of perception and memory in man: reflections on methods. In L. Weiskrantz (Ed.), Analysis of behavioral change. New York: Harper & Row, 1968.

Mooney, C. M. Closure with negative after-images under flickering light. Canadian Journal of Psychology, 1956, 10, 191-199.

Muller, G. E., & Pilzecker, A. Experimentelle Beitrage zur Lehre vom Gedachtnis. Zeitschrift fur Psychologie, Erganzungzband I, 1900, 1-288.

Newcombe, F. Double dissociation after focal cerebral injury. In M. Kinsbourne (Ed.), Hemispheric asymmetry of function. London: Butterworths.

Offner, F. Stimulation with minimum power. Journal of Neurophysiology, 1946, 9, 387-390.

Ottosson, J. O. Experimental studies of the mode of action of electroconvulsive therapy. Acta Psychiatrica Scandinavica, 1960, 35, Supplement 145.

Ottosson, J. O. Electroconvulsive therapy-electrostimulatory or convulsive therapy? Journal of Neuropsychiatry, 1962, 3, 216-220.

Ottosson, J. O. Seizure characteristics and therapeutic efficiency in electro-convulsive therapy: an analysis of the antidepressive efficiency of grand mal and lidocaine-modified seizure. Journal of Nervous and Mental Disease, 1962, 135, 239-251.

Pagano, R. R., Bush, D. F., Martin, G., & Hunt, E. B. Duration of retrograde amnesia as a function of electroconvulsive shock intensity. Physiology and Behavior, 1969, 4, 19-21.

Pearlman, C. S., Sharpless, S. K., & Jarvik, M. E. Retrograde amnesia produced by anesthetic and convulsant agents. Journal of Comparative and Physiological Psychology, 1961, 54, 109-112.

Penfield, W., & Milner, B. Memory deficit produced by bilateral lesions in the hippocampal zone. American Medical Association Archives of Neurology and Psychiatry, 1958, 79, 475-497.

Perlson, J. Case of schizophrenia treated with 248 electric shock treatments. Archives of Neurology and Psychiatry, 1945, 54, 409-411.

Petit-Dutaillis, D., Christophe, J., Pertuiset, B., Dreyfus-Brisac, C., & Blanc, C. Lobectomie temporale pour epilepsie: evolution des perturbations fonctionnelles post-operatoires. Revue Neurologique, 1954, 91, 129-133.

Piercy, M. Studies of the neurological basis of intellectual function. In D. J. Williams (Ed.), Modern trends in neurology, Series 4. London: Butterworths, 1967.

Poschel, B. P. H. Proactive and retroactive effects of electroconvulsive shock on approach-avoidance conflicts. Journal of Comparative and Physiological Psychology, 1957, 50, 392-396.

Proctor, L. D., & Goodwin, J. E. Clinical and electro-physiological observations following electroshock. American Journal of Psychiatry, 1945, 101, 797-800.

Quartermain, D., Paulino, R. M., & Miller, N. E. A brief temporal gradient of retrograde amnesia independent of situational change. Science, 1965, 149, 1116-1118.

Rabin, A. I. Patients who received more than 100 electric shock treatments. Journal of Personality, 1948, 17, 42-47.

Robustelli, F., Geller, A., & Jarvik, M. E. Potentiation of the amnesic effect of electroconvulsive shock by detention. Psychonomic Science, 1968, 12, 85-86.

Rochford, G., & Williams, M. Development and breakdown of the use of nouns. Journal of Neurology, Neurosurgery, and Psychiatry, 1962, 25, 222.

Rose, J. T. Reactive and endogenous depressions-response to ECT. British Journal of Psychiatry, 1963, 109, 213-217.

Russell, J. R., Page, L. G. M., & Jillett, R. L. Intensified ECT. Review of five years' experience. Lancet, 1953, 2, 1177.

Sargant, W., & Slater, E. Physical methods of treatment in psychiatry. London: Livingstone, 1963.

Sawa, M., Ueki, Y., Arita, M., & Harada, T. Preliminary report on the amygdaloidectomy on the psychotic patients, with interpretation of oral-emotional manifestation in schizophrenics. Folia Psychiatrica et Neurologica Japonica, 1954, 7, 309-329.

Schwartzman, A. E., & Termansen, P. E. Intensive electroconvulsive therapy: a follow-up study. Canadian Psychiatric Association Journal, 1967, 12, 217-218.

Scoville, W. B., & Milner, B. Loss of recent memory after bilateral hippocampal lesions. Journal of Neurology, Neurosurgery and Psychiatry, 1957, 20, 11-21.

Shankweiler, D. Effects of temporal-lobe damage on perception of dichotically presented melodies. Journal of Comparative and Physiological Psychology, 1966, 62, 115-119. (a)

Shankweiler, D. Defects in recognition and reproduction of familiar tunes after unilateral temporal lobectomy. Paper read at the 37th Annual Meeting of the Eastern Psychological Association, New York City, 1966. (b)

Shapiro, M. B., Campbell, D., Harris, A., & Dewsberry, J. P. Effects of ECT upon psychomotor speed and the "distraction" effect in depressed psychiatric patients. Journal of Mental Science, 1958, 104, 681-695.

Sherman, I., Mergener, J., & Levitin, D. Effect of convulsive therapy on memory. American Journal of Psychiatry, 1941, 98, 401-403.

Silfverskiold, W., & Dencker, S. J. Modifierad cardiazolschockbehandling. Nordisk Medicin, 1957, 57, 15-17.

Stengel, E. Intensive ECT. Journal of Mental Science, 1951, 97, 139-142.

Stone, C. P. Losses and gains in cognitive functions as related to electroconvulsive shocks. Journal of Abnormal and Social Psychology, 1947, 42, 206-210.

Strain, J. J., Brunschwig, L., Duffy, J. P., Agle, D. P., Rosenbaum, A. L., & Bidder, T. G. Comparison of therapeutic effects and memory changes with bilateral and unilateral ECT. American Journal of Psychiatry, 1968, 125, 294-304.

Sutherland, E. M., Oliver, J. E., & Knight, D. R. EEG, memory and confusion in dominant, non-dominant, and bilateral ECT. British Journal of Psychiatry, 1969, 115, 1059-1064.

Terzian, H. Observations on the clinical symptomatology of bilateral partial or total removal of the temporal lobes in man. In M. Baldwin & P. Bailey (Eds.), Temporal-lobe epilepsy. Springfield, Ill.: Charles C. Thomas, 1958.

Terzian, H., & Dalle Ore, G. Syndrome of Kluver and Bucy reproduced in man by bilateral removal of the temporal lobes. Neurology, 1955, 5, 373-380.

Thenon, J. Quoted by Kalinowsky, L., & Hippius, H., 1969.

Thomas, D. Prognosis of depression with electric treatment. British Medical Journal, 1954, 2, 950-954.

Thompson, R., & Dean, W. A further study on the retroactive effects of ECS. Journal of Comparative and Physiological Psychology, 1955, 48, 488-491.

Thorpe, J. G. Learning ability during a course of 20 ECTs. Journal of Mental Science, 1959, 105, 1017-1021.

Ule, G. Pathologische-anatomische befund bei korsakow-psychosen und irhe bedeutung fur die localisationslehre in der psychiatrie. Artzl. Wochenschrift, 1958, 13, 6-13.

Valentine, M., Keddie, K. M. G., & Dunne, D. A comparison of techniques in electroconvulsive therapy. British Journal of Psychiatry, 1968, 114, 989-996.

Victor, M., Angevine, J. B., Mancall, G. L., & Fisher, C. M. Memory loss with lesions of hippocampal formation. Archives of Neurology, 1961, 5, 244-263.

von Braunmuhl, A. Ein neues gerat fur die heilkramfbehandlung mittels elektrischen stromes. Fortschritte der Neurologie und Psychiatrie, 1951, 7, 325-332.

Warrington, E., & James, M. An experimental investigation of facial recognition in patients with unilateral cerebral lesions. Cortex, 1967, 3, 317-326.

Weiskrantz, L. Experimental studies of amnesia. In C. W. M. Whitty & O. L. Zangwill (Eds.), Amnesia. London: Butterworths, 1966.

Wilcox, K. W. Intellectual functioning as related to electronconvulsive therapy. Unpublished doctoral dissertation, University of Michigan, 1953.

Williams, M. Memory studies in ECT. Journal of Neurology, Neurosurgery and Psychiatry, 1950, 13, 314-319.

Williams, M. Memory disorders associated with electroconvulsive therapy. In C. W. M. Whitty & O. L. Zangwill (Eds.), Amnesia. London: Butterworths, 1966.

Williams, M. Traumatic retrograde amnesia and normal forgetting. In G. A. Talland & N. C. Waugh (Eds.), The pathology of memory. New York: Academic Press, 1969.

Wilson, I. C., & Gottlieb, G. Unilateral electroconvulsive shock therapy. Diseases of the Nervous System, 1967, 28, 541-545.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1962.

Winer, B. J. Statistical principles in experimental design. (2nd ed.) New York: McGraw-Hill, 1971.

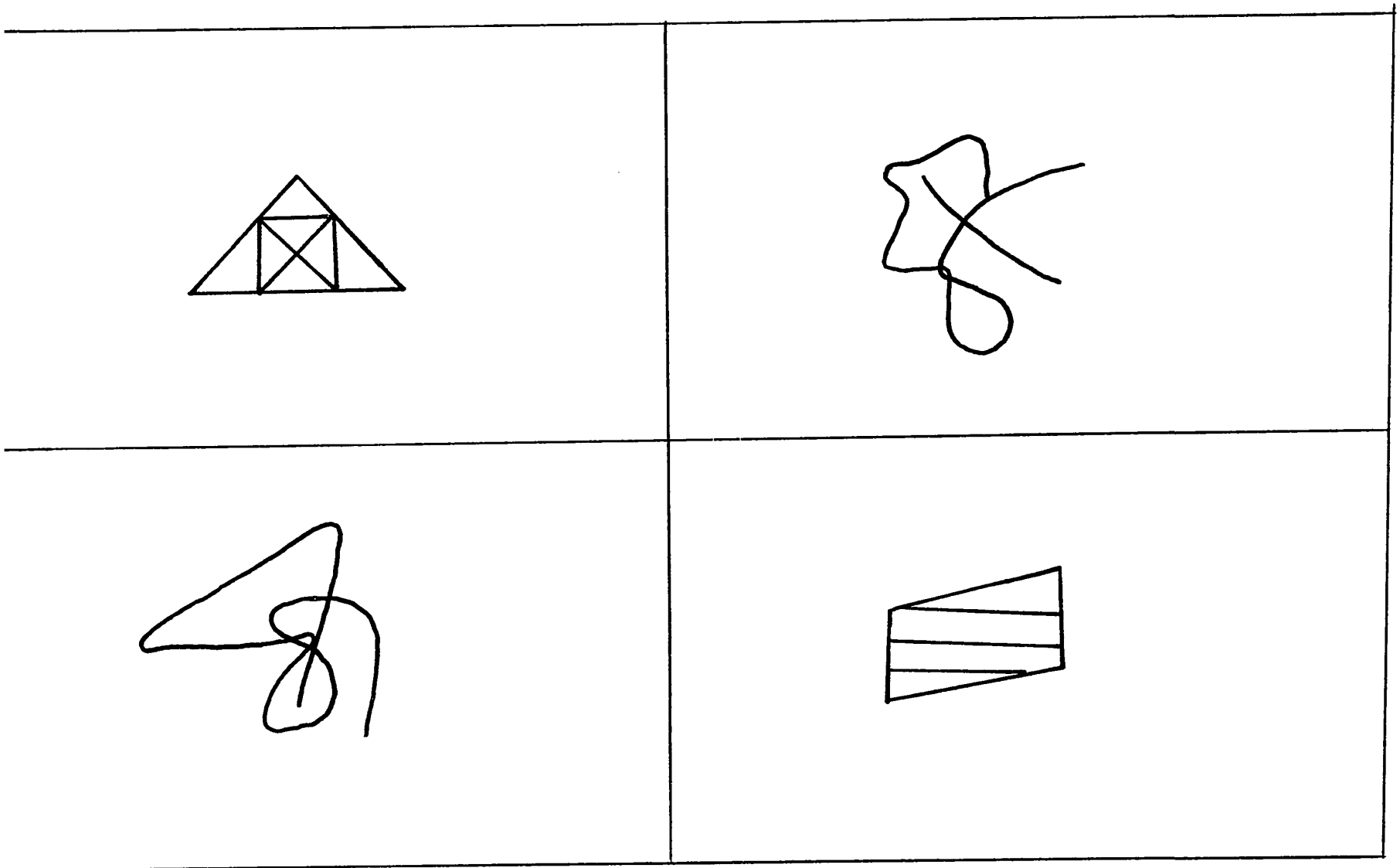
Zamora, E. N., & Kaelbling, R. Memory and electroconvulsive therapy. American Journal of Psychiatry, 1965, 122, 546-554.

Zangwill, O. L. Cerebral dominance and its relation to psychological functions. Edinburgh: Oliver and Boyd, 1960.

Zinkin, S., & Birtchnell, J. Unilateral electroconvulsive therapy: its effects on memory and its therapeutic efficacy. British Journal of Psychiatry, 1968, 114, 973-988.

Zubin, J., & Barrera, S. E. Effect of electric convulsive therapy on memory. Proceedings of the Society of Experimental Biology & Medicine, 1941, 48, 596-597.

APPENDICES



Appendix A

Sample of Non-Verbal Stimuli

Appendix B

Score Sheet for Non-Verbal Recognition Test: Parallel Form A

Set 1	Response: yes/no	Set 2	Response: yes/no	Set 3	Response: yes/no
17 N		37 N		57 N	
18 N		38 N		58 N	
19 r		39 N		59 N	
20 N		40 N		60 R	
21 O		41 o		61 N	
22 N		42 r		62 N	
23 N		43 N		63 N	
24 R		44 O		64 N	
25 N		45 N		65 r	
26 R		46 R		66 o	
27 N		47 N		67 O	
28 r		48 O		68 O	
29 N		49 N		69 N	
30 N		50 o		70 N	
31 O		51 N		71 N	
32 o		52 N		72 N	
33 N		53 N		73 r	
34 N		54 r		74 o	
35 N		55 N		75 R	
36 o		56 R		76 N	
Errors: R =		Errors: R =		Errors: R =	
r =		r =		r =	
O =		O =		O =	
o =		o =		o =	
F+=		F+ =		F+ =	
F-=		F- =		F- =	
Total Set =		Total Set =		Total Set =	

Full Test errors: R = ___ O = ___ F+ = ___ Total = ___
r = ___ o = ___ F- = ___

Symbols:
- R: recurring nonsense
- r: recurring geometric
- O: non-recurring nonsense
- o: non-recurring geometric
- N: new

Appendix C

Summary of Analysis of Variance: Parallel Forms of Non-Verbal Test

Source	df	MS	F
Between Ss			
Groups	8	71.59	1.04
Error	81	68.77	
Within Ss			
Form	8	2.31	1.50
Trial	8	1.94	1.26
Residual	56	1.54	.99
Error	648	1.54	

Appendix D

Test for Laterality

Name_____
Date_____

Part 1: Dominance Test Battery

1) "Hold a card with a pin hole to your eye with both hands and then read the printed material" (which was held at a distance of approximately 10-12 inches). The eye used was recorded.

2) "Sight carefully with a toy dart gun held with both hands and hit that object" (approximately 6 feet away). The eye used to sight the gun was recorded.

3) "Catch this ball, with one hand." The brightly colored ball was thrown to the patient and two of three catches would qualify the hand.

4) Then the patient was handed the same ball and requested to "throw the ball at this target as you would a dart" (pointing to an object about 6 feet away). Again, two of three attempts would qualify the hand.

5) "Pick up the scissors from the table and cut along this line as closely as possible." When halfway along the irregular line he was then asked to switch to the opposite hand to complete the cutting. The ease of movement, trueness and closeness of cut, were used to qualify the dominant hand.

6) "Reach" was established by having observed the hand used by the patient to pick up the card with the pin hole, the toy pistol, the ball, and the scissors. A simple majority qualified the hand.

7) The patient was asked to stand on a chair placed directly in front of him. The foot placed on the chair was noted. Two of three attempts qualified the foot.

8) While standing on the chair the patient was asked to balance on one foot. Again, two of three attempts qualified the foot.

9) The patient was instructed to kick a small ball, which was placed on the floor directly in front of him, through the legs of a nearby chair, as hard as he could. Only one attempt was asked of the patient.

10) "Write your name on that pad" (pointing to the pencil and paper on the table in front of the patient). "Reach" was noted. Upon completion the patient was asked to repeat this using the other hand. The hand having the most well coordinated movement and producing the best writing was recorded.

11) "Tear the sheet of paper with your name on it out of the pad and then rip the sheet in two." The hand with the greatest range of movement as well as the hand used to tear the sheet from the pad was noted.

12) "Tell me the hand you prefer for writing and fine work." The side was recorded as stated by the patient.

Each of the twelve items yielded one laterality score, and handedness was chosen as the side onto which fell at least nine scores. Patients who deviated from scoring on one and the same side in more than three of the twelve subtests were considered ambidextrous.

Stated Hand Preference

"Which hand do you normally use to":

a.) hold a slice of bread when buttering

b.) hold watch when winding it

c.) hold drinking glass when drinking

d.) hold a dish when wiping

e.) insert a key into a lock

f.) hold a comb when combing hair

g.) hold bottle when removing cap

h.) hold toothbrush when brushing teeth

i.) dial a telephone number

j.) hold a pitcher when pouring out of it

k.) turn on a water faucet

l.) hold a loaf of bread when cutting with knife.

Each item was scored 1 point. A score of nine out of twelve was needed to determine dominance.

Appendix D (Continued)

Part 2: Handedness of Family of Patient

R = right-handed; L = left-handed; S = strongly; M = moderately

Father_____

Mother_____

Brothers		Sisters	
Age	Handedness	Age	Handedness
____	_____	____	_____
____	_____	____	_____
____	_____	____	_____

Father's Side of Family		Mother's Side of Family	
Grandfather		Grandfather	
____	_____	____	_____
Grandmother		Grandmother	
____	_____	____	_____
Uncles		Uncles	
____	_____	____	_____
____	_____	____	_____
____	_____	____	_____
Aunts		Aunts	
____	_____	____	_____
____	_____	____	_____
____	_____	____	_____

Consistent familiar right-handedness was required for patient to be considered suitable for present study.

Appendix D (Continued)

Part 3: Possible Conversion of Handedness

1) Did your parents or teachers ever insist on your using either hand for writing?_____ Which hand?_____ Outcome?_____

2) Did you ever injure yourself so that it became difficult or even impossible for you to use either hand for a long period of time?_____ Which hand?_____ For how long?_____ How did this affect handedness?_____

3) Did you yourself ever practice doing various tasks with the hand with which you normally did not carry out these tasks?_____ Which tasks?_____ Outcome?_____

Appendix E

Summary of Analysis of Variance on Baseline Compared to Pseudo Scores

Source	df	MS	F
Between Ss			
Groups	3	7.69	.41
Error between	16	18.65	
Within Ss			
Tests	1	4.22	2.34
Error within	16	1.79	

Appendix F

Summary of Analysis of Variance on

Baseline Scores

Source	df	MS	F
Groups	3	1.33	.12
Error	16	11.07	

Appendix G

Table G.1

Summary of Analysis of Variance on R Set 1

Source	df	MS	F
Between Ss			
Orders	3	.1833	.1735
Error between	16	1.0562	
Within Ss			
Conditions	3	38.5833	86.1395***
Treatments	3	.1833	.4093
Residual	6	.7833	
Error within	48	.4479	1.7400

Note. - Significance levels in Appendix G calculated with conservative df.
***p < .001.

Table G.2

Summary of Analysis of Variance on NR Set 1

Source	df	MS	F
Between Ss			
Orders	3	.3458	.4191
Error between	16	.8250	
Within Ss			
Conditions	3	25.2458	38.3481***
Treatments	3	1.6125	2.4493
Residual	6	1.0125	1.5380
Error within	48	.6583	

***p < .001.

Appendix G (Continued)

Table G.3

Summary of Analysis of Variance on F+ Set 1

Source	df	MS	F
Between Ss			
Orders	3	5.2458	2.0983
Error between	16	2.5000	
Within Ss			
Conditions	3	47.4792	41.5876***
Treatments	3	2.7791	2.4343
Residual	6	3.5291	3.0914
Error within	48	1.1416	

***p < .001.

Table G.4

Summary of Analysis of Variance on F- Set 1

Source	df	MS	F
Between Ss			
Orders	3	.7125	.2886
Error between	16	2.4687	
Within Ss			
Conditions	3	126.0460	122.7220***
Treatments	3	1.2125	1.1805
Residual	6	2.7791	2.7058
Error within	48	1.0270	

***p < .001.

Appendix G (Continued)

Table G.5

Summary of Analysis of Variance on Total Error Set 1

Source	df	MS	F
Between Ss			
Orders	3	3.3000	.4967
Error between	16	6.6437	
Within Ss			
Conditions	3	328.2330	158.0260***
Treatments	3	5.2333	2.5195
Residual	6	4.9833	2.3990
Error within	48	2.0770	

***p < .001.

Table G.6

Summary of Analysis of Variance on R Set 2

Source	df	MS	F
Between Ss			
Orders	3	.6125	.8235
Error between	16	.7437	
Within Ss			
Conditions	3	21.2125	31.3292***
Treatments	3	1.0458	1.5446
Residual	6	.6625	.9784
Error within	48	.6770	

***p < .001.

Appendix G (Continued)

Table G.7

Summary of Analysis of Variance on NR Set 2

Source	df	MS	F
Between Ss			
Orders	3	.8500	1.1333
Error between	16	.7500	
Within Ss			
Conditions	3	24.3500	47.1290***
Treatments	3	.7500	1.4516
Residual	6	.8166	1.5825
Error within	48	.5166	

***$p < .001$.

Table G.8

Summary of Analysis of Variance on F+ Set 2

Source	df	MS	F
Between Ss			
Orders	3	16.4500	3.2655*
Error between	16	5.0375	
Within Ss			
Conditions	3	46.4833	31.6034***
Treatments	3	6.2833	4.2719
Residual	6	4.8500	3.2975
Error within	48	1.4708	

* $p < .05$.
***$p < .001$.

Appendix G (Continued)

Table G.9

Summary of Analysis of Variance on F- Set 2

Source	df	MS	F
Between Ss			
Orders	3	.9458	.4572
Error between	16	2.0687	
Within Ss			
Conditions	3	90.9792	108.9030***
Treatments	3	3.0458	3.6458
Residual	6	2.0958	2.5087
Error within	48	.8354	

***p < .001.

Table G.10

Summary of Analysis of Variance on Total Error Set 2

Source	df	MS	F
Between Ss			
Orders	3	16.4458	1.5183
Error between	16	10.8313	
Within Ss			
Conditions	3	266.2460	156.0420***
Treatments	3	6.0125	3.5238
Residual	6	4.4291	2.5958
Error within	48	1.7062	

***p < .001.

Appendix G (Continued)

Table G.11

Summary of Analysis of Variance on R Set 3

Source	df	MS	F
Between Ss			
Orders	3	1.9500	5.4736**
Error between	16	.3562	
Within Ss			
Conditions	3	16.3167	42.7978***
Treatments	3	.3166	.8306
Residual	6	.9666	2.5353
Error within	48	.3812	

** $p < .01$.
***$p < .001$.

Table G.12

Summary of Analysis of Variance on NR Set 3

Source	df	MS	F
Between Ss			
Orders	3	2.0333	3.2862*
Error between	16	.6187	
Within Ss			
Conditions	3	24.5000	41.2632***
Treatments	3	1.5666	2.6386
Residual	6	.5500	.9263
Error within	48	.5937	

* $p < .05$.
***$p < .001$.

Appendix G (Continued)

Table G.13

Summary of Analysis of Variance on F+ Set 3

Source	df	MS	F
Between Ss			
Orders	3	26.2167	3.9275*
Error between	16	6.6750	
Within Ss			
Conditions	3	54.6833	19.3569***
Treatments	3	4.8500	1.7168
Residual	6	4.3833	1.5516
Error within	48	2.8250	

* $p < .05$.
***$p < .001$.

Table G.14

Summary of Analysis of Variance on F- Set 3

Source	df	MS	F
Between Ss			
Orders	3	4.9125	5.1710*
Error between	16	.9500	
Within Ss			
Conditions	3	80.9458	97.1350***
Treatments	3	3.0458	3.6550
Residual	6	1.2125	1.4555
Error within	48	.8333	

* $p < .05$.
***$p < .001$.

Appendix G (Continued)

Table G. 15

Summary of Analysis of Variance on Total Error Set 3

Source	df	MS	F
Between Ss			
Orders	3	51.7792	4.7125*
Error between	16	10.9875	
Within Ss			
Conditions	3	263.8460	96.0895***
Treatments	3	11.5458	4.2048
Residual	6	6.7125	2.4446
Error within	48	2.7458	

* $p < .05$.
***$p < .001$.

Table G. 16

Summary of Analysis of Variance on Full Test R

Source	df	MS	F
Between Ss			
Orders	3	1.7458	.6511
Error between	16	2.6812	
Within Ss			
Conditions	3	217.6120	184.2220***
Treatments	3	2.6458	2.2398
Residual	6	1.9625	1.6600
Error within	48	1.1812	

***$p < .001$.

Appendix G (Continued)

Table G.17

Summary of Analysis of Variance on Full Test NR

Source	df	MS	F
Between Ss			
Orders	3	7.0458	1.5485
Error between	16	4.5500	
Within Ss			
Conditions	3	220.4130	105.3760***
Treatments	3	9.3791	4.4840
Residual	6	5.4125	2.5877
Error within	48	2.0916	

***$p < .001$.

Table G.18

Summary of Analysis of Variance on Full Test F+

Source	df	MS	F
Between Ss			
Orders	3	117.5790	3.6801*
Error between	16	31.9500	
Within Ss			
Conditions	3	442.4120	68.0635***
Treatments	3	29.4458	4.5301*
Residual	6	28.7790	4.4275*
Error within	48	6.5000	

* $p < .05$.
***$p < .001$.

Appendix G (Continued)

Table G. 19

Summary of Analysis of Variance on Full Test F-

Source	df	MS	F
Between Ss			
Orders	3	6.7333	.6170
Error between	16	10.9125	
Within Ss			
Conditions	3	876.0670	252.4080***
Treatments	3	16.3000	4.6962*
Residual	6	10.7166	3.0876
Error within	48	3.4708	

* $p < .05$.
***$p < .001$.

Table G. 20

Summary of Analysis of Variance on Full Test Total Error

Source	df	MS	F
Between Ss			
Orders	3	157.6790	2.3290
Error between	16	67.7000	
Within Ss			
Conditions	3	2552.9100	315.4990***
Treatments	3	63.4458	7.8408*
Residual	6	29.2123	3.6102
Error within	48	8.0916	

* $p < .05$.
***$p < .001$.

Appendix H

Newman-Keuls Test of Means for Conditions Effect

Variable					
R Set 1		Ps	D	Bi	ND
	Ps		4.677**	17.370**	18.710**
	D			6.014**	14.090**
	Bi				1.336
	ND				
NR Set 1		Ps	D	Bi	ND
	Ps		1.929	11.024**	12.127**
	D			9.095**	10.197**
	Bi				1.102
	ND				
F+ Set 1		Ps	D	Bi	ND
	Ps		2.720	11.929**	12.966**
	D			9.208**	10.045**
	Bi				.837
	ND				
F- Set 1		Ps	D	Bi	ND
	Ps		4.633**	20.300**	22.065**
	D			15.666**	17.431**
	Bi				1.765
	ND				
Total error Set 1		Ps	D	Bi	ND
	Ps		5.275**	23.117**	24.979**
	D			17.842**	19.704**
	Bi				1.861
	ND				

Note. - Numerical values in Appendix H are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix H (Continued)

Newman-Keuls Test of Means for Conditions Effect

Variable					
R Set 2		Ps	D	ND	Bi
	Ps		1.086	9.782**	10.598**
	D			8.695**	9.510**
	ND				.815
	Bi				
NR Set 2		Ps	D	ND	Bi
	Ps		.933	11.510**	13.065**
	D			10.577**	12.132**
	ND				1.555
	Bi				
F+ Set 2		Ps	D	Bi	ND
	Ps		2.396	10.693**	10.878**
	D			8.296**	8.481**
	Bi				.184
	ND				
F- Set 2		Ps	D	ND	Bi
	Ps		1.712	7.859**	19.816**
	D			16.146**	18.103**
	ND				1.957
	Bi				
Total error Set 2		Ps	D	ND	Bi
	Ps		3.423*	22.596**	23.794**
	D			19.172**	20.199**
	ND				1.983
	Bi				

* $p < .05$.
** $p < .01$.

Appendix H (Continued)

Newman-Keuls Test of Means for Conditions Effect

Variable					
R Set 3		Ps	D	ND	Bi
	Ps		0.000	10.140**	12.313**
	D			10.140**	12.313**
	ND				2.172
	Bi				
NR Set 3		Ps	D	Bi	ND
	Ps		1.740	11.317**	12.478**
	D			9.576**	10.737**
	Bi				1.607
	ND				
F+ Set 3		Ps	D	Bi	ND
	Ps		3.592*	8.913**	9.046**
	D			5.321**	5.454**
	Bi				.133
	ND				
F- Set 3		Ps	D	ND	Bi
	Ps		1.714	17.639**	18.129**
	D			15.924**	16.414**
	ND				.489
	Bi				
Total error Set 3		Ps	D	ND	Bi
	Ps		4.588**	18.892**	19.027**
	D			14.300**	14.439**
	ND				.134
	Bi				

* $p < .05$.
** $p < .01$.

Appendix H (Continued)

Newman-Keuls Test of Means for Conditions Effect

Variable					
Full Test R		Ps	D	ND	**Bi**
	Ps		3.703*	24.688**	**25.717****
	D			20.985**	**22.014****
	ND				**1.028**
	Bi				
Full Test NR		Ps	D	Bi	**ND**
			2.319	18.707**	**19.017****
				16.388**	**16.698****
					.309
Full Test F+		Ps	D	Bi	**ND**
	Ps		4.648**	15.962**	**16.488****
	D			11.314**	**11.840****
	Bi				**.526**
	ND				
Full Test F-		Ps	D	ND	**Bi**
	Ps		4.080*	29.286**	**29.526****
	D			25.205**	**25.445****
	ND				**.240**
	Bi				
Full Test Total error		Ps	D	Bi	**ND**
	Ps		6.839**	33.644**	**33.959****
	D			26.805**	**27.120****
	Bi				**.393**
	ND				

* $p < .05$.
** $p < .01$.

Appendix I

Newman-Keuls Test of Means for Orders Effect

Variable					
F+ Set 2		Order 2	Order 1	Order 4	Order 3
	Order 2		1.992	2.590	4.383*
	Order 1			.993	2.390
	Order 4				1.790
	Order 3				
R Set 3		Order 2	Order 1	Order 3	Order 4
	Order 2		1.870	4.120*	5.244**
	Order 1			2.247	3.371
	Order 3				1.123
	Order 4				
NR Set 3		Order 4	Order 2	Order 1	Order 3
	Order 4		.284	1.420	3.979
	Order 2			1.137	3.695*
	Order 1				2.558
	Order 3				
F+ Set 3		Order 2	Order 1	Order 4	Order 3
	Order 2		1.990	3.894*	4.327*
	Order 1			1.900	2.336
	Order 4				.432
	Order 3				

Note. - Numerical values in Appendix I are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix I (Continued)

Newman-Keuls Test of Means for Orders Effect

Variable					
F- Set 3		Order 2	Order 1	Order 4	Order 3
	Order 2		2.064	2.753	5.506**
	Order 1			.688	3.441
	Order 4				2.753
	Order 3				
Total error Set 3		Order 2	Order 1	Order 4	Order 3
	Order 2		2.158	3.845*	4.991*
	Order 1			1.686	2.833
	Order 4				1.146
	Order 3				
Full Test F+		Order 2	Order 1	Order 4	Order 3
	Order 2		2.492	3.164	4.588*
	Order 1			.632	2.096
	Order 4				1.424
	Order 3				

* $p < .05$.
** $p < .01$.

Appendix J

Newman-Keuls Test of Means for Treatments Effect

Variable					
Full Test F+		Treatment 1	Treatment 4	Treatment 2	Treatment 3
	1		3.069*	3.771*	4.999*
	4			.701	1.929
	2				1.227
	3				
Full Test F-		Treatment 1	Treatment 2	Treatment 3	Treatment 4
	1		1.080	2.040	5.040*
	2			.960	3.960*
	3				3.000*
	4				
Full Test Total error		Treatment 1	Treatment 2	Treatment 3	Treatment 4
	1		4.087*	5.817**	6.052**
	2			1.729	1.965
	3				.235
	4				

Note. - Numerical values in Appendix J are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix K

Table K.1

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: R

Source	df	MS	F
Subjects (Ss)	3	72.5374	184.222***
Conditions (C)	3	.5819	.6511
Groups (G)	2	20.6541	32.7195***
Sets (S)	16	.8937	
Ss (G)	9	.7300	1.8542
GC	6	1.0819	1.7140
GS	6	1.7875	3.2135
CS	48	.3937	
SsC (G)	32	.6312	
SsS (G)	18	.6967	1.2526
GCS	96	.5562	
SsCS (G)			

Note. - Significance levels in Appendix K calculated with conservative df.
***p < .001.

Appendix K (Continued)

Table K. 2

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: NR

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	73.5708	104.0688***
Groups (G)	3	2.1708	1.4759
Sets (S)	2	14.8791	41.1643***
Ss (G)	16	1.4708	
GC	9	2.1967	3.1074
GS	6	.5291	1.4640
CS	6	.2625	.4944
SsC (G)	48	.7069	
SsS (G)	32	.3614	
GCS	18	.3495	.6584
SsCS (G)	96	.5309	

***$p < .001$.

Appendix K (Continued)

Table K.3

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: F+

Source	df	MS	F
Subjects (Ss)	3	147.4708	68.0634***
Conditions (C)	3	39.1930	3.6801*
Groups (G)	2	40.8375	22.9263***
Sets (S)	16	10.6500	
Ss (G)	9	9.6671	4.4618*
GC	6	4.3597	2.4476
GS	6	.5875	.3592
CS	48	2.1666	
SsC (G)	32	1.7812	
SsS (G)	18	1.7393	1.0636
GCS	96	1.6354	
SsCS (G)			

* $p < .05$.

*** $p < .001$.

Appendix K (Continued)

Table K.4

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: F-

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	293.4820	254.8938***
Groups (G)	3	2.2374	.6068
Sets (S)	2	2.6000	2.8889
Ss (G)	16	3.6875	
GC	9	4.2634	3.70291*
GS	6	2.1666	2.4074
CS	6	2.2444	2.9065
SsC (G)	48	1.1513	
SsS (G)	32	.9000	
GCS	18	1.1148	1.4436
SsCS (G)	96	.7722	

* $p < .05$.
***$p < .001$.

Appendix K (Continued)

Table K.5

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: Total error

Source	df	MS	F
Subjects (Ss)	3	853.6055	322.1152***
Conditions (C)	3	52.3833	2.2984
Groups (G)	2	28.5875	10.0823**
Sets (S)	16	22.7916	
Ss (G)	9	13.5722	5.1216*
GC	6	9.5708	3.3755*
GS	6	2.3597	1.2166
CS	48	2.6500	
SsC (G)	32	2.8354	
SsS (G)	18	2.3875	1.2309
GCS	96	1.9395	
SsCS (G)			

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Appendix L

Table L.1

Newman-Keuls Test of Means for Errors Across Sets

Variable				
R		Set 3	Set 2	Set 1
	Set 3		1.829	10.698**
	Set 2			8.868**
	Set 1			
NR		Set 1	Set 2	Set 3
	Set 1		6.510**	12.834**
	Set 2			6.324**
	Set 3			
F+		Set 1	Set 2	Set 3
	Set 1		8.293**	8.293**
	Set 2			.000
	Set 3			
Total error		Set 1	Set 2	Set 3
	Set 1		4.714**	6.042**
	Set 2			1.327
	Set 3			

Note. - Numerical values in Appendix L are the computed Studentized range.
**$p < .01$.

Appendix L (Continued)

Table L.2

Newman-Keuls Test of Means for Conditions Effect Across Sets

Variable					
R		Ps	D	ND	Bi
	Ps		3.703*	24.690**	27.197**
	D			20.987**	22.016**
	ND				1.028
	Bi				
NR		Ps	D	Bi	ND
	Ps		2.458	18.587**	19.047**
	D			16.129**	16.589**
	Bi				.460
	ND				
F+		Ps	D	Bi	ND
	Ps		4.647**	15.960**	16.489**
	D			11.315**	11.842**
	Bi				.526
	ND				
F-		Ps	D	ND	Bi
	Ps		4.210**	29.477**	30.308**
	D			25.266**	25.506**
	ND				.240
	Bi				
Total error		Ps	D	Bi	ND
	Ps		6.660**	34.021**	34.339**
	D			27.043**	27.360**
	Bi				.317
	ND				

* $p < .05$.
** $p < .01$.

Appendix M

Table M.1

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable R Set 1

Source	df	MS	F
Conditions	3	10.4500	12.6667***
Subjects within Conditions	16	.8250	

***$p < .001$.

Table M.2

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable NR Set 1

Source	df	MS	F
Conditions	3	3.9166	7.1212**
Subjects within Conditions	16	.5500	

**$p < .01$.

Table M.3

Summary of Analysis of Variance on the Effect of a Single Treatment:

Variable F+ Set 1

Source	df	MS	F
Conditions	3	2.3330	1.7610
Subjects within Conditions	16	1.3250	

Appendix M (Continued)

Table M.4

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F- Set 1

Source	df	MS	F
Conditions	3	26.7999	17.2903***
Subjects within Conditions	16	1.5499	

***p <.001.

Table M.5

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Total error Set 1

Source	df	MS	F
Conditions	3	36.3330	11.0101***
Subjects within Conditions	16	3.2990	

***p <.001.

Table M.6

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable R Set 2

Source	df	MS	F
Conditions	3	6.3166	10.1067***
Subjects within Conditions	16	.6250	

***p <.001.

Appendix M (Continued)

Table M.7

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable NR Set 2

Source	df	MS	F
Conditions	3	5.3833	8.2821**
Subjects within Conditions	16	.6500	

**$p < .01$.

Table M.8

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F+ Set 2

Source	df	MS	F
Conditions	3	4.9833	2.8476
Subjects within Conditions	16	1.7500	

Table M.9

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F- Set 2

Source	df	MS	F
Conditions	3	22.6660	18.8889***
Subjects within Conditions	16	1.2000	

***$p < .001$.

Appendix M (Continued)

Table M.10

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Total error Set 2

Source	df	MS	F
Conditions	3	29.6500	7.9597**
Subjects within Conditions	16	3.7250	

**$p < .01$.

Table M.11

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable R Set 3

Source	df	MS	F
Conditions	3	3.6500	16.2220***
Subjects within Conditions	16	.2250	

***$p < .001$.

Table M.12

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable NR Set 3

Source	df	MS	F
Conditions	3	2.7333	3.6440*
Subjects within Conditions	16	.7500	

*$p < .05$.

Appendix M (Continued)

Table M.13

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F+ Set 3

Source	df	MS	F
Conditions	3	20.8499	3.7399*
Subjects within Conditions	16	5.5750	

*$p < .05$.

Table M.14

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F- Set 3

Source	df	MS	F
Conditions	3	11.9166	14.4440***
Subjects within Conditions	16	.8250	

***$p < .001$.

Table M.15

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Total error Set 3

Source	df	MS	F
Conditions	3	55.6660	9.1632***
Subjects within Conditions	16	6.0750	

***$p < .001$.

Appendix M (Continued)

Table M. 16

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test R

Source	df	MS	F
Conditions	3	54.4500	27.5696***
Subjects within Conditions	16	1.9750	

***$p < .001$.

Table M. 17

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test NR

Source	df	MS	F
Conditions	3	37.1166	9.9642***
Subjects within Conditions	16	3.7250	

***$p < .001$.

Table M. 18

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test F+

Source	df	MS	F
Conditions	3	65.4000	5.9863**
Subjects within Conditions	16	10.9250	

**$p < .01$.

Appendix M (Continued)

Table M.19

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test F-

Source	df	MS	F
Conditions	3	172.8500	29.9307***
Subjects within Conditions	16	5.7750	

***$p < .001$.

Table M.20

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test Total error

Source	df	MS	F
Conditions	3	338.9832	16.8439***
Subjects within Conditions	16	20.1250	

***$p < .001$.

Appendix N

Newman-Keuls Test of Means for Conditions Effect

After a Single ECT

Variable					
R Set 1		D	Ps	Bi	ND
	D		0.000	5.900**	6.400**
	Ps			5.900**	6.400**
	Bi				.603
	ND				
NR Set 1		D	Ps	ND	Bi
	D		1.200	4.820**	5.427**
	Ps			3.618*	4.220**
	ND				.603
	Bi				
F- Set 1		D	Ps	Bi	ND
	D		.718	7.540**	7.540**
	Ps			6.825**	6.825**
	Bi				0.000
	ND				
Total error		Ps	D	Bi	ND
Set 1	Ps		.984	5.660**	6.647**
	D			4.677**	5.660**
	Bi				.984
	ND				

Note. - Numerical values in Appendix N are the computed Studentized range.

* $p < .05$.

** $p < .01$.

Appendix N (Continued)

Newman-Keuls Test of Means for Conditions Effec After a Single ECT

Variable					
R Set 2		D	Ps	ND	Bi
	D		0.000	4.526*	6.223**
	Ps			4.526**	6.223**
	ND				1.697
	Bi				
NR Set 2		D	Ps	ND	Bi
	D		2.220	5.550**	6.110**
	Ps			3.330*	3.880*
	ND				.555
	Bi				
F- Set 2		D	Ps	ND	Bi
	D		1.630	7.349**	8.980**
	Ps			5.716**	7.349**
	ND				1.630
	Bi				
Total error Set 2		D	Ps	Bi	ND
	D		0.000	3.939*	5.560**
	Ps			3.939*	5.560**
	Bi				1.622
	ND				
R Set 3		D	Ps	Bi	ND
	D		0.000	3.770*	8.490**
	Ps			3.770*	8.490**
	Bi				4.716**
	ND				

* $p < .05$.
** $p < .01$.

Appendix N (Continued)

Newman-Keuls Test of Means for Conditions Effect After a Single ECT

Variable					
NR Set 3		D	Ps	Bi	ND
	D		1.540	3.615	4.132*
	Ps			2.066	2.582
	Bi				.516
	ND				
F+ Set 3		Ps	Bi	D	ND
	Ps		1.370	1.706	4.549*
	Bi			.568	3.410
	D				2.840
	ND				
F- Set 3		D	Ps	Bi	ND
	D		1.477	5.416**	8.370**
	Ps			3.938*	6.890**
	Bi				2.950
	ND				
Total error Set 3		Ps	D	Bi	ND
	Ps		1.088	2.540	6.895**
	D			1.450	5.800**
	Bi				4.354**
	ND				
Full Test R		D	Ps	Bi	ND
	D		0.000	8.592**	9.546**
	Ps			8.592**	9.546**
	Bi				.954
	ND				

* $p < .05$.
** $p < .01$.

Appendix N (Continued)

Newman-Keuls Test of Means for Conditions Effect After a Single ECT

Variable					
Full Test NR		D	Ps	ND	Bi
	D		2.317	6.257**	6.488**
	Ps			3.939*	4.170*
	ND				.231
	Bi				
Full Test F+		Ps	Bi	D	ND
	Ps		1.217	2.570	5.680**
	Bi			1.353	4.465*
	D				3.112*
	ND				
Full Test F-		D	Ps	Bi	ND
	D		1.670	10.049**	10.420**
	Ps			8.370**	8.746**
	Bi				.372
	ND				
Full Test Total error		Ps	D	Bi	ND
	Ps		.997	5.380**	8.873**
	D			4.386**	7.876**
	Bi				3.489*
	ND				

* $p < .05$.
** $p < .01$.

Appendix O

Table O.1

Results of Analysis of Variance on Responses to Nonsense Figures

Source	df	MS	F
Between Ss			
Orders	3	51.745	3.197
Error between	16	16.181	
Within Ss			
Conditions	3	645.146	215.798***
Treatments	3	27.245	9.113**
Residual	6	10.179	3.404
Error within	48	2.989	

Note. - Significance levels in Appendix O calculated with conservative df.

** $p < .01$.

***$p < .001$.

Appendix O (Continued)

Table O.2

Summary of Analysis of Variance on Responses to Geometric Figures

Source	df	MS	F
Between Ss			
Orders	3	35.233	2.143
Error between	16	16.437	
Within Ss			
Conditions	3	667.233	206.095***
Treatments	3	13.500	4.169*
Residual	6	13.316	4.113
Error within	48	3.237	

* $p < .05$.
*** $p < .001$.

Appendix P

Table P.1

Newman-Keuls Test of Means for Conditions Effect on Nonsense Figures

	Ps	D	Bi	ND
Ps		4.009**	27.030**	27.547**
D			23.020**	23.538**
Bi				.517
ND				

Note. - Numerical values in Appendix P are the computed Studentized range.
* $p < .05$.
**$p < .01$.

Table P.2

Newman-Keuls Test of Means for Conditions Effect on Geometric Figures

	Ps	D	ND	Bi
Ps		6.959**	27.218**	28.460**
D			20.258**	21.500**
ND				1.242
Bi				

**$p < .01$.

Appendix Q

Summary of Analysis of Variance on Baseline Compared to Pseudo Scores

Source	df	MS	F
Between Ss			
Groups	3	2.15	.35
Error between	16	6.06	
Within Ss			
Tests	1	3.02	2.39
Error within	16	1.26	

Appendix R

Summary of Analysis of Variance on

Baseline Scores

Source	df	MS	F
Groups	3	2.53	.78
Error	16	3.22	

Appendix S

Table S.1

Summary of Analysis of Variance on R Set 1

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	1.266	5.004*
Error between	16	.253	
Within Ss			
Conditions (C)	3	.916	5.269*
Treatments (T)	3	.216	1.245
Residual	6	.333	1.916
Error	48	.173	
Repeated Tests (R)	1	.225	1.531
R x O	3	.225	1.531
Error	16	.146	
R x T	3	.041	.199
R x C	3	.075	.358
Residual	6	.058	.278
Error	48	.209	

Note. - Significance levels in Appendix S calculated with conservative df.

*$p < .05$.

Appendix S (Continued)

Table S. 2

Summary of Analysis of Variance on NR Set 1

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.508	1.170
Error between	16	.434	
Within Ss			
Conditions (C)	3	7.641	30.953***
Treatments (T)	3	.291	1.181
Residual	6	.141	.573
Error	48	.246	
Repeated Tests (R)	1	.225	1.600
R x O	3	.175	1.244
Error	16	.140	
R x T	3	.425	1.441
R x C	3	.341	1.159
Residual	6	.425	1.441
Error	48	.294	

***$p < .001$.

Appendix S (Continued)

Table S.3

Summary of Analysis of Variance on F+ Set 1

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	1.475	.579
Error between	16	2.543	
Within Ss			
Conditions (C)	3	68.741	87.060***
Treatments (T)	3	.675	.854
Residual	6	1.850	2.343
Error	48	.789	
Repeated Tests (R)	1	19.600	82.526***
R x O	3	.450	1.894
Error	16	.237	
R x T	3	.116	.184
R x C	3	.816	1.289
Residual	6	.841	1.328
Error	48	.633	

***$p < .001$.

Appendix S (Continued)

Table S.4

Summary of Analysis of Variance on F- Set 1

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.675	.640
Error between	16	1.053	
Within Ss			
Conditions (C)	3	13.741	28.740***
Treatments (T)	3	.341	.714
Residual	6	.721	1.509
Error	48	.478	
Repeated Tests (R)	1	.000	.000
R x O	3	.350	1.898
Error	16	.184	
R x T	3	.383	.917
R x C	3	.216	.518
Residual	6	.525	1.256
Error	48	.417	

***$p < .001$.

Appendix S (Continued)

Table S.5

Summary of Analysis of Variance on Total error Set 1

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	1.733	.404
Error between	16	4.284	
Within Ss			
Conditions (C)	3	139.850	158.883***
Treatments (T)	3	.866	.984
Residual	6	.975	1.107
Error	48	.880	
Repeated Tests (R)	1	19.600	62.099***
R x O	3	.866	2.745
Error	16	.315	
R x T	3	.533	1.026
R x C	3	1.150	2.212
Residual	6	1.125	2.164
Error	48	.519	

***$p < .001$.

Appendix S (Continued)

Table S.6

Summary of Analysis of Variance on R Set 2

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.608	7.487**
Error between	16	.081	
Within Ss			
Conditions (C)	3	5.808	50.690***
Treatments (T)	3	.308	2.690
Residual	6	.566	4.945*
Error	48	.114	
Repeated Tests (R)	1	.900	4.965*
R x O	3	.316	1.747
Error	16	.181	
R x T	3	.350	2.666
R x C	3	.316	2.412
Residual	6	.158	1.206
Error	48	.131	

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Appendix S (Continued)

Table S.7

Summary of Analysis of Variance on NR Set 2

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.941	2.092
Error between	16	.450	
Within Ss			
Conditions (C)	3	9.541	17.890***
Treatments (T)	3	.975	1.828
Residual	6	.266	.499
Error	48	.533	
Repeated Tests (R)	1	.025	.056
R x O	3	.041	.093
Error	16	.443	
R x T	3	1.441	3.442
R x C	3	.275	.656
Residual	6	.416	.995
Error	48	.418	

***$p < .001$.

Appendix S (Continued)

Table S.8

Summary of Analysis of Variance on F+ Set 2

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	2.456	.994
Error between	16	2.468	
Within Ss			
Conditions (C)	3	59.972	79.742***
Treatments (T)	3	1.456	1.936
Residual	6	.581	.772
Error	48	.752	
Repeated Tests (R)	1	3.306	3.861
R x O	3	.706	.824
Error	16	.856	
R x T	3	2.272	3.218
R x C	3	2.422	3.430
Residual	6	.397	.563
Error	48	.706	

***p < .001.

Appendix S (Continued)

Table S.9

Summary of Analysis of Variance on F- Set 2

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.700	1.483
Error between	16	.471	
Within Ss			
Conditions (C)	3	29.783	62.021***
Treatments (T)	3	1.116	2.325
Residual	6	.500	1.041
Error	48	.480	
Repeated Tests (R)	1	1.225	2.214
R x O	3	.225	.406
Error	16	.553	
R x T	3	.575	1.292
R x C	3	1.075	2.416
Residual	6	.158	.353
Error	48	.444	

***$p < .001$.

Appendix S (Continued)

Table S. 10

Summary of Analysis of Variance on Total error Set 2

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	2.372	.605
Error between	16	3.918	
Within Ss			
Conditions (C)	3	173.906	210.264***
Treatments (T)	3	.472	.571
Residual	6	1.464	1.770
Error	48	.827	
Repeated Tests (R)	1	8.556	14.880**
R x O	3	.706	1.228
Error	16	.575	
R x T	3	1.206	1.492
R x C	3	1.139	1.409
Residual	6	.297	.368
Error	48	.808	

** $p < .01$.
***$p < .001$.

Appendix S (Continued)

Table S.11

Summary of Analysis of Variance on R Set 3

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.516	2.505
Error between	16	.206	
Within Ss			
Conditions (C)	3	5.400	36.507***
Treatments (T)	3	.516	3.492
Residual	6	.316	2.140
Error	48	.147	
Repeated Tests (R)	1	.100	.727
R x O	3	.150	1.090
Error	16	.137	
R x T	3	.083	.487
R x C	3	.033	.195
Residual	6	.116	.682
Error	48	.170	

***$p < .001$.

Appendix S (Continued)

Table S. 12

Summary of Analysis of Variance on NR Set 3

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.522	.571
Error between	16	.915	
Within Ss			
Conditions (C)	3	7.822	16.952***
Treatments (T)	3	.072	.158
Residual	6	.297	.645
Error	48	.461	
Repeated Tests (R)	1	.506	1.317
R x O	3	.906	2.357
Error	16	.384	
R x T	3	.056	.136
R x C	3	.139	.337
Residual	6	1.114	2.695
Error	48	.413	

***$p < .001$.

Appendix S (Continued)

Table S. 13

Summary of Analysis of Variance on F+ Set 3

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	3.656	1.095
Error between	16	3.337	
Within Ss			
Conditions (C)	3	44.456	36.045***
Treatments (T)	3	.506	.410
Residual	6	2.381	1.930
Error	48	1.233	
Repeated Tests (R)	1	11.556	14.674**
R x O	3	.656	.833
Error	16	.787	
R x T	3	.672	.877
R x C	3	4.022	5.247*
Residual	6	1.081	1.410
Error	48	.766	

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Appendix S (Continued)

Table S. 14

Summary of Analysis of Variance on F- Set 3

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.341	.264
Error between	16	1.293	
Within Ss			
Conditions (C)	3	23.691	32.772***
Treatments (T)	3	.208	.288
Residual	6	.308	.426
Error	48	.722	
Repeated Tests (R)	1	1.225	3.111
R x O	3	.908	2.306
Error	16	.393	
R x T	3	.175	.370
R x C	3	.025	.052
Residual	6	.741	1.568
Error	48	.472	

***$p < .001$.

Appendix S (Continued)

Table S.15

Summary of Analysis of Variance on Total error Set 3

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	2.972	.531
Error between	16	5.590	
Within Ss			
Conditions (C)	3	128.356	97.872***
Treatments (T)	3	1.106	.843
Residual	6	1.256	.957
Error	48	1.311	
Repeated Tests (R)	1	20.306	26.096***
R x O	3	2.456	3.156
Error	16	.778	
R x T	3	.889	1.388
R x C	3	3.539	5.525*
Residual	6	.222	.347
Error	48	.640	

* $p < .05$.
*** $p < .001$.

Appendix S (Continued)

Table S.16

Summary of Analysis of Variance on Full Test R

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	6.241	11.035***
Error between	16	.565	
Within Ss			
Conditions (C)	3	32.291	48.211***
Treatments (T)	3	2.408	3.595
Residual	6	1.958	2.923
Error	48	.669	
Repeated Tests (R)	1	3.025	14.892**
R x O	3	.408	2.010
Error	16	.203	
R x T	3	.141	.334
R x C	3	1.025	2.417
Residual	6	.275	.648
Error	48	.423	

** $p < .01$.
*** $p < .001$.

Appendix S (Continued)

Table S.17

Summary of Analysis of Variance on Full Test NR

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	3.806	1.065
Error between	16	3.571	
Within Ss			
Conditions (C)	3	70.939	58.456***
Treatments (T)	3	.422	.348
Residual	6	.631	.520
Error	48	1.213	
Repeated Tests (R)	1	.156	.205
R x O	3	1.022	1.347
Error	16	.759	
R x T	3	.972	1.121
R x C	3	.456	.525
Residual	6	2.031	2.340
Error	48	.867	

***$p < .001$.

Appendix S (Continued)

Table S.18

Summary of Analysis of Variance on Full Test F+

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	16.506	1.118
Error between	16	14.756	
Within Ss			
Conditions (C)	3	496.073	189.431***
Treatments (T)	3	.122	.046
Residual	6	8.264	3.155
Error	48	2.618	
Repeated Tests (R)	1	91.506	56.748***
R x O	3	.272	.169
Error	16	1.612	
R x T	3	2.022	1.566
R x C	3	5.906	4.572*
Residual	6	1.931	1.495
Error	48	1.291	

* $p < .05$.
***$p < .001$.

Appendix S (Continued)

Table S.19

Summary of Analysis of Variance on Full Test F-

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	.716	.127
Error between	16	5.637	
Within Ss			
Conditions (C)	3	196.717	109.287***
Treatments (T)	3	1.716	.953
Residual	6	1.591	.884
Error	48	1.800	
Repeated Tests (R)	1	4.900	6.877*
R x O	3	.150	.210
Error	16	.712	
R x T	3	.916	.956
R x C	3	.950	.991
Residual	6	1.275	1.330
Error	48	.958	

* $p < .05$.
***$p < .001$.

Appendix S (Continued)

Table S. 20

Summary of Analysis of Variance on Full Test Total error

Source	df	MS	F
Between Subjects (Ss)			
Orders (O)	3	11.122	.360
Error between	16	30.890	
Within Ss			
Conditions (C)	3	1315.870	397.870***
Treatments (T)	3	1.406	.425
Residual	6	2.714	.820
Error	48	3.307	
Repeated Tests (R)	1	138.756	76.423***
R x O	3	.106	.058
Error	16	1.815	
R x T	3	1.256	1.437
R x C	3	8.556	9.790**
Residual	6	1.664	1.904
Error	48	.873	

** $p < .01$.
***$p < .001$.

Appendix T

Newman-Keuls Test of Means for Conditions Effect

Variable					
R Set 1		Ps	D	ND	Bi
	Ps		0.000	3.414	4.931*
	D			2.655	4.172*
	ND				1.517
	Bi				
NR Set 1		Ps	D	ND	Bi
	Ps		1.591	9.864**	10.819**
	D			8.273**	9.228**
	ND				.954
	Bi				
F+ Set 1		Ps	D	ND	Bi
	Ps		9.430**	15.124**	22.064**
	D			5.694**	12.633**
	ND				6.939**
	Bi				
F- Set 1		Ps	D	ND	Bi
	Ps		1.600	9.146**	10.747**
	D			7.545**	9.146**
	ND				1.600
	Bi				
Total error Set 1		Ps	D	ND	Bi
	Ps		10.111**	21.032**	28.818**
	D			10.954**	18.706**
	ND				7.752**
	Bi				

Note. - Numerical values in Appendix T are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix T (Continued)

Newman-Keuls Test of Means for Conditions Effect

Variable					
R Set 2		Ps	D	ND	Bi
	Ps		0.000	8.875**	14.480**
	D			8.875**	14.480**
	ND				5.605**
	Bi				
NR Set 2		Ps	D	ND	Bi
	Ps		2.381	6.928**	9.310**
	D			4.546**	6.928**
	ND				2.381
	Bi				
F+ Set 2		Ps	D	ND	Bi
	Ps		4.558**	13.127**	20.055**
	D			8.569**	15.497**
	ND				6.928**
	Bi				
F- Set 2		Ps	D	ND	Bi
	Ps		2.509	11.636**	16.884**
	D			9.126**	14.374**
	ND				5.247**
	Bi				
Total error Set 2		Ps	D	ND	Bi
	Ps		6.258**	21.384**	31.990**
	D			15.125**	25.731**
	ND				10.605**
	Bi				

**$p < .01$.

Appendix T (Continued)

Newman-Keuls Test of Means for Conditions Effect

Variable					
R Set 3		Ps	D	ND	Bi
	Ps		0.000	7.400**	12.335**
	D			7.400**	12.335**
	ND				4.934**
	Bi				
NR Set 3		Ps	D	ND	Bi
	Ps		5.120**	6.051**	10.008**
	D			.931	4.887**
	ND				3.956*
	Bi				
F+ Set 3		Ps	D	ND	Bi
	Ps		1.566	10.678**	11.532**
	D			9.111**	9.966**
	ND				.854
	Bi				
F- Set 3		Ps	D	ND	Bi
	Ps		4.090*	8.182**	13.389**
	D			4.090*	9.298**
	ND				5.206**
	Bi				
Total error Set 3		Ps	D	ND	Bi
	Ps		4.556**	16.430**	21.124**
	D			11.873**	16.568**
	ND				4.694**
	Bi				

* $p < .05$.
** $p < .01$.

Appendix T (Continued)

Newman-Keuls Test of Means for Conditions Effect

Variable					
Full Test R		Ps	D	ND	Bi
	Ps		.386	8.887**	14.296**
	D			8.500**	13.910**
	ND				5.409**
	Bi				
Full Test NR		Ps	D	ND	Bi
	Ps		5.450**	12.774**	17.223**
	D			7.320**	11.769**
	ND				4.449**
	Bi				
Full Test F+		Ps	D	ND	Bi
	Ps		8.598**	22.570**	30.680**
	D			13.972**	22.081**
	ND				8.109**
	Bi				
Full Test F-		Ps	D	ND	Bi
	Ps		4.831**	16.027**	22.980**
	D			11.195**	18.149**
	ND				6.953**
	Bi				
Full Test Total error		Ps	D	ND	Bi
	Ps		11.215**	31.908**	44.253**
	D			20.692**	33.038**
	ND				12.345**
	Bi				

**$p < .01$.

Appendix U

Newman-Keuls Test of Means for Orders Effect

Variable					
R Set 1		Order 4	Order 3	Order 2	Order 1
	Order 4		1.257	4.399*	4.399*
	Order 3			3.142	3.142
	Order 2				0.000
	Order 1				
R Set 2		Order 4	Order 3	Order 2	Order 1
	Order 4		2.770	2.770	6.660**
	Order 3			0.000	3.880*
	Order 2				3.880*
	Order 1				
Full Test R		Order 4	Order 3	Order 2	Order 1
	Order 4		3.150*	5.466**	7.779**
	Order 3			2.312	4.625*
	Order 2				2.312
	Order 1				

Note. - Numerical values in Appendix U are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix V

Table V.1

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: R

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	7.4333	36.2846***
Groups (G)	3	1.6660	7.6712**
Sets (S)	2	.0874	.7434
Ss (G)	16	.1520	
GC	9	.3555	1.7356
GS	6	.2041	1.7345
CS	6	.4208	2.7359
SsC (G)	48	.2048	
SsS (G)	32	.1177	
GCS	18	.2708	1.7607
SsCS (G)	96	.1538	

Note. - Significance levels in Appendix V calculated with conservative df.
** $p < .01$.
***$p < .001$.

Appendix V (Continued)

Table V.2

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: NR

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	11.3500	47.1009***
Groups (G)	3	.6277	.7746
Sets (S)	2	28.1166	75.3966***
Ss (G)	16	.8104	
GC	9	.3759	1.5600
GS	6	.3611	.9683
CS	6	.4500	1.1510
SsC (G)	48	.2409	
SsS (G)	32	.3729	
GCS	18	.7092	1.8141
SsCS (G)	96	.3909	

***$p < .001$.

Appendix V (Continued)

Table V.3

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: F+

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	99.4930	180.2138***
Groups (G)	3	3.1152	.8511
Sets (S)	2	15.6166	16.4206***
Ss (G)	16	3.6604	
GC	9	1.2523	2.2683
GS	6	1.6944	1.7817
CS	6	1.0555	1.6110
SsC (G)	48	.5520	
SsS (G)	32	.9510	
GCS	18	1.3481	2.0576
SsCS (G)	96	.6552	

***$p < .001$.

Appendix V (Continued)

Table V.4

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: F-

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	36.4944	75.8326***
Groups (G)	3	.1055	.0774
Sets (S)	2	27.2041	72.7465***
Ss (G)	16	1.3645	
GC	9	.3611	.7504
GS	6	.5763	1.5413
CS	6	1.1652	2.0451
SsC (G)	48	.4812	
SsS (G)	32	.3739	
GCS	18	.5819	1.0213
SsCS (G)	96	.5697	

***$p < .001$.

Appendix V (Continued)

Table V.5

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: Total error

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	255.0042	425.0068***
Groups (G)	3	2.2041	.3108
Sets (S)	2	74.6375	63.6341***
Ss (G)	16	7.0916	
GC	9	.5486	.9144
GS	6	3.4208	2.9165
CS	6	.4041	.4190
SsC (G)	48	.6000	
SsS (G)	32	1.1729	
GCS	18	1.3875	1.4384
SsCS (G)	96	.9645	

***$p < .001$.

Appendix W

Table W.1

Newman-Keuls Test of Means for Errors Across Sets: Test 1

Variable				
NR		Set 1	Set 2	Set 3
	Set 1		6.590**	17.210**
	Set 2			10.610**
	Set 3			
F+		Set 1	Set 2	Set 3
	Set 1		6.650**	7.330**
	Set 2			.688
	Set 3			
F-		Set 1	Set 2	Set 3
	Set 1		7.320**	17.020**
	Set 2			9.699**
	Set 3			
Total error		Set 1	Set 2	Set 3
	Set 1		2.477	15.588**
	Set 2			4.852**
	Set 3			

Note. - Numerical values in Appendix W are the computed Studentized range.
**$p < .01$.

Appendix W (Continued)

Table W.2

Newman-Keuls Test of Means for Conditions Effect Across Sets:

Test 1

Variable					
R		Ps	D	ND	Bi
	Ps		.285	7.989**	12.270**
	D			7.818**	11.986**
	ND				4.280**
	Bi				
NR		Ps	D	ND	Bi
	Ps		4.730**	10.520**	15.780**
	D			5.786**	11.046**
	ND				5.260**
	Bi				
F+		Ps	D	ND	Bi
	Ps		9.733**	22.930**	30.066**
	D			13.200**	20.320**
	ND				7.132**
	Bi				
F-		Ps	D	ND	Bi
	Ps		3.558*	12.730**	19.280**
	D			9.170**	15.840**
	ND				6.557**
	Bi				
Total error		Ps	D	ND	Bi
	Ps		12.500**	33.300**	45.990**
	D			20.830**	33.490**
	ND				12.660**
	Bi				

* $p < .05$.
** $p < .01$.

Appendix X

Table X.1

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: R

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	3.6722	22.9913***
Groups (G)	3	1.0499	10.0800***
Sets (S)	2	.0291	.1134
Ss (G)	16	.1041	
GC	9	.4240	2.6551
GS	6	.2291	.8907
CS	6	.3013	2.1864
SsC (G)	48	.1597	
SsS (G)	32	.2572	
GCS	18	.1087	.7893
SsCS (G)	96	.1378	

Note. - Significance levels in Appendix X calculated with conservative df.
***$p < .001$.

Appendix X (Continued)

Table X.2

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: NR

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	12.4486	27.4939***
Groups (G)	3	.9819	1.5504
Sets (S)	2	20.0541	69.2517***
Ss (G)	16	.6333	
GC	9	.3708	.8190
GS	6	.3819	1.3189
CS	6	.5319	1.1913
SsC (G)	48	.4527	
SsS (G)	32	.2895	
GCS	18	.3486	.7807
SsCS (G)	96	.4465	

***$p < .001$.

Appendix X (Continued)

Table X.3

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: F+

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	68.5930	88.7457***
Groups (G)	3	2.4819	1.4199
Sets (S)	2	31.5125	21.5777***
Ss (G)	16	1.7479	
GC	9	1.3189	1.7065
GS	6	.2069	.1417
CS	6	5.1180	4.5578*
SsC (G)	48	.7729	
SsS (G)	32	1.4604	
GCS	18	.6939	.6180
SsCS (G)	96	1.1229	

* $p < .05$.
***$p < .001$.

Appendix X (Continued)

Table X.4

Summary of Analysis of Variance on Scores in Sets 1, 2, and 3.

Variable: F-

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	28.3833	68.1200***
Groups (G)	3	.2722	.3755
Sets (S)	2	20.2625	36.4270***
Ss (G)	16	.7250	
GC	9	.5944	1.4267
GS	6	.8347	1.5006
CS	6	.6625	1.3532
SsC (G)	48	.4166	
SsS (G)	32	.5562	
GCS	18	.3902	.7972
SsCS (G)	96	.4895	

***$p < .001$.

Appendix X (Continued)

Table X.5

Summary of Analysis of Variance on Scores in Sets 1, 2 and 3.

Variable: Total error

Source	df	MS	F
Subjects (Ss)			
Conditions (C)	3	185.1486	229.2468***
Groups (G)	3	1.4041	.3784
Sets (S)	2	79.9124	69.0513***
Ss (G)	16	3.7104	
GC	9	.7078	.8765
GS	6	.3291	.2844
CS	6	3.4902	4.2289
SsC (G)	48	.8076	
SsS (G)	32	1.1572	
GCS	18	.6106	.7399
SsCS (G)	96	.8253	

***$p < .001$.

Appendix Y

Table Y.1

Newman-Keuls Test of Means for Errors Across Sets: Test 2

Variable				
NR		Set 1	Set 2	Set 3
	Set 1		5.818**	16.415**
	Set 2			10.590**
	Set 3			
F+		Set 1	Set 3	Set 2
	Set 1		6.570**	9.163**
	Set 3			2.590
	Set 2			
F-		Set 1	Set 2	Set 3
	Set 1		3.897*	11.843**
	Set 2			7.945**
	Set 3			
Total error		Set 1	Set 2	Set 3
	Set 1		12.783**	15.589**
	Set 2			2.810
	Set 3			

Note. - Numerical values in Appendix Y are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix Y (Continued)

Table Y.2

Newman-Keuls Test of Means for Conditions Effect Across Sets:

Test 2

Variable					
R		Ps	D	ND	Bi
	Ps		.321	5.815**	10.013**
	D			5.493**	9.690**
	ND				4.198**
	Bi				
NR		Ps	D	ND	Bi
	Ps		3.837*	9.401**	11.511**
	D			5.564**	7.674**
	ND				2.110
	Bi				
F+		Ps	D	ND	Bi
	Ps		4.846**	14.688**	20.856**
	D			9.842**	16.010**
	ND				6.167**
	Bi				
F-		Ps	D	ND	Bi
	Ps		4.200**	13.400**	18.000**
	D			9.200**	18.000**
	ND				4.600**
	Bi				
Total error		Ps	D	ND	Bi
	Ps		7.757**	23.980**	32.753**
	D			16.230**	25.565**
	ND				9.334**
	Bi				

* $p < .05$.
** $p < .01$.

Appendix Y (Continued)

Table Y.3

Newman-Keuls Test of Means for Conditions by Sets Interaction: Test 2

Condition				
		Set 1	Set 3	Set 2
Dominant	Set 1		1.266	2.110
	Set 3			.844
	Set 2			
Non-dominant		Set 1	Set 2	Set 3
	Set 1		4.643**	5.276**
	Set 2			.633
	Set 3			
Bilateral		Set 1	Set 3	Set 2
	Set 1		.844	7.176**
	Set 3			6.331**
	Set 2			
Pseudo		Set 1	Set 2	Set 3
	Set 1		6.540**	7.598**
	Set 2			1.055
	Set 3			

**$p < .01$.

Appendix Z

Table Z.1

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable R Set 1

Source	df	MS	F
Conditions	3	.7166	7.1667**
Subjects within Conditions	16	.0999	

**$p < .01$.

Table Z.2

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable NR Set 1

Source	df	MS	F
Conditions	3	2.1833	8.7333**
Subjects within Conditions	16	.2500	

**$p < .01$.

Table Z.3

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F+ Set 1

Source	df	MS	F
Conditions	3	14.0500	29.5789***
Subjects within Conditions	16	.4750	

***$p < .001$.

Appendix Z (Continued)

Table Z.4

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F- Set 1

Source	df	MS	F
Conditions	3	4.4666	11.1667***
Subjects within Conditions	16	.4000	

***$p < .001$.

Table Z.5

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Total error Set 1

Source	df	MS	F
Conditions	3	31.3833	30.6179***
Subjects within Conditions	16	1.0250	

***$p < .001$.

Table Z.6

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable R Set 2

Source	df	MS	F
Conditions	3	1.3833	7.9048**
Subjects within Conditions	16	.1750	

**$p < .01$.

Appendix Z (Continued)

Table Z.7

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable NR Set 2

Source	df	MS	F
Conditions	3	.8666	1.4440
Subjects within Conditions	16	.6000	

Table Z.8

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F+ Set 2

Source	df	MS	F
Conditions	3	8.6660	9.1228***
Subjects within Conditions	16	.9500	

***$p < .001$.

Table Z.9

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F- Set 2

Source	df	MS	F
Conditions	3	4.1833	5.5778**
Subjects within Conditions	16	.7500	

**$p < .01$.

Appendix Z (Continued)

Table Z.10

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Total error Set 2

Source	df	MS	F
Conditions	3	23.650	13.514***
Subjects within Conditions	16	1.750	

***$p < .001$.

Table Z.11

Summary of Analysis of Variance on the Effect of a Single Treatment:

Variable R Set 3

Source	df	MS	F
Conditions	3	.450	6.000**
Subjects within Conditions	16	.075	

**$p < .01$.

Table Z.12

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable NR Set 3

Source	df	MS	F
Conditions	3	.983	2.809
Subjects within Conditions	16	.350	

Appendix Z (Continued)

Table Z.13

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F+ Set 3

Source	df	MS	F
Conditions	3	3.933	4.495*
Subjects within Conditions	16	.875	

*$p < .05$.

Table Z.14

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable F- Set 3

Source	df	MS	F
Conditions	3	2.533	4.825*
Subjects within Conditions	16	.525	

*$p < .05$.

Table Z.15

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Total error Set 3

Source	df	MS	F
Conditions	3	10.733	9.757***
Subjects within Conditions	16	1.100	

***$p < .001$.

Table Z.16

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test R

Source	df	MS	F
Conditions	3	5.916	19.722***
Subjects within Conditions	16	.300	

***$p < .001$.

Table Z.17

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test NR

Source	df	MS	F
Conditions	3	11.333	9.645***
Subjects within Conditions	16	1.174	

***$p < .001$.

Table Z.18

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test F+

Source	df	MS	F
Conditions	3	71.783	30.546***
Subjects within Conditions	16	2.350	

***$p < .001$.

Appendix Z (Continued)

Table Z.19

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test F-

Source	df	MS	F
Conditions	3	32.183	16.504***
Subjects within Conditions	16	1.950	

***$p < .001$.

Table Z.20

Summary of Analysis of Variance on the Effects of a Single Treatment:

Variable Full Test Total error

Source	df	MS	F
Conditions	3	184.800	35.710***
Subjects within Conditions	16	5.174	

***$p < .001$.

Appendix AA

Newman-Keuls Test of Means for Conditions Effect After a Single ECT

Variable					
R Set 1		ND	D	Ps	Bi
	ND		0.000	1.414	5.659**
	D			1.414	5.659**
	Ps				4.244**
	Bi				
NR Set 1		Ps	D	ND	Bi
	Ps		.890	4.470*	6.260**
	D			3.577*	5.366**
	ND				1.788
	Bi				
F+ Set 1		Ps	D	ND	Bi
	Ps		6.489**	10.382**	12.329**
	D			3.890*	5.840**
	ND				1.946
	Bi				
F- Set 1		D	Ps	ND	Bi
	D		0.000	2.828	7.072**
	Ps			2.828	7.072**
	ND				.707
	Bi				
Total error Set 1		Ps	D	ND	Bi
	Ps		4.417**	8.834**	12.310**
	D			4.417**	8.392**
	ND				3.975*
	Bi				

Note. - Numerical valies in Appendix AA are the computed Studentized range.
* $p < .05$.
** $p < .01$.

Appendix AA (Continued)

Newman-Keuls Test of Means for Conditions Effect After a Single ECT

Variable					
R Set 2		D	Ps	ND	Bi
	D		0.000	4.278*	5.347**
	Ps			4.278**	5.347**
	ND				1.069
	Bi				
F+ Set 2		Ps	D	Bi	ND
	Ps		1.376	5.048**	6.424**
	D			3.671*	5.048**
	Bi				1.376
	ND				
F- Set 2		Ps	D	ND	Bi
	Ps		1.033	3.667*	5.167*
	D			2.583	4.134*
	ND				1.550
	Bi				
Total error Set 2		Ps	D	Bi	ND
	Ps		1.690	7.099**	7.099**
	D			5.409**	5.409**
	Bi				0.000
	ND				
R Set 3		D	Ps	ND	Bi
	D		0.000	0.000	4.900*
	Ps			0.000	4.900**
	ND				4.900**
	Bi				

* $p < .05$.
** $p < .01$.

Appendix AA (Continued)

Newman-Keuls Test of Means for Conditions Effect After a Single ECT

Variable					
F+ Set 3		Ps	D	Bi	ND
	Ps		1.913	3.827*	4.784*
	D			1.913	2.870
	Bi				.956
	ND				
F- Set 3		Ps	D	ND	Bi
	Ps		.617	1.850	4.938*
	D			1.234	4.320*
	ND				3.086*
	Bi				
Total error Set 3		Ps	D	ND	Bi
	Ps		2.085	5.422**	6.673**
	D			3.336*	4.588*
	ND				1.250
	Bi				
Full Test R		D	Ps	ND	Bi
	D		.816	3.266	9.799**
	Ps			2.449	8.980**
	ND				6.533**
	Bi				
Full Test NR		Ps	D	ND	Bi
	Ps		1.650	4.538*	7.013**
	D			2.888	5.363**
	ND				2.475
	Bi				

* $p < .05$.
** $p < .01$.

Appendix AA (Continued)

Newman-Keuls Test of Means for Conditions Effect After a Single ECT

Variable					
Full Test F+		Ps	D	Bi	ND
	Ps		4.950**	11.086**	11.670**
	D			6.126**	6.710**
	Bi				.583
	ND				
Full Test F-		Ps	D	ND	Bi
	Ps		.960	4.480*	8.960**
	D			3.522*	8.006**
	ND				4.480**
	Bi				
Full Test Total error		Ps	D	ND	Bi
	Ps		3.933*	10.619**	12.979**
	D			6.686**	9.046**
	ND				2.359
	Bi				

* $p < .05$.
** $p < .01$.

END OF REEL