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THE RELATIONSHIP BETWEEN NORMALS AND SUBNORMALS INVOLVING TAPPING, THE PURDUE PEGBOARD, AND SIMPLE AND COMPLEX REACTION TIMES

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

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THE RELATIONSHIP BETWEEN NORMALS AND SUBNORMALS
INVOLVING TAPPING, THE PURDUE PEGBOARD, AND
SIMPLE AND COMPLEX REACTION TIMES

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CHAPTER I

INTRODUCTION

The purpose of this study is to investigate the relationship between normals and subnormals involving Tapping, the Purdue Pegboard, and Simple and Complex Reaction Times. There are very few forms of human behavior which do not involve some type of movement. Indeed, motility is one biological criterion for life itself. The study of motility and motor characteristics has important social, educational, and vocational implications beyond those relating to theoretical or scientific interest.

Coordination, speed, accuracy, gracefulness of movement in walking, dancing, and handling utensils, for example, can be expected to have some effect on responses of others to the individual. Every kind of occupational enterprise involves not only ability to distinguish what is required but also the capability to make appropriate motor responses at the proper time. In a very real sense, if a person is unable to perform required motor skills, he can not participate in educational enterprises or be self-dependent.

The major components of motor ability include force, speed, and precision. The force required to perform a given task becomes an index of the strength of the subject and the direction and persistence of movement involved. Francis and Rarick (1960) in comparing large groups of educable mentally retarded boys and girls with data on normal children on static strength (hand grip), running speed, power strength (jumping and throwing for distance), balance (beam walking), and agility (body squat thrusts) gave an excellent description of measures of strength. The findings indicated that the age trends in strength for each followed approximately the same pattern as those for normal children, although at a lower level at every age.

REACTION TIME

Speed of motor performance is a function of the intensity of the stimulus, the sense organ being stimulated, and the complexity of response required. Reaction time is one of the most widely reported variables in experimental psychology. Studies comparing reaction times of mental defectives and normals indicate that, in general, the lower the IQ the poorer the performance of defectives as compared with normals. Scott (1940) obtained a relationship between intelligence (IQ) and reaction time in children ranging in IQ from 63 to 200 and in CA from 9 to 12 years. His findings showed that bright school children had faster times than did dull children of the same CA, and he suggested that the relationship is curvilinear. Pascal (1953), testing the effects of noise on simple reaction time with twenty-two mental defective subjects, reported that simple reaction is correlated with mental age. He, too, believed the relationship to be curvilinear. Ellis and Sloan (1957) investigated the relationship between intelligence and simple reaction time as an extension of Scott (1940) and Pascal (1953) studies using 79 male and female Negro and Caucasian mental defective subjects. The task involved the subjects lifting their fingers from a telegraph key as a response to stop the stimulus of a buzzer. Their data failed to support the findings of Pascal (1953) and Scott (1940). Bensberg and Cantor (1957) investigated to determine whether or not the variable of etiology influences the speed of reaction time on simple and discrimination tasks. They matched 24 pairs of subjects on the basis of CA and MA. The familial group was significantly faster on both simple and discrimination tasks--the difference between the organics and familials being greater on the discrimination than on the simple tasks. However, their organic group included not only two subjects whose conditions were associated with convulsive disorders, but also ten subjects whose organic etiology was unspecified. These twelve subjects were compared with their matched familials again and the familials exceeded the organics on both tasks; however, in neither case was the value significant.

Berkson (1960a, 1960b, 1960c) undertook three experiments which included two in reaction time and one in speed of perception. In each experiment, cultural familial mentally deficient subjects were compared with normals of the same CA (15-16) and, in one experiment, with other mentally deficient subjects. These studies were concerned only with speed.

Berkson's (1960a) first study of the series was a comparison of visual duration thresholds of normal and mentally deficient subjects. Berkson thought that since the reaction times of the mentally deficient subjects tend to be slower than those of normals, duration thresholds of the defectives might be higher. The results failed to demonstrate a difference in visual duration threshold between the normal and mentally deficient groups.

Griffith (1960), employing more complex stimuli than Berkson, also found no relationship between exposure and IQ. Goldiamond (1960) used a variation of stimulus intensity, and he also showed no differences in threshold between defectives and normal subjects. Berkson's (1960b) second study, a reaction time technique, was employed to determine the relationship, if any, of IQ to psychological functions involved in reaction time situations which vary in complexity. The subjects were the same as those used in the first experiment.

The procedure consisted of a hand lift, a simple button press, and a choice button press. The results found retarded subjects were slower than normals, and the more complex tasks elicited slower response than did the simple tasks. However, no interaction of IQ and task complexity was observed. Both IQ groups showed a decrease in speed which was unrelated to IQ over blocks of trials. Berkson suggested that this "decrease in speed may have been due to the fact that subjects planning of a movement became more complex and required more time" (Berkson, 1960b, p. 67). Berkson's (1960c) third study repeated parts of the second experiment with samples from a wider population of mentally deficient subjects. In addition, the experiment tested the hypothesis that IQ is positively related to the speed of performing a movement. Five groups of subjects were used--normals (male staff members in the Institute of Psychiatry, students and a bank clerk) and four mentally deficient (workers, subnormal, severely subnormal, and mongol). The workers were men who lived in the institution but who were employed in the community. The only difference between this experiment and the second was a complex response which consisted of the subject's lifting his finger from a button and turning a knob ten degrees to turn off the light and stop the clock. This experiment was said to have confirmed the existence of a relationship between IQ and speed of reaction in the lower half of the IQ range. It is interesting to note, however, that in the first two experiments Berkson controlled CA and found no difference between his groups. Yet in the three experiments his only control was CA for the normals and workers. There seem to be some questions in his findings.

Dingman and Silverstein (1964) investigated reaction time in relation to intelligence. This was accomplished by means of a research design in which speed and precision of movement were also taken into account. They hypothesized that the latter variables would account for a greater portion of variance than intelligence in simple reaction time; whereas, the opposite could be true in the case of complex reaction time. A steadiness test, a tapping test, and simple and complex reactions were given. Their initial hypothesis was only partially confirmed in that tapping (but not steadiness) accounted for a greater portion of variance than intelligence in both simple and complex reaction time.

An attempt to influence reaction time in young adult normals and low educable retardates of approximately the same CA by varying warning conditions was reported by Terrell and Ellis (1964). Irrespective of warning conditions, normal subjects had significantly faster reaction times than mentally retarded subjects. Retardates were especially penalized by a silent warning interval. Terrell and Ellis interpreted this as a deficiency in short-term memory in defective subjects. Hawkins and Baumeister (1965) attempted to confirm the findings of Terrell and Ellis, with respect to their retarded subjects, by employing a different method of preparatory interval (PI) presentation. Whereas Terrell and Ellis used an irregular presentation of PI's, a regular procedure was used by Hawkins and Baumeister in order to avoid the penalizing effects which occur at the shorter intervals whenever these are preceded by a longer PI. Half the subjects were assigned to a filled condition in which the WS remained for the entire PI. The remaining subjects were placed in an unfilled condition in which the duration of the WS was 1.5 seconds. The PI's were given in the same order to all subjects--2, 4, 8, 12; 2, 4, 8, 12 seconds. Their findings were that the unfilled conditions resulted in faster reaction times than the filled, which appears to be exactly contrary to what Terrell and Ellis (1964) reported--at least with respect to the performance of retarded subjects. Baumeister and Hawkins (1965) presented various PI's in both irregular and regular procedures to a group of 24 male retardates. Both regular and irregular procedures were given at 2, 4, 7.5 and 15 second PI. The regular procedure produced significantly faster reaction times, but only at the 2 and 4 second PI. Under the regular procedures there was virtually a linear relationship between PI and

and reaction time. The most nearly optimal PI under the irregular procedure was 7.5 seconds with mean reactions significantly slower at the 2 and 15 second PI's. Virtually the same phenomenon had been reported for normal subjects (Klemmer, 1956 and Karlin, 1959). In studies of precision, or accuracy of movements in general, when lowgrade defectives were compared with normals, they demonstrated greater difficulty in placing, turning, and positioning movements in control of continuous movement and in muscular steadiness. These characteristics, too, vary as a function of the complexity of the task required (DeStefano, Ellis and Sloan, 1958; Health, 1942, 1953).

RELATIONSHIP BETWEEN MOTOR PROFICIENCY AND MENTAL ABILITY

Doll (1946) and Tredgold (1947) concluded that intelligence and motor proficiency are related. Using groups of twenty institutionalized mental defectives and a group of twenty normal children matched for age and sex, (Sloan, 1951) presented data confirming this relationship. However, another study of sixty institutionalized retardates (Rabin, 1957) failed to reveal a significant relationship between these variables.

Malpass (1960) replicated the preceding experiments with modification. He compared groups of institutionalized and non-institutionalized retarded children to determine whether they could be differentiated on the basis of motor proficiency and whether the motor ability of retardates would be distinguished from that of normal children. In addition, the relationship between motor proficiency and intelligence for each group was also investigated.

The Wechsler Intelligence Scale for Children Full Scale IQ was used as the intelligence indicator for retarded children. The California Test of Mental Maturity which has a correlation of .81 with the WISC (Altus, 1957), was used to measure the IQs of normal children. The Lincoln revision (Sloan, 1955) of the Oseretsky Motor Development Scale was used as the indicator of motor proficiency.

The findings strongly confirmed claims by Tredgold, Doll, and Sloan of the relationship of motor proficiency to intellectual ability--with regard, at least, to the comparisons of mildly retarded and normal children. As for intelligence and motor proficiency, the data suggest that the relationship can be predicted for mentally retarded, but not for normal children.

MANUAL DEXTERITY

Motor skills which require accuracy, steadiness and/or speed (such as placing, turning and positioning) have been measured by use of the Purdue Pegboard, (Tobios, and Gorelick, 1960; Cantor and Stacey, 1951; Eyman, Dingman, and Windle, 1959), the Minnesota Rate of Manipulation

Test, (Di Stefano, Ellis, and Sloan, 1958). These studies reported covariations between manual dexterity and age, sex, and IQ. In general "one can expect to find marked inability to perform tasks involving manual dexterity in those whose IQs are roughly below 60" (Cantor and Stacey, 1951, p. 409). However, there was a great deal of overlapping of scores in the Cantor and Stacey study when defectives were compared with the normals. One inference seemed warranted: That many individual defectives are capable of performing particular tasks requiring eye-hand coordination as competently as the majority of normals.

CHAPTER II

PROBLEM

This study was designed to investigate the relationship between normal and subnormal subjects on Tapping, the Purdue Pegboard, and Simple and Complex Reaction Times.

There have been numerous studies comparing normal and defective subjects. However, these studies have been concerned primarily with comparing simple reaction time with intelligence (Ellis and Sloan, 1957; Pascal, 1953; Bensberg and Cantor, 1957; Dingman and Silverstein, 1964); warning conditions (Terrell and Ellis, 1964; Hawkins and Baumeister, 1965; Baumeister and Hawkins, 1965); motor proficiency and mental ability (Doll, 1946; Tredgold, 1947; Sloan, 1951; Robin, 1957; Molpass, 1961); manual dexterity and mental age (Cantor and Stacey, 1951; Eymon, Dingman, and Windle, 1959; Tobias and Gorelick, 1960). Only three studies actually dealt with complex reaction time (Scott, 1940; Berkson, 1960b, c); yet, these along with the simple reaction time studies used an apparatus on which the subjects either pressed a button or lifted their fingers from one button and pressed another button. The complex task did not deviate from the simple task a great deal.

This study was designed to incorporate Tapping, the Purdue Pegboard, and Simple and Complex Reaction Times, which would permit some general conclusions about relationships which exist within groups, as well as between them, involving these tasks.

The following hypotheses were tested:

1. There will be no association between Inter-tau's for subnormals.

2. There will be no association between Inter-tau's for normals.

3. There will be no difference between normal and subnormal subjects on tapping.

4. There will be no difference between normal and subnormal subjects on the Purdue Pegboard.

5. There will be no difference between normal and subnormal subjects on simple reaction time (Task I).

6. There will be no difference between normal and subnormal subjects on complex reaction time (Task II).

7. There will be no difference between normal and subnormal subjects on complex reaction time (Task III).

8. There will be no difference between normal and subnormal subjects on complex reaction time (Task IV).

CHAPTER III

METHOD

SUBJECTS

The normal subjects were twenty boys from the Reynolds Elementary School, Morrilton, Arkansas. The twenty subnormal boys were residents of the Arkansas Children's Colony, Conway, Arkansas. The age and IQ characteristics of the groups are summarized in Table I. The normal boys ranged in CA from 105 months to 134 months with a mean of 117 months. Their IQ on the California Test of Mental Maturity (Elementary S-Form) were between 98 and 125, with a mean of 110.

TABLE I

Characteristics of the Groups

Group	N	Measure	CA (Mo.)	Individual Test IQ
		Mean	117	110
Normals	20			
		SD	2.97	2.33
		Mean	117	55
Subnormals	20	SD	3.40	2.49

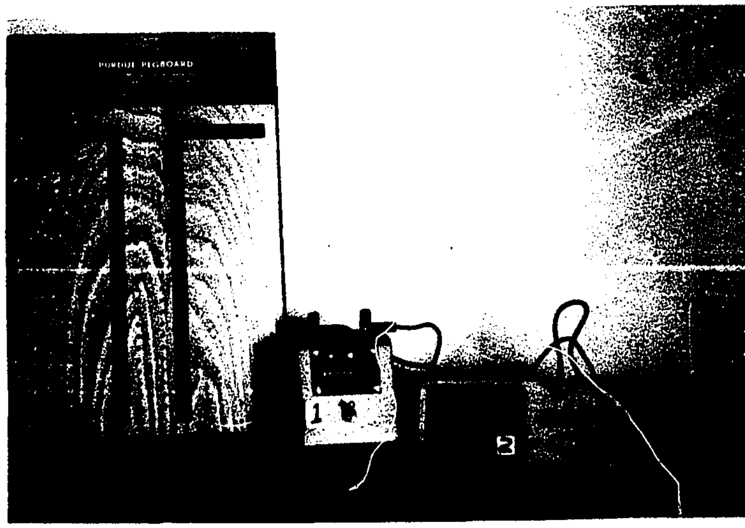
The subnormal boys ranged in CA from 110 months to 134 months, with a mean CA of 117 months--the IQ scores being derived from the latest individual intelligence test (WISC). The subnormals ranged from 40 to 66, with a mean IQ of 55. None of these subjects was found to have significant sensory or motor impairments.

APPARATUS

Tapping (Figure 1). This apparatus consisted of Two 4 1/2 inch square, stainless steel plates mounted on a wooden base. A metal stylus and the steel plates were wired to an impulse counter. The impulse counter contained a power supply that operated at 115 volts, 60 cycle, A-C, in order to supply 6 volts D. C. to actuate the counter whenever the circuit was closed. ARC suppression was built in. The power switch was arranged so that it could be used as a key. When the switch was depressed the counter was on momentarily. The switch locked on in the upward position. There were four numeral dials that could be reset quickly to 0,000 from any reading. The upper limit of the speed was 600 counts per minute.

Purdue Pegboard (Figure 1). This apparatus consisted of two rows of small holes (25 holes in each row) and four small cups containing either pegs, washers, or collars.

Figure 1



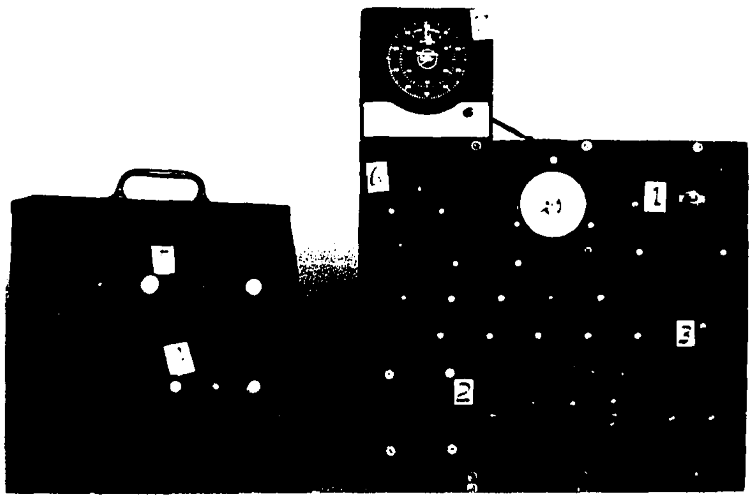
Purdue Pegboard: 1. Impulse Counter; 2. Stainless Steel Plates Mounted on a Wooden Base; 3. Metal Stylus

Reaction Time Apparatus. The apparatus[1] constructed for this part of the experiment is shown in Figure 2; a circuit diagram with a brief description of its method of operation is located in the appendix. Except for the electrical timing clock, all electrical equipment was enclosed in a case. The only parts visible on the subject apparatus were four light bulbs and four one-way telephone switches. The bulbs were covered with colored caps (orange, white, red, and yellow). On the experimenter's side, the clock, four small lights, switches, and jacks were visible. The subject's apparatus was housed in a small box with a 25 degree slant

[1]The experimenter is indebted to Dr. S. I. B. Corrigan for designing and building all electrical circuits and for many suggestions which went into this apparatus.

for better vision. The lights were spaced two inches apart with four inches between the lights and switches; the switches were spaced one and one-half inches apart.

Figure 2



Reaction Time Apparatus

1) Power switch, 2) Switches that control the various lights on the subject's apparatus, 3) Jacks that control the switches on subject's apparatus. These can be changed so that any switch may turn off any light. 4) Subject's switches that control the lights and stop the clock, 5) Subject's lights which are turned on by switches on examiner's apparatus, 6) Reset button that resets the clock.

The apparatus was constructed so that any switch could turn off any light by changing the jacks (3--Figure 2). The simple reaction time (Task I) involved the subject's responding to the appearance of a single orange light (first light on the left side of subject apparatus) by pushing the switch below that light to turn it off. The switch for Task I was the same color as the light. The remaining three switches were uncovered (no covers or caps). Turning the light on automatically activated the clock which was stopped when the subject pushed the switch. The clock measured the time interval to .01 seconds.

Complex reaction time (Task II) involved two lights and two switches; the switches being crossed. See Figure 3.

Figure 3

Orange	White
White	Orange

The clock was started when the light came on and stopped when the subject pushed one of the two switches. The apparatus was constructed so that either switch would stop the clock. In case of the correct response, the time was recorded as a correct response. In case of incorrect response the time was recorded as a reaction time to this task, but in error.

Task III involved three lights and three switches. The orange light was turned off by switch 3 (see Figure 4);

the white light was turned off by switch 2; the red light was turned off by switch 1. Each switch was the same color as the light turned off.

Figure 4

Orange	White	Red
Red	White	Orange

Task IV involved four lights and four switches. The orange light was turned off by switch 3; the white by switch 4; the red by switch 1; and the yellow by switch 2 (see Figure 5).

Figure 5

Orange	White	Red	Yellow
Red	Yellow	Orange	White

In Tasks II, III, and IV, the lights or stimuli were presented in the following random order:

Task II: W-W-W-OR-W-OR-OR-OR-OR-OR

Task III: OR-OR-W-R-W-R-W-R-R-W

Task IV: Y-OR-Y-OR-W-R-W-R-Y-W.

PROCEDURE

The experiment was administered in two sessions, a week apart, to avoid the possibility of fatigue. The first part involved the Purdue Pegboard and Tapping. The second part involved simple and complex reaction times. Both sessions were administered between eight and ten o'clock in the morning to normals and subnormals.

The experiment was performed in two rooms. The normal subjects were tested in a room located in their school and the subnormal subjects were tested in a room at the institution where they resided. In both rooms a low level of illumination was maintained. Each subject was brought individually into the room and seated before the apparatus. Prior to the start of the task, an attempt was made to determine handedness and to test for color blindness. The subject was handed a pencil and asked to write his name. It was assumed that he would use the dominant hand. Each subject was required to use the preferred hand on all tests. To test for visual discrimination each subject was asked to identify the color of the four lights.

The following instructions were given:

Tapping. "I want to see how fast you can tap. Hold this (stylus) in your hand like a pencil and rest your forearm on the table (the correct procedure was demonstrated to each subject). Now you practice." After it was assumed he understood the task, a ten second rest period was given. The subject was told: "When I say 'go' I want you to tap as fast as you can until I tell you to stop." At the "go" signal, the impulse counter switch was held in the down position, and at the same time a stopwatch was started. At the end of fifteen seconds the switch was released and the subject was asked to stop. The counter score was recorded and reset. The subject had about ninety seconds rest while the experimenter changed the apparatus. The Purdue Pegboard was placed in front of the subject. The administrative procedure outlined in the Examiner's Manual for the Purdue Pegboard was followed exactly, except that the subject used his dominant hand and only one trial was administered.

The second session dealt with reaction times. The subject was seated in front of the apparatus, and the preferred hand was placed on a two by four inch pad which was located six inches in front of the center of the subject's apparatus. He was required to return the hand to the pad after each trial.

Simple Reaction Time--Task I. The subject was told: "Let's see how fast you can turn off the light." The procedure was demonstrated, and several practice trials were given so that the subject understood the procedure. A "ready" signal was given from two to four seconds before the light was turned on. After a short rest, the subject then received ten trials which were recorded. The experimenter could see the subject from the side so as to be sure he was reacting properly. Now and then the subject was encouraged to react as fast as possible. Care was taken to vary the warning interval within the two to four seconds and to make sure that the subject was always "set" to respond before the sign was given. If there were reason to think that a distraction had occurred, the reaction time was not recorded.

Complex Reaction--Task II. The instructions were similar to those of Task I except that the subject was told: "This time we are going to do two lights and two switches. You might see one light more than the other."

Complex Reaction Time--Task III. The instructions were similar to those of Task I except that the subject was told: "This time we are going to do three lights and three switches. This time any one of the three lights might come on."

Complex Reaction Time--Task IV. The instructions were similar to those of Task I except that the subject was told: "This time we are going to use all the lights and any one of the four lights might come on."

A demonstration and several practice trials were given to make sure the subject understood the procedure for each task. Each subject received ninety second rest periods between each task. This allowed the experimenter time to change the jacks and cover the switches.

COLLECTING DATA

The procedure for collecting data was to record the number of taps in fifteen seconds and the number of pins placed in Purdue Pegboard in thirty seconds. Ten trials in .01 seconds for each reaction time task were recorded. The detailed record of a specific individual from the normal group may help to form an idea of how the data were collected. (See Table 2).

TABLE 2

Individual Data Sheet

Name____________________ Date of Test__________ IQ_____

Date of Birth__________ Age_____

Trials	Tap	PB	T^1	T^2	T^3	T^4
1	76	15	.52	1.04	.92	1.00
2			.64	.94	.76	.99
3			.56	.81	.89	1.05
4			.47	.73	.83	.81
5			.48	.79	.57	1.07
6			.49	.95	.85	.98
7			.53	.89	.81	.98
8			.50	1.10	1.15	1.00
9			.45	.89	.81	1.28
10			.51	.56	.71	.98
Total			5.15	8.70	8.30	10.16
Mean			.52	.87	.83	1.02
Error						

CHAPTER IV

RESULTS

The individual results of the testing of the forty subjects used in the study are recorded in the appendix for examination. Tables 11 and 12 in the appendix show the CA, IQ, means for Tapping, Purdue Pegboard, Simple Reaction Time (T^1), Complex Reaction Time (T^2), (T^3), and (T^4) for each subject as well as means for each group on the various tasks. In order to test Hypothesis 1 and 2, Kendall Rank Correlation Coefficient (Tau) was used. To determine value of Tau, because of the numerous ties, the following formula was used (Kendall, 1948, p. 33).

$$\text{Tau} = \frac{S}{\sqrt{1/2N\ (N-1) - Tx}\ \sqrt{1/2\ N\ (N-1) - Ty}}$$

The results obtained are found in Tables 3 and 4 which show the inter-taus for subnormals and normals. In order to test the significance of the taus the following formula was used:

$$z = \frac{}{\sqrt{\frac{2\ (2N + 5)}{9\ N\ (N - 1)}}}$$

TABLE 3

Matrix of Inter-Taus for Subnormals
N = 20

Variable	Tap	PB	T^1	T^2	T^3	T^4
Tap		.33*	.30*	.13	.11	.02
PB			.32*	.42*	.35*	.33*
T^1				.26	.36*	.08
T^2					.74*	.48*
T^3						.56*
T^4						

* Significant at or beyond .05 level.

TABLE 4

Matrix of Inter-Taus for Normals
N = 20

Variable	Tap	PB	T^1	T^2	T^3	T^4
Tap		.31*	.25	.18	.03	.06
PB			.64*	.50*	.58*	.44*
T^1				.64*	.73*	.49*
T^2					.72*	.49*
T^3						.41*
T^4						

* Significant at or beyond .05 level.

The results obtained are in the appendix in Tables 13 and 14, which show the variables t , z, and p for subnormal and normal subjects.

Hypothesis 1 stated that there would be no association between inter-taus for subnormals. Table 11 in the appendix shows the means for the variables of each subject. Table 3 reveals an association between Tap, PB, T^1; between PB T^1, T^2, T^3, and T^4; between T^1 and T^3; between T^2, T^3, and T^4; and between T^3 and T^4. There was no association between Tap, T^2, T^3, and T^4; and between T^1, T^2, and T^4. The hypothesis that there would be no association between inter-taus for subnormals was rejected because ten of the fifteen inter-taus were associated in the subnormal population from which this sample was drawn. The .05 level of confidence was used throughout the study as the level required for the acceptance or rejection of the hypotheses.

Hypothesis 2 stated that there would be no association between inter-taus for normals. Table 12 in the appendix shows the means for the variables of each subject. Table 4 reveals as association between all variables except tapping. Tapping was associated with PB, but not with T^1, T^2, T^3, and T^4. Therefore, the hypothesis that there is no association between inter-taus for normals was rejected because eleven of the fifteen inter-taus were associated in the normal population from which this sample was drawn. In order to test Hypotheses 3, 4, 5, 6, 7 and

8, the Mann-Whitney U Test was used to correct for ties. Because of large samples, Auble (1953) Extended Tables for the Mann-Whitney U Test was used to determine the significant value of U for each hypothesis.

$$U = MN + \frac{M\ (N-1)}{2} - T$$

Hypothesis 3 stated that there would be no difference between normal and subnormal subjects on tapping. Tables 11 and 12 in the appendix show the means for each subject on tapping. Table 5 shows the variable arranged in rank order. For this comparison U = 281. Referring to Auble (1953), Table 7 shows that for N = M = 20 the calculated value of U lies between the critical values of 138 to 262. Therefore, the hypothesis that there would be no difference between normal and subnormal subjects on tapping was rejected. This hypothesis could be accepted at .01 level in that the critical value for U lies between 114 and 286.

Hypothesis 4 stated that there would be no difference between normal and subnormal subjects on the Purdue Pegboard. Tables 11 and 12 in the appendix show the means for each subject on the Purdue Pegboard. Table 6 shows the variable arranged in rank order. For this comparison U = 293. Referring to Auble (1953), Table 7 shows that for N = M = 20 the calculated value of U lies between the critical values of 138 to 262. Therefore, the hypothesis that there would be no difference between normal and subnormal subjects

TABLE 5

Rank Order for Normal (1) and Subnormal (2) Subjects in Tapping

Rank	Score	Group	Rank	Score	Group
1	42	2	22.5	76	2
2	44	2	22.5	76	1
3	46	2	22.5	76	1
4	57	2	22.5	76	1
5	58	2	22.5	76	1
6.5	62	2	22.5	76	1
6.5	62	2	27	79	1
8	63	2	10	80	2
9.5	64	2	30	80	1
9.5	64	2	30	80	1
11.5	68	2	30	80	1
11.5	68	2	30	80	1
13	69	2	33.5	82	1
14.5	70	2	33.5	82	1
14.5	70	1	35	84	1
16	72	1	36	85	1
17.5	73	2	37.5	86	1
17.5	73	1	37.5	86	2
22.5	76	2	39	87	1
22.5	76	2	40	98	1

TABLE 6

Rank Order for Normal (1) and Subnormal (2) Subjects on Purdue Pegboard

Rank	Score	Group	Rank	Score	Group
1.5	6	2	20	13	2
1.5	6	2	20	13	2
4	7	2	25.5	14	1
4	7	2	25.5	14	1
4	7	2	25.5	14	1
7	8	2	25.5	14	1
7	8	2	25.5	14	1
7	8	2	25.5	14	1
10.5	9	2	32	15	1
10.5	9	2	32	15	1
10.5	9	2	32	15	1
10.5	9	2	32	15	1
13.5	10	2	32	15	1
13.5	10	2	32	15	1
15	11	2	32	15	1
16.5	12	2	36	16	2
16.5	12	1	36	16	1
20	13	1	36	16	1
20	13	1	36	16	1
20	13	2	36	16	1

on the Purdue Pegboard was rejected.

Hypothesis 5 stated that there would be no difference between normal and subnormal subjects on Simple Reaction Time (Task I). Tables 11 and 12 in the appendix show the means for each subject on Task I. Table 7 shows the variable arranged in rank order. For this comparison U = 294. Referring to Auble (1953) Table 7 shows that for N = M = 20, the calculated value of U lies between the critical values of 138 to 262. Therefore, the hypothesis that there will be no difference between normal and subnormal subjects on Task I is rejected.

Hypothesis 6 stated that there would be no difference between normal and subnormal subjects on Complex Reaction Time (Task II). Tables 11 and 12 in the appendix show the means for each subject on Task II. Table 8 shows the variable arranged in rank order. For this comparison U = 298. Referring to Auble (1953), Table 7 shows that for N = M = 20 the calculated value of U lies between the critical values of 138 to 262. Therefore, the hypothesis that there would be no difference between normal and subnormal subjects on Task II was rejected.

Hypothesis 7 stated that there would be no difference between normal and subnormal subjects on Complex Reaction Time (Task III). Tables 11 and 12 in the appendix show the means for each subject on Task III. Table 9 shows the variable arranged in rank order. For this comparison U =

TABLE 7

Rank Order for Normal (1) and Subnormal (2) Subjects on Simple Reaction Time (Task I)

Rank	Score	Group	Rank	Score	Group
1	.37	1	21.5	.59	1
2	.40	1	21.5	.59	2
3	.41	1	23	.63	1
4	.43	1	24	.64	1
5	.44	1	25	.65	2
6	.45	1	26	.67	2
7	.46	1	27	.68	2
8	.49	1	28	.70	2
9.5	.50	1	29	.74	2
9.5	.50	1	31.5	.75	2
11.5	.52	1	31.5	.75	2
11.5	.52	1	31.5	.75	2
13	.53	2	31.5	.75	2
14.5	.54	1	34	.77	2
14.5	.54	2	35.5	.78	2
16.5	.57	1	35.5	.78	2
16.5	.57	1	37	.93	2
19	.58	1	38	1.04	2
19	.58	1	39	1.13	2
19	.58	2	40	1.48	2

TABLE 8

Rank Order for Normal (1) and Subnormal (2) Subjects on Complex Reaction Time (Task II)

Rank	Score	Group	Rank	Score	Group
1	.54	1	21	.91	1
2	.56	1	22	.96	1
3	.59	1	23	.99	2
4.5	.61	1	24	1.09	2
4.5	.61	1	25	1.10	2
6.5	.67	1	26	1.11	2
6.5	.67	1	27	1.18	2
8	.69	1	28.5	1.21	2
9	.73	1	28.5	1.21	2
10	.75	2	30.5	1.27	2
11.5	.79	1	30.5	1.27	2
11.5	.79	1	32	1.32	2
13	.81	1	33	1.34	2
14.5	.83	1	34	1.40	2
14.5	.83	1	35	1.41	2
16	.84	1	36	1.43	2
17	.86	1	37	1.44	2
18.5	.87	1	38	1.78	2
18.5	.87	1	39	1.96	2
20	.90	2	40	2.93	2

TABLE 9

Rank Order for Normal (1) and Subnormal (2) Subjects on Complex Reaction Time (Task III)

Rank	Score	Group	Rank	Score	Group
1	.62	1	21	1.03	1
2	.64	1	22	1.05	2
4.5	.68	1	23	1.07	1
4.5	.68	1	24	1.14	2
4.5	.68	1	25	1.25	2
4.5	.68	1	26	1.31	2
7	.71	1	27	1.33	2
8.5	.75	1	28.5	1.34	2
8.5	.75	1	28.5	1.34	2
10	.78	1	30	1.39	2
11	.81	1	31.5	1.40	2
12.5	.83	1	31.5	1.40	2
12.5	.83	1	33	1.41	2
14	.85	1	34	1.62	2
15	.87	1	35	1.63	2
16	.88	1	36	1.65	2
17	.91	1	37	1.69	2
18	.92	1	38	2.07	2
19	.95	2	39	2.36	2
20	.97	2	40	2.60	2

302. Referring to Auble (1953), Table 7 shows that for N = M = 20 the calculated value of U lies between the critical values of 138 to 262. Therefore, the hypothesis that there would be no difference between normal and subnormal on Task III was rejected.

Hypothesis 8 stated that there would be no difference between normal and subnormal subjects on Complex Reaction Time (Task IV). Tables 11 and 12 in the appendix show the means for each subject on Task IV. Table 10 shows the variable arranged in rank order. For this comparison U = 302. Referring to Auble (1953), Table 7 shows that for N = M = 20 the calculated value of U lies between the critical values of 138 to 262. Therefore, the hypothesis that there would be no difference between normal and subnormal subjects on Task IV is rejected.

TABLE 10

Rank Order for Normal (1) and Subnormal (2) Subjects on Complex Reaction Time (Task IV)

Rank	Score	Group	Rank	Score	Group
1	.69	1	21	1.22	2
2	.81	1	22	1.25	2
3	.86	1	23	1.29	2
4.5	.88	1	24	1.42	2
4.5	.88	1	25	1.46	1
6.5	.95	1	26	1.56	2

TABLE 10.--Continued

Rank	Score	Group	Rank	Score	Group
6.5	.95	1	27	1.69	2
8.5	.98	1	28.5	1.70	2
8.5	.98	1	28.5	1.70	2
10.5	1.00	1	30	1.76	2
10.5	1.00	1	31	1.78	2
12.5	1.02	1	32	1.86	2
12.5	1.02	1	33	1.88	2
14	1.07	1	34	2.01	2
15.5	1.09	1	35	2.13	2
15.5	1.09	1	36	2.21	2
17	1.11	1	37	2.28	2
18	1.16	1	38	2.56	2
19	1.17	1	39	3.04	2
20	1.21	2	40	3.13	2

CHAPTER V

DISCUSSION AND CONCLUSION

This study was an investigation of the relationship between normal and subnormal subjects on Tapping, the Purdue Pegboard, and Simple and Complex Reaction Times. Two hypotheses were tested to determine whether or not the various tasks were associated within these groups. Six hypotheses were tested to determine whether or not differences existed between groups on the various tasks. Table 3 reveals ten associations out of fifteen between the various tasks within the subnormal group. Table 4 reveals eleven associations out of fifteen between the various tasks within the normal group. Tapping accounted for seven of the inter-taus that were not associated within groups. This relationship may simply be due to the different motor skills involved in the various tasks. Tapping involved only hand and wrist movement, while the arm was held in a stationary position; whereas the other tasks required the entire arm movement of each subject. The lack of association between T^1, T^2, and T^4 within the subnormal group was the result of tardy initiation of performance of a movement for these tasks.

The decision time from T^1 to T^2 was .57 seconds and from T^1 to T^4 was 1.10 seconds.

The fact that eight subnormals performed faster or showed little difference in their reaction times on T^3 than T^2 seems to account for the association between T^1 and T^3.

In order to determine whether or not any difference existed between groups on the various tasks, six hypotheses stated that there would be no differences between normal and subnormal subjects on Tapping, the Purdue Pegboard, and Simple and Complex Reaction Times. The results clearly demonstrated a significant difference between normal and subnormal subjects at the .05 level of confidence. However, when the data were checked at .01 level of confidence there was a relationship between normal and subnormal subjects on Tapping. Table 15 in the appendix shows that both groups were slower as the reaction task became more complex.

One surprising result for this study was that the subnormals were significantly more accurate than normals. They made six errors on T^2, five on T^3 and four on T^4 as opposed to 13, 11 and 15 for the normals on the same tasks.

It is possible that different motivational levels for the two groups could account for the superior performance of the normal group on all the various tasks. It is the belief of the investigator that the subnormal subjects were as highly motivated as the normal subjects. Every evidence pointed to the fact that subjects in both groups enjoyed the experience and participated to the best of their ability. Both groups seemed particularly eager to leave with the investigator each day to participate in the experiment. Most expressed pride and pleasure in their performance, regardless of the nature of their performances.

In conclusion, it can be stated that the subnormal subjects in this investigation were markedly inferior to normal subjects on all tasks.

EDUCATIONAL AND PSYCHOLOGICAL IMPLICATIONS

An important issue for educators is to determine whether motor skills of subnormals can be modified by systematic instruction. Most motor skills are learned incidently by the typical elementary aged child in regular classrooms. It is already evident in certain academic and social areas that subnormals must be taught specifically what normal children seem to learn incidentally. Perhaps educators will need to plan more specific, structured programs for subnormals in the area of motor skills. One of the aims of educating the subnormals is to help them to function in a normal society. If training in motor skills would help them in vocational areas, then it would enhance their potential to function in a normal society.

IMPLICATIONS FOR RESEARCH

A number of interesting ideas for future study have arisen out of this research.

1) Though tapping was not associated with the other tasks, it is felt that if this task had required the subject to tap alternating between the two plates, an association might have existed.

2) Replicate this study using institutionalized and noninstitutionalized subjects of same CA.

3) Replicate this study without a "ready" signal and compare the results with results of this study.

4) Compare good readers and poor readers of same CA and MA on simple and complex reaction time.

5) Because the reaction apparatus used in this study has never been used before, there seems to be many possibilities for future research using this apparatus.

REFERENCES

Altus, G. A note on the validity of the WISC. Journal of Consulting Psychology, 1952, 6, 231.

Auble, D. Extended tables for the Mann-Whitney Statistic. Bulletin of Institutional Educational Research, Indiana University, 1953, I, No. 2.

Baumeister, A. F. and Hawkins, W. F. Variations of the preparatory interval in relation to the reaction times of mental defectives. American Journal of Mental Defectives, 1965, 70, 689-694.

Bensberg, F. J. and Cantor, G. N. Reaction time in mental defectives with organic and familial etiology. American Journal of Mental Defectives, 1957, 62, 534-537.

Berkson, G. An analysis of reaction time in normal and deficient young men Part I. Duration threshold experiment. Journal of Mental Defectives, Research, 1960, 4, 51-58.

Berkson, G. Part II. Variation of complexity in reaction time tasks. Journal of Mental Defectives, Research, 1960, 4, 59-67.

Berkson, G. Part III. Variation of stimulus and of response complexity. Journal of Mental Defectives, Research, 1960, 4, 69-77.

Cantor, G. N. and Stacey, C. M. Manipulative dexterity in mental defectives. American Journal of Mental Defectives, 1951, 56, 401-410.

DeStefano, M. K., Jr., Ellis, N., and Sloan, W. Motor proficiency in mental defectives. Perceptual and Motor Skills, 1958, 8, 231-234.

Dingman, H. F. and Silverstein, A. B. Intelligence motor disabilities and reaction time in the mentally retarded. Perceptual and Motor Skills, 1964, 19, 791-794.

Doll, E. A. The Oseretsky Scale. American Journal of Mental Deficiency, 1946, 50, 485-486.

Ellis, N. R. and Sloan, W. Relationship between intelligence and simple reaction time in mental defectives. Perceptual and Motor Skills, 1957, 7, 65-67.

Eyman, R. K., Dingman, H. F. and Windle, C. Manipulative dexterity and movement history of mental defectives. Perceptual and Motor Skills, 1959, 9, 291-294.

Francis, R. J. and Rarick, G. L. Motor characteristics of the mentally retarded. American Journal of Mental Deficiency, 1958, 63, 292-311.

Goldiamond, I. Visual signal detection, perception and response variables as functions of development and mental retardation, in Anderson, J. O. (Ed.) Perceptual and Response Abilities of Mentally Retarded Children. Carbondale: Southern Illinois University, 1960.

Griffith, A. The effects of retention interval exposure time and IQ on recognition in a mentally retarded group. American Journal of Mental Deficiency, 1960, 64, 1000-1003.

Hawkins, W. F. and Baumeister, A. A. Effect of warning signal duration on reaction times of mental defectives. Perceptual and Motor Skills, 1965, 21, 179-182.

Health, S. R. Jr. Railwalking performance as related to mental age and etiological types. American Journal of Psychology, 1942, 55, 240-247.

Health, S. R. Jr. The relations of railwalking and other motor performances on mental defectives to mental age and etiological types. Training School Bulletin, 1953, 50, 110-127.

Karlin, L. Reaction time as a function of fore period duration and variability. Journal of Experimental Psychology, 1959, 58, 185-191.

Kendall, M. Rank Correlation Method, 1948, London, Griffin.

Klemmer, E. T. Time uncertainty in simple reaction time. Journal of Experimental Psychology, 1956, 51, 179-184.

Malpass, L. F. Motor proficiency in institutionalized and noninstitutionalized retarded children and normal children. American Journal of Mental Deficiency, 1960, 64, 1012-1015.

Pascal, G. R. The effect of a disturbing noise on the reaction time of mental defectives. American Journal of Mental Deficiency, 1953, 57, 691-699.

Rabin, H. M. The relationship of age, intelligence and sex to motor proficiency in mental defectives. American Journal of Mental Deficiency, 1957, 62, 507-516.

Scott, W. S. Reaction time of young intellectual deviates. Archives of Psychology, 1940, 36, No. 256.

Sloan, W. Motor proficiency and intelligence. American Journal of Mental Deficiency, 1951, 55, 394-406.

Sloan, W. The Lincoln-Oseretsky motor development scale. Genetic Psychology Monographs, 1955, 51, 183-252.

Tobias, J. and Gorelick, J. The effectives of the Purdue Pegboard in evaluating work potential of retarded adults. Training School Bulletin, 1960, 57, 94-104.

Terrill, C. G. and Ellis, N. R. Reaction time in normal and defective subjects following varied warning conditions. Journal of Abnormal and Social Psychology, 1964, 69, 449-452.

Tredgoald, A. F. A Textbook of Mental Deficiency (7th Edition). Baltimore: Williams and Wilkins, 1947.

A P P E N D I X

TABLE 11

Subnormals Mean Score for Various Tasks

Subjects	C.A.	I.Q.	Tapping	Purdue Pegboard	T^1	T^2	T^3	T^4
1	9.3	50	46	8	1.13	1.96	2.36	2.13
2	9.4	47	62	9	1.48	1.78	1.62	2.01
3	9.4	54	76	8	.93	1.43	1.41	1.70
4	11.1	66	68	13	.65	1.21	1.33	1.86-1
5	10.2	62	58	9	.75	1.10-1	1.14	1.22-1
6	10.11	57	76	13	.58	.90	.97	1.21
7	10.1	66	69	13	.53	.99	1.05	1.69
8	8.10	58	73	11	.74	1.11	1.69	3.13
9	9.6	62	64	9	.70	1.18	1.34	1.70
10	10.6	46	68	8	1.04	1.09	1.25	1.25
11	9.6	52	42	7	.77	1.27-1	1.40-1	1.42-1
12	10.11	46	44	7	.68	1.21	1.31-1	1.76
13	10.1	51	64	7	.75	1.41	2.07	2.21-1
14	10.11	65	80	16	.59	.75	.95	1.29
15	10.7	64	63	12	.78	1.44	1.65	1.78
16	10.8	48	57	6	.78	1.32	1.40	2.28
17	11.1	45	86	6	.67	2.93-3	2.60-3	3.04
18	11.2	45	70	9	.54	1.40-1	1.34	2.56
19	11.0	54	62	10	.75	1.34	1.63	1.88
20	10.9	65	76	10	.75	1.27	1.39	1.56
Means	9.9	55	65	9.55	.78	1.35	1.49	1.88
Errors*						6	5	4

* Number connected by hyphen to means RT indicate errors (e.g., 1.27-1).

TABLE 12

Normals Mean Scores for Various Tasks

Subjects	C.A.	I.Q.	Tapping	Purdue Pegboard	T^1	T^2	T^3	T^4
1	10.8	112	72	15	.50	.67	.71-2	.95
2	9.8	110	87	15	.57	.73	.83-1	1.00-1
3	10.2	120	70	15	.45	.79-1	.68-2	.88-1
4	11.0	108	76	14	.50	.69-1	.75	.88-1
5	11.1	117	85	15	.43	.67	.68	.86-3
6	10.2	123	76	16	.37	.59-3	.64	.98-1
7	10.11	101	80	15	.49	.83-1	.78	1.17
8	11.0	115	80	14	.44	.54-2	.75-1	.81
9	10.6	113	86	16	.41	.61	.68	.69-1
10	10.5	103	76	14	.63	.91	1.03	1.00
11	8.9	98	80	13	.59	.96	1.07	1.46-1
12	9.4	102	80	14	.46	.56-5	.62-4	1.07-3
13	10.10	105	73	15	.52	.87	.83	1.02
14	10.1	114	76	14	.64	.86	.91	1.09
15	9.7	110	82	14	.58	.83	.81	1.16-1
16	10.1	107	76	12	.57	.79	.85	1.02
17	9.7	103	82	15	.54	.81	.92	1.09
18	9.9	125	98	16	.52	.84	.87	.95
19	10.8	106	79	13	.58	.87	.88	1.11
20	10.5	117	84	16	.40	.61	.69-1	.98-2
Means	9.85	110	80	14	.51	.75	.80	1.01
Errors*						13	11	15

* Number connected by hyphen to means RT indicate errors (e.g., .79-1).

TABLE 13

Significance of Inter-Taus for Subnormals

Variables	Tau	z	p
Tap - PB	.33	2.04	.0207
Tap - T^1	.30	1.9	.0287
Tap - T^2	.13	.08	.4681
Tap - T^3	.11	.07	.4721
Tap - T^4	.02	.01	.4960
PB - T^1	.32	2.00	.0228
PB - T^2	.42	2.05	.0202
PB - T^3	.35	2.01	.0222
PB - T^4	.33	2.04	.0207
T^1 - T^2	.26	1.06	.1446
T^1 - T^3	.37	2.3	.0107
T^1 - T^4	.08	.05	.4801
T^2 - T^3	.74	4.5	.00003
T^2 - T^4	.48	3.0	.0013
T^3 - T^4	.56	3.5	.00023

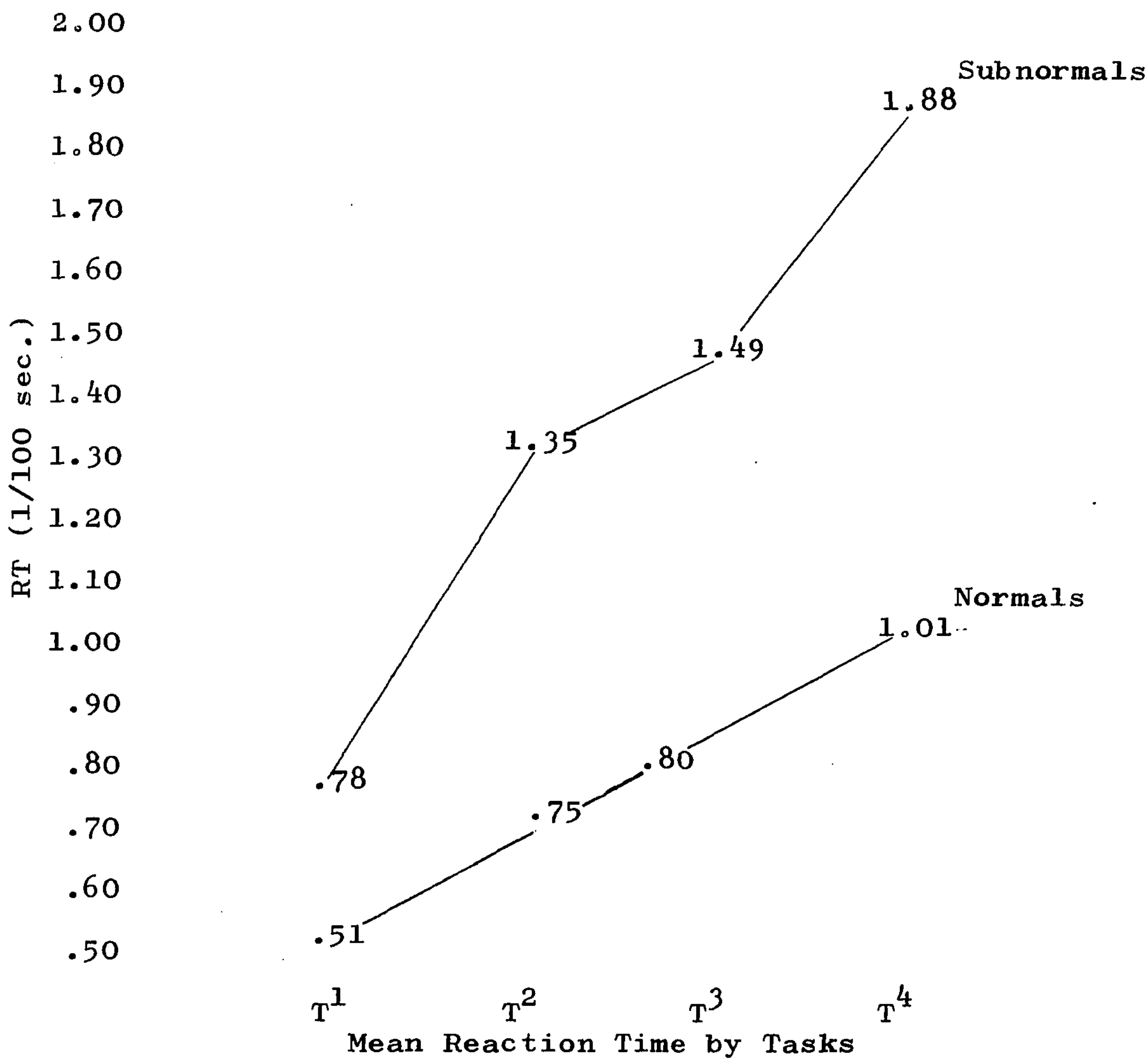
TABLE 14

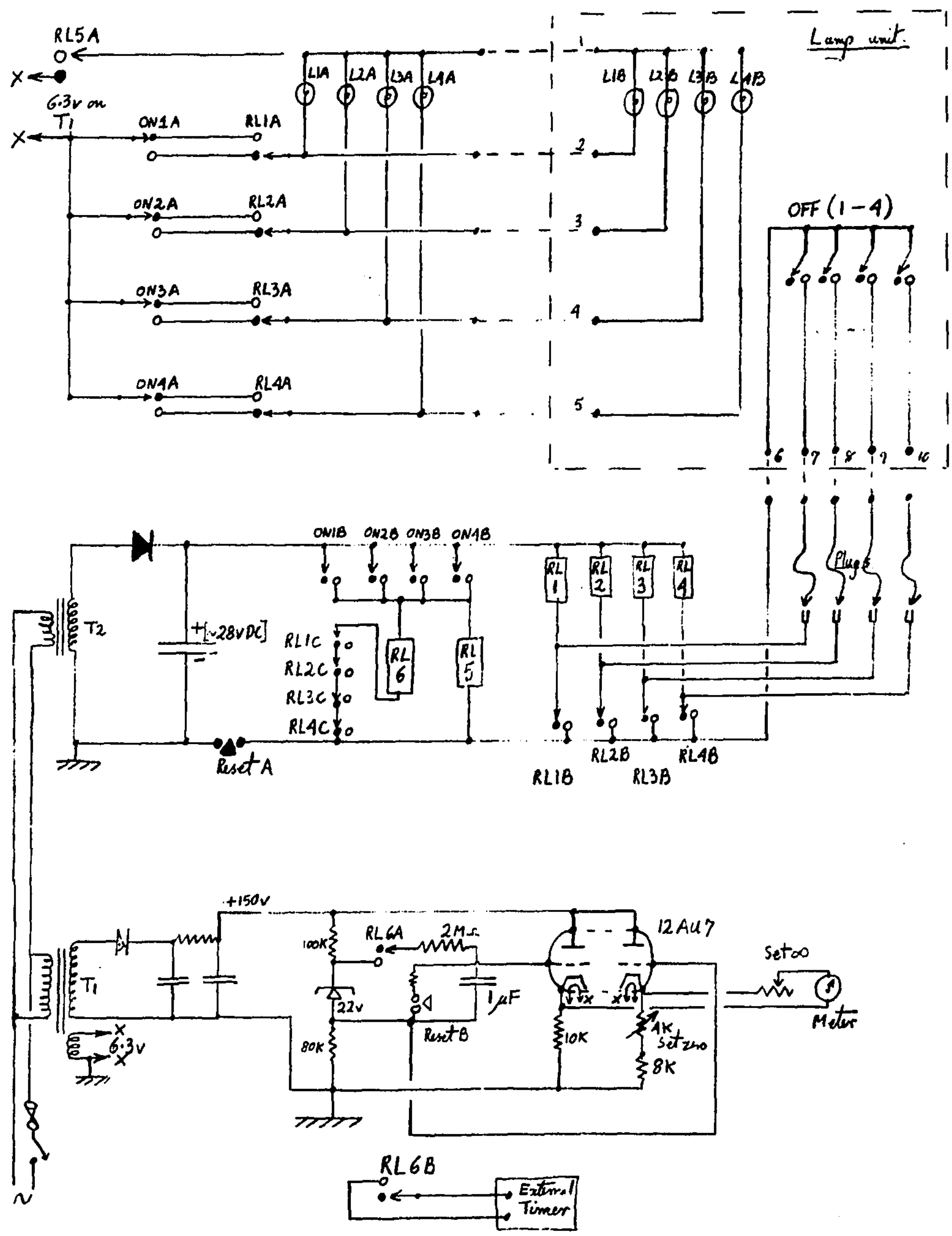
Significance of Inter-Taus for Normals

Variables	Tau	z	p
Tap - PB	.31	1.9	.0287
Tap - T^1	.25	1.5	.0669
Tap - T^2	.18	1.1	.1357
Tap - T^3	.03	.02	.4920
Tap - T^4	.06	.04	.4840
PB - T^1	.64	3.9	.00005
PB - T^2	.50	3.1	.0010
PB - T^3	.58	3.7	.00011
PB - T^4	.44	2.7	.0035
T^1 - T^2	.64	3.9	.00005
T^1 - T^3	.73	4.5	.00003
T^1 - T^4	.49	3.0	.0013
T^2 - T^3	.72	4.4	.00003
T^2 - T^4	.49	3.0	.0013
T^3 - T^4	.41	2.5	.0062

TABLE 15

Trend of Reaction Times Over the Various Tasks





CIRCUIT DIAGRAM OF REACTION TIME APPARATUS

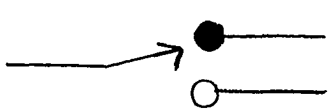
DESCRIPTION OF THE METHOD OF OPERATION

ON1 ON2 ON3 ON4	Switches to turn on lights.	(Each of these has two contacts, which are labelled ON1A, ON1B, etc.)
OFF1 OFF2 OFF3 OFF4	Key switches to turn off lights. These have one contact each.	

L1A L2A L3A L4A	Lamps on the control box.	L1B L2B L3B L4B	On the lamp unit.

RL1 RL2 RL3 RL4	Relays in the control unit which are operated when the subject moves the corresponding key switch. Each of these relays has three sets of contacts which are labelled RL1A, RL1B, RL1C, etc.
RL5	A lamp control relay operated whenever one of the "ON" switches is closed.
RL6	The timing relay - two sets of contacts.

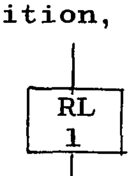
Switches and relay contacts are shown thus:



←Normally closed contact

←Normally open contact

The normally closed connection is made when switches are in the off position, or when relays are not energised.

The symbols 

and so forth mean the operating coil of the relay whose symbol is in the box.

Sequence of operations

Initially all relays and switches are in normal position.

1. An ON switch is closed. (e.g. ON1)
    a. Connection to lamps through ON1A.
    b. Connection to RL5, RL6 which operate.
    c. Lamp lights through RL5A etc.
    d. Timer starts through contacts on RL6.

2. Subject turns off light by moving one of the OFF keys. Here there are two possibilities according to whether or not the correct corresponding key has been operated.
When subject moves an OFF key the corresponding relay RL (1---A) operates and holds through its B contact. Timing relay stops through RL(1---A) C contacts in series.
   a. Correct relay has operated lamp goes out by opening of "A" contact on the relay.
   b. The wrong switch was pushed, the light corresponding to this relay comes on through its "A" contact.

3. When the ON switch is turned off, RL5A opens to extinguish lights.

4. When the "Reset" button is pushed, any of RL (1--A) which are holding operated return to normal position as "Reset A" contacts open.

   The internal timer returns to zero as "Reset B" discharges the 1 μF timing capacitor.

The circuit is now ready to go again.

Description of the internal timing unit

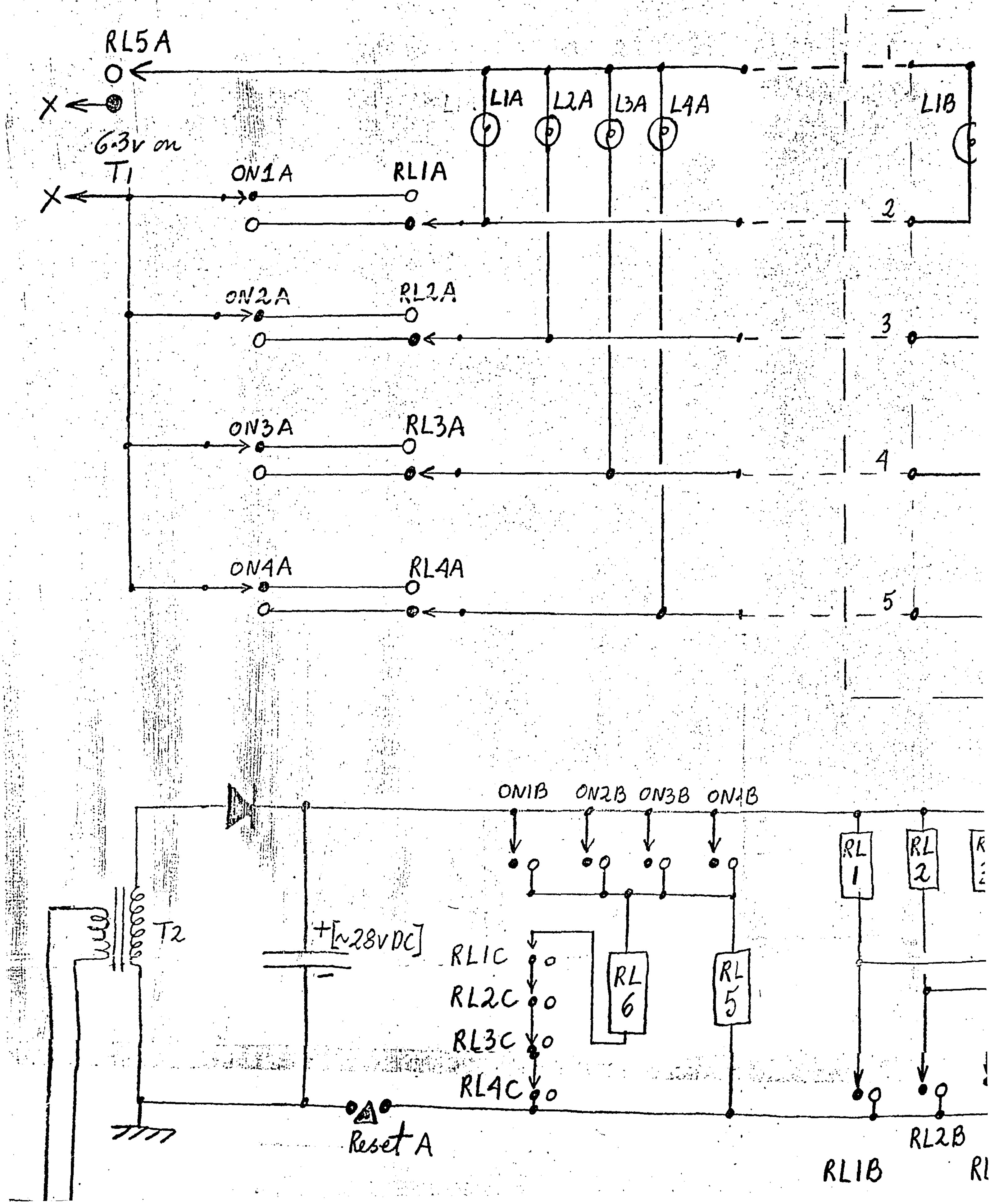
The internal timing unit operates by measuring the charge accumulated on a 1 μF capacitor which is connected to a stable 22v supply through a 2MΩ resistor while the timing relay RL6 is operated. The voltage across this 1 μF capacitor is applied to the two grids of a double triode tube with separate cathode loads across which a voltmeter is connected. The zero of the voltmeter is set by adjustment of one of the triode cathode resistors. This adjustment is made with the "Reset" button depressed. The full-scale sensitivity of the voltmeter is adjusted by allowing the capacitor to charge to its final voltage and the "Set∞" resistor in series with the voltmeter is varied to give a deflection to the ∞ mark on the meter scale.

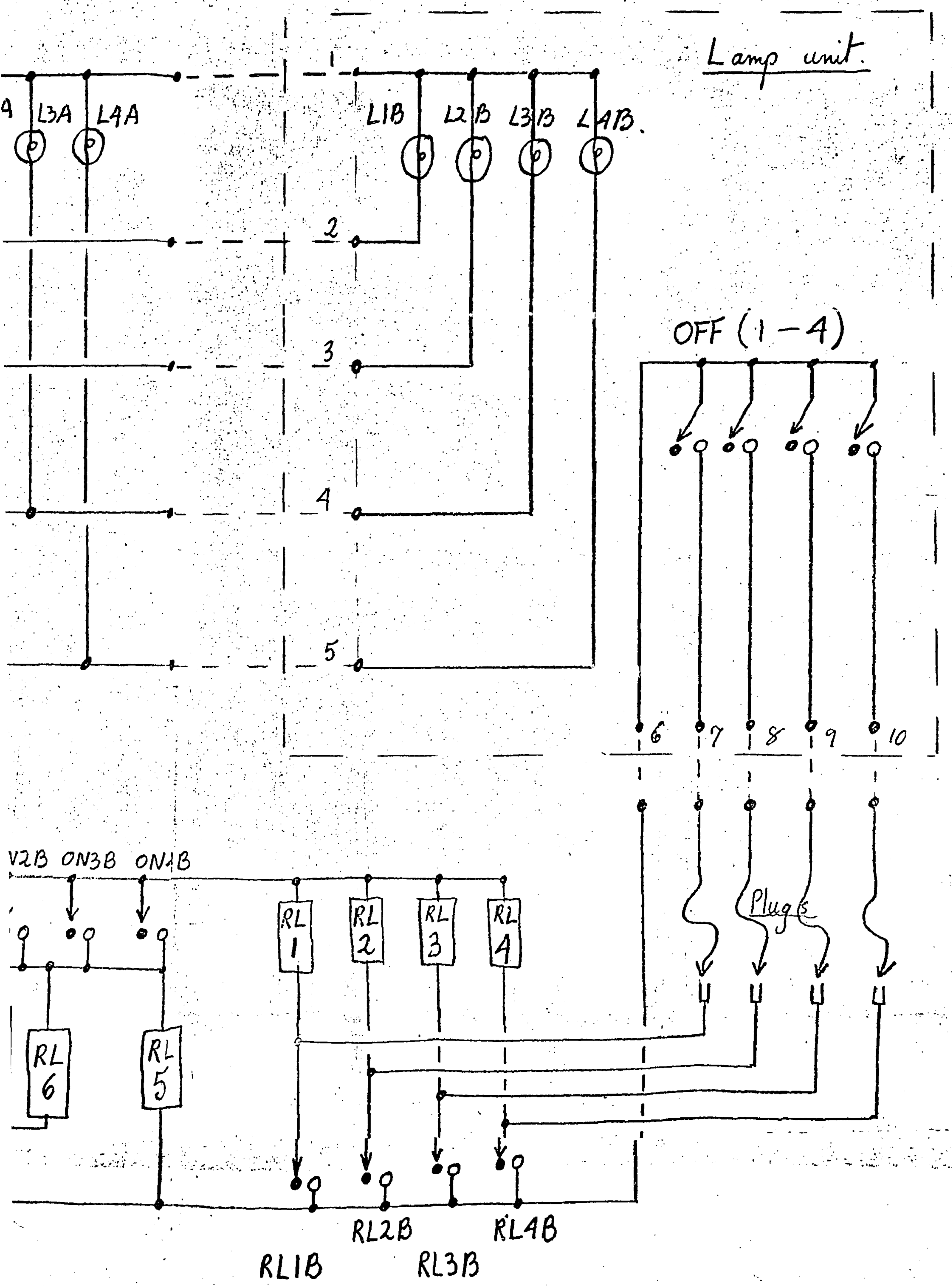
The meter is calibrated according to the charging law of a resistor - capacitor series combination.

$$V = V_o \left(1 - e^{-\frac{t}{cr}}\right)$$

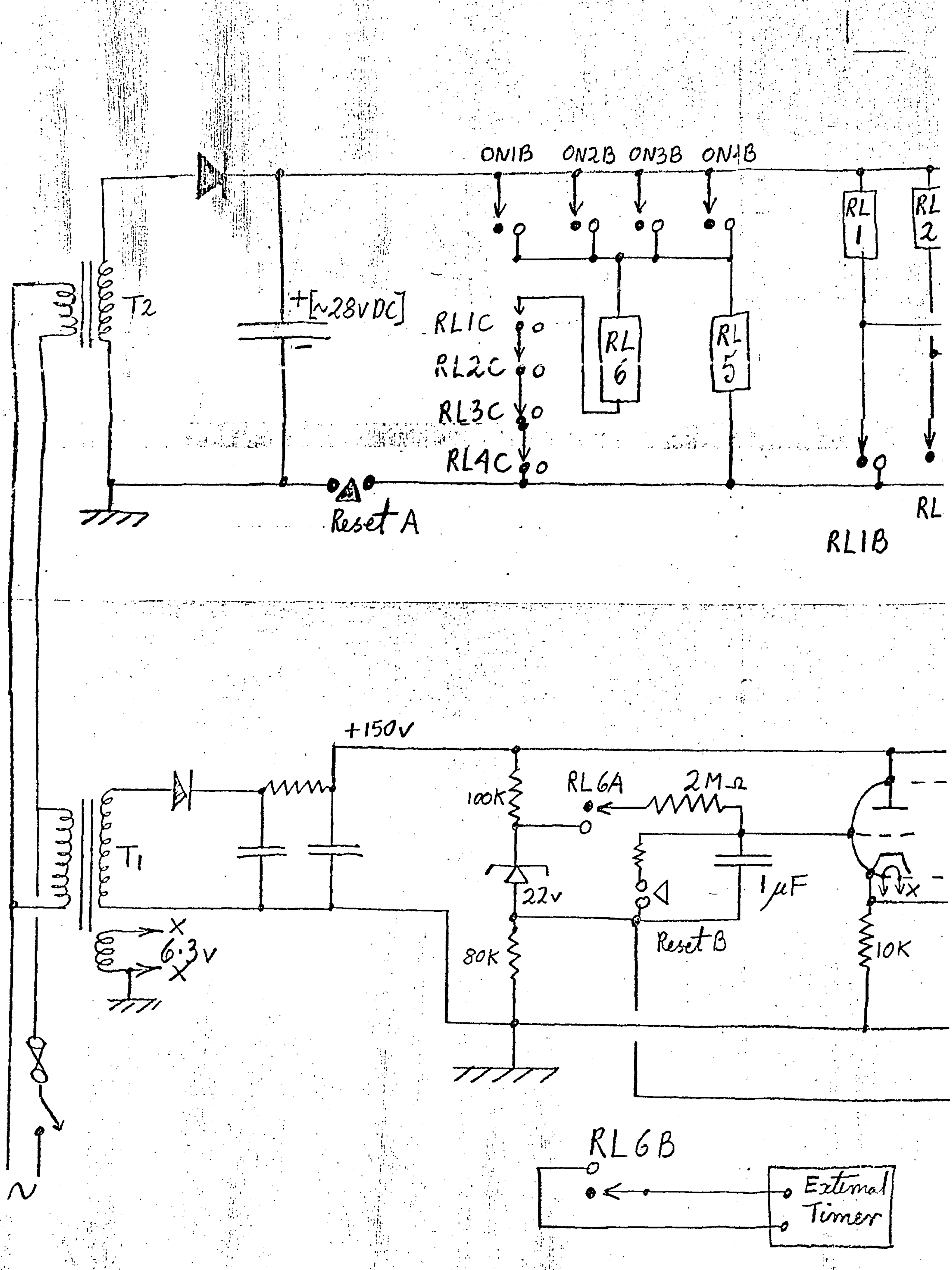
where CR, the charging time constant was adjusted to 2.0 sec.

An additional set of contacts on RL6, (RL6B) are brought out for an external timer.

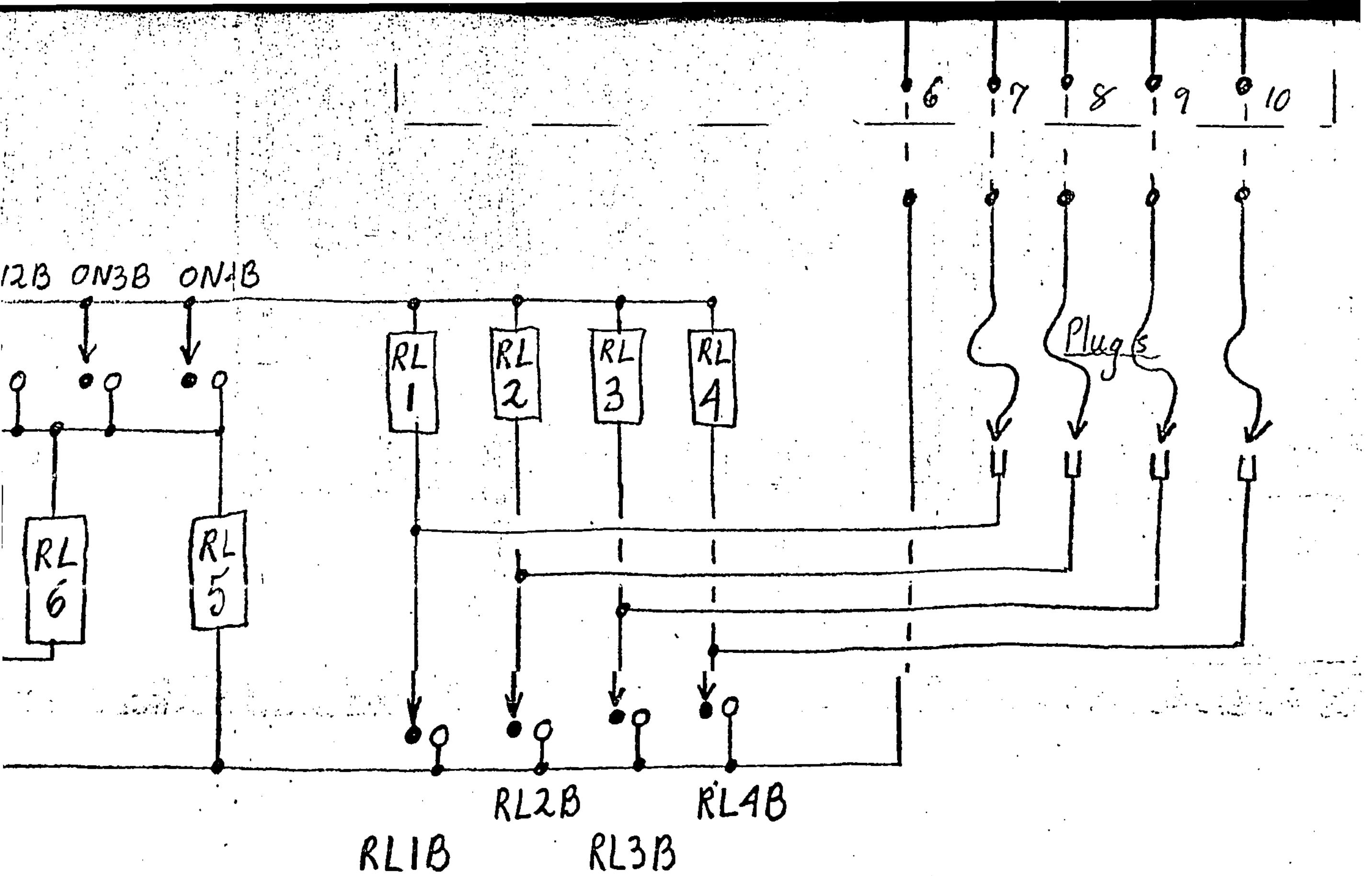

RL5A
X
6.3v on T1
X
ON1A
RL1A
L1A
L2A
L3A
L4A
L1B
1
2
ON2A
RL2A
3
ON3A
RL3A
4
ON4A
RL4A
5
ON1B
ON2B
ON3B
ON4B
RL 1
RL 2
T2
+[~28VDC]
RL1C
RL2C
RL3C
RL4C
RL 6
RL 5
Reset A
RL2B
RL1B

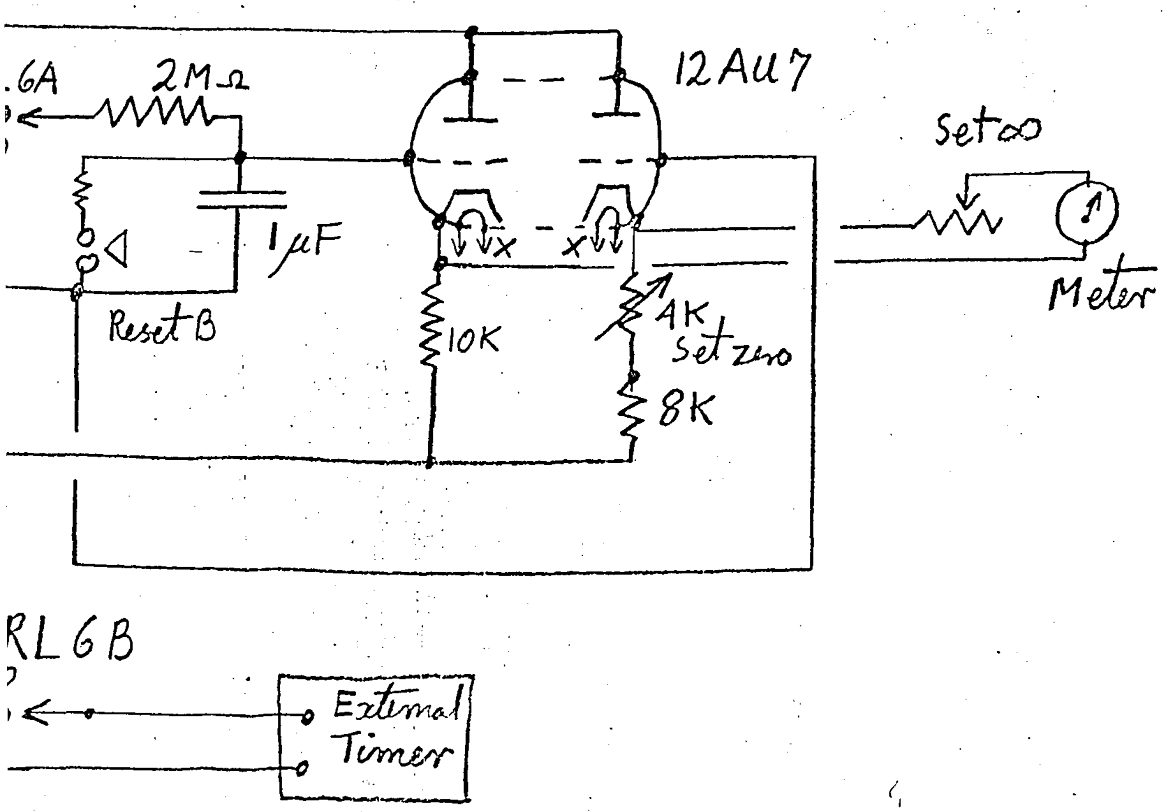


Lamp unit.
A
L3A
L4A
L1B
L2B
L3B
L4B.
1
2
3
4
5
OFF (1 – 4)
6
7
8
9
10
V2B
ON3B
ON4B
RL 1
RL 2
RL 3
RL 4
RL 6
RL 5
Plugs
RL1B
RL2B
RL3B
RL4B



ON1B
ON2B
ON3B
ON4B
RL 1
RL 2
T2
+[~28VDC]
RL1C
RL2C
RL3C
RL4C
RL 6
RL 5
Reset A
RL1B
RL
+150V
100K
RL6A
2MΩ
T1
22v
1μF
Reset B
6.3v
80K
10K
RL6B
External Timer


6
7
8
9
10
12B
ON3B
ON4B
RL 1
RL 2
RL 3
RL 4
Plugs
RL 6
RL 5
RL2B
RL4B
RL1B
RL3B


.6A
2MΩ
12AU7
Set ∞
1µF
Reset B
10K
4K
Set zero
8K
Meter
RL6B
External
Timer