EFFECT OF VARYING "REACTION TIME" FOREPERIODS UPON OVERT PERFORMANCE, AS MEASURED BY MUSCULAR POWER

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LA THÈSE A ÉTÉ MICROFILMÉE TELLE QUE NOUS L'AVONS REÇUE

Effect of varying 'Reaction Time' foreperiods upon overt performance, as measured by muscular power.

by

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A Thesis submitted in partial fulfilment of the requirements for the degree of Master of Physical Education

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St. John's Newfoundland

ABSTRACT

This study examined the possible relationship between reaction time 'foreperiod' length and optimal performances as measured by a test of muscular power. Specifically, several questions were asked:

1. Would the use of 5 different foreperiods (i.e. 1.0, 1.5, 2.0, 2.5 and 3.0 seconds) produce significantly different measures of muscular power for the same individual, using the same sub-maximal load* for all trials?

2. Which of the 5 chosen foreperiods would have 'no' effect or an 'equal' effect upon measured muscular power?

3. Could various foreperiods be used in a future investigation with reasonable certainty of no inherent experimental bias being introduced into the data, which might contaminate recorded measures of muscular power?

The ultimate problem was defined: Did 24 force-velocity trials with the same sub-maximal load, but with randomly varied reaction time foreperiods, induce significantly different scores of muscular power from the same individual? This was determined by comparing optimal performances for each foreperiod.

The alternative hypothesis (H_1) was tested:+ Any individual's average score of muscular power,** with a pre-determined sub-maximal load,* will be significantly different++ for each of 5 different foreperiods.

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* A load equivalent to 20% of each subject's maximal lift was used throughout.

\+ The author hoped to indicate that the Null Hypothesis (H_0) was, in fact, true.

** As measured using the apparatus designed for this investigation.

++ i.e. 'better' or 'worse'.

To test the Alternative hypothesis, a one-group repeated measures design, involving a single test, was employed. A random sample of 7 male students was tested, using specially constructed apparatus designed to (a) measure muscular power*, (b) vary foreperiods. The test consisted of 24 trials with randomly varied foreperiods; the subject was asked to respond to a green light, by kicking against a resistance as hard and fast as possible.

Mechanical principles governed both the construction of the measuring instruments, and the calculation of scores of muscular power from observed data. (A high reliability score ($r = 0.99$) was obtained for the measuring technique employed.)

The effect of the independent variable (i.e. randomly varied foreperiod) upon the dependent variable (i.e. measured muscular power) was ascertained; to compare performances with each of the 5 chosen foreperiods, an analysis of variance, utilising a repeated measures design with two experimental variables, was undertaken. Statistical analysis (two-tailed, at the 0.05 level of significance) indicated that the treatments effects (i.e. varying foreperiods) were insignificant, since the tabled F value was considerably greater ($= 5.664$) than the obtained value ($= 0.722$). Consequently no reasonable evidence existed for rejecting the Null Hypothesis (H_0); the Alternative Hypothesis (H_1) could be rejected with reasonable confidence, since the low observed F value indicated a relatively small chance of making a type II error.

* A bicycle-wheel lever was employed.

Differences between subjects were highly significant ($\alpha = 0.05$) with an obtained F value much larger (= 440.647) than the tabled value (= 2.214). Order of trials had no significant effect on performance ($\alpha = 0.05$), the obtained F value being smaller (= 2.532) than the tabled value (= 2.719). Each of the three first-order interactions was insignificant ($\alpha = 0.05$).

It was concluded that:

(1) Whilst an optimum foreperiod may exist for any reaction time task, results indicated that no such optimum foreperiod* exists for the muscular power task outlined in this investigation.

(2) Similar randomly varied foreperiods would not act as an intervening variable, contaminating observed scores of muscular power, in future investigations.

It was subsequently recommended for future investigations, that various sub-maximal loads be used together with randomly varied foreperiods*, when measuring simultaneously muscular power and reaction time.

* As defined in this investigation.

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*Not used in this investigation.

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PREFACE

This investigation represents one of a series of investigations, conducted as a pre-requisite for a future final investigation, in which it was hoped to consider the effect of a stressor on two performance parameters - SIMPLE REACTION TIME and MUSCULAR POWER - simultaneously.

It was hoped that data from these two potentially easily correlated performance parameters would enhance the predictive value of any experimental findings of the FINAL INVESTIGATION.

Specifically, the experimental design of the final investigation required a pre-test and post-test of each subject, each test being composed of 10 similar trials, but with (a) various pre-determined sub-maximal loads, (b) various pre-determined foreperiod times (between 1 and 3 seconds), randomly varied throughout the test. Both (a) simple reaction time and (b) muscular power, were to be measured on each trial of both tests. Performances under (1) no stress, and (2) stress, were then to be compared statistically.

CHAPTER ONE

INTRODUCTION

1.1 JUSTIFICATION:

Previously, some indirect relationships between muscular power and reaction time have been indicated (see: Review of Literature, p. 38, p. 40). Additionally, the relationship of reaction time and foreperiod has been clearly documented (see: Review, p. 36). However, few researchers have previously considered the possible relationship which might exist between reaction time foreperiod length and optimal performance, as measured by a test of muscular power.

This investigation was further justified, since the author hoped eventually, through a future investigation, to compare muscular power scores and reaction time scores of individuals under conditions of (a) 'no induced stress' with scores of individuals under (b) 'induced stress'. In this latter investigation, the foreperiod was to be necessarily varied, so that the subject would not 'react' to a constant time interval, which might otherwise provide a source of experimental contamination, when measuring reaction time. However, inherent in this suggested procedure was a further possible contaminating factor; since both optimal power output and reaction time (for any individual) were to be calculated on the basis of performance over 10 trials with various, randomly varied, sub-maximal loads, and since both the sub-maximal load and the foreperiod were to be randomly, and therefore independently, chosen for each trial of the test, it became essential to first determine whether ONE OF THESE INDEPENDENT VARIABLES (i.e. FOREPERIOD) WOULD AFFECT THE DEPENDENT VARIABLE (i.e. MUSCULAR POWER). It became necessary, therefore, to eliminate 'foreperiod', as a contaminating factor, for any future investigation, by indicating experimentally that no trials of muscular power were biased, either favourably or unfavourably, due to the use of any 1 of the 5 chosen foreperiods.* Such a bias would have prevented accurate prediction of optimal performance from observed scores.

For the two above mentioned reasons, this investigation attempted to determine the precise relationship of foreperiod (as here defined)* and measured muscular power.

1.2 STATEMENT OF THE PROBLEM:

Previous investigations (see: Review of Literature, p. 36, have indicated that:

(1) there was an optimum foreperiod for any reaction time task (2.11, p. 37);

(2) use of the optimum foreperiod, for any reaction time task, resulted in the fastest reaction times (2.11, p. 37);

(3) reaction time was correlated with speed of movement in a knee extension action (2.15, p. 40);

(4) reaction time varied inversely with the magnitude of muscular tension (2.12, p. 38);

(5) foreperiod length and muscular tension were independent in their effects on reaction time (2.12, p. 38);

(6) the amount of work required to make a response movement was directly related to reaction time (2.12, p. 39).

Several questions were thus posed:

(1) What was the relationship between foreperiod duration and overt performance (as measured by muscular power)?

* Foreperiods chosen = (1) 1.0 seconds, (2) 1.5 seconds, (3) 2.0 seconds, (4) 2.5 seconds, (5) 3.0 seconds.

(2) Would use of different foreperiods produce significantly different measures of muscular power for the same individual, using the same sub-maximal load for all trials?

(3) Which of the 5 foreperiods chosen for a future final investigation (i.e. 1.0, 1.5, 2.0, 2.5 and 3.0 seconds) would contaminate experimental data in the final investigation, thereby influencing recorded measures of muscular power?

(4) Which of the 5 chosen foreperiods would have 'no' effect, or an 'equal' effect upon measures of muscular power, and would therefore be permissible in a future final investigation?

(5) Could various foreperiods be used in a future investigation with reasonable certainty of no inherent experimental bias being introduced into the data?

The ultimate problem was thus defined:

(6) Did 24 force-velocity trials with the same sub-maximal load, but with randomly varied reaction time foreperiods, produce significantly different measures of muscular power for the same individual, as determined by comparing average scores of attained muscular power for each foreperiod?

1.3 RESEARCH HYPOTHESES:

Hypotheses were derived from the following statements:

(1) Movement of the same pre-determined sub-maximal load* by any individual over a set of 24 trials,+ by kicking a

* 20% of each subject's maximal lift was used.

\+ N.B. "Fatigue" was not considered to be an experimental variable in this investigati

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bicycle wheel lever with maximum effort, may or may not produce significantly different performances within the set, as measured by the maximum velocity* obtained during the movement, due to the use of randomly varied foreperiods.

(2) Use of 1, several or all 5, of the randomly varied foreperiods may or may not contribute towards significantly different results, as determined by the above criteria.

(3) An optimum foreperiod may, or may not, exist for optimum performance.

A. SCIENTIFIC HYPOTHESES:

1. MAIN HYPOTHESIS:

1 (a) Any individual will perform differently (i.e. 'better' or 'worse' on a simple motor task (muscular power test) with each of 5 different foreperiods, randomly assigned over a test of 24 trials.

1 (b) Optimum performance on a simple motor task (muscular power test) for any individual will be achieved by use of an optimum foreperiod.+

2. SUBSIDIARY HYPOTHESIS:

2 (a) Average performances of a group of 7 subjects on a simple motor task (muscular power test) will be different (i.e. 'better' or 'worse') with each of 5 different foreperiods, randomly assigned over a test of 24 trials.

---

* Measures of maximum velocity were converted to measures of maximum power by a simple calculation.

\+ i.e. within the range of foreperiods considered.

2 (b) Optimum performance on a simple motor task (muscular power test) for a group of 7 subjects, will be achieved by use of an optimum foreperiod for that group.

B. STATISTICAL HYPOTHESES (Alternative Hypotheses):

1. MAIN HYPOTHESIS:

1 (a) and 1 (b):

Any individual's average score of muscular power,* with a pre-determined sub-maximal load equivalent to 20% of his total possible 'lift', will be significantly different (i.e. 'better' or 'worse') for each of 5 different foreperiods.

i.e. $\langle \mu p^{s} f(1) \rangle$ or $\langle \mu p^{s} f(2) \rangle$ or $\langle \mu p^{s} f(3) \rangle$ or $\langle \mu p^{s} f(4) \rangle$ or $\langle \mu p^{s} f(5)$

Where: μp^{s} = Individual Average score of Muscular Power with a pre-determined sub-maximal load.

$f(1)$ = foreperiod of 1.0 seconds.

$f(2)$ = foreperiod of 1.5 seconds.

$f(3)$ = foreperiod of 2.0 seconds.

$f(4)$ = foreperiod of 2.5 seconds.

$f(5)$ = foreperiod of 3.0 seconds.

2. SUBSIDIARY HYPOTHESIS:

2 (a) and 2 (b):

Group average scores of muscular power, with a pre-determined sub-maximal load equivalent to 20% of each subject's total possible 'lift', will be significantly different (i.e. 'better' or 'worse') for each of 5 different foreperiods.

* As measured using the apparatus designed for this investigation (see p. 44).

i.e. $\mu p^s f(1) >$ or $< \mu p^s f(2) >$ or $< \mu p^s f(3) >$ or $<$ $\mu p^s f(4) >$ or $< \mu p^s f(5)$

Where: μp^s = Group Average score of Muscular Power with a pre-determined sub-maximal load.

$f(1)$ = foreperiod of 1.0 seconds.

$f(2)$ = foreperiod of 1.5 seconds.

$f(3)$ = foreperiod of 2.0 seconds.

$f(4)$ = foreperiod of 2.5 seconds.

$f(5)$ = foreperiod of 3.0 seconds.

1.4 LIMITATIONS OF THE STUDY:

(a) Apparatus:

(1) The lever attached to the bicycle wheel could be adjusted within a limited range of positions only. Consequently, some subjects found the lever ankle rest somewhat uncomfortable, even when the lever was adjusted to its optimum length. Such discomfort may have adversely affected performance for those subjects concerned.

(2) Due to crude measuring instruments, it became impossible to adjust lever length precisely* in relation to any individual's 'lower leg' length.+

(3) Precise calculation of the radius and hence circumference, of the bicycle wheel, around which the pulley chain was wound on kicking the lever, was impossible, due to the

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* See p. 45.

+ Lower leg length was measured between lateral condyle (right femur) and lateral malleolus (right fibula) - accurate to 0.5 cms.

existence of a groove around the rim of the wheel which housed the chain when the lever was kicked.*

(4) A constant amount of friction was caused by: (i) movement of the bicycle wheel, (ii) movement of the weights via a pulley system, (iii) grooving of the chain along the rim of the wheel; unfortunately, the pulley system was not exactly aligned with the rim of the bicycle wheel (see diagram 4, p. 47).

(5) Foreperiods were adjustable to within one-tenth of a second only.

(6) Some subjects were kicking the lever with the 'preferred' leg and some with the non-preferred leg. Due to the arrangement of the apparatus, this situation was unavoidable (see: p. 40, Review of Literature).

(b) Subjects:

(1) Unfortunately, as excessive amounts of time were required to (a) adequately familiarise each subject with the experimental apparatus, (b) conduct a pre- and post-test with sufficiently long inter-trial and inter-test rest intervals for each individual, only <u>10+ subjects</u> were tested. (Additionally, as only a relatively small finite population of physical education students existed for sample selection, and as other, future investigations remained to be conducted, sample size was restricted for each investigation.) The statistical treatment chosen

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* See: Apparatus, p. 77.

\+ Due to injury/illness, only 7 subjects completed the test.

for data analysis (F ratio test) would, more favourably, have utilised a somewhat larger sample size.*

(2) The random sample was selected from the total population of Physical Education students of Memorial University of Newfoundland.+ Accurately, any observations or inferences were therefore applicable only to this, or similar, populations in other Universities. (Any generalisations should therefore be applied with considerable caution.)

(3) Subject motivation levels were difficult to (a) ascertain, (b) stabilise, from day to day.

(c) <u>Testing Procedures</u>:

(1) The maximum weight that could be lifted by any individual 'kicking' the lever was determined by <u>estimating</u> the maximum lift, and working 'up' or 'down' to the maximum in as few increments as possible; however, since the number of trials needed to establish the maximum varied from subject to subject, varying fatigue levels influenced the maximum obtained.** Any limitations were partly overcome, however, by verifying each subject's maximum lift

* Final conclusions were based on data from a sample of only 7 subjects.

+ See p. 43, Sample Selection.

** This 'isotonic' method was considered superior, however, to the measurement of 'isometric' strength (by a cable tension testing method) since the <u>method chosen</u> was specific to the investigation.

on a second occasion.*

(2) Each subject required testing on 3 separate days, and although attempts were made to test any individual at the same time of day on each occasion, such a task proved extremely difficult. Consequently, Diurnal Rhythm may have been a slight contaminating factor in some instances, especially with respect to:

(i) STRENGTH - which has been shown to exhibit a diurnal variation.+ A source of error arose, since it was impossible to determine the subject's 'maximum lift' on the day of the final test, due to a possible fatigue effect. The maximum lift was assumed to equal that measured on the day previously.

(ii) MUSCULAR POWER - which may have been affected by the subject's diurnal rhythm.

(3) Although attempts were made to control diet, health, exercise and fitness during the course of testing, any one of several factors may have contributed to changing 'physiological' or 'psychological' states of any individual(s), which may have affected performance on one, or more occasions. Associated with this possible source of experimental contamination, was the likelihood of individual variability in motivation level over the 3-day period of testing.

* See p. 97 , Procedure.

+ Evidence of variation in grip strength with time of day has been presented; (see: Wright, D., 'for review'; 'Research Quarterly', 1959, Vol. 30, p. 114).

(4) Although leg power only was being measured, any individual may have used other muscles (e.g. back muscles) during the test. Although strict instructions were given to subjects, uniformity of interpretation could not be guaranteed.

(5) Since foreperiods were randomly varied, it was hoped that any practice or learning effect would be nullified. However, such an inference was not proven conclusively.

(6) Although random variation of foreperiods was designed to eliminate subject anticipation of the stimulus (i.e. eliminate a contaminating variable) such anticipation may have occurred anyway during some trials.

(7) As the test was composed of 5 blocks of 6 trials, better performances may have been biased in favour of certain foreperiods, depending upon their relative positions within each block of trials.

(d) Interpretation of Data:

(1) Human error may have arisen in fitting the 'line of best fit' to velocity curves obtained on the Beckman Recorder (see 'Methodology', p. 52).

(2) Only 30 trials were possible, to help guarantee no fatigue effect. Consequently, limited data was available for analysis.

(3) Obtained measures of muscular power could not be considered to be 'absolute' measures, since various limitations of the apparatus design could not be overcome within available time. Certain limitations of apparatus design have been enumerated (see: Methodology, p. 87); these limitations, fortunately, did not affect the

validity of any interpretation of data.

1.5 BASIC ASSUMPTIONS:

The following assumptions were made during this investigation:

(1) 'Fatigue' was not a contaminating variable. (This assumption was partially justified through a previous investigation in which subjects were tested on 2 occasions, the scores on each trial of test 1 being compared with those of test 2; scores at the beginning of each test were also compared with scores at the end of the test. No fatigue effect was found to be operating.

(2) The random sampling procedure adopted ensured selection of a representative group of subjects from the population of physical education students.

(3) Inferences made about the general population from the experimental sample, were necessarily valid; such inferences could be applied at least to similar populations in other Universities.

(4) All subjects carried out faithfully directions/instructions presented to them prior to the testing programme; subjects indicated honestly any variable factors (e.g. injury) which may have influenced performance, thereby constituting a threat to the internal validity of the investigation.

1.6 DEFINITION OF TERMS:

1. ANTAGONISTIC/AGONISTIC MUSCLE ACTION:

Movement depends not only on the co-ordinated activity of the muscles primarily responsible for the movement (agonists or protagonists) but also on that of antagonistic muscles.[1]

Each muscle or set of muscles that acts in one manner is balanced by another set that acts in the opposite manner. Muscles that act in an opposite fashion are called antagonists.[2]

2. BICYCLE ERGOMETER:

An ergometer ..... provides a precise means of controlling the amount of exercise (work) subjects perform when submitted to experimental treatment. The term "ergometer" means "work-measuring device".[3]

The friction type bicycle ergometer is often used in investigations.

WORK = FORCE x DISTANCE

Force is provided by friction between the belt and rim of the wheel; Distance is dependent on the distance the rim of the wheel travels.

3. FATIGUE:

A condition resulting from previous stress which leads to reversible impairment of performance and function, affects the organic interplay of the functions and finally may lead to disturbance of the functional structure of the personality; it is generally accompanied by a reduction in readiness to work and a heightened sensation of strain. Fatigue is dependent on the degree of stress or effort and on the characteristics and duration of the latter.[4]

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(1) Ganong, W. F.
'Review of Medical Physiology'
Lange Medical Publications, 1975, 7th Edition, p. 146.

(2) Thompson, R. F.
Introduction to Physiological Psychology
Harper and Row, New York, 1975, p. 254.

(3) Sinning, W. F.
Experiments and Demonstrations in Exercise Physiology
W. B. Saunders Co., London, 1975, pps. 9-10; p. 96.

(4) Eysenck, H. J., and Arnold, W. Encyclopedia of Psychology
Herder and Herder, New York, 1972, Vol. 1, A-F, pps. 369-370.

Here, 'fatigue' denotes the state which <u>results from</u> stress.

<u>Symptoms of fatigue</u>: Physical fatigue; changes in the muscle system; changes in muscular force, colloidal condition of the muscles, and disturbed peripheral co-ordination.[4]

<u>Causes of fatigue</u>: In the case of muscle fatigue, due to the impaired contractile capacity of the muscles, the cause is seen in metabolic disorders, primarily due to a lack of oxygen in the muscles.[4]

4. <u>MUSCULAR POWER</u>:

Considine[5] defined power as:

.... force times distance divided by time .... ; (5)

although frequently referred to as a motor element, <u>Power</u> is probably a composite of several different factors,

operating together to produce an explosive effort. Thus, muscular power should be defined as the rate of performing muscular work ... that is, power = $\frac{\text{work}}{\text{time}}$[6]

An accepted definition of power is that power equals force x velocity, interpreting force to mean strength and velocity to mean speed.[7]

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(4) Eysenck, H. J., and Arnold, W.
<u>Encyclopedia of Psychology</u>
Herder and Herder, New York, 1972, Vol. 1, A-F, pps. 369-370.

(5) Considine, W. J., and Sullivan, W. J.
Relationships of Selected Tests of Leg Strength and Leg Power on College Men
(<u>Research Quarterly</u>, 1973, Vol. 44, No. 4, p. 407.)

(6) Gray, R. K., Start, K. B., and Walsh, A.
Relationship between Leg Speed and Leg Power
(<u>Research Quarterly</u>, 1962, Vol. 33, No. 3, p. 395.)

(7) McCloy, C. H.
Recent Studies in the Sargent Jump
(<u>Research Quarterly</u>, May, 1932, Vol. 3, No. 2, p. 671.)

Glencross [8] has stated:

> Muscle Power, the ability to release maximum force as fast as possible, is displayed in the shot put, sprint start, jumping events, and in any movement which involves a maximum or near maximum muscular contraction against a resistance in a minimum of time.[8]

5. STRENGTH:

(i) Strength is the ability to exert force.[9]

(ii) Isometric/Isotonic Contractions:

Muscle contractions may be isometric or isotonic. An isometric contraction is the application of force with the muscle at constant length and with no limb movement. An isotonic contraction involves the application of force with a change in muscle length and limb movement. Two forms of isotonic contraction are identified: the concentric contraction, during which the muscle shortens, and the eccentric contraction during which the muscle elongates in a controlled, progressive manner, and resists the application of an external force.[9]

6. VELOCITY:

A vector quantity, specifying the rate of change of position of a body, together with its direction of motion.[10] The time rate of change of position. Velocity is a vector quantity; a statement of velocity therefore includes both a scaler magnitude, expressed in units of length divided by time, and a direction relative to some frame of reference. The defining equation for instantaneous velocity is: $v = dx / dt$, where x is the vector specifying position relative to an origin and t is the

(8) Glencross, D. J.
The Power Lever: An Instrument for Measuring Muscle Power
Research Quarterly, 1966, Vol. 37, No. 2, p. 202.

(9) Sinning, W. F.
Experiments and Demonstrations in Exercise Physiology
W. B. Saunders Co., London, 1975, pps. 9-10, p. 96.

(10) Thewlis, J.
Concise Dictionary of Physics
Perganon Press Ltd., Oxford, 1973, p. 346.

time.[11]

7. WHITE NOISE:

Noise is used as a technical term by communications engineers to refer to background interference irrelevant to the signal being transmitted. If this interference is random and contains many frequency components, it is called white noise.[12]

White noise is: .... random fluctuation noise; the noise that is heard when very many sound waves of different lengths are combined so that they reinforce or cancel one another in haphazard fashion.[13]

8. CHOICE REACTION TIME:

When a subject has learned various responses to various stimuli, the time measured from the presentation of a certain stimulus, to the beginning of the response of the subject that is correct for that stimulus.[14]

9. FOREPERIOD:

'Foreperiod' may be defined as the length of time between a warning signal, alerting a person to a stimulus, and the stimulus.

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(11) Van Nostrand, D.
The International Dictionary of Physics and Electronics
Van Nostrand Company Inc., Princetown, New Jersey
2nd Edition, 1961, p. 1216.

---

(12) Frith, C. D.
Encyclopedia of Psychology
Herder and Herder, 1972, Vol. 2, p. 327.

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(13) English, H. B., and English, A. C.
A Comprehensive Dictionary of Psychological and Psychoanalytical Terms
David McKay Co. Inc., New York, 1958, p. 347.

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(14) Wolman, B. B.
Dictionary of Behavioural Science
Van Nostrand Reinhold Co., 1973, p. 313.

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10. PSYCHOLOGICAL REFRACTORY PERIOD:

(i) A brief period following stimulation of a nerve or muscle during which it is unresponsive to a second stimulus.[15]

(ii) A brief period following the first movement of a movement system or set of related movements, when a second movement cannot be initiated, even though it is not antagonistic to the first.[15]

11. REACTION TIME:

Teichner (1954) stated:

Reaction time is the interval between the onset of the stimulus and the initiation of the response under the conditions that the subject has been instructed to respond as rapidly as possible.[16]

Reaction time is:

The time between the onset of a stimulus and the start of an overt response.[17]

Reaction time is the time required to get the overt

response started - i.e. the stimulus-response time interval.

12. SET OR DIRECTIONS:

An individual's set, or readiness for response, has a considerable effect on reaction time. The standard practice in experiments, is to signal the subject during a 'foreperiod' that a stimulus will soon be presented.[18]

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(15) English, H. B., and English, A. C.
A Comprehensive Dictionary of Psychological and Psychoanalytical Terms
David McKay Co. Inc., New York, 1958, p. 449.

(16) Teichner, W. H.
Recent studies of simple reaction time
Psychological Bulletin, 1954, Vol. 51, p. 128.

(17) Goldenson, R. M.
The Encyclopedia of Human Behaviour, Psychology, Psychiatry, and Mental Health
Doubleday and Co. Inc., New York, 1970, Vol. 2, p. 1099.

(18) Goldenson, R. M.
The Encyclopedia of Human Behaviour, Psychology, Psychiatry, and Mental Health
Doubleday and Co. Inc., New York, 1970, Vol. 2, p. 1100.

13. SIMPLE REACTION TIME:

Simple reaction time involves only one stimulus and one prescribed response.(19)

Four main latencies contribute to the length of Simple Reaction Time:

(1) Sense Organ Time, which varies between 140-180 milliseconds for the 'major' sense organs;

(2) Decision Time, in the central mechanism of the brain;

(3) Nerve Transmission Time;

(4) Muscle Time, the delay between the impulse arriving at the motor end-plate* and the actual muscular response.

(19) Wilson, G. D.
Encyclopedia of Psychology
Herder and Herder, New York, Editors: Eysenck, H. J., and Arnold, W., 1972, Vol. 3, p. 121.

* Motor end-plate: = terminal ending of nerve fibre.

CHAPTER TWO

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 The Concept of Muscular Power:

Muscular Power has been, and is, regarded as an important basic component of motor performance. Although frequently referred to as a motor element, Power is probably a composite of several different factors,

> operating together to produce an explosive effort. Thus, muscular power should be defined as the rate of performing muscular work .... that is, power = $\frac{\text{work}}{\text{time}}$ (22, p. 395).

An immediate problem was noted by Barlow (1):

> In physical education, the term explosive power is utilised in conjunction with the mechanical principle of power, that is, the rate of doing work. However, most efforts in this field to determine the generation of power by the human body have not adhered to mechanical definitions that govern the use of this term in the mechanical sense of force, work and power. (1, p.233)

Barrow and McGee (2) stated:

> Power is required for efficiency in such activities as jumping for height or distance, kicking a soccer ball or football, throwing or putting a ball or weight, striking with a bat or club, charging an opponent, and sprinting with short bursts of speed. (2, p. 246)

Elsewhere, Considine (14), referring specifically to the calculation of power generated in a vertical jump, defined power as:

> .... force times distance divided by time ....

The formula used to compute this composite power measure was:

$$\text{Power} = \frac{\text{force } gt^2}{t_1}$$

Where: force = the force of the accelerated object, that is, the weight of the man;

g = acceleration due to gravity.

t = the total elapsed time spent in the air.

t_1 = the length of time the force is applied. (14, p. 407)

Glencross (19) included 'near maximum' muscular contractions in his definition: *

> Muscle Power, the ability to release maximum force as fast as possible, is displayed in the shot put, sprint start, jumping events, and in any movement which involves a maximum or <u>near maximum</u>+ <u>muscular contraction against a resistance in a minimum</u> of time. (19, p. 202)

McCloy was more concise:

> An accepted definition of power is that: 'power equals force x velocity', interpreting force to mean strength and velocity to mean speed. (36, p. 235).

McCloy considered the concept of muscular power in considerable detail:

> In the human body, the power developed from an isotonic muscle contraction is dependent upon the force and the velocity of the contraction. McCloy (1954) has indicated that ... restrictions are placed upon the velocity of contraction of muscles functioning 'agonistically' by muscles functioning antagonistically. (35, p. 71)

McCloy has maintained that the speed of relaxation of antagonistic muscles is less than the speed of contraction of agonistic muscles; therefore, in activities where speed of contraction is important, the antagonists tend to restrict the agonists. <u>HOWEVER</u>, <u>McCloy's theory has NOT been proven</u>; antagonists may influence development of usable power.

2.2. <u>Relationships between Power, Speed and Strength</u>:

Berger and Henderson (3) indicated that:

> The relationships between leg power and both static and dynamic leg strength were highly significant, but not significantly different from each other. (3, p. 9)

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* This definition was probably more accurate, when considering <u>practical</u> examples of power.

\+ Author's emphasis.

Neither static nor dynamic strength was found to be more related to leg power than the other.* McClements (35) found that:

> Although strength (agonistic and antagonistic) is related to power, gains in strength are not related to gains in power. (35, p. 78)

However, conflicting evidence was produced by Start et al (52). Data indicated that power was linked with speed rather than strength:

> Speed, being the rate of change of position, involves no energetics (kinetic energy) which in a movement amounts to half the mass of the moving body times the square of its speed ($KE = \frac{1}{2} MS^2$). Power, being the rate of doing work, is twice the kinetic energy divided by time. With a known mass it should thus be possible to relate this specifically, i.e. $P = \frac{m}{t} . S^2$. (52, p. 558)

Several other studies have indicated a relationship between speed and power (see: 22, p. 396).

2.3 Measuring Muscular Power: The Sargent Jump:

Glencross (19) correctly insisted:

> There is a large variety of tests of muscle power, having their bases in physiological, physical and mechanical procedures. Of these different approaches, the mechanical methods+ when accurately applied, offer a valuable technique and lead into the measurement of muscle power developed by the human body. (19, p. 202)

Sargent regarded the original 'Sargent Jump' as a measure of power rather than of just work, for the velocity of the body and rate of doing work were important aspects of performance.**

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* This factor was considered when obtaining subjects' maximum lifts as a basis for measurements of power with various sub-maximal loads (see experimental procedure, p. 95).

+ Author's emphasis.

** See: Sargent, L. W.
Some observations in the Sargent Test of Neuro-Muscular Efficiency.
American Physical Education Review, 1924, Vol. 29, pps. 47-56.

However, the Sargent Jump (presented in 1921 as a test which Sargent called '<u>the physical test of a man</u>') as McCloy (36) pointed out:

> ... is primarily a test of the ability of the body to develop '<u>power</u>' relative to the weight and size of the individual. (36, p. 241)

Barlow (1) has found experimentally that:

> Power and total body weight were shown to have a high positive relationship in the Jump and Reach Test and the Modified Vertical Jump (r = .91 and .85 respectively). The development of power was shown to increase almost in direct linear manner with increases in weight.* This variable of weight was moderately related (r = .52) to physical height. (1, p. 233)

McCloy (36) has stated that:

> (i) The Sargent Jump when standardised, practised and correctly administered, is undoubtedly a valuable test. (36, p. 241)
>
> (ii) The Sargent type jump .... is probably the one best test we have for predicting the explosive energy (power). (36, p. 242)

However, both statements have been questioned and contradicted by recent experimental evidence;+

Val Dalen (56) has indicated possible contaminating variables:

> ... the record of any individual for the Sargent Jump may be affected by one or both of two factors. The first is the skill and co-ordination required to execute the jump correctly. The second is the ability to do one's best at any given time. (56, p. 113)**

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* This finding was in direct contradiction of the statements of previous investigations (1, p. 239).

+ See: Pardy, W.
A Comparison of Different Measures of Muscular Power
Unpublished Thesis, Memorial University of Newfoundland, 1976.

** In the following investigation, an attempt was made, through the <u>method of testing employed</u>, to eliminate both sources of possible contamination (see: procedure, p. 95).

Glencross (19), for aforementioned reasons, emphasised the:

> ... need for a measure of muscle power directly in terms of the mechanical principle of power,
>
> $$\text{POWER} = \frac{\text{FORCE x DISTANCE}}{\text{TIME}},$$
>
> which can be applied to numerous movements of the body and be more generally applicable than the measuring procedures reported above. (19, p. 203)

2.4 Measuring Muscular Power: Use of Mechanical Principles:

Some experimenters have measured work* rate during a constant time period:

> Power is the time rate of doing work over a given period of time. (56, p. 112)

Wilkie (59) employed a revolving crank attached to a bicycle wheel and measured speed of movement+ by scoring the number of revolutions in a given time. (59, p.249)

> The author preferred the bicycle ergometer as an instrument for measuring leg speed because the many variables involved in running were eliminated; whereas on the bicycle, with the feet strapped to the pedals, the distance the feet move at each revolution remains constant for all subjects, and standard conditions can be more easily maintained in the laboratory. (59, p.249)

Several other possible contaminating variables were overcome by Wilkie:

(i) The ergometer was bolted to a rigid framework which prevented unwanted movement when pedalling at high speed.

(ii) Toeclips and stop attachments on pedals prevented subjects' feet from leaving the pedals at maximum effort.

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* Work = Force x Distance.

\+ Author's emphasis.

(iii) Optimum duration of the test ride was sufficient to allow initial inertia of the machine to be overcome and full speed to be reached/maintained for a short period.

Glencross (19) has rightly insisted that, whilst most 'explosive' movements are mechanically complex, it is possible to measure the power exerted during this type of movement by permitting the body to work against an external load.*

Glencross (19) constructed a Power Lever,+ based on a wheel and axle lever system, to satisfy the following requirements:

(i) The body was allowed to work against an external load.

(ii) The body operated as the work input or effort source of this machine system.

(iii) All individuals had the same opportunity and were not handicapped or limited in any way in this force development.

(iv) The human body put INTO the machine all the force that it developed.

(N.B. It was assumed that the power developed in the movement of the external load could be used as a measure of the power developed by the body.)

Design of Apparatus

Structurally:

(i) the lever arm was attached to a similar steel rod forming the axle, which was firmly attached to a steel base;

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* (N.B. The power developed in the movement of this load can be used as a measure of the power developed by the body.)

+ The basic principles involved in Glencross' study were incorporated into this investigation (see Procedure, pps. 94-103).

(ii) the lever arm could be freely moved - clockwise and anti-clockwise - through 190°;

(iii) at the other end of the axle to the lever arm was a pulley, locked to the axle by a steel pin;

(iv) the resistance against which the body exerted its effort was supplied by known weights that could be attached to the pulley by means of a steel rope;

(v) the body/limb was attached to the power lever by means of a handle attached to the lever arm;

(vi) the effective lever length could be altered by changing the position of the handle on the lever through an adjustable screw;

(vii) timing devices were controlled by three micro-switches.

Measuring power developed by the body

(i) the 3 components of the power equation - FORCE, DISTANCE and TIME - were calculated.

(ii) Distance measured = distance through which the force travelled.

(iii) Point of application of force = handle on the lever arm to which the body was attached, (thus, the distance the force travelled = the arc distance (d), with the lever length, from the fulcrum to the handle, as the radius).

(iv) Arc distance (d) was directly proportional to the height (h); the weights were raised on the pulley in accordance with the velocity ratio (n) of the power lever.

(v) The component time (t)(= the time taken for the applied force at the handle to travel distance (d)) was measured using a chronoscope.

POOR PRINT

(vi) The force exerted over distance (d) was also estimated:

2 force components were considered:-

(1) STATIC FORCE (F), required to move the weights with low velocity and zero acceleration (determined by using a spring balance attached at right angles to the lever arm);

(2) FORCE exerted in ADDITION to static force, giving the weights, their acceleration and resultant velocity.*

(vii) The average H.P.+ developed by the body was determined from the equation:

$$\text{Average H.P.} = \frac{F \times d + \frac{v^2}{64}\left[\frac{M_1}{\frac{1}{n^2}} + M_2 + M_3 \frac{1}{\sqrt{3.r}}\right]^2}{550t}$$

(viii) this equation was reduced to a more workable form;** the only calculation involved was 'V_1': the tangential velocity at the handle, obtained directly from specially constructed tables.

GLENCROSS' STUDY REPRESENTED A MORE PRECISE ATTEMPT TO MEASURE MUSCULAR POWER ON THE BASIS OF MECHANICAL PRINCIPLES.

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* This was the kinetic energy of the moving parts, and depended upon their mass and velocity. (Moving parts = weights (including pulley and attachments) lever and handle. N.B. To determine the kinetic energy of any moving part, its mass and final velocity must be known).

+ (= Horse Power).

** The values of the static force F, masses M_1, M_2, M_3, distance (d), and velocity ratio (n) were constants.

POOR PRINT

Glencross found that average H.P. developed by legs in a preferred leg extension was 0.44, and in a non-preferred leg extension was 0.45.*

Reliability and objectivity reported for Glencross' instrument indicated a high level of stability and consistency for the tests conducted. The validity of this instrument depended mainly upon assumptions and conditions involved in the application of the above mentioned mechanical principles:

(i) During the test, the experimenter ensured that the subject was comfortable.

(ii) All subjects were given adequate prior practice to control any learning factor in the re-test.+

(iii) No fatigue effect was assumed to be operating (see: p. 92 (c).

(iv) The subject was told to move the lever as fast as he possibly could through the range of movements.

2.5 Knee Angle and the Measurement of Leg Strength:

Carpenter found that highest scores for static leg strength were obtained with knee angles between 115°-124°.**

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* This finding applied only to the population of students studied in his investigation.

\+ This consisted of trials on the power lever until a plateau in performance was reached.

** See: Carpenter, A.
A Study of Leg Angles in the Measurement of Leg Lifts. Research Quarterly, 1938, Vol. 9, pps. 70-72.

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Everts and Hathaway recommended a knee angle of approximately 130°.[*] McCloy reported highest readings at an angle of 120°.[+] Hugh-Jones reported that leg strength scores increased with progressively greater knee angles up to 160°.[**] Haxton estimated a 42% increase in leverage as knee angle increased from 60° - 125°.[++]

Lindeburg found no significant difference in maximum strength in an inverted leg press at the beginning of the pull in angles ranging from 100° - 140°.[***] But knee angles at the moment of maximum score were approximately 20° greater than at starting angles.[+++]

In an attempt to clarify this somewhat conflicting evidence, Linford and Rarick (31) conducted a similar study. All angles

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* See: Everts, E. W. and Hathaway, G. J.
The use of a Belt to Measure Leg Strength Improves the Administration of Physical Fitness Tests.
Research Quarterly, 1938, Vol. 9, pps. 62-69.

\+ See: McCloy, C. H. and Young, N. D.
Tests and Measurements in Health and Physical Education.
New York : Appleton-Century Crofts Inc., 1954.

** See: Hugh-Jones, P. H.
The Effect of Limb Position in the Seated Subject on Ability to Utilise the Maximum Contractile Force of the Limb Muscles.
Journal of Physiology, 1947, Vol. 105, pps. 332-344.

++ See: Haxton, H. A.
A Comparison of the Extension of the Knee and Elbow Joints in Man. Anatomical Records, 1945, Vol. 93, pps. 279-86.

*** This finding served as a basis for determination of subjects' maximum lift in the following investigation (see: Procedure, pps. 87-94).

+++ See: Lindeburg, F. A.
Leg Angle and Muscular Efficiency in the Inverted Leg Press.
Research Quarterly, 1964, Vol. 35, pps. 179-83.

within the range 135° - 164° produced leg strength scores which were significantly higher than those obtained with knee angles between 115° - 134°.

Knee angles between 125° and 134° produced significantly higher scores than those obtained with knee angles in 115° - 124° range.*

McClements (35) has used this finding to investigate the relationship of Power to Strength of leg muscles. He placed the subject in an upright sitting position at one end of a table with his test leg flexed at the knee at 115°, his hands placed flat on the table, and his shoulders stabilised from a position on top of the table by an assistant.

2.6 Fatigue and Muscular Power:

Relatively few studies have attempted to:

(a) measure the effect of fatigue on muscular power;

(b) control the investigation of muscular power sufficiently to reduce or prohibit any possible endurance factor contaminating the results;

(c) statistically assess the reliability of the controls, and the possible fatigue effects, by determining whether any significant impairment of performance has occurred+ during any investigation of muscular power. Here, a major weakness of most studies of muscular power has existed (but, see Lotter (32)).

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* These results were similar to those of Lindeburg and Berger.

\+ As measured by muscular power on a pre/post-test basis.

Gray, Start and Walsh (22), in an investigation of leg power, attempted to prevent the introduction of an endurance factor, by allowing a 'test ride' of only short duration. However, they assumed that this aim was accomplished, but obtained no statistical evidence to reinforce their belief. The problem of test-retest reliability involved multiple efforts, and the possible fatigue effects of consecutive efforts needed to be considered.

Glencross (19) attempted to control error variance due to fatigue by providing adequate time for recovery after the first test. Again, however, no statistical evidence was presented to verify the assumption that error variance was not a contaminating factor.

2.7 <u>Sample Selection for Muscular Power Investigations</u>:

Linford and Rarick (31) used 20 randomly selected male University graduate students to measure the effect of knee angle on leg strength. McClements (35) chose 86* male, college physical education students to compare power with leg and thigh muscles strength. Berger and Henderson (3) selected a population of 66 male college weight-lifting students to determine the relationship of power to static and dynamic strength. Start et al (52) subjected 63 first-year male members of a primary teachers' College to a variety of physical measures (including power) of the lower limbs. Considine and Sullivan (14) tested 38 male undergraduate physical education student <u>volunteers</u> for leg power.

Gray, Start and Walsh (22) collected an:

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* (i.e. the total population of physical education students.)

available sample of 62 medically fit male Teachers' College students.*

to investigate the relationship between leg speed and leg power. Barlow (1) tested 30 male student volunteers to investigate the relationships between power and measures of vertical displacement. Gray, Start and Glencross (21) selected 80 male Teachers' College students to test vertical leg power.

Glencross (19) measured the power developed in four movements on 85 male Teachers' College students.

Observations

(i) All investigations used Male subjects.

(ii) All investigations selected students.

(iii) Usually Student Teachers were tested; most often these were students of physical education.

(iv) Sample numbers varied from 30 to 86.

(v) The random sampling process adopted in most studies allowed valid inferences/generalisations to be made on the basis of careful observations/manipulation of specific variables within a small representative proportion of the population. However, several studies (35, 3, 52) used the whole population available. Logically, any inference could be accurately related only to the population studied.

(vi) Two studies (1, 14) used volunteers, which may have introduced 'selection bias' as a contaminating factor, thereby affecting the internal validity of any findings.

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* (22, p. 397).

(vii) One study (22) used an available sample. This was a questionable procedure, since ordinary methods of statistical inference were not validly applicable to such groups.*

(viii) Several studies (19, 21) did not indicate a random sampling procedure; this could only be assumed.+

2.8 Relationship Between Force and Velocity:

Although it has been reasonably supposed that movement of an optimum load allows maximal power output, almost no research has attempted to indicate the percentage maximal load necessary for such optimal performances. Glencross (19) recommended:

> There is a need to determine the optimum load for maximum power development. This load could be expressed as a percentage of the isotonic or isometric strength of the muscle groups involved. (19, p. 210)

Load-Speed Relationships:

The effect of load on the speed of muscle contraction was studied originally in excised muscles; as the load placed on the muscle increases, the rate of shortening (i.e. contraction) decreases, until a rate of zero velocity is reached at maximum isometric tension. A. V. Hill (24) has derived a mathematical equation to express this effect.

Idealised Relationships:

Sinning (50) has indicated idealised relationships between:

(a) angular velocity and load (see diagram 1),

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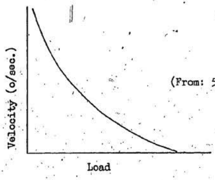
* This research, therefore, cannot be considered satisfactory.

\+ Caution was therefore exercised when considering the findings of these studies.

(b) work accomplished and load (see diagram 2), and

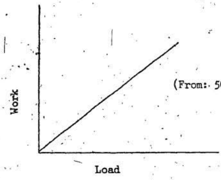
(c) power and load of muscle shortening in vivo (see diagram 3).

(a) Diagram 1 : Relationship between angular velocity and load of muscle shortening in vivo.*



(From: 50, p. 16)

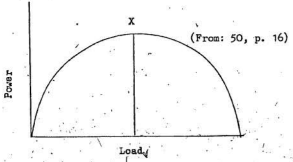
(b) Diagram 2 : Relationship between work accomplished and load of muscle shortening in vivo.



(From: 50, p. 16)

* See: Hill, A. V.
Proceeds of the Royal Society, 1938, B, Vol. 126, p. 136.

(c) Diagram 3 : Relationship between power and load of muscle shortening in vivo.*



(N.B. Optimum load for developing maximum power when the muscle contracts at its maximum rate = X, where broken line intersects the abscissor.)

2.9 SIMPLE REACTION TIME (Introduction)+:

Teichner's classical definition of Reaction Time stated:

> Reaction time is the interval between the onset of the stimulus and the initiation of the response, under the conditions that the subject has been instructed to respond as rapidly as possible. (53, p. 128)

Woodworth and Schlosberg (60) have identified two categories of reaction time (R.T.):

(1) Simple R.T.

(2) Choice R.T. (or Disjunctive R.T.).**

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* See: Hill, A. V.
Proceeds of the Royal Society, 1938, B, Vol. 126, p. 136.

\+ As a wealth of verified experimental knowledge abounds in this area, some important established concepts have been noted in the following review, many of which have been assumed to be accurate, and have been utilised as the basis for this investigation.

** The following study required an understanding of the underlying principles governing SIMPLE REACTION TIME only.

Simple Reaction Time (S.R.T.):

Here a fixed stimulus and a fixed response have been recognised. S.R.T. was usually established by a Keypress response to a single illuminated light in the laboratory. (For example, see 13).

A digital timer has been used to ascertain the time delay between the onset of the presentation of the light and the subject's response in pressing the key (see 10).*

Reaction time has been shown to be not constant, but likely to be affected by several variables. Robb (48, p. 87) has indicated that the response at any given moment depends upon both internal and external factors, including:

(1) learning and anticipation;

(2) the probability or certainty of the stimulus occurring;

(3) the presence or absence of a warning signal before the stimulus occurs;

(4) the psychological refractory period;

(5) the compatability of the response to the stimulus;

(6) the type of reaction time test (simple or choice);

(7) the length of the neural impulse;

(8) set, or directions.+

2.10 THE PROBABILITY OF STIMULUS OCCURRENCE:

It has been shown (48) that if a person knows when a stimulus will occur, reaction time may approach zero, due to anticipation.

* The average S.R.T. which might be expected as a result of stimulation of vision (180 milliseconds) was estimated by Woodworth and Schlosberg (60).

+ Only some of these factors were relevant to the following study.

(If a person cannot anticipate a stimulus, referred to as temporal uncertainty) the reaction time will be longer than if the stimulus appears at regular intervals.

2.11 PRESENCE OR ABSENCE OF WARNING SIGNALS:

A warning signal alerting a person to the stimulus has been found to affect R.T. The length of time between the warning signal and the stimulus has been termed the FOREPERIOD.* Several investigations have attempted to determine the effect of length of the foreperiod on simple reaction time (see: 17, 18, 33, 41). Although conflicting results have sometimes been presented, some general conclusions have been made. Druzin (15) investigated the effect of foreperiod length on reaction time, varying the foreperiod from 2 seconds to 0.125 seconds. Results indicated that R.T. was slower for relatively short foreperiods. When the range of foreperiods exceeded 0.5 seconds, R.T. tended to decrease initially as a negatively accelerated function of foreperiod.

Foley (17) found that an effective foreperiod of 2 seconds resulted in significantly faster reaction times than those of 4 and 8 seconds.+ Geblewicz (18) found that when differences between successive preparatory periods were small and regular, reaction times were 'shorter'; when differences were greater and irregular, reaction times were 'longer'. He concluded that the optimal length of the preparatory period:

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* The foreperiod is varied so that the subject will not react to a constant interval.

\+ Foley (17) also found that the duration of the ready signal was not a factor in determining an optimum reaction time.

(i) depended on the size of differences between preparatory periods;

(ii) was 1.0 to 1.5 seconds for 'small', regular differences;

(iii) was 1.5 to 2.0 seconds for 'greater' differences.

He also found that:

(i) longest reaction times were obtained after preparatory periods of 0.5 seconds;

(ii) reaction times were shortest (in a series of measurements) when the preceding preparatory period was shorter than the last one.

Lueft (33) found that when foreperiods were varied (1, 3 and 5 seconds), no differential effect upon speed of response among foreperiods occurred. (However, his experimental design seems doubtful (see 33).)

Näätänen (41) concluded that the main reason for diverging tendencies noted was the information - generating nature of passage of time following warning signals, in R.T. experiments with randomised foreperiods of different durations.

Available data was accurately summarised by Welford (57):

> The warning period, or foreperiod, is usually varied between 1 and 4 seconds, and the longer the foreperiod, the more hesitant will be the response, and a foreperiod longer than 3 seconds was found to be of no advantage to the subject. (57, p. 189).

2.12 RELATIONSHIP OF MUSCULAR TENSION AND REACTION TIME:

Teichner (54) found that foreperiod length and muscular tension were independent in their effects on reaction time. He concluded that R.T. varied inversely with the magnitude of muscular tension.

Kayan (27) investigated the effect of induced tension on R.T.

Results suggested that induced tension was often superfluous to already existing muscular tension created by "set".*

Murphy (38) concluded that the amount of "work"+ required to make a response movement was directly related to R.T. He also observed that the amount of pre-stimulus induced muscular tension significantly affected R.T. performance.** Overall effect of muscular tension levels on R.T. showed both linear and curvilinear components.

2.13 CONSTRUCTION OF R.T. APPARATUS:

Kerr (29) has designed and constructed apparatus which was used to measure R.T. of a knee-extension movement. The unit employed a 'Honeywell' standard microswitch. Two neon lights served as warning and stimulus lights.

Cahoon (10) has described 2 methods of modifying a standard electric stop-clock to serve as a reaction time device; an easily constructed control box was used to interrupt the power source of the clock. However, this approach was less accurate than a second method, where the control box was wired into the clutch control circuit of the timer. The latter modification was more complicated and relatively permanent.++

* Findings are questionable, since only 2 subjects were used in this investigation.

\+ Work = Force x Distance (through which force acts).

** Initially, the amount of muscular tension was directly related to R.T., but as subjects reached a certain '<u>level</u>' of skilled performance, there was little, if any, effect of tension on R.T.

++ The apparatus design for the present study was based on apparatus designed by the author for a previous investigation (see: 39).

(v) The component time (t)(= the time taken for the applied force at the handle to travel distance (d)) was measured using a chronoscope.

2.14 METHODS OF MEASURING REACTION TIME:

Many investigators have measured R.T. by asking subjects to press a telegraph key in response to an auditory or visual stimulus thereby stopping a timing device upon initiation of an overt response (see 44).

Richter and Hyman (47) demonstrated a shorter response time (i.e. shorter R.T.) for a hand-initiated response than for a foot-initiated response. Nakamura and Saito (43) found that flexion of the non-preferred hand was faster than that of the preferred hand, and supination of the preferred hand was faster than that of the non-preferred hand. Peisakhov (45) concluded that simple R.T. was 20-30 milliseconds shorter ($p = .001$) and more stable ($p = .001$) when subjects released a response button than when they pressed it.

2.15 RELATIONSHIP BETWEEN SPEED OF REACTION AND SPEED OF MOVEMENT:

Kerr (29) tested 47 male students for speed of reaction in a knee extension movement of 68°. Each subject was tested over 20 trials. To avoid any contaminating effect, only the last 15 trials were analysed. A week later, the subjects were retested. In both tests, R.T. correlated with speed of movement. ($r = 0.538$ and 0.629 respectively).

CHAPTER THREE

METHODOLOGY

3.1 NULL HYPOTHESES (Experimental Hypotheses)

1. MAIN HYPOTHESIS:

1 (a) and 1 (b):

Any individual's average score of muscular power, with a pre-determined sub-maximal load equivalent to 20% of his maximal 'lift', will not differ significantly (i.e. be 'better' or 'worse') for each of 5 different foreperiods.

i.e. $\mu p^s f(1) = \mu p^s f(2) = \mu p^s f(3) = \mu p^s f(4) = \mu p^s f(5)$.

Where: μp^s = Individual Average score of Muscular Power, with a pre-determined sub-maximal load;

$f(1)$ = foreperiod of 1.0 seconds;

$f(2)$ = foreperiod of 1.5 seconds;

$f(3)$ = foreperiod of 2.0 seconds;

$f(4)$ = foreperiod of 2.5 seconds;

$f(5)$ = foreperiod of 3.0 seconds.

2. SUBSIDIARY HYPOTHESIS:

2 (a) and 2 (b):

Group average scores of muscular power, with a pre-determined sub-maximal load, will not differ significantly for each of 5 different foreperiods.

i.e. $\mu p^s f(1) = \mu p^s f(2) = \mu p^s f(3) = \mu p^s f(4) = \mu p^s f(5)$.

Where: μp^s = Group Average score of Muscular Power with a pre-determined sub-maximal load;

$f(1)$ = foreperiod of 1.0 seconds;

$f(2)$ = foreperiod of 1.5 seconds;

$f(3)$ = foreperiod of 2.0 seconds;

$f(4)$ = foreperiod of 2.5 seconds;

$f(5)$ = foreperiod of 3.0 seconds.

3.2 EXPERIMENTAL DESIGN:

This investigation employed a ONE GROUP DESIGN, involving a single test of 20 observations.* (i.e. 4 observations for each of 5 different treatments) per subject. Measures of muscular power were obtained under 5 different conditions, the condition being randomly varied from trial to trial. The effect of a single INDEPENDENT variable (i.e. randomly varied FOREPERIOD) upon a single DEPENDENT variable (i.e. measured muscular power with a predetermined sub-maximal load) was ascertained.

3.3 SAMPLING PROCEDURE:

An original sample of 10 naive subjects+ was obtained, with homogeneity for sex, occupation, and educational level. Ten male physical education students (mean age = 22 years, 9 months; standard deviation = 5.7) were randomly sampled from a population of 94 male physical education students (age range = 17 years, 0 months - 36 years, 4 months; mean age = 21 years, 9 months) at Memorial University of Newfoundland.

A random sampling number table was used to select subjects (see: Table 3, p. 139 Appendix) thereby ensuring, through this sampling with replacement technique, that for all subjects, there was equal probability of being selected.

These 10 selected subjects comprised the single group required for this investigation.

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* Although 24 trials were administered, 4 trials were incorporated randomly into the test only to help prevent subject anticipation (see p. 103). In 4 instances the red 'warning' light was not followed by a green 'go' light (see p. 61).

\+ Unfortunately, due to illness or injury, only 7 subjects completed the testing procedure.

3.4 APPARATUS:

(N.B. For comprehensive list of apparatus, see Table 4, Appendix, p. 140).

(a) Measurement of Muscular Power

Introduction

Apparatus was designed specifically to measure muscular power of a group of muscles, by recording graphically the velocity at which a pre-determined (sub-maximal) load was moved at any instant over a set distance. The maximum attained velocity was graphically determined, and hence a maximal measure of muscular power calculated, for that load.

A POWER LEVER was constructed, based on a wheel lever and pulley system, to satisfy the following requirements:

(i) The right leg was allowed to work against an external load.

(ii) The human body (i.e. subject's right leg) operated as the work input or effort source of the machine system.

(iii) All individuals had the same opportunity and were not handicapped, except that any limitations* were STANDARDISED, in this force development.

(iv) Maximum possible velocity was attained during any trial.+

(v) Measurements could be compared over several trials, for any subject.

(N.B. It was assumed that:

(i) the power developed in the movement of the external load could be used as a measure of the power developed by the

* These were necessary to ensure measurement of specific muscle groups.

\+ i.e. The limb had reached maximum rate of acceleration, and was decelerating, at the conclusion of the trial.

limb;*

(ii) this measurement of power could be used as a reliable measure of muscular power for ANY INDIVIDUAL.)

(i) Bicycle Wheel and Attached Lever:

(See: Table 4, Appendix, p. 140; see also: plate 1, p. 67; plate 6, p. 77; diagram 4, p. 47; plate 3, p. 71).

(1) A bicycle wheel (radius = 30 cms.) was attached, from its axle, by a steel support frame securely to a stone beam. (See: diagram 4; plate 1; plate 6) with the axle at a variable vertical distance from the floor.

(2) Two safety 'brakes'+ were attached securely to the wheel rim at specific locations (see: 6, plate 3; 5, 10, plate 6).

(3) A steel/aluminium lever arm was firmly attached to the inside of the wheel axle, and to the wheel rim (see: 12, plate 6).

(4) An adjustable curved ankle rest, composed of similar material, was attached securely to the lever arm (see: 14, plate 6). Ankle rest and lever arm constituted the lever.

(5) The lever could be freely moved from its resting position (hanging vertically) through 122.5° in a clockwise direction, movement being finally limited by one safety brake. Movement of the lever, and thus wheel, in an anti-clockwise direction from their resting position, was prevented by the other safety brake (see: 6, plate 3; 10, plate 6).

* N.B. Apparatus did not measure absolutely power or force produced by the muscle(s).

\+ One safety brake prevented the lever from being kicked too high and hitting the subject. The other prevented the lever from swinging back beyond the vertical position, thus preventing injury to the subject's foot.

(ii) Pulley System

(See: Table 4, Appendix, p. 140; plate 1, p. 67; plate 3, p. 71; plate 6, p. 77; diagram 4, p. 47).

(1) Attached to the bicycle wheel was a pulley system, comprising a fixed wheel, chain and weight container (see: diagram 4).

(2) A small bicycle wheel (radius = 20 cms.) was attached securely, by a steel supporting arm (see: 24, plate 1) and steel corner pieces, to a second beam, such that the vertical distance from the axle of this wheel to the floor was 1.44 metres (see: 23, plate 1; diagram 4).

(3) A tyre (pressure = 2.46 - 2.81 kg./sq. cm.) was placed around the rim of this wheel (see: 23, plate 1).

(4) A fixed wheel (18 teeth) was attached to the axle of the small bicycle wheel (see: diagram 4). (The distance from the axle of the large bicycle wheel to the axle of the fixed wheel (see: diagram 4) was 2.08 metres.)

(5) A third safety brake was firmly bolted to the small wheel supporting arm (see: diagram 4; 25, plate 1) and positioned 0.2 cms. away from the tyre of the small wheel, with the brake arm in the 'release' position.

(6) The pulley chain (composed of bicycle chain links) was attached at one end to the rim of the large bicycle wheel by a steel pin (see: plate 1; 4, plate 3; diagram 4). The chain passed over the teeth of the fixed wheel (see: 15, plate 1; diagram 4) and was attached at the other end securely to the central support of a weight container (see: 22, plate 1; diagram 4) by steel pins.

(7) The pulley system was constructed such that, in the resting position, with the weight container resting on the floor, and

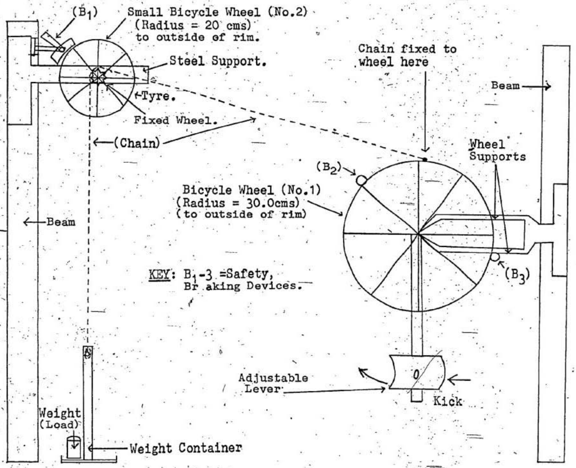

Diagram 4: Arrangement of Lever and Pulley System for measuring muscular power.

with the bicycle wheel lever in the vertical position (see: diagram 4; plate 6) the chain was taut.

(8) The weight container consisted of a steel tray with a rim to stabilise the contained weights, and a central support, to which was attached the pulley chain (see: 22, plate 1).

(9) The resistance, against which the body exerted its effort, was supplied by known weights (see: 16-21, plate 1) placed into the weight container.

(iii) Subject Position

(See: plate 3, p. 71; plate 6, p. 77).

(1) The subject was seated on a reinforced wooden table (see: plate 3; 17, plate 4) secured in position by a nylon rope attached to beams. The position of the table could be adjusted to suit individual requirements.

(2) A foam sponge seat, attached to the table (see: 11, plate 3) allowed the leg to be positioned comfortably for kicking the lever.

(3) The table was arranged such that: (i) the subject's right ankle rested gently on the back of the lever ankle rest (see: 14, plate 6); (ii) right knee-angle was 90^{o} (+ or - 5^{o}).

(4) Position of the large bicycle wheel could be adjusted to suit individual requirements, such that the wheel axle was in line with the subject's knee axis (see: plate 6).

(5) The effective lever length could be altered by changing the position of the ankle rest on the lever through an adjustable screw.

(iv) Recording Measurements of Muscular Power

(See: diagram 5, p. 50; diagram 6, p. 51; plate 6, p. 77).

(1) A potentiometer (see: 8, plate 6) attached securely to the

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outside of the large bicycle wheel axle, and to one of the wheel spokes, was electrically linked to an input channel of a Beckman, Type R411, Dynograph Recorder (see: diagram 5; 2, plate 1; 15, plate 6).

(2) The Beckman Recorder was pre-set to monitor changes in potential difference, due to mechanical movement of the bicycle wheel, through the subject kicking the lever, as a pen deflection on the graph paper.* The graph paper was set at a speed of 50 millimetres/second, prior to the subject kicking the lever against a resistance, allowing a trace to be recorded. (see: diagram 6).

(3) The magnitude of the pen displacement reflected exactly the magnitude of the lever movement; upon returning the lever to its former 'resting' position, the pen returned to its original 'base-line' position (see: diagram 6).

(4) The lever was prevented from injuring the subject, either on its upward or downward arc, by use of 2 safety brakes (see: (1), (2) above).

(5) Kicking the lever against a pre-determined resistance caused the pulley chain to ride over the 'fixed' wheel sprocket. Upon completing the kicking action, the fixed wheel prevented the attached load (see: 22, plate 1) from crashing to the floor.+ The small bicycle wheel (see: 23, plate 1) was

* As the wheel was moved in a clockwise direction (from its resting position) the increased voltage (and therefore resistance) caused by change in position of the sliding resister, caused a deflection of the pen on the graph paper.

\+ The fixed wheel could turn in an anti-clockwise direction only (as viewed in PLATE 1).

Diagram 5: Schematics of Electric Circuit, linking Beckman Recorder to Potentiometer attached to spoke of Bicycle Wheel, for recording Measures of Muscular Power.

(Method of electrically recording Mechanical movement occurring during Performance of Test of Muscular Power.)

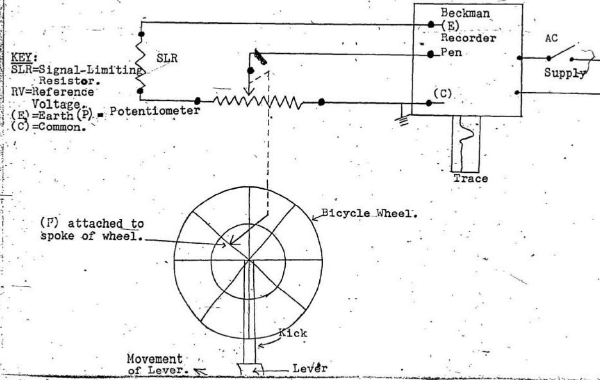

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Diagram 6: Method of Recording Measurements of Muscular Power.

(Example of Trace obtained from Beckman Recorder due to subject kicking bicycle lever against resistance.)

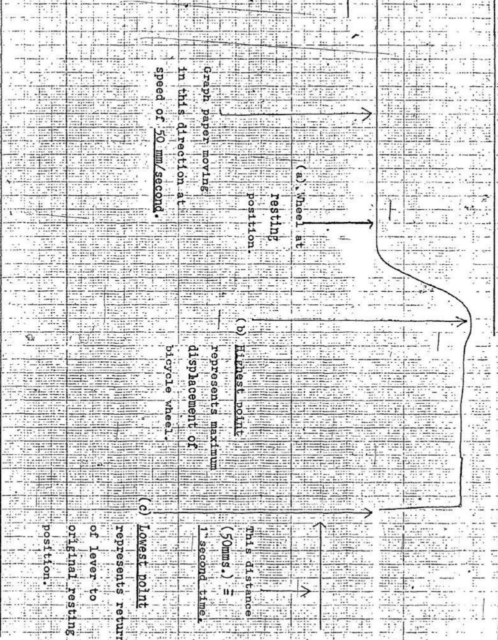
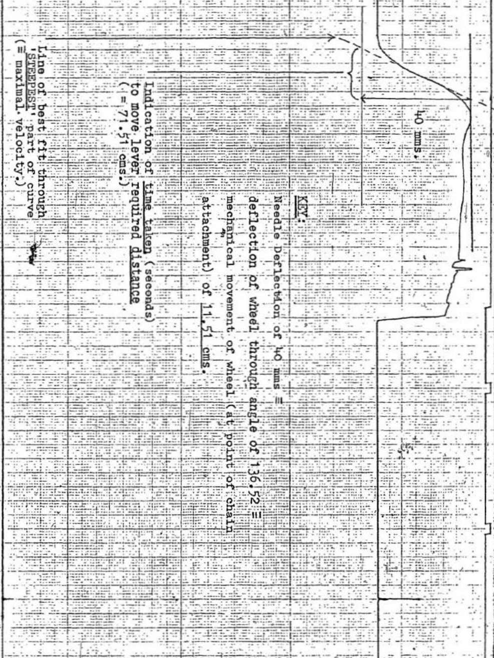


Diagram 7: Method of Recording Measurements of Muscular Power.

(Example of Trace obtained from Beckman Recorder due to subject kicking lever against resistance.



prevented from turning in a clockwise* direction by the third safety brake (see: 15, 22, plate 1).

(6) After each trial, the load was gently lowered to the floor, by releasing the safety brake (see: 25, plate 1).

(b) Audio Apparatus

(See: plate 1, p. 67; plate 2, p. 69; diagram 8, p. 55; diagram 9, p. 56; plate 3, p. 71).

(1) Audio apparatus consisted of a Roberts stereophonic 4-track tape recorder (see: 6, plate 1; 2, plate 2; diagram 8; diagram 9) both inputing to a specially constructed tape track/headset control panel (see: 4, plate 2; diagram 8; diagram 9) by specially constructed leads.

(2) Only 1 track of the 4-track tape recorder was used in this investigation.+ However, the apparatus was designed to allow information from either of 2 tracks to be used.**

(3) The tape track/headset control panel controlled input to two sets of earphones: (a) experimenter's monitor headset earphones (see: 6, plate 1; diagram 8; diagram 9; 3, plate 2); (b) subject's Roberts stereo headphones (see: 2, plate 3; diagram 8; diagram 9). The 3-way switch on the control panel (see: 4, plate 2; diagram 9) allowed the experimenter to control which of the 3 tracks was heard, at any time, by the subject.

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* (i.e. as viewed in PLATE 1).

\+ 2 tracks were used simultaneously in other investigations which have been described elsewhere.

** (i.e. tracks 1 and 3 could be used simultaneously).

(4) White noise (see: p. 16) was recorded* on track 1 of the 4-track tape recorder, using 'Tenzar' low noise, professional quality oxide recording tape. The intensity of the white noise through the subject's earphones was adjusted to 75 decibels (db)+ using a General Radio Company Sound Level Meter (Type 1551-C), recalibrated in September, 1975. Volume and tone controls of the subject's earphones were adjusted and taped (see: 2, plate 3) to prevent subject interference.**

(5) Subject instructions were recorded on the cassette tape recorder, using a 'Hi-dynamic Emitape', low noise cassette tape. The intensity of recorded instructions was adjusted to 70 db (+ or - 5 db) using the Sound Level Meter.

(6) 'Tone' and 'volume' controls on both tape recorders were standardised throughout the investigation.

(7) The 4-track tape recorder incorporated a dual-speed control switch, allowing the tape to play at: (a) 9.33 cms./sec.; (b) 19.05 cms./sec. The slower speed was chosen for playing back continuously during the investigation, output to the earphones being determined by the experimenter's control panel. When the subject listened to white noise, the cassette recorder was temporarily switched off.

(8) The above arrangement allowed easy experimenter control of the audio system. White noise, or recorded instructions, could be

* White noise was recorded from a white noise 'generator'.

\+ A 10-fold increase in sound intensity is called 1 bel; one-tenth bel is called 1 decibel. One decibel represents an actual increase in intensity of 1.26 times.

** The intensity of the white noise was monitored again at the end of the investigation, to check the reliability of the measurement.

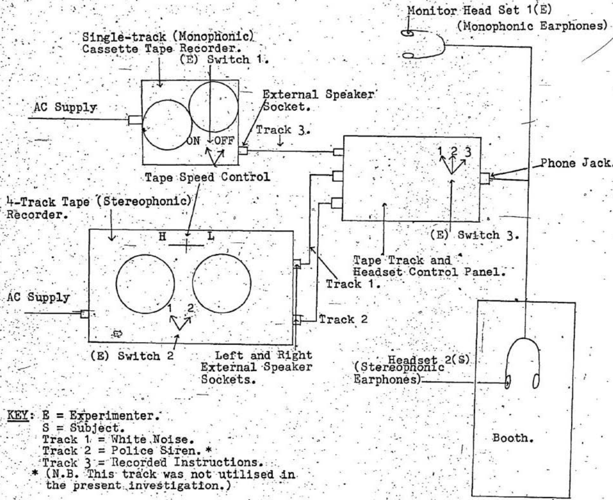
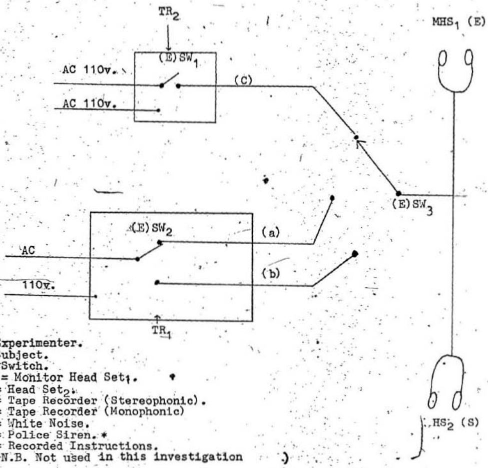


Diagram 8: Pictorial Representation Of Audio Apparatus.

<u>Diagram 9</u>: <u>Schematics of Audio-Electric Circuit</u>.

(<u>From</u>: Diagram 8)



<u>KEY</u>: E = Experimenter.
S = Subject.
SW = Switch.
MHS$_1$ = Monitor Head Set$_1$.
HS$_2$ = Head Set$_2$.
TR$_1$ = Tape Recorder (Stereophonic).
TR$_2$ = Tape Recorder (Monophonic)
(a) = White Noise.
(b) = Police Siren. *
(c) = Recorded Instructions.
*(b) (N.B. Not used in this investigation)

followed by a green 'go' light (see p. ...).

+ Unfortunately, due to illness or injury, only 7 subjects completed the testing procedure.

initiated or terminated at appropriate times during the investigation. By setting the control panel to allow input from the second stereo track, a period of 'silence' could be presented to the subject.

(c) Experimental Booth

(1) (See: plate 1, p. 67; plate 2, p. 69; plate 3, p. 71; plate 4, p. 73).

The subject, large bicycle wheel and lever, part of the converted table, and part of the pulley chain, were housed in a white polystyrene booth (see: 14, plate 1; 5, plate 2; 3, plate 3; 1, plate 4).

(2) The bottom half of the back wall was cut away, to allow positioning of the table (see: plate 4). The nearer two-thirds of the table projected into the booth; a gap of 5 cms. was allowed between table top and back wall.

(3) Small holes in the walls (see: plate 1) allowed passage of all electrical wires.

(4) Part of the front wall was cut away (see: 14, plate 1; plate 4) allowing: (i) subject entry; (ii) the subject to observe weights (i.e. resistance) kicked against (see: plate 4).

(5) An additional section of the front wall was cut away (see: plate 1; plate 4) allowing passage of the pulley chain out of the booth.

(d) Apparatus required for initiating subject response

(See: plate 1, p. 67; plate 2, p. 69; plate 3, p. 71; plate 4, p. 73; plate 5, p. 75; diagram 10, p. 59; diagram 11, p. 60).

(1) A black plywood board, housing 2 bulb sockets containing 1 red light bulb (left centre) and 1 green light bulb (right centre)

was suspended* from the inside of the front wall of the booth at subject eye-level. The height of the board above the ground could be adjusted to suit individual requirements (see: 1, plate 1; 3, 4 and 5, plate 4; diagram 10).

(2) The lights were linked, by an electrical wiring system (see: diagram 10; diagram 11) to a control panel which received an A. C. supply (see: diagram 10; diagram 11; 7, plate 2).

(3) The specially designed control panel incorporated: (i) a press-button switch, controlling initiation of (a) the red 'warning' light and (b) the green 'go' light; (ii) a Metrix Model MX solid state timer, controlling the foreperiod+ between 0.0 and 5.0 seconds (see: 1-6, plate 5). A variable foreperiod after the red 'warning' light came on (see: 3, plate 4) the green 'go' light came on (see: 4, plate 4).

(4) The red light was initiated by the experimenter pressing the mains off/on switch on the control panel (see: 3, plate 5). Both lights remained on until the mains off/on switch was pressed a second time, when both lights were cancelled (see: diagram 11).

(5) The red light warned the subject that the green light would come on between 1 and 3 seconds later. The green light served as a stimulus, and indicated to the subject that he was required to kick the lever as hard and fast as possible.

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* String, passing through the roof of the booth, and attached to the board by nails, allowed the position of the board to be adjusted.

\+ FOREPERIOD = the time interval between initiation of the red 'warning' light and onset of the green 'go' light.

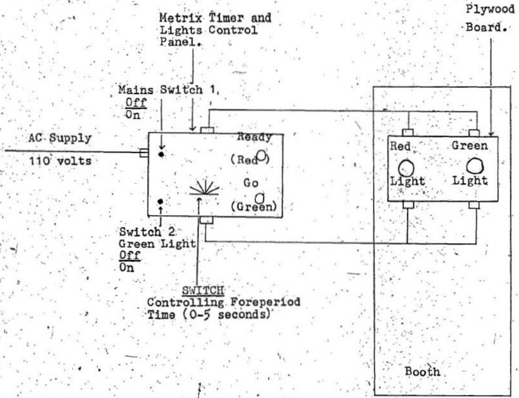
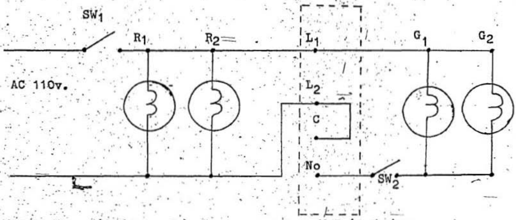


Diagram 10: Pictorial Representation of Apparatus Required to Initiate Subject Response (in test of Muscular Power)

Diagram 11: Schematics of Electric Circuit for Initiating Subject Response (in Test of Muscular Power)

(From Diagram 10.)



KEY: M.T = Metrix Timer (0-5 seconds)
R_1 = Red (Warning) Light (Subject)
R_2 = Auxillary Red (Warning) Light (Experimenter)
G_1 = Green (Stimulus) Light (Subject) - (25 watts, 115-125 volts)
G_2 = Auxillary Green (Stimulus) Light (Experimenter)
SW_1 = Mains Switch $\frac{\text{Off}}{\text{On}}$
SW_2 = Green Light Switch $\frac{\text{Off}}{\text{On}}$

(6) Small red and green auxillary lights, fitted into the electric circuit (see: diagram 11) indicated to the experimenter whether the lights were 'on' or 'off' in the booth (see: 2, 6, plate 5).

(e) Apparatus required for random variation of foreperiods

The foreperiod was randomly varied (see: Procedure, p. 101) by means of the Metrix Model MX solid state timer (see: 7, plate 2, p. 69; 4, plate 5, p. 75; diagram 10, p. 59; diagram 11, p. 60; plate 6, p. 77).

(1) By adjusting the dial on the timer (see: 4, plate 5) the subject was asked to respond to any 1 of 5 foreperiods on each trial, viz: (1) 1.0 seconds; (2) 1.5 seconds; (3) 2.0 seconds; (4) 2.5 seconds; (5) 3.0 seconds. In this way, the experimenter could attempt to prevent subject anticipation of the stimulus.

(2) To further prevent anticipation, on some occasions, controlled by the experimenter, the red 'warning' light came on, but the green 'go' light did not come on afterwards. Under such circumstances, the subject was required not to kick the lever. To prevent the green light from coming on, the experimenter was required to press the green, off/on light switch (see: diagram 10; 5, plate 5) prior to commencing the trial. This procedure 'opened' the circuit which normally allowed automatic triggering of the green light (see: diagram 11, p. 60).

(f) Apparatus used for measuring Reaction Time

(N.B. Although Reaction Time data collected in this investigation was not utilised, apparatus and procedure for measuring Reaction Time were standardised here, for use in future investigations.)

(<u>See</u>: plate 1, p. 67; plate 2, p. 69; plate 4, p. 73; plate 5, p. 75; diagram 12, p. 63; diagram 13, p. 64).

(1) A Model 1520 'Millisecond' <u>electronic digital timer</u> was used to measure subject <u>Reaction Time</u> (<u>see</u>: 10, plate 1; 8, plate 2; 7-10, plate 5; diagram 12).

(2) The <u>digital timer</u> was linked, by an electric wiring system (<u>see</u>: diagram 12; diagram 13) to the <u>control panel</u> which determined initiation of the <u>red warning light</u>.

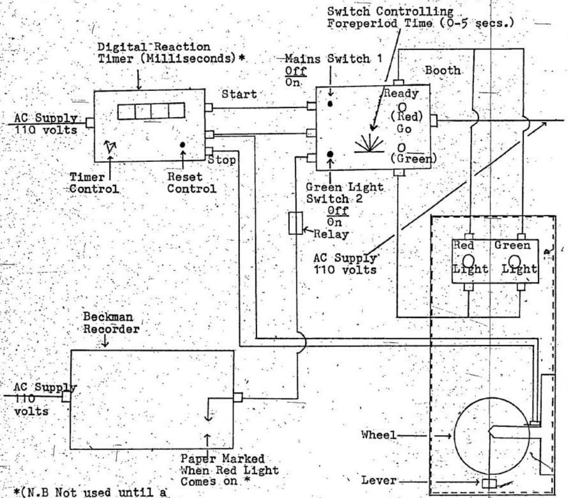
(3) The <u>Metrix</u> Model MX solid state <u>electronic timer</u>, housed in the control panel, possessed 2 sets of electrical contacts (<u>see</u>: Y, Z, diagram 13). A variable foreperiod (pre-set) after the <u>red 'warning' light</u> came on, the <u>green 'go' light</u> came on. One set of <u>contacts</u> (<u>see</u>: Z, diagram 13) was used to "switch on" 110 volts, to turn on the <u>green 'go' light</u>. The second set of <u>contacts</u> (<u>see</u>: Y, diagram 13) was used to start the <u>digital reaction timer</u>. Initiation of the <u>green light</u> and <u>digital reaction timer</u> occurred simultaneously.

(4) A <u>steel strip</u>, housing a microswitch (<u>see</u>: 6, plate 6) was bolted to the upper supporting frame of the large bicycle wheel (<u>see</u>: 7, plate 6) such that, with the wheel in its resting position, a contact was made between the microswitch and a second <u>steel strip</u> (<u>see</u>: 6, plate 6) attached to the rim of the wheel.

(5) The <u>microswitch</u> was electrically linked to the <u>Model 1520 digital timer</u> (<u>see</u>: diagram 12, diagram 13) via a wiring system approximately 4.5 metres long.

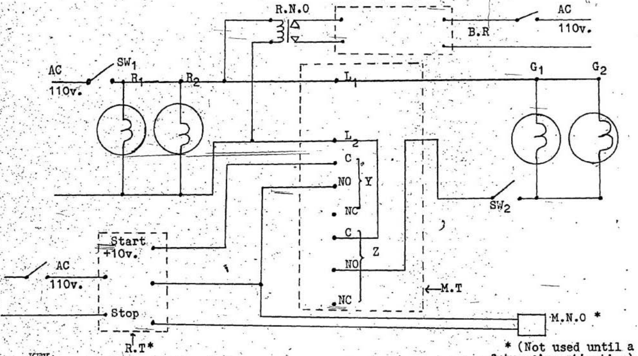
(6) The <u>microswitch</u> was used to <u>'turn off'</u> the model 1520 reaction timer. Slightest pressure on the <u>wheel lever</u>, when the subject began to kick the lever, caused release of the microswitch from

Diagram 12: Pictorial Representation of Apparatus used to: (a) Initiate Subject Response, (b) Measure Reaction Time, (c) Monitor Onset of Warning Light (for Person Moving Weight)



*(N.B Not used until a future investigation)

Diagram 13: Schematics of Circuit for (a) Initiating Subject Response, (b) Measuring Reaction Time, (c) Monitoring Onset of Warning Light (for person moving weight) (From Diagram 12.)



* (Not used until a future investigation)

KEY:
R.T = Model 1520 Digital Timer.
SW_1 = Mains Switch Off/On.
SW_2 = Green Light Switch Off/On.
M.N.O = Microswitch (N.O)
R_1 = Red (Warning) Light (Subject)
R_2 = Auxillary Red (Warning) Light (Experimenter)
G_1 = Green (Stimulus) Light (Subject)
G_2 = Auxillary Green (Stimulus) Light (Experimenter)

M.T= Metrix Timer(0-5 secs.)
B.R= Beckman Recorder(Marker Pen Circuit)
R.N.O= Relay(Normally open)
L_1/L_2= A.C Line

C= Common.
NO= Normally Open.
NC= Normally Closed.
Y= Set 1 contacts(start RT)
Z= Set 2 contacts(turn on G_1/G_2.

its steel contact, causing the microswitch to be closed (see: diagram 13).

(7) Damage to the microswitch was prevented by the second braking device, attached to the rim of the wheel (see: p. 47) when the lever was returned to its resting position.

(8) Summary of mode of operation (see: diagram 13):

(i) When voltage was applied to the circuit, by the experimenter pressing the mains switch (see: 3, plate 5) both the red lights (i.e. subject warning light and experimenter, auxillary warning light) came on immediately.

(ii) Voltage was simultaneously applied to the Metrix timer, initiating the foreperiod.

(iii) Upon termination of the foreperiod (1-3 seconds) both sets of contacts (Y and Z) were closed, causing simultaneously (a) the green light to 'come on' and (b) the digital reaction timer to start counting (in milliseconds).

(iv) Illumination of the green light initiated a subject response (i.e. the lever was kicked). 'Slightest' pressure on the lever (i.e. slightest movement of the wheel) closed the microswitch, stopping the digital reaction timer.

(v) After recording the reaction time score (see: 8, plate 5) the timer was reset (see: 9, plate 5) the foreperiod was adjusted (see: 4, plate 5) and another trial could begin.

(g) Additional, required measuring instruments.

(See: plate 1, p. 67, and plate 6, p. 77, and plate 2, p. 69).

(1) Detecto-Medic Scales (see: 1, plate 1) allowed accurate weighing of subjects (accurate to 0.1 Kgs.).

(2) Holtain height measurement apparatus (see: 26, plate 1) allowed accurate measurement of subjects' heights (accurate to 0.1 cms.).

(3) A sliding centimetre rule was used to adjust and measure the length of the lever arm, for each subject.

(4) A Kodak Timer Clock (see: 7, plate 1; 6, plate 2) was used to measure: (a) the time interval between trials; (b) the time interval between sets of trials (in minutes and seconds).

(5) A spirit measure and centimetre tape measure were used to measure and confirm the relationship of the angle of the mechanical movement of the bicycle wheel to the degree of pen deflection on the Beckman Recorder (see: diagram 7). The spirit measure also ensured that the lever arm was hanging exactly vertically, in the resting position (see: plate 6).

PLATE 1 – GENERAL ARRANGEMENT OF APPARATUS.

FOR KEY, SEE OVERPAGE.

PLATE 1 : General Arrangement of Apparatus:

KEY:

1 = Detecto-Medic Scales.
2 = Beckman Type R411, Dynograph Recorder.
3 = Exercise Cardio-Tachometer, Model 609.*
4 = 12-100 (12-13T) Student Model G. S. R.*
5 = 'Sensiphone Superex' Earphones (Experimenter).
6 = Roberts 1725-II Stereophonic 2-Track Tape Recorder.
7 = 'Kodak Second Timer' Clock.
8 = Tape Track/Headset Control Panel (Audio Control).
9 = Redux Creme (Hewlett, Packard Medical Electronics) for Electro-cardiography.*
10 = Model 1520 'Millisecond' Electronic Timer (Reaction Time).
11 = Reaction Time (foreperiod) Control Panel (incorporating a Metrix Model MX Solid State Timer).
12 = Roberts Portable Single-Track Tape Recorder.
13 = Subject, correctly positioned for testing in Booth.
14 = Experimental Booth (Polystyrene).
15 = Chain (part of pulley system).
16 = 20-Kilogram Toledo Weight.
17 = 25-Kilogram Toledo Weight.
18 = 0.5-Kilogram Toledo Weight.
19 = 2-Kilogram Toledo Weight.
20 = 1-Kilogram Toledo Weight.
21 = 5-Kilogram Toledo Weight.
22 = Tray (container for Toledo Weights).
23 = Wheel, incorporating 'fixed wheel' as part of pulley system.
24 = Supporting arm of pulley wheel.
25 = Safety 'braking device' of pulley system.
26 = Adjustable height measurement apparatus (Holtain Ltd.).

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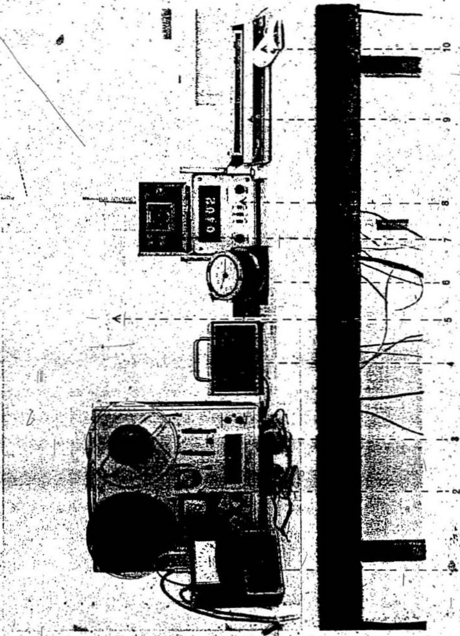
* (N.B. This apparatus was not required in this investigation, but was utilised in subsequent investigations.)

PLATE 2: APPARATUS — ARRANGEMENT OF CONTROLS FOR TESTING.



FOR KEY SEE OVERPAGE.

PLATE 2 : Apparatus: Arrangement of Controls for Testing:

KEY:

1 = 12-100 (12-13T) Student Model G. S. R. (Skin Conductance).*

2 = Roberts 1725-II, Stereo 2-Track Tape Recorder.

3 = 'Sensiphone Superex' Earphones (Experimenter).

4 = Tape Track/Headset Control Panel (Audio Control).

5 = Experimental Booth (Polystyrene).

6 = 'Kodak Second Timer' Clock.

7 = Reaction Time (Foreperiod) Control Panel (incorporating a Metrix Model MX Solid State Timer).

8 = Model 1520 'Millisecond' Electric Timer (Reaction Time).*

9 = Roberts Portable Single-track Tape Recorder.

10 = Redux Creme (Electrocardiography).*

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* (N.B. This apparatus was not required in this investigation, but was utilised in subsequent investigations.)

PLATE 3: SUBJECT IN BOOTH READY TO RESPOND TO VISUAL STIMULUS.

FOR KEY, SEE OVERPAGE.

PLATE 3 : Subject in Booth 'READY' to Respond to Visual Stimulus:

KEY:

1 = Eyes watching lights, 'ready' for stimulus.

2 = Roberts Deluxe Model 4850A Stereo Headphones (Subject).

3 = Wall of Polystyrene Booth.

4 = Chain attached to wheel (part of pulley system).

5 = Elastic belt (for maintaining Electrocardiograph electrodes in position).*

6 = Safety 'braking' device attached to wheel.

7 = Electrodes (Electrocardiography).*

8 = Wheel (to which lever is attached).

9 = Finger electrodes for measuring G. S. R. (Galvonic Skin Response).*

10 = Attachment of lever to centre of Bicycle Wheel.

11 = Foam padding (over edge of table).

* (N.B. This apparatus was not required in this investigation, but was utilised in subsequent investigations.).

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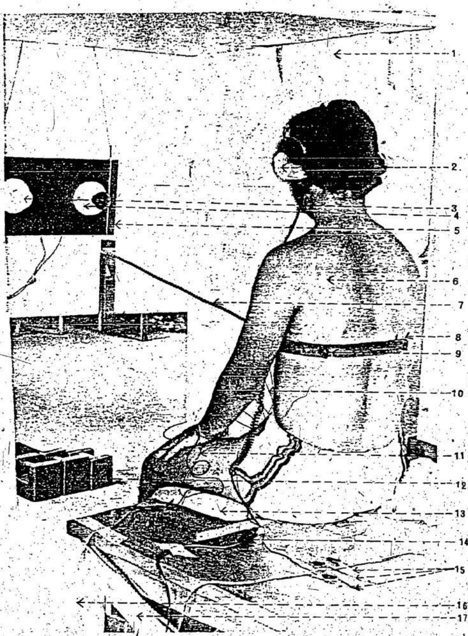
PLATE 4 : SUBJECT IN CORRECT POSITION READY TO RESPOND TO VISUAL STIMULUS.



FOR KEY, SEE OVERPAGE.

PLATE 4 : Subject in Correct Position 'Ready' to Respond to Visual Stimulus:

KEY:

1 = Polystyrene Booth.

2 = Roberts Deluxe Model 4850A Stereo Headphones (Subject).

3 = 'Ready' Warning (RED) Light ('On').

4 = 'Go' Stimulus (GREEN) Light ('Off').

5 = Black Adjustable board, housing lights.

6 = Subject's back (= straight).

7 = Chain, attached to bicycle wheel and to pulley system and weights.

8 = Electrode (Electrocardiography).*

9 = Elastic Belt (for maintaining Electrocardiograph electrodes in position).*

10 = Spokes of Bicycle Wheel.

11 = Finger Electrodes for Measuring G. S. R. (Galvonic Skin Resistance).*

12 = Toledo Weights (for attachment to Pulley System).

13 = Foam Padding (over edge of table).

14 = Wired Connection from Tape Recorder to Headphones.

15 = Wires to Exercise Cardio Tachometer, connected to Electrocardiograph electrodes (Subject).*

16 = Wire connecting G. S. R. electrodes to 12-100 (12-13T) Student model G. S. R. amplifier, and hence to Beckman Type R411, Dynograph Recorder.*

17 = Reinforced Table (immobilised by use of nylon rope).

* (N.B. This apparatus was not required in this investigation, but was utilised in subsequent investigations.)

PLATE 5 : APPARATUS USED FOR: (a) MEASURING REACTION TIME (b) VARYING FOREPERIOD (c) INITIATING SUBJECT RESPONSE

FOR KEY SEE OVERPAGE.

PLATE 5 : Apparatus used for: (a) Measuring Reaction Time,
(b) Varying Foreperiod, (c) Initiating Subject Response:

KEY:

1 = Custom-made 'Foreperiod' Control Panel, housing Metrix Model MX Solid State Timer.

2 = 'Ready' Warning Timer, Red Light Indicator ('On').

3 = Press-Button Switch controlling initiation of 'Warning' light, and hence automatic initiation of Green Stimulus light.

4 = Adjustable 'Foreperiod' Dial Control (allowing variation of foreperiod from 0 to 5.0 seconds).

5 = Press-Button Switch, controlling initiation of 'Go' light.

6 = 'Go' Stimulus, Green Light Indicator ('Off').

7 = Model 1520 'Millisecond' Electronic Timer (Reaction Time).*

8 = Electronic digital display (time shown in milliseconds).*

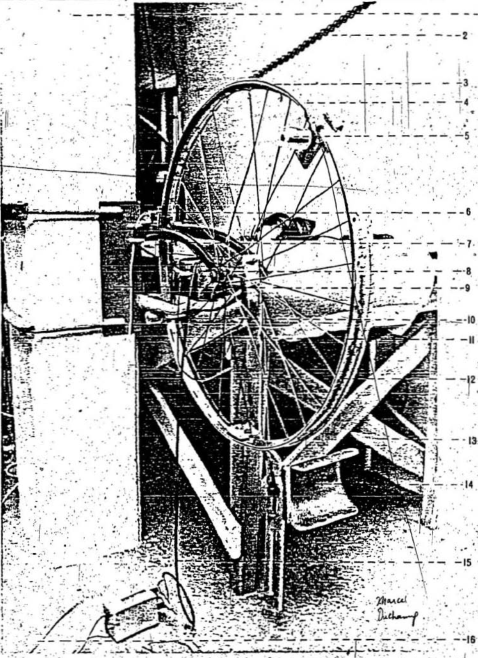
9 = 'Reset' control (for clearing digital display ready for next trial).*

10 = 'Function' control (allowing measurement of Reaction Time in milliseconds).*

* (N.B. This apparatus was not required in this investigation, but was utilised in subsequent investigations.)

PLATE 6: WHEEL AND LEVER WITH ATTACHMENTS USED FOR MEASURING:

(a) MUSCULAR POWER, (b) SIMPLE REACTION TIME.



FOR KEY, SEE OVERPAGE

PLATE 6 : Wheel and Lever, with Attachments Used for Measuring:

(a) Muscular Power, (b) Simple Reaction Time.

KEY:

1 = Stone Beam.

2 = Pulley Chain (attached to rim of wheel by steel pin).

3 = Rim of Bicycle Wheel.

4 = Wheel groove (stabilising position of chain).

5 = Safety brake No. 1.

6 = Microswitch.*

7 = Tubular Steel support frame.

8 = Potentiometer.

9 = Steel corner pieces (attaching wheel securely to beam).

10 = Safety brake No. 2.

11 = Attachment of Potentiometer to spoke of wheel.

12 = Steel/aluminium Lever Arm.

13 = Reinforced Wooden Table.

14 = Adjustable Ankle Rest.

15 = Electrical link of Potentiometer to Input Channel of Beckman Recorder.

16 = Electrical link of Microswitch to Model 1520 Digital Reaction Timer.*

* (N.B. This apparatus was not required in this investigation, but was utilised in subsequent investigations.)

3.5 ANALYSIS OF VARIABLES:

An attempt was made to preserve both INTERNAL and EXTERNAL validity; procedures were designed to: (a) maximise primary variance, (b) minimise secondary variance, (c) minimise error variance.

(a) PRIMARY VARIANCE

The primary independent variable (i.e. foreperiod) was maximised as far as possible by:

(1) testing subjects with 5 different foreperiods, thereby providing ample opportunity for observed differences in performance;

(2) testing subjects over a wide range of foreperiods (1.0 seconds to 3.0 seconds);

(3) testing subjects over 24 trials, allowing collection of data describing 4 trials with each foreperiod;*

(4) randomly varying the foreperiod, thereby preventing any anticipation effect masking possible differences;

(5) controlling foreperiod accurately on each trial, through use of reliable measuring instruments (but see later).

(b) SECONDARY VARIANCE

An attempt was made to control (i.e. minimise) the effect of most of the interfering variables by:

(1) eliminating them; (2) randomising them. These variables were considered within the following categories:

(1) PRIOR MANIPULATION of variables;

(2) EXPERIMENTER INFLUENCE;

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* A large number of trials proved impractical, due to fatigue effects, and other extraneous variables (but see later).

(3) DEMAND CHARACTERISTICS.

(1) PRIOR MANIPULATION:

(i) Subject Selection Procedure:

A random sampling procedure was adopted, thereby effectively eliminating 'systematic bias', and minimising the effect of extraneous variables.* Volunteers were not used.+

(ii) Organismic Variables:

The random sample was homogeneous for sex, race, occupation and educational level,* but not for age.**

(iii) Maturation:

Each subject was required for testing on 3 separate days.++ In an attempt to minimise possible 'subject changes' during this period (i.e. changes in attitudes, motivation, interest, strength, body weight, fitness, learning experiences outside the experimental situation, 'performance capacity')***, the following procedures were adopted:

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* See: Procedure, p. 43.

\+ Performances may have been more easily influenced by motivation, otherwise.

** Average age was 22 years, with S.D.=5.7 years.

++ See: Procedure, p. 94.

*** 'Performance capacity' depended upon many variables, some of which are listed above.

(1) Subjects were tested on 3 consecutive days (to reduce the time during which maturation could occur).

(2) Body weight was ascertained on 2 separate occasions.

(3) Leg strength was compared on 2 separate occasions.

(4) Subjects were provided with a written set of instructions (see: Table 1, p. 137) which were rigorously adhered to by all subjects during the testing period.

(5) Subjects were additionally instructed to speak to no-one about the investigation in which they were engaged.

Although motivation, attitudes and interest were difficult to control, the following variables were successfully minimised: (1) fitness level;* (2) attire for tests; (3) amount of physical activity 24 hours prior to testing; (4) diet and liquid intake; (5) amount of sleep; (6) alcohol intake; (7) cigarette consumption; (8) coffee and/or tea intake; (9) partaking of other drugs; (10) other health hazards/ailments (see: Table 1, p. 137); (11) subject interaction with other subjects.

Maturation during the final investigation was largely negated since:

(1) Subjects remained in the experimental booth throughout the final testing period;

(2) as the final test consisted of 5 sets of 6 trials with a 2-minute break between each set, a pre-test/post-test design was unnecessary; all measurements were obtained in

* Fitness level was subjectively ascertained by verbal questioning prior to testing.

a single testing period. Consequently, any maturation effects during the course of the final test were largely eliminated (see: points (1) - (4), pps. 101-103);

(3) an attempt was made to ensure that all learning experiences encountered through the testing procedure were overtly identical (see: p. 102).

(iv) History:

Indefinable, specific, external events, beyond the experimenter's control, may have had a stimulating or disturbing effect upon individual performances. All subjects were concerned over pending examinations, for instance; however, control here was impossible. Consequently, subject 'anxiety' level was considered to be largely uncontrollable.

(v) Testing:

To help prevent subject sensitisation (i.e. prevent subject awareness of the concealed purpose of the investigation) the following precautions were observed:

(1) The testing composed 5 sets of 6 trials, with the foreperiod varied randomly throughout the 30 trials.*

(2) The subject was told that the randomly varied foreperiod was merely to prevent anticipation (see: p. 155).

(3) The importance of optimum performance+ was

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* Equal numbers of trials for each foreperiod were administered.

\+ The subject was continually reminded to kick the lever as hard and fast as he could. (A practice test was first conducted, emphasising this instruction.)

emphasised; the subject was told that: (a) reaction time, and (b) muscular power were being measured.*

(4) The subject was informed that the 30 trials simply represented a single test.

(5) Non-reactive, unobtrusive recording instruments were used for obtaining data.+

(6) Subjects were given standard, pre-recorded instructions prior to and during the test. (N.B. A control group design was considered unnecessary for this investigation.)

An attempt was made to eliminate any possibility of subject ANTICIPATION of the time of initiation of the green 'go' light by: (i) randomly varying the foreperiod; (ii) introducing a procedure whereby subjects were unsure whether the green light would come on at all, after the red light (see: Apparatus, p. 61 (e)).

An attempt was also made to negate any possible PRACTICE effect by:

(1) allowing subjects to become fully familiarised with the apparatus before commencing the final investigation;

(2) conducting a practice test (of 18 trials) with each subject on the day preceding the final test;**

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* Both measurements were emphasised to subjects, and both measurements were initially recorded in a practice test, since it was essential to provide exactly similar conditions to those that would be experienced in the FINAL INVESTIGATION.

\+ (See: Apparatus, p. 48).

** N.B. Subjects were not informed that the test was a 'practice' test, until afterwards. This procedure ensured maximum effort from subjects; hence it was hoped that, prior to the final test, subjects would have reached an optimum level of performance, such that the effects of further practice would be minimal.

(3) discounting the <u>initial 6 trials</u> of the final test, to allow:

(a) the subject to become physically and mentally 'tuned' to the task (i.e. to allow the subject to '<u>warm-up</u>' (<u>see</u>: p. 101));

(b) the subject to reagh his optimum performance level prior to the recording of final observations.*

(vi) <u>Diurnal Rhythm</u>:

Diurnal rhythm+ was randomised as an independent variable, by (a) testing subjects at different times of the day, (b) testing any individual at the same time on 3 consecutive days of testing. Experimental contamination was minimised by randomly allocating subjects to testing times by use of an unbiased matrix (<u>see</u>: Table 1, p. 85),** constructed by using a <u>random sample number</u> table (<u>see</u>: Table 3, p. 139 Appendix).

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* <u>N.B.</u> Subjects were not informed that the initial 6 trials of the final test were practice trials. This procedure helped ensure maximum effort in the 'warm-up' period.

\+ Performance has been shown to be affected by diurnal rhythm (<u>see</u>: Melton, M. G. 'Motor Skills Projects', Unpublished Thesis, Loughborough College of Education (1973), p. 57).

** If a subject was unable to attend a testing session on any day, that test was carried out at the same time on the following day.

Table 1 : Unbiased Method of Allocating Subjects to Testing Times by use of a MATRIX.

A.M./P.M.	TIME(hrs.)	SUBJECT NUMBER
MORNING	9.00	7
	11.00	2
AFTERNOON	1.00	1
	3.00	6
	5.00	4
EVENING	7.00	3
	9.00	5

(vii) Mortality:

Three subjects were lost /discarded through illness or injury during the course of the investigation. Possibly, survivors represented a sample which was completely different from the unbiased representative sample which began the experiment. This factor limited the external validity of this study.

(2) EXPERIMENTER INFLUENCE:

Experimenter influence was largely negated by:

(1) testing subjects with no prior knowledge of (a) the experimenter, (b) the experimenter's study;

(2) using a naive assistant to aid in collecting data;

(3) reducing contact between experimenter and subject. (This was achieved by: (a) housing subject and relevant apparatus in a polystyrene booth, separate from the experimenter and his recording apparatus (see: Plate 1, p. 67; see: p. 57, Apparatus); (b) employing tape-recorded instructions throughout, thereby reducing subject-experimenter contact to a minimal necessary level; (c) providing written instructions prior to testing);

(4) employing a one-group design; thus placebo controls were unnecessary.

Experimenter bias was consequently reduced by: (a) reducing indirect influence on subject performance; (b) reducing direct influence on collection and analysis of data.*

(3) DEMAND CHARACTERISTICS:

(a) Subject perception of cues relative to performance:

(1) Pre-enquiry data determined that all subjects were naive.+

(2) Post-enquiry data determined that no subjects realised the purpose of the investigation.

(b) Subject perception of evaluation demands:

(1) An attempt was made to alleviate EVALUATION APPREHENSION** by: (a) use of deception (through recorded instructions) to disguise the real intent of the experiment (see: p.154); (b) fully informing subjects of the requirements for the test (see: instructions, p. 151); (c) asking for full co-operation of all subjects; (d) standardising instructions.

(2) Subject interaction with other subjects was prevented by: (a) testing subjects on different occasions;++

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* It should be noted that these procedures also reduced subject influence on the experimenter.

\+ No subjects had preconceived ideas of (a) the nature of the investigation, (b) the reasons behind it.

** Evaluation Apprehension: is generated when subjects perceive what is required in different ways.

++ No two subjects were allowed into the laboratory on the same occasion.

(b) insisting that no discussion of the investigation occurred outside the laboratory.

(c) ERROR VARIANCE

(1) Error variance was minimised by choosing a reliable recording technique (Beckman Recorder trace - see: p. 51) to measure muscular power. However, human error may have arisen in the interpretation of the raw data (see: p. 104).

(2) Several features of the apparatus designed to measure muscular power (see: p. 44) represented potential sources of experimental error, viz:

(i) position of subject's kicking leg with relation to the lever;

(ii) length of lower limb of student's kicking leg, and consequent length of the kicking lever;

(iii) specificity of the test and localisation of muscular effort;

(iv) maintenance of tension in the chain of the pulley system;

(v) ability of the kicking lever to withstand stress/force imposed against it;

(vi) position of subject's right knee (i.e. kicking knee) with relation to the axle of the bicycle wheel;

(vii) mechanical disadvantages of the pulley system, producing additional resistance to movement of the pre-determined load;

(viii) relationship of deflection amplitude (Beckman Recorder) to movement (degrees) of bicycle wheel.

However, an attempt was made to minimise, or standardise, any error through a standardised procedure:

(i) Position of subject's kicking leg:

Specific tape-recorded instructions (see: p.151) ensured that all subjects placed their kicking (right) legs in a very similar position, at the commencement of each trial.

(ii) Length of kicking lever:

The lever length was adjusted to suit the physique and comfort of the individual subject (see: p. 151). The lever length (from the centre of the wheel axle to a pre-determined mark on the foot lever) was based upon the subject's bone length (from lateral condyle of femur, to lateral malleolus of right fibula). Error was minimised by: (a) adopting a standard procedure for all measurements; (b) recording bone length (accurate to 0.5 cms.) and lever length (accurate to 0.25 cms.) for each subject, prior to initial testing; (c) maintaining exactly the same lever length for subsequent testing periods (for any subject).

(iii) Specificity of test and localisation of muscular effort:

To help ensure that performance measures represented only desired muscle groups, subject positions, prior to, during, and immediately following each trial, were rigorously standardised (see: p. 151). Additionally, each subject was asked to react with exactly the same movement in response to the presented stimulus, and in exactly the same manner, at the commencement of each trial (see: p. 151). Despite precautions however,* this variable factor represented one of the biggest limitations governing the reliability of this investigation.

(iv) Maintenance of tension in the chain of the pulley system:

To ensure that all subjects were applying force against the pre-determined load throughout the range of lever movement produced, necessitated an equal amount of tension in the chain of the pulley system at the commencement of each trial of the test. Prior to testing each subject, the degree of tension in the pulley system (with the lever in the resting position) was subjectively and objectively assessed by the experimenter (see: p. 95). Such precautions ensured that any changes in the physical nature of the pulley system, were corrected immediately, preventing any variable contaminating (mechanical) effect. Any effects were therefore constant throughout the test.

(v) Ability of the kicking lever to withstand 'stress':

Due to the excessive amount of force applied against the foot lever, it was liable to bend. This possible source of experimental contamination was guarded against through a routine inspection, immediately prior to testing each subject.

(vi) Position of subject's right (kicking) knee, with relation to axle of bicycle wheel:

Specific tape-recorded instructions (see: p. 151) ensured

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* Whilst this source of error could not be completely eliminated, it was controlled by adopting a procedure based on a previous pilot investigation (using 7 subjects) designed to test the reliability and validity of the apparatus used for measuring muscular power.

that all subjects placed their kicking (right) knees in a similar position, with the axis of the knee in line with the axle of the bicycle wheel.*

(vii) Resistance to movement produced by the pulley system:

Mechanical disadvantages were produced by: (a) friction incurred through the pulley system (see: diagram 4, p. 47); (b) slight misalignment of the fixed wheel of the pulley and the large bicycle wheel attaching the kicking lever; (c) relative positions of the load, fixed wheel of the pulley system, and the foot lever (to which effort was applied). Although such design faults produced slight inaccuracies in measures of muscular power, these effects were constant throughout (see: p. 104).

(viii) Relationship of deflection amplitude (Beckman Recorder) to movement of the bicycle wheel:

The magnitude of deflection of the needle on the graph paper was directly related to the degree (i.e. distance) that the bicycle wheel lever was moved+ on each trial (see: p. 105; see: diagram 5, p. 50). The exact relationship between these 2 variables was ascertained (using tape measure and ruler, and further checked by using a spirit level) at the beginning of the investigation. This relationship was confirmed by repeating the original

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* Position of the table, on which the subject sat, and the vertical distance of the bicycle wheel from the floor, were both adjustable.

\+ i.e. Movement of the lever in a clockwise direction caused a needle deflection away from a basal (resting value). Movement in an anticlockwise direction caused the needle to return to the basal position.

procedure at the termination of the investigation, thereby ensuring the reliability of this measurement, and thus minimising measurement error.

(3) Measurement of Strength: (see: p. 15)
Assessment of each subject's leg strength was made by a 'trial and error' process. The reliability of this measure was confirmed by assessing leg strength on a second occasion, however, when the subject was not fatigued by previous trials (see: p. 98).

(4) Measurement of inter-trial intervals and foreperiod intervals:
Time between trials was accurately determined by using a reliable 'Kodak Second Timer' clock (see: p. 66). Foreperiod was also standardised by using a very accurate and reliable 'Metrix Model MX solid state Timer' (see: p. 62).

(5) Measurement of Height and Weight:
Subject's height and weight were accurately and reliably ascertained by using the 'Holtain' adjustable height measurement scale (accurate to 0.1 cms.), and the 'Detecto-Medic' scales (accurate to 0.1 Kg.) respectively. Weight was measured on 2 separate occasions.

(6) Standardised Conditions:
All testing was conducted under standardised conditions. Other factors (additional to those already mentioned) included:

(i) use of a polystyrene booth (see: p. 57) and white noise through earphones (see: p. 54), which:

(a) prevented peripheral disturbance (i.e. from external auditory or visual cues) which may have distracted the subject, thereby producing experimental contamination, and (b) provided uniform conditions throughout the test;

(ii) recorded instructions and white noise through earphones;

(iii) similar attire for all subjects:

(iv) adjustable 'warning' and 'stimulus' lights (see: p. 58); these were adjusted to suit individual requirements;*

(v) exactly similar sequence of trials for all subjects.

(7) Reliability and Validity of the measurement of muscular power:

(i) Some objections to the validity of this measure have already been stated. However, the validity of the instrument used depended largely upon assumptions and conditions involved in the application of certain mechanical principles (see: p. 109). Also: (a) the subject was given a prior practice test in an attempt to control any learning factor operating in the final test (see: Procedure, p. 98); (b) the subject was told to move the lever as hard and fast as he could through the range of movement (see: p. 157); (c) a previous pilot investigation had indicated that no 'fatigue effect' was operating

* It was found that the most suitable position for the lights was in front of the subject, at his 'eye level'.

during the course of the investigation.

(ii) Reliability and objectivity reported for a previous preliminary pilot investigation, in which 7 subjects were tested over 6 trials, with a weight equivalent to 20% of their maximum (see: Table 5, p. 149, Appendix) indicated a high level of stability and consistency in recorded observations (r = 0.99).

(8) Reduction of operational error:

(See: p. 94).

Standardised procedures were finalised due to:

(i) observations gleaned from a previous Pilot Investigation;

(ii) observations gleaned from an 18-trial PRACTICE test, immediately prior to the final test.

(9) Valid method of calculating measures of Muscular Power from Raw Data:

(See: 'Treatment of Data', p. 104, p. 106, for comprehensive description, and justification of method.)

(10) Suitability of Statistical Tests:

An analysis of variance, utilising a repeated measures design with two experimental variables, was chosen to examine obtained measures of muscular power. Its purpose was to compare r (r > 2) population means by selecting r independent random samples from those populations and testing the equality of the sample means. It was hoped that the test would indicate with some confidence whether the effects of the 5 different foreperiods on muscular power were different from each other. (See: 'Treatment of Data', p. 109, for comprehensive discussion of justifications.)

3.6 TESTING PROCEDURE:

Each of 10* subjects, chosen by the random sampling procedure outlined, was tested on 3 consecutive days.+ Specific procedures were adopted on each day underlying certain intended aims and objectives, which included:

Day 1:

(a) familiarising naive subject with apparatus designed to measure muscular power;

(b) determining each subject's maximal load (i.e. minimal load that could not be moved** by kicking the lever in a defined manner);

Day 2:

(a) reminding subject of Experimental Procedure;

(b) retesting individual maximal load;

(c) familiarising subject with apparatus designed to measure reaction time;

(d) conducting an initial (PRACTICE) test of (a) muscular power, (b) reaction time, with 20% of subject's maximal load;

---

* Only 7 subjects completed all tests. 3 subjects retired midway through the testing procedure, due to illness or injury.

\+ Each subject was tested at a similar time on each of the 3 days.

** (= as defined by any change in the pen position of the Beckman Recorder from its baseline, resting position.)

(9) The subject was told that the maximum load that he could move, by kicking the lever with his right leg, would be recorded. He was also informed that the slightest movement of the load would produce a recognisable deflection of the Beckman Recording pen.

(10) The subject was instructed to kick the lever as hard and fast as he could on each trial.

(11) A foreperiod of 3 seconds was used throughout the testing procedure.

(12) Before placing a 'heavy' load on to the weight container (see: 22, plate 1, p. 67) the subject received 5 practice trials, with a load of 15 Kg., which provided an opportunity to: (a) warm-up; (b) further familiarise himself with the apparatus and task demands.

(13) A 1-minute rest period was allowed between each practice trial.

(14) During each trial the subject received pre-recorded white noise (75 db) through the earphones (see: 2, plate 4, p. 73). The white noise: (a) commenced 5 seconds prior to initiation of the red 'warning' light; (b) was terminated 5 seconds after the initiation of the green 'go' light.

(15) The subject was asked to kick the lever when the green light 'came on'.

(16) The white noise did not commence until the subject indicated verbally that he was ready.

(17) The load was returned to its initial 'resting' position after each trial.

Day 3:

(a) reminding subject of Experimental Procedure;

(b) determining the effect of randomly varied foreperiods on measures of muscular power (with a 20% of maximum load).

Day 1:

PROCEDURE FOR DETERMINATION OF INDIVIDUAL MAXIMAL LOAD

(a) Familiarising naive subject with apparatus designed to measure muscular power:

(1) Prior to initial testing, all subjects were issued with written instructions (see: Table 1, Appendix, p. 137) and asked to follow these instructions rigorously (a) 2 days prior to, and (b) during the 3 days of testing.

(2) (i) Age (years and months), (ii) height, (iii) weight, and (iv) right leg length (lateral condyle of right femur to lateral malleolus of right fibula) were measured and recorded (see: Table 4, p. 114).

(3) The bicycle wheel lever was adjusted to suit individual requirements. Length of lever (from axle of wheel to mark on ankle rest) was recorded (see: Table 4).

(4) Date and time of testing were recorded (see: Table 4).

(5) All other apparatus was adjusted to suit individual requirements, including: (i) position of wheel (above ground); (ii) position of table; (iii) mode of operation of the apparatus (see below).

(7) All apparatus was thoroughly checked to ensure standardisation of testing procedure.

(8) The subject was completely familiarised with all apparatus used to measure Muscular Power, (see below).

(b) Determining Maximal Load:

(1) A trial-and-error process was used to ascertain the subject's maximum lift.

(2) Initially, the subject was asked to kick against a load of 50 Kg. This load was increased or decreased accordingly, after the initial trial, depending upon subject performance.

(3) In order to determine 'maximal load', several trials were required. Number required varied between 4 and 10, for the sample tested.

(4) A 3-minute rest period was allowed between trials.

(5) For any subject, the minimum load that could not be moved (as measured by the Beckman Recorder - see: p. 48, Apparatus) was recorded as the maximum lift. (Available weights allowed measurement only to the nearest 0.5 Kg.)

(6) For any subject, maximum load was verified by conducting 2 further trials with that load.

(7) Procedures and instructions were strictly standardised for all subjects (see: Appendix, Table 6 (i), p. 151).

Day 2:

PROCEDURE FOR TESTING SUBJECT WITH 20% MAXIMAL LOAD

(a) Reminding subject of Experimental Procedure:

(1) See: Day 1, points (a) 3 - (a) 8, p. 95.

(2) The subject was informed that his maximum lift (recorded the day before) would be checked to ensure accuracy.

(3) The subject was reminded to kick the lever as hard and fast as he could on each trial.

(4) See: Day 1, points (a) 11 - (a) 17, p. 96.

(b) Retesting individual maximal load:

(1) The subject was tested with his previously recorded maximum lift.

(2) Three consecutive trials were conducted, to verify observations.

(3) A 3-minute rest period was allowed between trials.

(4) If the previous maximum lift was found to differ from the present maximum, the load was increased or decreased accordingly, until the new maximum was ascertained.

(5) Number of trials required for any subject varied between 3 and 8, for the sample tested.

(6) If 2 measurements of maximum lift were obtained on consecutive days for any subject, the larger measure was assumed to be the more accurate estimate.*

(7) For any subject, the minimum load that could not be moved (as measured by the Beckman Recorder) was recorded (see: Table 4, p. 114) as the maximum lift (accurate to within + or - 0.25 Kg.)

(c) Familiarising subject with apparatus designed to measure reaction time:

(1) The subject was informed that, henceforth, all tests would be done with a load (i.e. resistance) equal to 20% of his maximum lift.

(2) The subject was instructed to kick the lever as hard and fast as possible on each trial, when the green 'go' light 'came on'.

* Due to the trial-and-error process adopted on Day 1, fatigue may have affected maximum lift. However, this was less likely on Day 2.

(3) The subject was fully familiarised with all new apparatus. He was informed that (a) muscular power, (b) reaction time, would be measured on each trial.

(4) Eighteen trials were administered, with a 3-minute rest period after trials 6 and 12, and a 60-second rest period after all other trials.

(5) The foreperiod was randomly varied over 12 trials (see: Table 2, p. 100).* Trials 1 - 6 did not represent a random number process, but were designed to familiarise subjects with all possible foreperiods.

(6) Overt performance, as measured by (a) muscular power, and (b) reaction time, was determined for each trial, by asking the subject to kick against a load (i.e. resistance) equivalent to 20% of his maximum lift.+

(7) During each trial the subject received white noise (75 db) through the earphones (see: plate 4, p. 73). The white noise: (a) commenced 5 seconds prior to initiation of the red 'warning' light; (b) was terminated 5 seconds after the initiation of the green 'go' light.

(8) A measure of bicycle wheel velocity was obtained as a trace on the Beckman Recorder, for each trial (see: diagram 6, p. 51). This could be converted to a measure of muscular power by the method outlined in Section 3.7,

* On some occasions, the green light did not 'come on' after the red light. This procedure helped prevent subject anticipation.

\+ A relatively small load was used, to prevent fatigue as a contaminating variable. The load kicked against did not correspond EXACTLY to 20% of the subject's maximum lift; loads were limited by the variety of available Toledo weights.

Table 2 : Practice Test.

SUBJECT NO:

DATE:

TIME TESTED:

MAXIMUM LIFT: KG.

20% MAXIMUM LIFT: KG.

KEY:

(1) S.R.I. = Stimulus-Response Interval.

(2) E = Error made by subject.

(3) 0.0 Foreperiod = Red light is not followed by green light.

TRIAL NO.	FOREPERIOD (SECONDS)	S.R.I. (MILLISECONDS)	E = ✓
1	3.0		
2	2.5		
3	1.0		
4	0.0		
5	1.5		
6	2.0		
4-MINUTE BREAK - Check for Problems			
7	1.0		
8	2.5		
9	1.5		
10	2.0		
11	3.0		
12	1.5		
4-MINUTE BREAK			
13	0.0		
14	2.5		
15	0.0		
16	2.0		
17	1.0		
18	3.0		

'Treatment of Data' (see: pps. 104-111). Reaction Times, obtained from the digital timer (see: diagram 12, p. 63) were recorded for each trial (see: specimen record sheet, Table 2, p. 100).

(9) The pulley system was taken into consideration when calculating the load to be kicked against.

(10) Procedures and instructions were strictly standardised throughout (see: Appendix, Table 6 (ii), p. 153).

DAY 3:

PROCEDURE FOR FINAL TEST OF SUBJECT WITH 20% MAXIMAL LOAD:

(a) Reminding subject of Experimental Procedure:

(1) See: Day 1, points (a) 3 - (a) 7, p. 95.

(b) Determining the effect of randomly varied foreperiods on measures of muscular power (with a 20% of maximum load):

(1) Thirty trials were administered, with a 4-minute rest period after trials: 6, 12, 18 and 24, and a 60-second rest period after all other trials.

(2) The foreperiod was randomly varied over 24 trials (see: Table 3, p. 103). Trials 1 - 6 did not represent a random number process, but were designed to familiarise subjects with all possible foreperiods.

(3) Overt performance, as measured by (a) muscular power, (b) reaction time, was determined for each trial, by asking the subject to kick against a load (i.e. resistance) equivalent to 20% of his maximum lift,* when the green

* (1) Use of a relatively small load prevented fatigue, as a contaminating variable, affecting results. (2) The pulley system was taken into consideration when calculating loads. (3) Load kicked against did not correspond exactly to 20% of each subject's maximum.

light came on.

(4) During each trial, the subject received white noise (75 db) through the earphones (<u>see</u>: 2, plate 4, p. 73). The white noise: (a) commenced 5 seconds prior to initiation of the red 'warning' light, (b) was terminated 5 seconds after the initiation of the green 'go' light.

(5) Prior to commencement of the white noise on each trial, the subject was instructed to kick the lever as <u>hard and fast</u> as he could.

(6) A measure of <u>bicycle wheel</u> velocity was obtained as a trace on the Beckman Recorder, for each trial (<u>see</u>: diagram 6, p. 51). (For raw scores, <u>see</u> p. 115.)

(7) Reaction times, obtained from the <u>digital timer</u> (<u>see</u>: diagram 12, p. 63) were recorded for each trial (<u>see</u>: subject record sheet, Table 3, p. 103). Any <u>errors</u> were also recorded. No reaction time data was utilised in this investigation (<u>see</u>: Table 8, Appendix, p. 160). However, scores were recorded to aid standardisation of procedural routines for future investigations.

(8) The above procedure allowed comparison of performances (as measured by muscular power) for each of 5 different foreperiods. This comparison indicated the extent of any foreperiod/performance (muscular power) interaction.

(9) Procedures and instructions were strictly standardised throughout (<u>see</u>: Appendix, Table 6 (iii), p. 156).

Table 3 : Test (Proper).

SUBJECT NO: ; DATE:

TIME TESTED:

MAXIMUM LIFT: KG.

20% MAXIMUM LIFT: KG.

KEY: (1) E = Error made by subject.
(2) S.R.I. = Stimulus-Response Interval.
(3) 0-0 = Red light is not followed by green light.

TRIAL NO.	FOREPERIOD (SECONDS)	S.R.I. (MILLISECS.)	E = ✓
1	3.0		
2	2.5		
3	1.0		
4	0.0		
5	1.5		
6	2.0		
4-MINUTE BREAK			
7	2.5		
8	3.0		
9	0.0		
10	2.0		
11	2.0		
12	1.0		
4-MINUTE BREAK			
13	2.0		
14	1.0		
15	3.0		
16	2.5		
17	2.5		
18	1.5		
4-MINUTE BREAK			
19	0.0		
20	2.5		
21	1.0		
22	3.0		
23	2.0		
24	3.0		
4-MINUTE BREAK			
25	1.5		
26	1.5		
27	1.0		
28	0.0		
29	0.0		
30	1.5		

END OF TEST.

3.7 TREATMENT OF DATA:

(i) Method of Measuring Power developed by the body:

(1) Mechanical Principles:

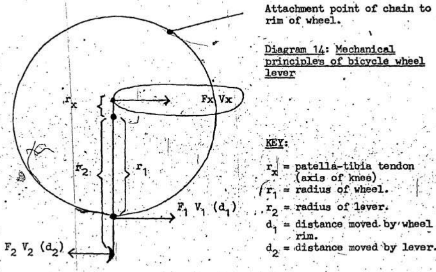

Diagram 14: Mechanical principles of bicycle wheel lever

KEY:

r_x = patella-tibia tendon (axis of knee)
r_1 = radius of wheel.
r_2 = radius of lever.
d_1 = distance moved by wheel rim.
d_2 = distance moved by lever.

(1) The 3 components of the power equation – FORCE, DISTANCE and TIME–could be calculated.

(2). Distance measured = distance through which force travelled.

(3) Point of application of force = point on ankle rest on wheel lever, on which the foot was resting. (Thus, the distance the force travelled = the arc distance (d_1), with the lever length, from the fulcrum (i.e. wheel axle) to a point on the foot rest, as the radius (r_2).)

(4) Arc distance (d_2) = proportional to the lever length (r_2), and could be calculated by: (i) determining distance that rim of wheel moved (d_1); (ii) measuring radius of wheel (r_1); (iii) measuring radius of lever (r_2); (iv) calculating arc distance (d_2) by: $d_2 = \frac{r_2}{r_1} \times d_1$.

(5) The component time (t) = the time taken for the applied force at the ankle rest to travel distance (d_2), and could be calculated by determining the time taken for a fixed point on the rim of the wheel to travel d_1. This time could be measured using a Beckman Recorder (see: p. 51).

(6) The force exerted over distance d_2, could be estimated: (1) STATIC FORCE required to move the weights with low velocity and zero acceleration; (this could be determined by using a spring balance attached at right angles to the lever arm). (2) FORCE exerted in addition to static force, giving the weights their acceleration and resultant velocity.*

(7) Mechanical principles may be applied to the lever system (see: diagram 14):

(1) $Fx.Vx$ = Power generated by muscle(s).

(2) $r_2.F_2 = rx.Fx$, therefore $Fx = \frac{F_2.r_2}{rx}$

(3) $Vx = V_2.\frac{rx}{r_2}$

(4) $F_2 = \frac{r_1}{r_2}.F_1$

(5) $V_2 = t.\frac{r_2}{r_1}.d_2$

(6) $Fx\ Vx = F_2.\frac{r_2}{rx} \times V_2.\frac{rx}{r_2}$

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* This was the kinetic energy of the moving parts, and depended upon their mass and velocity. (Moving parts = weights, including pulley and attachments, lever and handle.) To determine the kinetic energy of any moving part, its mass and final velocity must be known.

(7) therefore $Fx.Vx. = F_2.V_2.$

(8) $$Fx.Vx = \frac{r_1}{r_2}.F_1 \quad \dot{x} \quad t.\frac{r_2}{r_1}.d_1$$

(9) therefore $Fx.Vx = F_1.t.d_1$

(10) P (Power) $= \frac{\text{Force x Distance}}{\text{Time}} = F.V.$

(11) $Px = F_1.t.d_1$

(2) Use of mechanical principles in computing measure of muscular power:

(i) The above principles were applied in computing measures of power for any subject, allowing performances to be compared FOR ANY INDIVIDUAL ONLY.

(ii) When the subject kicked the lever, the potentiometer attached to the axle and wheel spoke, caused a pen deflection on the graph paper of the Beckman Recorder (see: diagram 6, p. 51).

(iii) The magnitude of the deflection was directly proportional to the degree of turning of the wheel.

(iv) The distance the wheel was turned (i.e. the distance that the attachment point of the chain moved) in order to produce a maximum deflection of the marker pen, was measured.

(v) In all computations, the variable of distance was made constant, by calculating the distance that the wheel (attachment point) would move in causing a specific deflection of the pen (see: diagram 7, p. 52).

(vi) The graph paper travelled at a speed of 50 mms./second throughout the recording phase. Consequently, the time required for the attachment point of the chain to travel the constant distance could be computed for each trial (see: diagram 7, p. 52) by first determining the maximum attained velocity during the trial.

(vii) The line of 'best fit'* through the 'steepest' part of the curve, was assumed to represent a measure of maximal velocity (see: diagram 7, p. 52).

(viii) The time (seconds) required to move the lever the set distance, at maximum attainable velocity, was thus easily computed (see: diagrams 6, 7, pps. 51 - 52), providing a measure of MAXIMUM VELOCITY for each trial, of the attachment point of the chain to the wheel rim (see: Table 6, p. 116).

(ix) Measures of muscular power were consequently computed for the different loads kicked against on each trial (see: Table 8, p. 118).

Method of Calculating Maximal Velocity for Each Trial: -
(See: diagrams 6, 7, pps. 51 - 52).

(a) CALCULATION OF DISTANCE TRAVELLED ON EACH TRIAL.
(N.B. See: Ch. 4, p. 115, for complete table of results.)

(1) Full (i.e. Maximum possible), deflection of pen (Beckman Recorder) = 35.8 mms. (due to maximum possible displacement of lever from resting position).

(2) Radius of wheel (to which kicking lever is attached) = 30.0 cms. Therefore, circumferences of wheel =

$$2\pi r = 2 \times \frac{22}{7} \times 30 = 188.57 \text{ cms.}$$

* 'Human error' may have occurred in interpreting the curves.

(3) For a pen deflection of 35.8 mms., the attachment point of chain (to wheel) travelled 64.0 cms.* Therefore, (from 3):

For a pen deflection of 40 mms., the attachment point of chain would move $\frac{40}{35.8}$ x 64 cms. = 71.508 cms. $\simeq$ 71.51 cms.

(4) Assume a pen deflection of 40 mms. for each sub-maximal trial:

Then: distance travelled by attachment point of chain = 71.51 cms. on each occasion.

(5) Paper Speed = 50 mms./second.

(6) If distance travelled by paper = 50 mms./second,

Then: time taken (in seconds) for attachment point of chain to travel 71.51 cms. on each occasion may be calculated for each trial, by measuring distance travelled by paper in order to travel 71.51 cms., and then dividing this figure by 50.

(b) CALCULATION OF MAXIMAL ATTAINED VELOCITY FOR EACH TRIAL:

The following procedure was adopted for all calculations/subjects : (N.B. See: Ch. 4, p. 116, for complete table of results.)

EXAMPLE - SUBJECT X:

TRIAL 1:

20.8 mms. = paper distance (i.e. distance paper travelled).

Therefore, attachment point travelled 71.51 cms. in

$\frac{20.8}{50}$ sec. = 0.416 seconds. Therefore, Maximum Velocity of

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* i.e. 64 cms. out of a total circumference distance of 188.57 cms.

attachment point = $\frac{1.000}{0.416}$ x 71.51 = 171.899 cm./sec.

$\simeq$ 171.9 cm./sec.

TRIAL 2:

17.9 mms. = paper distance. Therefore, attachment point travelled 71.51 cms. in $\frac{17.9}{50}$ sec. = 0.3581 seconds.

Therefore, Maximum Velocity of attachment point =

$\frac{1.000}{0.358}$ x 71.51 = 199.749 cm./sec. $\simeq$ 199.8 cm./sec.

(ii) Justification for statistical analysis undertaken:

(1) Strictly, obtained measures of muscular power: (a) could not be considered 'absolute' measures, (b) could not be used to compare performances of different individuals; both apparatus design, and validity and reliability of the measuring techniques adopted, presented several objections to this approach. Several variable factors have been enumerated elsewhere (see: Error Variance, p. 87, Limitations, p. 7). These included:

(i) Moment of inertia of wheel.

(ii) Muscle(s) length(s); tendon(s) length(s).

(iii) Knee position relative to wheel axle.

(iv) Effective lever length.

(v) Knee angle (starting).

(vi) Exact position of ankle rest at ankle.

(vii) Length (i.e. representing a given weight) of chain either side of pulley system at any point in time.

(viii) Friction/moment of inertia of apparatus.

(ix) Bicycle wheel radius.

(x) Body position, and localisation of effort.

(2) Obtained measures of muscular power could be compared for any individual on several different occasions. (Reliability of measurements was discussed previously (see: p. 92).)

(3) Accordingly, all statistical procedures attempted to compare performance of the same subjects on different occasions, with different foreperiod treatments.

(4) To test several alternative* hypotheses an analysis of variance, utilising a repeated measures design with two experimental variables, was undertaken.+ The following assumptions were justified in conducting this analysis:

(1) Data, (measures of muscular power), was measured on an interval scale.

(2) Columns of data were independent, random samples from the treatment populations.

(3) Treatment populations were normal.

(4) Treatment populations had the same variance.

(5) Samples of equal size were studied. (This both avoided the problem of unequal population variances, and also allowed an efficient comparison between means (i.e. Tukey tests) if such a comparison proved to be necessary).

(6) It was assumed that this test (two-tailed, at the 0.05 level of significance), would indicate with

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* Since it was hoped to disprove the hypothesis of significant difference in this investigation, the alternative hypothesis became the test hypothesis.

+ Hypotheses 1(a), 1(b), 2(a), and 2(b), pps. 6–7 confidence whether the effects of the 5 different fore-periods on measured muscular power were significantly different from each other.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 SUMMARY OF DATA:

Table 4 Subject information/data collection sheet.

Table 5 Calculated distance (mms.) graph paper travelled for the subject to move the bicycle lever a set distance at 'estimated' maximum velocity.

Table 6 Maximal estimated velocities obtained by 7 subjects for each of 30 trials of a test of muscular power with a 20% sub-maximal load.

Table 7 (a) Maximum weight (Kg.) moved, (b) value of load (Kg.) equivalent to 20% (approximately) of that maximum, for 7 subjects.

Table 8 Measures of maximal muscular power obtained by 7 subjects for each of 30 trials with a 20% sub-maximal load.

Table 9 Mean scores (muscular power) obtained by 7 subjects for each of 5 foreperiod treatments with a 20% sub-maximal load.

TABLE 4 : SUBJECT INFORMATION/DATA COLLECTION SHEET.

SUB-JECT	AGE (YRS/MTHS)	HEIGHT (CMS)	WEIGHT (KGS.) (a) TEST 1 (b) RETEST 2	LENGTH OF BICYCLE WHEEL LEVER (CMS)	'LOWER LEG' LENGTH (CMS)	MAXIMUM WEIGHT (KG.) LIFTED* (a) TEST 1 (b) RETEST 2	TIME TESTED (TEST 1)	DATE TESTED (TEST 1)
1	22,9	181.0	(a) 85.5 (b) 85.0	42.5	41.5	(a) 88.0 (b) 88.0	1.00p.m.	1.4.76.
2	36,4	175.1	(a) 76.6 (b) 76.7	41.0	40.0	(a) 70.0 (b) 72.0	11.00a.m.	2.4.76.
3	19,8	175.7	(a) 69.5 (b) 71.3	41.0	40.0	(a) 47.0 (b) 47.0	7.00p.m.	1.4.76.
4	19,6	180.2	(a) 80.9 (b) 81.3	44.5	43.5	(a) 80.5 (b) 81.0	5.00p.m.	1.4.76.
5	19,6	186.3	(a) 77.5 (b) 77.5	44.5	43.5	(a) 66.0 (b) 68.0	9.00p.m.	2.4.76.
6	19,1	179.8	(a) 77.0 (b) 77.2	47.0	46.0	(a) 61.0 (b) 61.0	3.00p.m.	1.4.76.
7	22,2	167.6	(a) 80.3 (b) 80.5	41.5	40.5	(a) 67.0 (b) 67.0	9.00a.m.	2.4.76.

* (N.B. All maximum lifts were measured accurately, + or - 0.25 Kg.)

TABLE 5 : CALCULATED DISTANCE (mms.) GRAPH PAPER TRAVELLED FOR SUBJECT TO MOVE BICYCLE LEVER A SET DISTANCE AT ESTIMATED MAXIMUM VELOCITY.

	SUBJECT NUMBER						
TRIAL NO.	1	2	3	4	5	6	7
1	14.8	22.8	15.8	16.3	16.7	18.1	18.1
2	16.7	18.6	18.4	16.1	18.2	17.6	18.6
3	13.7	20.9	16.7	15.3	17.0	19.1	18.6
4	—	—	—	—	—	—	—
5	14.7	18.2	16.5	16.7	18.0	18.9	17.8
6	14.1	20.3	16.0	15.6	18.5	22.6	21.8
7	13.3	20.8	15.7	14.8	16.0	18.8	18.4
8	13.1	18.6	15.4	15.7	16.2	20.8	17.8
9	—	—	—	—	—	—	—
10	13.5	18.3	16.0	16.6	17.1	20.2	17.8
11	15.3	19.0	18.7	15.6	17.3	19.1	19.7
12	13.4	18.1	17.4	14.7	16.8	21.5	18.0
13	12.9	18.6	15.7	13.7	14.8	19.8	20.0
14	14.0	21.3	19.1	13.9	14.5	20.3	22.3
15	14.2	21.5	18.3	14.8	19.0	19.4	21.1
16	13.6	20.5	18.9	16.0	17.0	22.0	20.1
17	13.6	21.2	17.5	15.2	18.1	21.9	22.0
18	14.4	19.0	14.9	16.6	16.4	19.4	18.2
19	—	—	—	—	—	—	—
20	14.2	20.8	17.3	14.5	15.7	21.1	20.0
21	15.5	19.0	17.7	15.7	16.4	17.3	21.7
22	13.6	19.0	16.0	15.2	17.7	17.8	22.6
23	14.9	19.8	18.6	14.8	16.1	17.3	25.2
24	13.0	18.3	18.3	16.7	16.7	19.0	23.7
25	14.3	21.4	15.3	14.5	15.0	19.9	20.9
26	14.2	18.6	20.5	14.4	17.2	19.9	20.7
27	13.8	17.8	17.7	15.3	14.8	18.9	16.3
28	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—
30	13.8	15.8	16.7	15.5	16.2	21.2	19.2

TABLE 6 : ESTIMATED MAXIMAL VELOCITIES OBTAINED BY 7 SUBJECTS FOR EACH OF 30 TRIALS OF A TEST OF MUSCULAR POWER WITH A 20% SUB-MAXIMAL LOAD.

MAXIMAL VELOCITIES OBTAINED (CM./SEC.)

SUBJECT NUMBER

TRIAL NO.	1	2	3	4	5	6	7
1	241.6	156.8	226.3	219.4	214.1	197.5	197.5
2	214.1	192.2	194.3	222.1	196.5	203.2	192.2
3	261.0	171.1	214.1	233.7	210.3	187.2	192.2
4	—	—	—	—	—	—	—
5	243.2	196.5	216.7	214.1	210.3	189.2	200.9
6	253.6	176.1	223.5	229.2	193.3	158.2	164.0
7	268.8	171.9	227.7	241.6	223.5	190.2	194.3
8	272.9	192.2	232.2	227.7	220.7	171.9	200.9
9	—	—	—	—	—	—	—
10	264.9	195.4	223.5	215.4	209.1	177.0	200.9
11	233.7	188.2	191.2	229.2	206.7	187.2	181.5
12	266.8	197.5	205.5	243.2	212.8	166.3	198.6
13	277.2	192.2	227.7	261.0	241.6	180.6	178.8
14	255.4	167.9	187.2	257.2	246.6	176.1	160.3
15	251.8	166.3	195.4	241.6	188.2	184.3	169.5
16	262.9	174.4	189.2	223.5	210.3	162.5	177.9
17	262.9	168.7	204.3	235.2	197.5	163.3	162.5
18	248.3	188.2	240.0	215.4	218.0	184.3	196.5
19	—	—	—	—	—	—	—
20	251.8	171.9	206.7	246.6	227.7	169.5	178.8
21	230.7	188.2	202.0	227.7	218.0	206.7	164.8
22	262.9	188.2	223.5	235.2	202.0	200.9	158.2
23	240.0	180.6	192.2	241.6	222.1	206.7	141.9
24	275.0	195.4	195.4	214.1	214.1	188.2	150.9
25	250.0	167.1	233.7	246.6	238.4	179.7	171.1
26	251.8	192.2	174.4	248.3	207.9	179.7	172.7
27	259.1	200.9	202.0	233.7	241.6	189.2	219.4
28	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—
30	259.1	226.3	214.1	230.7	220.7	168.7	186.2

END OF TEST.

TABLE 7 : (a) MAXIMUM WEIGHT (KG.) MOVED, (b) VALUE OF LOAD (KG.) EQUIVALENT TO 20% (APPROXIMATELY) OF THAT MAXIMUM for 7 SUBJECTS.

SUBJECT NUMBER	MAXIMUM WEIGHT LIFTED (KGS.)	WT. (KG) EQUIVALENT TO 20% OF MAXIMUM	NEAREST WT. (KG) AVAILABLE (WITH APPARATUS)	% OF MAXIMUM LIFT EQUIVALENT TO WEIGHT CHOSEN
1	88.0	17.6	17.5	19.9
2	72.0	14.4	14.5	20.1
3	47.0	9.4	9.5	20.2
4	81.0	16.2	16.0	19.8
5	68.0	13.6	13.5	19.9
6	61.0	12.2	12.0	19.7
7	67.0	13.4	13.5	20.1

TABLE 8 : MEASURES OF MAXIMAL MUSCULAR POWER OBTAINED BY 7 SUBJECTS FOR EACH OF 30 TRIALS WITH A 20% SUB-MAXIMAL LOAD.

(SEE: TABLES 6, 7, pps. 116, 117).

	MAXIMAL MEASURES OF MUSCULAR POWER OBTAINED (KG. M./SEC.)						
	SUBJECT NUMBER						
TRIAL NO.	1	2	3	4	5	6	7
1	42.3	22.7	21.5	35.1	28.9	23.7	26.7
2	37.5	27.9	18.5	35.4	26.5	24.4	25.9
3	45.7	24.8	20.3	37.4	28.4	22.5	25.9
4	—	—	—	—	—	—	—
5	42.6	28.5	20.6	34.3	28.4	22.7	27.1
6	44.4	25.5	21.2	36.7	26.1	19.0	22.1
7	47.0	24.9	21.6	38.7	30.2	22.8	26.2
8	47.8	27.9	22.1	36.4	29.8	20.6	27.1
9	—	—	—	—	—	—	—
10	46.4	28.3	21.2	34.5	28.2	21.2	27.1
11	40.9	27.3	18.2	36.7	27.9	22.5	24.5
12	46.7	28.6	19.5	38.9	28.7	20.0	26.8
13	48.5	27.9	21.6	41.9	32.6	21.7	24.1
14	44.7	24.3	17.8	41.2	33.3	21.3	21.6
15	44.1	24.1	18.6	38.7	25.4	22.1	22.9
16	46.0	25.3	18.0	35.8	28.4	19.5	24.0
17	46.0	24.5	19.4	37.6	26.7	19.6	21.9
18	43.5	27.3	22.8	34.5	29.4	22.1	26.5
19	—	—	—	—	—	—	—
20	44.1	24.9	19.6	39.5	30.7	20.3	24.1
21	40.4	27.3	19.2	36.4	29.4	24.8	22.[illegible]
22	46.0	27.3	21.2	37.6	27.3	24.1	21.4
23	42.0	26.2	18.3	38.7	30.0	24.8	19.2
24	48.1	28.3	18.6	34.3	28.9	22.6	20.4
25	43.8	24.2	22.2	39.5	32.2	21.6	23.1
26	44.1	27.9	16.6	39.7	28.1	21.6	23.3
27	45.3	29.1	19.2	37.4	32.6	22.7	29.6
28	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—
30	45.3	32.8	20.3	36.9	29.8	20.2	25.1

TABLE 9 : MEAN SCORES (MUSCULAR POWER) OBTAINED BY 7 SUBJECTS FOR EACH OF 5 FOREPERIOD TREATMENTS WITH A 20% SUB-MAXIMAL LOAD. (SEE: TABLE 8, p. 118).

(N.B. All scores = Kg. M./Sec.)

1. FOREPERIOD 1 (1.0 SECONDS):

TRIAL NO.	SUBJECT NUMBER						
	1	2	3	4	5	6	7
12	46.7	28.6	19.5	38.9	28.7	20.0	26.8
14	44.7	24.3	17.8	41.2	33.3	21.3	21.6
21	40.4	27.3	19.2	36.4	29.4	24.8	22.2
27	45.3	29.1	19.2	37.4	32.6	22.7	29.6
$\bar{x}$ (Kg.M./Sec.) POWER	44.275	27.325	18.925	38.475	31.0	22.2	25.05
S.D. (Standard Dev.)	2.716	2.155	0.757	2.087	2.288	2.054	3.821

2. FOREPERIOD 2 (1.5 SECONDS):

TRIAL NO.	SUBJECT NUMBER						
	1	2	3	4	5	6	7
18	43.5	27.3	22.8	34.5	29.4	22.1	26.5
25	43.8	24.2	22.2	39.5	32.2	21.6	23.1
26	44.1	27.9	16.6	39.7	28.1	21.6	23.3
30	45.3	32.8	20.3	36.9	29.8	20.2	25.1
$\bar{x}$ (Kg.M./Sec.)	44.175	28.05	20.475	37.65	29.875	21.375	24.5
S.D.	0.789	3.558	2.794	2.457	1.711	0.818	1.608

TABLE 9 (Cont.):

3. FOREPERIOD 3 (2.0 SECONDS):

TRIAL NO.	SUBJECT NUMBER						
	1	2	3	4	5	6	7
10	46.4	28.3	21.2	34.5	28.2	21.2	27.1
11	40.9	27.3	18.2	36.7	27.9	22.5	24.5
13	48.5	27.9	21.6	41.9	32.6	21.7	24.1
23	42.0	26.2	18.3	38.7	30.0	24.8	19.2
$\bar{x}$ (Kg.M./Sec.)	44.45	27.425	19.825	37.95	29.675	22.55	23.725
S.D.	3.597	0.914	1.733	2.844	2.159	1.593	3.297

4. FOREPERIOD 4 (2.5 SECONDS):

TRIAL NO.	SUBJECT NUMBER						
	1	2	3	4	5	6	7
7	47.0	24.9	21.6	38.7	30.2	22.8	26.2
16	46.0	25.3	18.0	35.8	28.4	19.5	24.0
17	46.0	24.5	19.4	37.6	26.7	19.6	21.9
20	44.1	24.9	19.6	39.5	30.7	20.3	24.1
$\bar{x}$ (Kg.M./Sec.) POWER	45.775	24.9	19.65	37.9	29.0	20.55	24.05
S.D.	1.212	0.327	1.482	1.602	1.824	1.542	1.756

TABLE 9 (Cont.):

5. FOREPERIOD 5 (3.0 SECONDS):

TRIAL NO.	SUBJECT NUMBER						
	1	2	3	4	5	6	7
8	47.8	27.9	22.1	36.4	29.8	20.6	27.1
15	44.1	24.1	18.6	38.7	25.4	22.1	22.9
22	46.0	27.3	21.2	37.6	27.3	24.1	21.4
24	48.1	28.3	18.6	34.3	28.9	22.6	20.4
$\bar{x}$ (Kg.M./Sec.)	46.5	26.9	20.125	36.75	27.85	22.35	22.95
S.D.	1.821	1.911	1.799	1.884	1.933	1.443	2.951

4.2 ANALYSIS OF DATA:

(See: Raw Data, Table 9, pps. 119–121.)

1. Main Null Hypothesis (Ho):

$$\mu p^s f(1) = \mu p^s f(2) = \mu p^s f(3) = \mu p^s f(4) = \mu p^s f(5)$$

Where:

μp^s = Individual average score of muscular power, with a pre-determined (20%) sub-maximal load;

$f(1)$ = Foreperiod of 1.0 seconds;

$f(2)$ = Foreperiod of 1.5 seconds;

$f(3)$ = Foreperiod of 2.0 seconds;

$f(4)$ = Foreperiod of 2.5 seconds;

$f(5)$ = Foreperiod of 3.0 seconds.

2. Subsidiary Null Hypothesis (Ho):

$$\mu p^s f(1) = \mu p^s f(2) = \mu p^s f(3) = \mu p^s f(4) = \mu p^s f(5)$$

Where:

μp^s = Group average score of muscular power with a pre-determined (20%) sub-maximal load;

$f(1)$ = Foreperiod of 1.0 seconds;

$f(2)$ = Foreperiod of 1.5 seconds;

$f(3)$ = Foreperiod of 2.0 seconds;

$f(4)$ = Foreperiod of 2.5 seconds;

$f(5)$ = Foreperiod of 3.0 seconds.

Analysis:

To test the alternative hypotheses:

$H_1(1)\ \mu p^s f(1) \rangle$ or $\langle \mu p^s f(2) \rangle$ or $\langle \mu p^s f(3) \rangle$ or $\langle \mu p^s f(4) \rangle$ or $\langle \mu p^s f(5)$

$H_1(2)\ \mu p^s f(1) \rangle$ or $\langle \mu p^s f(2) \rangle$ or $\langle \mu p^s f(3) \rangle$ or $\langle \mu p^s f(4) \rangle$ or $\langle \mu p^s f(5)$

An analysis of variance, utilising a repeated measures design with two experimental variables, was conducted. (For details of analysis see: Table 9, p. 162, Appendix.) An analysis of variance table was completed (Table 9 (i), p. 162). Observed F ratios were compared with tabled values for $\alpha = 0.05$ (two-tailed test) with appropriate degrees of freedom:

(a) MAIN EFFECTS

(i) Between subjects variance

Entering the table of the F distribution* for $\alpha = 0.05$, with $N_1 = 6$ and $N_2 = 72$, an F value of 2.214 was required for significance. A value of 440.647 was experimentally obtained. Therefore differences between subjects were shown to be highly significant.

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* Kmietowicz, Z. W., and Yannoulis, Y. Mathematical, Statistical and Financial Tables for the Social Sciences. Longman : London, 1976, p. 22.

(ii) Between foreperiods variance

For $\alpha = 0.05$, with $N_1 = 72$ and $N_2 = 4$, an F value of 5.664 was required for significance. A value of 0.722 was obtained. Therefore the treatments effects (i.e. foreperiods) appeared to be highly insignificant.

(iii) Between trials variance

For $\alpha = 0.05$, with $N_1 = 3$ and $N_2 = 72$, an F value of 2.719 was required for significance. A value of 2.532 was obtained, indicating that differences between trials were insignificant.

(b) FIRST-ORDER INTERACTIONS

(iv) (Subjects x foreperiods) variance

For $\alpha = 0.05$, with $N_1 = 72$ and $N_2 = 24$, an F value of 1.800 was required for significance. A value of 0.930 was obtained, indicating that the interaction between subjects and foreperiods was highly insignificant.

(v) (Subjects x trials) variance

For $\alpha = 0.05$, with $N_1 = 18$ and $N_2 = 72$, an F value of 1.703 was required for significance. A value of 1.582 was obtained, supporting an insignificant interaction between subjects and trials.

(vi) (Foreperiods x trials) variance

For $\alpha = 0.05$, with $N_1 = 12$ and $N_2 = 72$, an F value of 1.875 was required for significance. A value of 1.687 was obtained, indicating that the interaction between foreperiods and trials was insignificant.

4.3 DISCUSSION OF RESULTS:

(1) Individual performances (as measured by muscular power, with a load equivalent to 20% of an individual's maximum lift) were found to be not significantly different (i.e. either better or worse) with any of the 5 chosen foreperiods.

(2) No reasonable evidence existed for rejecting the null hypotheses (Ho):

$Ho(1)\ \mu p^s f(1) = \mu p^s f(2) = \mu p^s f(3) = \mu p^s f(4) = \mu p^s f(5)$

$Ho(2)\ \mu p^s f(1) = \mu p^s f(2) = \mu p^s f(3) = \mu p^s f(4) = \mu p^s f(5)$

(3) The alternative hypotheses (H_1) could be rejected with reasonable confidence, since the very low observed F value for between foreperiods variance (= 0.722) compared with the required value (= 5.664) suggested a relatively small possibility of making a type II error.

(4) A highly significant variation in performance between subjects existed due to various individual innate and acquired characteristics. Such a finding was expected in a randomly chosen sample where the dependent variable examined was considered to be normally distributed.

(5) Differences between trials was not a significant source of variance. Similarly, each of the first-order interactions was insignificant, suggesting that: (a) effects of subjects and foreperiods were independent; (b) effects of subjects and order of trials were independent; (c) effects of foreperiods and order of trials were independent. Consequently, no important contaminating effect was shown to be operating (see: p. 162, Appendix).

(6) Statistical results indicated that no particular foreperiod, within experimental limits, was correlated with optimal

performance. Mean scores* of muscular power with each foreperiod were ranked as follows:

Foreperiod	Mean Score (Muscular Power, Kg.M./Sec.)	Rank
1.0 seconds	29.6	1
1.5 seconds	29.4	2
2.0 seconds	29.4	2
2.5 seconds	28.8	5
3.0 seconds	29.0	4

(7) Subjective analysis (see table above) indicated that optimal performances were obtained with the shortest foreperiod (i.e. 1 second). Although ranks indicated a trend towards worsening performance with increased foreperiod, all scores were so similar (range = 0.8 Kg.M./Sec.) that no differences could be inferred from obtained data. Any possible contaminating effect, which might result from future investigations, was thus considered to be minimal.

(8) Average performances of a group of 7 subjects were found to be not significantly different (i.e. better or worse) with any of 5 different foreperiods, randomly assigned.

(9) It has been consequently suggested that, in future investigations, randomly varied foreperiods+ would not act as an intervening variable, contaminating observed scores of muscular power obtained with various sub-maximal loads.

* (i.e. group mean scores of individual mean scores.)

+ As defined in this investigation.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

5.1 CONCLUSIONS:

(1) Whilst an optimum foreperiod may exist for any reaction time task (see: literature review) results have indicated that no such optimum foreperiod exists for the muscular power task outlined in this investigation.

(2) It has been consequently suggested that similar randomly varied foreperiods would not act as an intervening variable, contaminating observed scores of muscular power, in future investigations.

(3) In future investigations, various sub-maximal loads could reasonably be used in conjunction with randomly varied foreperiods, to measure simultaneously muscular power and reaction time, respectively.*

(4) None of the 5 tested foreperiods appeared likely to contaminate experimental data adversely in a future investigation. All 5 foreperiods would probably have an equal effect upon measures of muscular power, and would, consequently, be permissible in a future investigation.

(5) All 5 tested foreperiods could be used in a future investigation, with reasonable certainty of no inherent experimental bias being introduced into the data.

5.2 RECOMMENDATIONS:

For a future final investigation, which would consider the effects of a stressor on performance (as measured by muscular power and reaction time), it was recommended that:

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* Acceptance of this conclusion assumed that the result of no significant difference, obtained using the same sub-maximal load for all trials, was equally applicable to a test where sub-maximal loads varied.

(i) Various <u>sub-maximal loads</u> (i.e. %'s of maximum) could be reasonably used together with <u>randomly varied</u> foreperiods, to measure simultaneously <u>muscular power</u> and <u>reaction time</u>, respectively.

(ii) The <u>order</u> of randomly varied <u>foreperiods</u> (including 'warm-up' trials) should be exactly similar to the order adopted in this investigation.

(iii) Standardised apparatus and procedural format followed here for recording reaction time should be incorporated into a future investigation.

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APPENDIX

APPENDIX

Table 1

INSTRUCTIONS GIVEN TO SUBJECTS PRIOR TO TESTING

Name: ______________________________

Please try to follow these instructions carefully before the test.

1. Come dressed in tracksuit/gym shoes.

2. Do not engage in any physical activity during the period three hours before the test.

3. Eat 'normal' diet and drink 'normal' amount of liquid 48 hours before the test. (Record diet on diet sheet; i.e. types of foods at each meal and type of meal.)

4. Do not engage in 'exhaustive' physical activity in 48 hours prior to test.

5. Do not eat or drink anything in the 60-minute period prior to test.

6. Have 'normal' amount of sleep on the evening before test.

7. Do not drink any alcohol in the 36-hour period prior to test.

8. Do not smoke any cigarettes within the 3-hour period prior to testing.

9. Do not drink any tea or coffee within the 3-hour period prior to testing.

10. Do not partake of any other drug within 24-hours prior to testing.

11. Ensure that you are in 'normal' health on the day of the testing. (i.e. not suffering from influenza etc.).

12. Ensure that you are not physically injured on the day of testing. (If you have received any injury within 1 week prior to test, inform the examiner.)

13. Please inform the examiner prior to the test, if, for any reason, you fail to meet all requirements.

14. Report to examiner at ______________ on ______________ in ______________.

15. Do not discuss testing with anyone else. Thank you.

16. If there are any questions concerning instructions, please see examiner.

Table 2 : ALGEBRAIC EQUATION OF FORCE-VELOCITY CURVE

$$(P + a) \quad (Vmax\ p + b) = (Po + a)\ b$$

Where:

P = force,

v = dx/dt = velocity,

Po = isometric tension,

a and b are constants with the dimensions of a force and a velocity respectively.

$$P.Vmax\ p + a.Vmax\ p + Pb + a.b = Po.b + a.b$$

$$P.Vmax\ p + a.Vmax\ p = Po.b - Pb$$

$$Vmax\ p\ (P + a) = b\ (Po - P)$$

$$P + a = b.\ \frac{(Po - P)}{Vmax\ p}$$

$$P = b.\ \frac{(Po - P)}{Vmax\ p} - a\ *$$

* This is a straight line with slope b and intercept-a.+

+ See: Hill, A. V.
Proceeds of the Royal Society, 1938, B, Vol. 126, p. 136.

Table 3 : TABLE OF RANDOM NUMBERS

2017	4228	2317	5966	3861	0210	8610	5155	9252	4425
7449	0449	0304	1033	5370	1154	4863	9460	9449	5738
9470	4931	3867	2342	2965	4088	7871	3718	4864	0657
2215	7815	6984	3252	3254	1512	5402	0137	3837	1293
9329	1218	2730	3055	9187	5057	5851	4936	1253	9640
4504	7797	3614	9945	5295	6985	0383	5187	8556	2237
4491	9949	8939	9460	4849	0677	6472	5926	0851	2557
1623	9102	1996	4759	8965	2784	3092	6337	2624	2366
0450	6504	6565	8242	7051	5501	6147	8883	9934	8237
3270	1772	0361	6626	2471	2277	8833	1778	0892	7349
0364	5907	4295	8139	0641	2081	9234	5190	3908	2142
6249	0090	6786	9348	3183	1907	6768	4903	2747	5203
6100	9586	9836	1403	4888	5107	3340	0686	3376	6857
8903	9049	2874	2104	0996	6045	2203	5280	0179	3381
0172	3385	5240	6007	0671	8927	1429	5524	8579	3196

From: The Open University - "Educational Studies: A Third Level Course, Methods of Educational Enquiry Block 2". (The Open University Press, 1973, p. 39).

Table 3 : TABLE OF RANDOM NUMBERS

Table 4 : APPARATUS

(a) Measurement of Muscular Power:

(i) Bicycle Wheel (no. 1) and Attached Lever:

1. Bicycle Wheel (Radius = 30 cms. - to outside rim of wheel); Circumference ≏ 188.6 cms.; width of rim ≏ 3.3 cms. Circumference (inside rim of wheel, in chain groove ≏ 182.4 cms.)

2. Two sets of supporting (bicycle wheel) staves attaching wheel indirectly to beam, and arranged equidistant (12.0 cms.) from each other and 6 cms. from the horizontal line representing the diameter of the wheel (made of hollow tubular steel, length of each = 38.5 cms.).

3. Additional hollow tubular steel rod (≏ 14.5 cms. long) welded to staves and attaching staves firmly to beam via steel corner pieces (29 cms. long, 0.6 cms. thick, 9.6 cms. wide on one side of beam corner, and 14.4 cms. wide on other side).

4. Strong steel bolts and stansions, attaching corner piece securely to beam.

5. Two 'braking' devices, attached securely to wheel, consisting of 2 steel bars (9.0 cms. long, 1.2 cms. in diameter) and a strong plastic hollow tube (2.4 cms. in diameter, with 1.2 cms. hole in centre) over each end of each bar.

6. Stone Beam supporting bicycle wheel (height = 2 metres 3.4 cms., width ≏ 25.2 cms.; length ≏ 28.8 cms.).

7. Lever (length = 70.0 cms.; width = 5.0 cms.; thickness* = 0.6 cms.) attached to inside of bicycle wheel axle, composed of

* 'Thickness' refers to diameter of the CROSS SECTIONAL AREA of the metal.

steel/aluminium alloy. (Width of axle ≏ 6.0 cms.)

8. Steel Block (length = 6.0 cms.; width = 3.0 cms.; thickness = 1.5 cms.) securely attaching lever to inside of wheel axle by strong nuts and bolts.

9. Steel Block (length = 4.8 cms.; width = 3.6 cms.; thickness = 0.6 cms.), securely attaching lever to periphery of wheel by strong nuts and bolts.

10. Sliding unit, composed of steel/aluminium alloy lever extension, (thickness = 0.6 cms.) and ankle rest, attached securely to lever by strong nut and bolt, and allowing lever length to be varied within 31 cms. vertical range.

11. Ankle rest (i.e. adjustable part of lever), curved inwards to fit the subject's ankle. (Convex surface = 21.6 cms. long; concave surface = 20.7 cms. long; width = 14.4 cms.; thickness = 0.3 cms.).

(ii) Pulley System:

1. Small bicycle wheel (no. 2) (Radius = 20 cms.; Circumference = 125.7 cms.; width of rim = 1.75 cms.).

2. Tyre for wheel (Pressure = 2.46 - 2.81 Kg./sq.cm.; Radius of wheel (with tyre) = 23.0 cms.).

3. "Fixed" wheel (18 teeth) attached to wheel (diameter ≏ 7.2 cms.).

4. Steel supporting arm (3-sided) attaching "fixed" bicycle wheel securely to 2 corner plates (width of side of arm = 7.6 cms.; thickness of steel = 0.6 cms.; width of top and bottom surfaces of arm = 2.4 cms.; length of arm = 85.2 cms.).

5. Two strong steel bolts (lengths = 31.2 cms. each) attaching supporting arm securely to stone beam via 2 steel corner pieces, welded to supporting arm.

6. Two steel corner pieces, welded to supporting arm (lengths = 33.6 cms. each; widths (of both sides) of both corner pieces = 7.2 cms.).

7. Additional steel plate, reinforcing supporting arm on fourth side of stone beam (length = 36.0 cms.; thickness = 0.9 cms.; width = 7.2 cms.).

8. Stone beam (height ≏ 2 metres, 3.4 cms.; width ≏ 25.2 cms.; length ≏ 28.8 cms.) supporting above mentioned "pulley" system. (Vertical distance from axle of "fixed" wheel to ground = 144.0 cms.).

9. Steel brake arm and safety brake, attached securely to supporting arm, and positioned 0.2 cms. away from tyre of fixed wheel, with brake arm UP. (Length of brake arm = 24.3 cms.; diameter of arm = 2.0 cms.; length of safety brake = 15.3 cms.; width of brake ≏ 4.0 cms.; thickness of brake ≏ 0.8 cms.).

10. Pulley chain, composed of bicycle chain links (length each link = 1.8 cms.; width of each link = 0.6 cms.), and attached at both ends: End 1: attached to fixed position in groove on inside of rim of wheel no. 1 by means of nut and bolt; End 2: attached securely to central support of weight container (see later), and reinforced at this point by doubling and redoubling of the chain and by supporting bolts. (Total length of chain = 3 metres, 36.6 cms.)

11. Pulley system, formed by taut chain (see above) passing over teeth of "fixed" wheel between two ends of attachment (see above).

12. Steel weight container, consisting of: (a) tray (width = 22.2 cms.; length = 31.8 cms.; height of tray = 1.8 cms., with rim of height 1.2 cms. stabilising contained weight);

(b) central support of container, attaching container to chain of pulley (see 10 above) via steel bar, and stabilising the container securely by means of 2 metal rings over the steel bar either side of the chain. (Length of support = 37.8 cms.; width = 7.6 cms.)

13. 2 x 25 - Kilogram Toledo Weights.

2 x 20 - " " "		
4 x 5 - " " "		used for measuring strength and muscular power by means of the pulley system.
2 x 2 - " " "		
2 x 1 - " " "		

(iii) Recording Muscular Power:

1. Potentiometer (Ohmite Type AB RV4NAYSD5DIA, No. CMU 5011), attached securely to outside of axle of wheel (no. 1), and to one of the wheel spokes, and linked to input channel of Beckman, through Universal Coupler, via cable wires to B. N. C. connector (Voltage = 1.5v; resistance = 500 Ω).
2. A. C. supply (115 volts), to Beckman Recorder via lead from adapter (length = 4.0 metres).
3. Wires ('Positive', 'Negative' and 'Earth') relaying to Beckman Recorder.
4. Beckman Type R411, Dynograph Recorder (and Recording Graph Paper), monitoring changes in potential difference, due to movement of the bicycle wheel (no. 1), as a pen deflection on the graph paper.
5. Beckman Type R411 Dynograph Recorder Ink Cartridges.

(iv) Additional apparatus required to measure muscular power:

1. Wooden table, one end converted into adjustable seat for subjects performing tests (height = 72.0 cms.; width = 64.2 cms.;

length = 1 metre, 14.6 cms.) and reinforced lengthwise on 2 sides by wooden cross stays (length = 120 cms.; width = 6.6 cms.; thickness = 2.4 cms.) and also widthwise on 2 sides by cross stays (length = 74.4 cms.; width = 6.6 cms.; thickness = 2.4 cms.).

2. Nylon rope, attached securely to stone beams and around table, securing table in correct position, alongside lever, during performance of trials. (Length = 5 metres; diameter = 1.2 cms.).

3. Foam sponge seat, covering top, undersurface and edge of one table end, and constructed from a piece of foam sponge (length = 50 cms.; width = 30 cms.; thickness = 3.5 cms.).

(b) 'Audio' Apparatus:

1. Roberts 1725-II, Stereophonic 4-track Tape Recorder, inputting to specially constructed tape track/headset Control Panel by specially constructed 2-track lead. (Controls: (i) 2 speeds (9.33 cms./sec.; 19.05 cms./sec.); (ii) separate volume/tone controls for tracks 1 and 4, 2 and 3; (iii) automatic position marker; (iv) recording level indicator.)

2. Roberts Model 80 Portable single-track monophonic tape recorder, inputting to tape track/headset control panel by specially constructed single-track lead.

3. Tape track/headset Control Panel, receiving input from 2 tape recorders, and inputting to: (1) Experimenter's Earphones; (2) Subject's Earphones (height = 10.5 cms.; length = 15.5 cms.; width = 9.0 cms.).

4. 'Sensiphone Superex' Earphones (Experimenter), receiving input from 2 tape recorders (3 tracks), via Control Panel (i.e. Track selector), through Monitor Headset output.

5. Roberts Deluxe Model 4850A Stereo Headphones (Subject), receiving input from 2 tape recorders (3 tracks), via Control Panel (i.e.track selector).
6. Tenzar 1.5 Mil Backing, Low Noise, Professional Quality Oxide Recording Tape (AV 176), for use with Roberts 1725-II Tape Recorder (size of tape = 6.35 mms. x 360 metres). (N.B. Tape used to record WHITE NOISE (see p. 16), at 75 db on 1 track, from white noise generator)
7. Hi-dynamic Emitape Cassette, low noise, for use with Roberts portable tape recorder. (N.B. Tape used to record experimental instructions at 70 db.)
8. A. C. Supply (125 volts) to: (a) Roberts 1725-II, Stereo 2-track Tape Recorder (85 Watts); (b) Roberts portable tape recorder (15 Watts); (length of leads ≏ 2 metres, 50 cms.).
9. 2-Track Leads, from Roberts 1725-II Stereo Tape Recorder (right and left external speaker sockets), to Audio Control Panel. (Length = 2.0 metres.)
10. 1-Track lead from Roberts portable tape recorder (external speaker socket), to control panel (length = 2.0 metres).
11. 'Monitor Head Set' output, incorporated into design of Control Panel, and lead (from output socket) to Earphones (Experimenter). (Length of lead = 1 metre, 15 cms.)
12. Headset output lead to Roberts Deluxe Model 4850A Stereo Headphones. (Length = 8.5 metres.)
13. Multi-socket adapter, to accommodate electrical appliances.

(c) Initiation of Subject Response:

1. Two general electric light bulbs (25 Watts, 115-125 volts); 1 red light (= warning light); 1 green light (= 'go' light).

2. Adjustable plywood board, painted non-gloss black, housing 2 bulb sockets (diameter = 10.8 cms.) containing 1 red light (left centre) and 1 green light (right centre), receiving input from AC supply (115 volts), via lead from Control Panel (see: 4 below). (Length of board = 24.0 cms.; width = 42.0 cms.; thickness = 1.2 cms.)
3. String and nails, supporting board on inside of front wall of booth, and attached to cross bar bolted to beam 22.0 cms. from ceiling. (Length of string ≃ 4 metres.)
4. Leads (length = 6.0 metres), from Control Panel (see: 5 below) to red and green bulbs.
5. Specially designed Control Panel, incorporating: (a) Press-Button Switch, controlling initiation of (i) Red 'warning' light, and (ii) Green 'go' light; (b) Metrix Model MX solid state Timer, controlling foreperiod between 0.0 and 5.0 seconds (for use with AC current, 110-120 volts, 3 Watts).
6. AC supply (115 volts), to Control Panel, and hence to red and green lights.
7. Multi-socket adapter, to accommodate electrical appliances.

(d) Polystyrene Booth:

1. composed of white polystyrene (thickness = 4.5 cms.);
2. surrounding subject, bicycle wheel (no. 1) and lever, part of table, and part of pulley chain;
3. dimensions: (Height = 1 metre, 88.4 cms.; length = 1 metre, 52.4 cms.; width = 1 metre, 17.6 cms.);
4. roof completely covered with polystyrene
5. bottom half of back wall of booth cut away, to allow positioning of table, for subject to sit on;

6. front two-thirds of table projecting into booth, (distance between table top and bottom of back wall of booth = 5.0 cms.);
7. small holes (1.2 cms. long x 2.4 cms. high) at bottom of sides of booth, allowing passage of all electrical wires;
8. part of front wall of booth cut away (height = 1 metre, 0.8 cms.; width = 72.0 cms.) allowing: (i) subject entry, (ii) subject to observe weights to be kicked against;
9. additional section from front wall (24 cms. high x 7.2 cms. wide) cut away, allowing passage of pulley chain out of booth;
10. small hole (2.4 cms. wide x 2.4 cms. high, 80.4 cms. from ground) in one side wall of booth, allowing passage of wire from potentiometer to Beckman Recorder.

(e) Other Measuring Instruments:

1. Detecto-Medic Scales (for weighing subjects, Kgs.).
2. Holtain (Ltd.) adjustable height measurement apparatus (cms.).
3. Adjustable ('sliding') centimetre rule (for adjusting length of lever).
4. Kodak Timer Clock (for measuring time interval between trials, in seconds and minutes).
5. Spirit Measure for assessing the relationship of angle of wheel (no. 1) movement to degree of pen deflection on Beckman Recorder, and for ensuring that lever was in exact vertical position at rest.
6. One Crescent (AT112) spanner (length = 33 mms.) for adjusting lever length.
7. General Radio Company Sound Level Meter Type 1551-C (Recalibrated September, 1975), to measure sound level of white noise and instructions.

(f) Other Important Dimensions of Apparatus Design:

1. Distance from axle of bicycle wheel (no. 1) to axle of 'fixed' wheel (no. 2) = 2 metres, 8.2 cms.

2. Distance from bottom of supporting arm to floor = 1 metre, 44.9 cms.

3. Depth, from centre of outside tyre groove of bicycle wheel to rim of tyre groove of bicycle wheel = 0.94 cms.

4. Wheel (No. 1): viewed from subject's position:

(a) Range of Movement of Wheel at Rest.	(1) Anticlockwise movement = 0°. (2) Clockwise movement = 122.182°.	due to braking devices.
(b) Range of Movement of Wheel after maximum displacement of lever from resting position.	(1) Anticlockwise movement = 122.182°. (2) Clockwise movement = 0°.	due to braking devices.

5. Resting Knee angle (subject): = 90° (+ or − 5°).

6. Magnitude of needle deflection (millimetres of graph paper) caused by maximum clockwise movement of lever (from resting position) = 35.8 mm.

7. Paper Speed (Beckman Recorder) = 50 mm./second, for recording measures of muscular power.

8. (a) Weight of Weighing Container = 7 Kg.

   (b) Weight of Chain and Bicycle Lever = 2 Kg. (= including load required to move wheel against resistance caused by moment of Inertia of wheel, at resting position).

Table 5 : TEST OF RELIABILITY, USING SPLIT-HALF METHOD: SCORES (MUSCULAR POWER) OBTAINED FOR 7 SUBJECTS WITH 20% MAXIMUM LIFT

5 (a)

SUBJECT	TRIAL NUMBER					
	1	2	3	4	5	6
1	42.3	37.5	45.7	42.6	44.4	47.0
2	22.7	27.9	24.8	28.5	25.5	24.9
3	21.5	18.5	20.3	20.6	21.2	21.6
4	35.1	35.4	37.4	34.3	36.7	38.7
5	28.9	26.5	28.4	28.4	26.1	30.2
6	23.7	24.4	22.5	22.7	19.0	22.8
7	26.7	25.9	25.9	27.1	22.1	26.2

5 (b) Mean scores (muscular power) on Odd and Even items for each Subject.

SUBJECT	MEAN (ODD SCORES)	MEAN (EVEN SCORES)
1	44.10	42.37
2	24.33	27.10
3	21.00	20.23
4	36.40	36.13
5	27.80	28.37
6	21.73	23.30
7	24.90	26.40

5 (c) Pearson Product - Moment Correlation Coefficient:

(Using mean scores from odd and even items).

SUBJECT	ODD x	EVEN y	x^2	y^2	xy
1	44.10	42.37	1944.81	1795.22	1868.52
2	24.33	27.10	591.95	734.41	659.34
3	21.00	20.23	441.00	409.25	424.83
4	36.40	36.13	1324.96	1305.38	1315.13
5	27.80	28.37	772.84	804.86	788.69
6	21.73	23.30	472.19	542.89	506.31
7	24.90	26.40	620.01	696.96	657.36

Σx	Σy	Σx^2	Σy^2	Σxy
200.26	203.90	6167.76	6288.97	6220.18

$$rxy = \frac{N \Sigma xy - \Sigma x \Sigma y}{\sqrt{(N \Sigma x^2 - (\Sigma x)^2)\ (N \Sigma y^2 - (\Sigma y)^2)}}$$

$$= \frac{7 \times 6220.18 - 200.26 \times 203.90}{\sqrt{(7 \times 6167.76 - (200.26)^2)\ (7 \times 6288.97 - (203.90)^2)}}$$

$$= \frac{2708.25}{\sqrt{3070.25 \times 2447.58}}$$

$$r = \frac{2708.25}{2741.29} = 0.99$$

= Very high reliability.

Table 6 (i) : PROCEDURE FOR DETERMINATION OF INDIVIDUAL MAXIMAL LOAD

(a) Procedure for familiarising naive subjects with apparatus prior to determination of Maximal Load:

KEY: (A) = subject must answer to indicate that he understands the directions.

1. Ask subject to go into booth, sit on table, with back of legs against edge of table, and with 'lower' legs at right angles to table top.
2. Adjust height of wheel and position of table so that axle of wheel is level with axis of knee of right leg, with leg resting comfortably on table.
3. Adjust length of bicycle lever, so that point of contact of right ankle is at previously marked point on lever.
4. Measure: (a) length of bicycle lever (axle to point of contact); (b) axis of knee to axis of ankle of lower right limb (i.e. lateral condyle (femur) to lateral malleolus (fibula).)
5. Check apparatus: (i) Beckman Recorder; (ii) pulley system; (iii) weights; (iv) braking devices; (v) warning and stimulus lights; (vi) white noise; (vii) time recorder; (viii) recorded instructions; (ix) score sheets.
6. Instruct subject to put headphones on.
7. Place load of 15 Kgs. onto pulley attached to wheel.
8. Ensure that both tape recorders are operating adequately, and that "white noise" track is running.
9. Say: "Can you hear me clearly?" (A).
10. Say: "These instructions are recorded."
11. Say: "If you are asked a question, please answer to indicate that you understand. Is that clear?" (A).
12. Position of subject:
    Say: "Please do exactly as you are instructed."
13. Say: "Place your right foot behind the lever, with your ankle resting on the lever. Make sure that your right leg is as close to the bicycle wheel as possible. Have you done this?" (A).
14. Say: "Please check that the axle of the wheel goes through the axis of your knee. If it does not please adjust the position of your right leg now. Is your right leg in the correct position now?" (A).
15. Say: "Good." Instruct subject: "Keep your back straight during each trial of the test. Do not use any other part of your body to kick this lever except your right leg. Is this clear?" (A).
16. Instruct subject: "Place your hands on your knees at the beginning of each trial." Say: "Have you done this?" (A).
    Say: "Check that your back is straight now."
17. Maximum Load:
    Say: "I will explain how the apparatus works, and then you can have 5 practice trials. Okay?" (A).
18. Explain: "I want to find out what the maximum load is that you can move by kicking the lever with your right leg. If you manage to move the load, then the movement will be recorded as a trace on the graph paper. Do you understand?" (A).
19. Say: "Different loads will be attached to the bicycle wheel. You will see what each load is, before being asked to move it, but you will be told nothing. Do you understand?" (A).

20. Instruct subject (at the same time pointing to relevant weights): "Please note that the following weights will be used: 25 Kg., 20 Kg., 5 Kg., 2 Kg., 1 Kg., and ½ a Kg. The weight of the bicycle wheel is 2 Kg. The weight of the container is 7 Kg. On each trial it is important that you observe what each load is. Please observe clearly the extent of the load that you will be kicking against on each trial. Is this clear?" (A).
21. Warning Light:
Say: "The red light on the left of the board in front of you is a warning light. It will come on like this."
22. Press switch, causing red light to come on. (Ensure that F.P. delay is 3 seconds.)
23. Say: "The red light means 'get ready' for a second light to come on which is to the right-hand side of the red light. This green light will come on 3 seconds after the red light. Watch." (Allow green light to come on.) Ask: "Do you understand?" (A).
24. Ask: "Did you see the warning light come on, followed by the second green light?" (A).
25. Say: "The green light means 'go'. When it comes on, try to move the load by kicking the lever as hard and fast as you can. Do not move your foot back, away from the lever. Simply kick forwards and upwards when you see the green light. Is all that clear?" (A).
26. Say: "The wheel has a load of only 15 Kg. on it at the moment. Kick the lever as hard as you can now." (Subject kicks lever with right foot.)
27. Say: "Good." Ask subject: "Please would you keep your right leg extended, with the lever resting on it, at the end of each trial? You can lower your leg when I return the load to its original position. This will help me with my readings. Do you understand?" (A).
28. Reassure subject: "As you can see, the safety devices built into this apparatus make it absolutely safe. There is no possibility of you injuring yourself. So please do not worry. Okay?" (A).
29. Say: "The lights will disappear when you kick the lever."
30. Say: "I'll recap so far. First, the red warning light comes on. This means that you must 'get ready' to kick the lever. Is this clear?" (A). Say: "Then, 3 seconds later, the green light will come on. When it does, kick the lever as hard and fast as you can. Is that clear?" (A).
31. Instruct subject: "Remember, don't move the lever until the green light comes on. Alright?" (A).
32. Instruct subject: "Keep your ankle just touching the lever until the green light comes on."
33. Explain: "Before I place a heavy load on the wheel you will have 5 practice trials with a relatively small load of 15 Kg., to allow your muscles to get 'warmed-up'. Do you understand?" (A).
34. Say: "You will be given a one-minute rest period between each practice trial."
35. Say: "During the trials I am not allowed to speak to you. Also, you will hear what is called 'white noise' in your earphones. This is to 'cut out' any disturbing sound influence. Listen, and I will demonstrate."

36. Switch on white noise. Five seconds on, then switch off. Ask: "Does the noise distress you, or is it comfortable?" (A). Say: "That's alright then." (Adjust white noise accordingly.)
37. Say: "The white noise will be switched on just before each trial is to be commenced. In the rest intervals, between trials, I will switch off the white noise. You can then relax. Is all this clear?" (A).
38. Say: "Between trials you may stand up and walk about, but please keep the earphones on. When the white noise is switched on, then take your position ready to kick the lever. When you are ready, say: "Ready." Shortly afterwards, the red light will come on. Do you understand?" (A).
39. Ask: "Are you ready?" (A).
40. Say: "Let's start with the 5 practice trials then."
41. Give subject 5 practice trials (15 Kg.).
42. At the end of the fifth trial say: "That is your last practice trial. Before we start the test, are there any questions or problems?" (A).

(b) Procedure for Determination of Maximal Load:

43. Say: "Okay. In order to find out the maximal load that you can move, we will start with a load of 50 Kg., which will be increased or decreased depending on your performance. Alright?" (A).
44. Say: "There will be a 3-minute rest period between trials. We will continue until your maximum load is found. Is that clear?" (A).
45. Say: "Remember to keep your back straight, and to kick as hard and fast as you can at each trial. Are you ready?" (A).
46. Test subject with various loads. Start at 50 Kg. and work up/down in 5 Kg. divisions initially, as necessary. Then change load by 1 Kg. at a time. Find the minimum load that cannot be moved. Verify this maximum load by checking subject on 3 consecutive trials.
47. When maximum load has been found, say: "Thank you. That's all for today. But I should like to check the maximum load that you can move on another occasion, to ensure that this figure is accurate. You can take off the earphones now." Say: "You did well."

Table 6 (ii) : PROCEDURE FOR TESTING SUBJECT WITH 20% MAXIMAL LOAD

(a) Reminding subject of Experimental Procedure:

KEY: (A) = subject must answer to indicate that he understands the directions.

1. See page 151, 1 - 8.
2. Ask: "Do you remember what you must do?" (A). "When the green light comes on, you must kick the lever as hard and fast as you can. Please keep your back straight, and your hands on your knees. Is all that clear?" (A).
3. Say: "As before, you will first receive 5 practice trials with a load of 15 Kg., with a 1-minute rest between each trial. Remember to keep your right ankle just touching the lever until

the green light comes on. Okay?" (A).

4. Say: "Before we begin, please listen to the white noise."
5. Switch on white noise (5 seconds) then switch off. Ask: "Does the noise distress you, or is it comfortable?" (A). Say: "That's alright then."
6. Instruct subject: "Remember to say 'ready' when you are ready, prior to each trial. Also, remember to check that your right leg and knee are correctly positioned before saying ready. Okay?" (A).
7. Ask: "Are you ready for the practice trials?" (A).
8. Give subject 5 practice trials (15 Kg.).
9. At the end of the fifth trial say: "That is your last practice trial. Any questions?" (A).

(b) Retesting individual maximal load:

10. Say: "I will now check the maximum load that you can move. Are you ready for the test?" (A). Say: "Remember to kick as hard and fast as you can. There will be a 3-minute rest period between trials."
11. Test subject with previous maximum load. If this is not the present maximum load, increase or decrease load until maximum load is ascertained. (N.B. Verify maximum by checking subject on 3 consecutive trials.)
12. When subject's present maximum load has been found say: "Thank you. I have checked your maximum load. You can relax now. While you are resting, listen carefully to the following instructions."

(c) Procedure for Familiaring Subject with apparatus designed to measure Reaction Time:

1. Say: "From now on, all tests will be done with a weight which is equal to 20% of your maximum. Is that clear?" (A).
2. Say: "I am now going to put a weight equivalent to 20% of your maximum onto the pulley attached to the wheel. Please observe."
3. Put 20% of subject's maximum weight into the container, on the end of the pulley (allowing for the weight of the wheel, lever, pulley system and container).
4. Say: "I would like you to do a test for me. This is what you must do."
5. Explain: "First, the red warning light will come on. This means 'get ready'. Then the second green light will come on. When it does, kick the lever with your right leg, as quickly and as hard as possible. Do you understand?" (A).
6. Explain: "I am measuring two things. Listen carefully. Firstly, for each trial, I will measure the time between the second green light coming on, and you kicking the lever. So keep your foot just touching the lever, between each trial. Is this clear?"(A). "Secondly, I will measure how hard you kick the lever. So, kick the lever as hard and fast as you can. Is this clear?" (A). "Do you understand what two things I am measuring?" (A).
7. Say: "Let's try it. Are you ready?" (A).
8. Press switch (Foreperiod (F.P.) = 2 seconds). (Subject reacts). Say: "Good."

Foreperiod Time Interval

9. Say: "During the test, the time interval between the red light coming on, and the second green light coming on, will vary. I will show you each alternative. Watch, but do not do anything yet."
10. (F.P. = 1 second.) Say: "This is the first one." Press 'ready' switch.
11. Ask: "Okay?" (A). (Alter F.P. to 1.5 seconds.)
12. Say: "This is the second one." Press 'ready' switch.
13. Ask: "Alright?" (A). (Alter F.P. to 2.0 seconds.)
14. Say: "This is the third one." Press 'ready' switch.
15. Ask: "Okay?" (A). (Alter F.P. to 2.5 seconds.)
16. Say: "This is the fourth one." Press 'ready' switch.
17. Ask: "Okay?" (A). (Alter F.P. to 3.0 seconds.)
18. Say: "This is the fifth one." Press 'ready' switch.
19. Ask: "Alright?" (A).
20. Say: "Any of these intervals may occur on any trial. There is no particular sequence. Do you understand?" (A). Say: "Fine."
21. Say: "Listen carefully now. Sometimes, after the warning light, the second, green light will not come on. In this case, do <u>not</u> kick the lever. If you do, this is counted as an error. Is this clear?" (A). Say: "Watch, and I'll show you what I mean."
22. Turn F.P. to 5-seconds; turn off green 'go' light. Press 'ready' switch. Wait 5-seconds. Press 'ready' switch again, to turn off red light. Press green 'go' switch, ready for the next trial.
23. Ask: "Okay?" (A).
24. Ask: "Do you understand the sequence?" (A). Say: "Good."
25. Say: "For each trial, I will measure the time between the second light coming on, and you <u>starting</u> to kick the lever. As soon as you start to put pressure on the wheel, the timer will stop. I will also measure, on the graph paper, the speed with which you kick the lever. So, when the green light comes on, kick the lever as hard and fast as you can. Is all this clear?" (A).
26. Say: "Let's try the whole thing then. Are you ready?" (A). Press 'ready' switch (F.P. = 3 seconds). Subject reacts. Say: "Good."
27. Say: "Now we are ready to begin the test. BUT ARE THERE ANY QUESTIONS FIRST OF ALL?" (A).
28. Say: "Remember to check the position of your right leg and knee, before each trial, and to keep your back straight."
29. Say: "If you make an error, don't worry."
30. Explain: "I will give you 18 trials; 6 trials, then a 3-minute rest period; then 6 more trials, followed by a 3-minute rest period; finally, the last 6 trials. Is that clear?" (A). Say: "Good."
31. Explain: "Between each trial, you will receive a 60-second rest. Alright?" (A). Say: "You can stand up and move about between trials, if you wish. During trials, I am not allowed to speak to you. Also, you will hear the white noise in your earphones just before each trial is due to begin. When you hear the white noise please take your position. When you are ready, say: "ready". Is this clear?" (A).
32. Explain: "Between each set of trials, you can relax. I can speak to you, and you can then ask any questions. You will be told when each set of trials is over, and when each new set is

due to begin. Alright?" (A).

33. Say: "Let's start then. Are you ready for the first set of trials?" (A). Say: "I will switch on the white noise, and shortly afterwards the first trial will start. Okay?" (A). Say: "Kick as hard and fast as you can."

Procedure for Initial Reaction Time Test

34. Check that all apparatus is functional; ensure that Beckman Recorder is operating correctly, and that Millisecond Reaction Timer is set at zero.
35. Switch on white noise, for first trial. Wait for subject to say 'ready'. Allow 5-seconds after switching on white noise before pressing 'ready' switch; adjust foreperiod intervals as necessary; turn off white noise immediately after each trial. Reset timer after each trial.
36. Conduct trials 1 - 6. Record scores (Reaction Time and Muscular Power).
37. After trial 6, say: "The first set is now over. Any problems?" (A). Say: "You now have a 3-minute rest period."
38. After 3-minute rest period, say: "Are you ready for the second set of trials?" (A). Say: "Remember, as hard and fast as you can."
39. Conduct trials 7 - 12. Adopt exactly the same procedure as for trials 1 - 6.
40. After trial 12, say: "The second set is now over. Is everything alright?" (A). Say: "Good." (3 minutes rest)
41. After 3-minute rest period, say: "Are you ready for the third set of trials?" (A). Remind subject: "Remember, as hard and fast as you can."
42. Conduct trials 13 - 18. (Use same procedure as previously)
43. After trial 18, ask: "Any problems?" (A).
44. Say: "That's all then for today. But the final test will be exactly the same sort of thing, except that you will receive 30 trials. Is that clear?" (A).
45. Say: "This practice test is over." Instruct subject: "Please take off the headphones now." (Subject leaves booth)
46. Say: "You did alright."
47. Say: "If you make any errors during the final test, don't worry about it. Okay?" (A). Say: "Thank you. That's all for today."
48. Arrange a time for the actual test. Give subject instruction sheet (See: Table 1, p. 137) and ask: "Please follow these instructions carefully."

Table 6 (iii) : PROCEDURE FOR FINAL TEST OF SUBJECT WITH 20% MAXIMAL LOAD

KEY: (A) = subject must answer to indicate that he understands the directions.

1. See: Day 1, points 1 - 6; 8; 9, p. 151.
2. Say: "I would like to check the white noise first."
3. Switch on white noise (5 seconds) then switch off. Ask: "Does the noise distress you, or is it comfortable?" (A). Ask: "Does it cut out any background noise?" (A). Say: "Good."

(a) <u>Procedure for Reminding Subjects of Experimental Procedure</u>:

4. Say: "You will receive 30 trials with a 60-second rest period between each trial. After each set of trials, there will be a 4-minute rest period. Alright?" (A).
5. Say: "You can stand up and walk about the booth between trials if you wish. But when you hear the white noise in your earphones, please take your 'ready' position. When you are ready, say: "ready". Is this clear?" (A).
6. Say: "Please do not leave the booth; and please keep the earphones on. Okay?" (A).
7. Say: "All these trials are with a weight equivalent to 20% of your maximum lift. Do you remember what you must do?" (A).
8. Say: "Remember, you must kick the lever as quickly as possible when the green light comes on. You must also kick the lever as hard and fast as possible. Okay?" (A). (Emphasize <u>this</u> point) Say: "If you make an error, don't worry."
9. Explain: "During trials, I am not allowed to speak to you. Between each set of trials you can relax. I can then speak to you. You will be told when each set of trials is over, and when the next set is due to begin. Alright?" (A).
10. Instruct: "Please remember to keep your back straight, and your right knee and leg in the correct position. DO NOT USE ANY OTHER PART OF YOUR BODY TO KICK THE LEVER. IS THAT CLEAR?" (A).
11. Instruct: "Please, also remember to keep your right leg extended after the trial, until I lower the weight. Alright?" (A).
12. Say: "Let's start then. Are you ready for the first set of trials?" (A).
13. Say: "I will switch on the white noise, and shortly afterwards, the first trial will start. Okay?" (A).
14. Place a load, equivalent to 20% of subject's maximum load, into the container on the end of the pulley.*

(b) <u>Procedure for Final Reaction Time and Muscular Power Test</u>

15. Check again that all apparatus is functional.
16. Switch on white noise for the first trial. Wait for subject to say: 'ready'.
17. Allow 5 seconds, after switching on white noise, before pressing 'ready' switch.
18. Conduct trials 1 - 6. Record, but do not count scores (= PRACTICE trials). Adjust foreperiod as necessary. Turn off white noise immediately after each trial. Reset timer after each trial.
19. After trial 6, say: "The first set is now over. Any problems?" (A). Say: "You now have a 4-minute rest period."
20. Fifteen seconds before the end of the rest period, say: "Remember, as hard and fast as you can. Are you ready for the second set of trials?" (A).
21. Conduct trials 7 - 12. (Adopt same procedure as for trials 1 - 6, but 'count' scores, and record measurements for (a) Muscular Power, (b) Reaction Time.)

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* (<u>N.B.</u> All loads took into consideration weight of container, pulley chain, etc.)

22. After trial 12, say: "The second set is now over. Is everything alright?" (A). Say: "Good; 4 minutes rest."
23. Fifteen seconds before the end of the rest period, say: "Are you ready for the third set of trials?" (A). Say: "As hard and fast as you can."
24. Conduct trials 13 - 18. (Use same procedure as previously.)
25. After trial 18, say: "The third set is now over. Alright?" (A). Say: "Okay; you have 4 minutes rest now."
26. Fifteen seconds before the end of the rest period, say: "Are you ready for the fourth set of trials?" (A). Say: "As hard and fast as you can."
27. Conduct trials 19 - 24. (Use same procedure as previously.)
28. After trial 24, say: "The fourth set is now over. Is everything okay?" (A). Say: "Four minutes rest."
29. Fifteen seconds before the end of the rest period, say: "Are you ready for the fifth set of trials?" (A). Remind subject: "As hard and fast as you can."
30. Conduct trials 25 - 30. (Use same procedure as previously.)
31. After trial 30, say: "The test is now over. Thank you. Please take off the earphones, and leave the booth."
32. Say to subject: "You did alright."

Table 7 : (PRACTICE TEST) REACTION TIME SCORES

Raw Data : Simple Reaction Time Scores of 7 Subjects with Randomly Varied Foreperiods (N.B. All Scores = Milliseconds)

TRIAL NO.	F.P. (SECS.)	SUBJECT 1(S.R.T.)	SUBJECT 2(S.R.T.)	SUBJECT 3(S.R.T.)	SUBJECT 4(S.R.T.)	SUBJECT 5(S.R.T.)	SUBJECT 6(S.R.T.)	SUBJECT 7(S.R.T.)
1	3.0	275	307	394	302	287	ERROR	344
2	2.5	314	318	391	282	443	400	333
3	1.0	340	392	406	353	362	365	379
4	0.0	-	-	-	-	-	-	-
5	1.5	360	328	377	335	446	358	368
6	2.0	267	275	306	301	314	407	395
7	1.0	319	288	356	333	286	347	348
8	2.5	269	268	337	287	370	329	428
9	1.5	357	313	351	258	ERROR	443	391
10	2.0	264	296	400	329	305	352	326
11	3.0	230	252	373	431	314	445	394
12	1.5	283	267	435	309	732	306	365
13	0.0	-	-	-	-	-	-	-
14	2.5	251	271	388	371	697	381	424
15	0.0	-	-	-	-	-	-	-
16	2.0	241	ERROR	370	299	255	416	441
17	1.0	278	372	351	397	302	311	379
18	3.0	256	397	468	ERROR	346	372	446

(ERROR = subject made error)

Table 8 : (TEST PROPER) REACTION TIME SCORES

(Test Proper) Raw Data: Reaction Time Scores of 7 Subjects with Randomly Varied Foreperiods (N.B. All Scores = Milliseconds)

TRIAL NO.	F.P. (SECS.)	SUBJECT 1(S.R.T.)	SUBJECT 2(S.R.T.)	SUBJECT 3(S.R.T.)	SUBJECT 4(S.R.T.)	SUBJECT 5(S.R.T.)	SUBJECT 6(S.R.T.)	SUBJECT 7(S.R.T.)
1	3.0	249	362	350	302	284	400	356
2	2.5	244	302	343	282	266	394	364
3	1.0	293	299	351	353	399	376	363
4	0.0	-	-	-	-	-	-	-
5	1.5	256	306	321	335	303	400	375
6	2.0	285	289	301	301	287	380	390
7	2.5	347	308	348	328	279	372	325
8	3.0	282	282	374	343	275	362	430
9	0.0	-	-	-	-	-	-	-
10	2.0	286	386	439	299	314	366	374
11	2.0	319	259	326	239	314	359	357
12	1.0	295	300	364	290	517	347	391
13	2.0	242	275	359	276	279	325	384
14	1.0	275	343	407	ERROR	431	388	379
15	3.0	273	303	332	303	271	439	375
16	2.5	265	275	351	294	319	333	378
17	2.5	261	321	451	288	315	393	394
18	1.5	273	517	321	280	285	417	385
19	0.0	-	-	-	-	-	-	-
20	2.5	243	283	322	255	ERROR	457	362
21	1.0	286	354	352	ERROR	321	374	414
22	3.0	267	343	421	270	302	397	356
23	2.0	252	304	351	237	391	379	451
24	3.0	263	299	275	260	301	409	366
25	1.5	311	354	412	ERROR	384	349	349
26	1.5	297	309	314	313	474	371	384
27	1.0	244	339	ERROR	304	336	333	444

/Cont..

Table 8 (Cont.)

28	0.0	-	-	-	-	-	-	-
29	0.0	-	-	-	ERROR	-	-	-
30	1.5	270	331	357	ERROR	333	456	398

(ERROR = subject made error)

Table 9 : STATISTICAL ANALYSIS OF DATA

ANALYSIS OF VARIANCE, UTILISING A REPEATED MEASURES DESIGN

WITH TWO EXPERIMENTAL VARIABLES *

(See: (1) Raw Data, Table 8, p. 118).

(2) Null Hypotheses 1(a), 1(b), 2(a), 2(b).)

Table 9 (i) : Sum of Squares

(1) Total S.O.S.+ = 10,549.5669

(2) MAIN EFFECTS

(i) Between Subjects: $S\,(\bar{X}_a - \bar{X})^2 = 9{,}970.6089$

(ii) Between Foreperiods: $S\,(\bar{X}_b - \bar{X})^2 = 10.8948$

(iii) Between Trials: $S\,(\bar{X}_c - \bar{X})^2 = 28.6412$

(3) FIRST-ORDER INTERACTIONS

(iv) Subjects x foreperiods (a b):

Interaction S.O.S. for a b = 84.1282

(v) Subjects x trials (a c):

Interaction S.O.S. for a c = 107.4088

(vi) Foreperiods x trials (b c):

Interaction S.O.S. for b c = 76.3595

(4) SECOND-ORDER INTERACTION (RESIDUAL)

(vii) Residual (a b c) = 271.5255

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* See: Chambers, E. G.
Statistical calculation for beginners.
Cambridge University Press, 1958, pps. 142-146.

\+ S.O.S. = Sum of Squares.

Table 9 (ii) : ANOVA Summary

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares (Variance Estimate)	F (Variance Ratio)
Between Subjects (a)	9,970.6089	6	1,661.7682	440.6471
Between Foreperiods (b)	10.8948	4	2.7237	0.7222
Between Trials (c)	28.6412	3	9.5471	2.5316
Interaction Subjects x Foreperiods (ab)	84.1282	24	3.5053	0.9295
Interaction Subjects x Trials (ac)	107.4088	18	5.9672	1.5823
Interaction Foreperiods x Trials (bc)	76.3595	12	6.3633	1.6873
Interaction Subjects x Foreperiods x Trials (Residual) (a x b x c)	271.5255	72	3.7712	–
TOTAL	10,549.5669	139	–	–

Table 9 (iii) : Comparison of Required and Obtained F Values

(0.05 Level of Significance)

	Source of Variation	Required F (0.05 level)*	Obtained F (See: Table 9(ii), p. 163)	Whether Significant
(i)	Between Subjects	2.214	440.647	Yes
(ii)	Between Foreperiods	5.664	0.722	No+
(iii)	Between Trials	2.719	2.532	No
(iv)	Interaction Subjects x Foreperiods	1.800	0.930	No
(v)	Interaction Subjects x Trials	1.703	1.582	No
(vi)	Interaction Foreperiods x Trials	1.875	1.687	No

* See: Kmietowicz, Z. W., and Yannoulis, Y.
Mathematical, Statistical and Financial Tables for the Social Sciences.
Longman, London, 1976; pps. 22-23.

\+ The treatments effects (i.e. various foreperiods) were shown to be INSIGNIFICANT (0.05 level of significance).