A STUDY OF THE PHYSIOLOGICAL COSTS OF
SYMMETRICAL AND SIMULTANEOUS MOTIONS

by

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TABLE OF CONTENTS

INTRODUCTION

Motion study had its beginning in the early 1900's when Frank B. Gilbreth (1911) observed the methods by which work was performed in a given task situation. These first observations gradually developed into a set of "rules for motion economy and efficiency." These rules relating to motion study were used throughout industry until R. M. Barnes (1940) reviewed these rules and others that were being used at that time and formulated what is known as the "Principles of Motion Economy." Since that time, these rules have been the basis for evaluation and improvement of given work situations.

The evaluation of these principles of motion economy has been done largely with the criterion of time. The set of motions required to perform a given task situation that results in the least amount of time required to accomplish the task is defined as "best." It has been the opinion of some persons that least time may or may not be the best criterion from the standpoint of physiological cost to the worker.

If the shortest time doesn't necessarily determine the optimum set of motions, what criterion does? Several investigations have been made along this line using some physiological properties related to time as the criteria. Examples of these are: Oxygen consumption per unit of time, pulse rate and the increase in body temperature.

The investigations have been successful in demonstrating that to a certain degree, i.e. under strained work conditions, that physiological variations do arise as a result of task variation. Recently, a new measuring device of the physiological cost to the worker has come from the work begun by Lucien Lauru (1957). Lauru developed a force platform to be used as a means of recording physical effort resulting from the performance of light tasks. Greene (1957) improved and calibrated the platform. The data obtained from the instrument correlates significantly with the physical definition of work, i.e. force acting through a distance.

It is therefore, the purpose of this paper to investigate the principle of motion economy established by Barnes that states, "motions of the arms should be performed symmetrically and simultaneously." Physiological cost as measured by a force platform will be the criterion.

LITERATURE REVIEW

Symmetrical and Simultaneous Motions.

Frank B. Gilbreth (1911) revolutionized the field of scientific management by presenting his ideas on motion economy. His now famous bricklayer illustration was the basis of his studies. Mr. Gilbreth stated that "When work is done with both hands simultaneously, it can be done quickest and with least mental effort if the work is done by both hands in a similar manner; that is to say, when one hand makes the same motions to the right as the other does to the left." This was the beginning of organized thought on the subject of related arm motions. Mr. Gilbreth, however, did not specifically demonstrate this to be true in the bricklaying illustration. Mr. Gilbreth's laws of motion economy were not immediately accepted. It took some time before they were understood and put to use.

Later, Hartson (1932) spoke of putting special emphasis on the idea that "elements of movements occur simultaneously." It wasn't until 1937 that Barnes reviewed the original laws of motion economy by Gilbreth and developed what is known and used today as the "Principles of Motion Economy." As one of his principles, Barnes (1940) states "Motions of the arms should be made in opposite and symmetrical directions and should be made simultaneously." He further says, "There is apparently less body strain when the hands move symmetrically than when they make non-symmetrical motions, because of this matter of balance." This statement was illustrated by the use of a bolt and washer assembly task. The old method of performance was improved by 53% using time as the criterion. Barnes and Mundel (1939) made an investigation of the effect of the angle in the horizontal frontal plane upon the efficiency with which the subject moved his hands in a simultaneous, symmetrical fashion. The results of the study showed that when visual direction of the hands was required to perform the task, the 90° position was best for both hands. The "three o'clock" position was defined as zero. For the task where visual direction was not required, the 60° and 120° angle was best for the right and left hands respectively. These angles were also measured from the three o'clock position. Time was used as the criterion.

Briggs (1955) also investigated the effect of angle in the design of work areas. He had ten right handed male students from the psychology classes of Purdue University perform a simple motor task of moving a stylus from one position to another with their right hand. The angles investigated were 0°, 30°, 60°, 90° and 120° with varying distances. All angles were measured at the three o'clock position. The effect of angles was significant. The criterion used was the number of correct hits on a target per 20 seconds. From the results, Briggs plotted a curve of score versus angle as shown in Fig. 1. The plot shows that the score is maximum when the angle is 57.2° and that the maximum average response score is between angles of 62.8° and 52.7°.

It may be noted from Fig. 1 that a higher score was obtained per 20 seconds for outward motions than for inward motions. Wu (1965) investigated the effect of angle and work table height for ten right-handed subjects. He found that the amount of work exerted was dependent on angle. It can also be shown from Wu's data that there is a difference in the amount of work required of inward and outward motions of the arms. This can be explained from Fig. 2 which was reproduced from an investigation by Dudek and Petruno (1965). The mechanical advantage of the arm is best when the arm is contracted as at the beginning of an outward motion. The mechanical advantage changes to a "least" value when the arm is extended as at the beginning of an inward movement. This causes differences in the amount of energy the subject must expend to move his arm in to and out from his body. From this it may be concluded that when the arm is considered to be a lever, it will require more energy expenditure to move the arm in toward the body than to move it away from the body.

From this discussion, the question arises: Does the shortest time represent the smallest amount of work done by the operator? H. L. Gantt in Gilbreth (1911) related the story of the time that Mr. Gilbreth applied his laws of motion economy to a task that was already being performed with exceptional speed. At the time, it was considered that the task was at a point of maximum production, beyond which it was almost impossible for anyone to achieve. Although this was the general opinion, Mr. Gilbreth improved the job by analyzing its component motions. The results were a easier method by which the task could be performed and increased output. From this story, the question of the shortest time representing the smallest amount of work done by the operator may be answered by concluding that the shorter time does not necessarily represent least work. This was demonstrated by the elimination of the extra motions of the task in the story to obtain a task that could be performed easier and faster.

There have been a few attempts to evaluate Barnes' principles; however, they have used time as the criterion. The problem of finding the best criterion on which to base decisions about physical work has plagued scientists. Schmidtke and Stier (1961) investigated the possibility of a physiologically optimum motion time. The experiment required the subject to move her hands between fixed points to the beat of a metronome. In order to avoid static muscular work, her arms were suspended by two flexible loops. A gas meter measured the expired air and analyzed its content of O_2 and CO_2. The energy expended in the task performance was calculated from the CO_2 value. The results of the experiment showed the optimum time values to be dependent on distance traveled, motion pattern and weight transported. The conclusions were good only for continuously swinging motions. Greene, Morris and Wiebers (1959) mentioned three methods of determining energy expenditure. The first two methods dealt with measurement of caloric consumption as the criteria. These methods are difficult to perform; consequently, they are not used except under laboratory conditions. The third is based on the oxygen consumed during the performance of the task. This method is used because of its portability for use in the shop as well as the laboratory situation. One problem is the time lag before the body actually begins to absorb O_2 and expell the CO_2. The O_2 is used in a "burning" process of the stored carbohydrates in the body. Therefore, the results of this method do not give a precise account of the work being done by the operator in performing the task.

A few months later, Nichols and Amrine (1959) investigated simultaneous and symmetrical use of the hands using as their criterion, minimum increase in heart rate. According to their results, simultaneous and symmetrical motions, in addition to accomplishing twice as much work, are physiologically better than non-simultaneous and non-symmetrical motions. The criterion used, however, must be questioned. Nichols and Amrine do not state for what length of time the operators performed the task. Fahnestock, Boys, Sargent, Springer and Siler (1963) performed an experiment involving an operator pedaling a bicycle. Figure 3 (reproduced from their report) indicates that for the first thirty minutes of physical activity, the heart rate increased. After that the body adjusted to the conditions it was being subjected to and the heart rate maintained a constant level. Any conclusions based on less than thirty minutes continuous work are likely to be erroneous if heart rate is used as a criterion. The study done by Nichols and Amrine assumes that the increase in heart rate as a result of work is a straight line relationship. It doesn't take into account the ability of the body to investigate the constraints it is operating under and adjust its physiological functions accordingly. Therefore, it still remains to find an appropriate criterion to evaluate bodily motions.

The writer of the paper was unable to find any other published papers that evaluated the principles established by Gilbreth and Barnes. The next sedion will review the literature obtained on the force platform.

Force Platform. The force platform was built by Lauru (Greene, 1957) as a means of obtaining a record of an operator's motion pattern. The best method to perform the task was determined by the "smoothest" force trace. Lauru interpeted "smoothest" as meaning that the smallest force-time trace obtained from task performance (elimination of peaks from the trace) was a representation of least physical work.

Later Greene, Morris and Wiebers (1959) developed a new platform design. It was constructed in the shape of a triangle resting on a frame with the frame supported by ball bearings resting on cantilever beams. Meriam (1961) tells us that the deflection of a cantilever beam is proportional to the applied force. Because of this relationship, the beam deflection may be used to measure the applied force. Greene's (1957) platform used three linear variable differential transformers (LVDT) to detect the bodily forces in three directions. Hill (1961) explains that the LVDT consists of three coils surrounding a moveable iron core. With the core centered in the coil, the alternating current in the primary winding induces equal voltages in the two secondaries. These produce zero output when the coils are connected in phase opposition as shown in Fig. 4. However, when the core is moved either to the left or the right, the system is thrown out of balance and an output voltage occurs. The linearity of the response indicates that the instrument is useable for measuring large displacements, i.e. the increasing voltage being proportional to the distance moved.

The platform uses three of these LVDT's to obtain output voltages in the three co-ordinate planes. The output voltages of the LVDT's may be recorded on a strip chart recorder. This results in a record of the bodily forces exerted in performing a task. The recording may be made for the three force planes. Greene points out that the force-time trace shouldn't be confused with impluse which is a force-time value. Even though the platform measures force on a time axis, it does not represent impluse. Impluse is a measure of only dynamic forces whereas the force-time value obtained from the platform included static forces as well as dynamic forces for a measure of the total forces exerted in performing a task. Greene demonstrated that the data obtained from the platform can indicate differences in amount of work due to the high correlation with the physical concept of work, i.e. force moved through a distance.

Barany and Whetsel (1962) developed another platform with a National Science Foundation grant. The new platform, Fig. 5, a redesigned version of Greene's platform, utilized the same geometrical properties of its predecessor and the feature of the LVDT's but it was also portable and less expensive. It is this design that was used in this experiment.

In summary, the principles of motion economy as established by Barnes have been investigated using the criteria of time and heart rate. Physiological cost has also been investigated from the standpoint of oxygen consumption. The question arises, however, from the evidence presented: Are these valid criteria? It is the purpose of this paper, therefore, to investigate the symmetrical and simultaneous motions versus non-symmetrical and non-simultaneous motions on the basis of a fourth criteria, force exerted. For the purpose of this investigation, physiological cost will be defined as the amount of force exerted for a given period of time in units of pound-seconds.

Hypothesis:

1. Motions of the arms which are made symmetrically and simultaneously will result in a significantly smaller amount of physiological cost to the worker than non-symmetrical but simultaneous motions.
2. Motions which are made symmetrically and simultaneously will result in a significantly smaller amount of physiological cost to the worker than those made symmetrically and non-simultaneously.

3. Arm motions made toward the body will result in significantly larger amounts of physiological cost to the worker than motions made away from the body.

METHOD

Experimental Task. The experimental task was designed so that the subjects moved a two pound weight in each hand between two specified points. Two basic movement pattern designs were used for this research. See Fig. 6. In condition A, the subject's hands moved simultaneously from points A and B to points C and D. The motions were made symmetrically in that the path of the hands was made at an angle of 53° and 127° (zero is three o'clock). Fifty-three degrees was determined to be the angle that required the smallest amount of physiological cost to the worker in the study done by Wu (1965). Condition B required the hands to move along paths simultaneously but not symmetrically to perform the task. In condition B, the left hand was rotated counter-clockwise to a new angle of 143°. Condition C was the same as condition A with the exception that the hands did not move simultaneously. In all three conditions, the distance moved was eighteen inches.

Each subject performed each condition fifteen times. The experimental cycle began with the subject's hands at the starting point (positions A and B) and ended after the hands had traveled to points C and D (E for condition B) and returned to the starting position, i.e. each cycle consisted of one "out" and one "in" motion of each arm. Each subject performed a condition five times in succession. Readings were taken of the forces exerted in each of the three planes. A reading was taken each time the subject "touched down" on each black circle. Each subject performed each set of five trials three times for a total of fifteen sample readings per subject per condition. The experimental tasks were ordered according to the arrangement of Fig. 7 in an effort to counterbalance any fatigue or learning. In order to eliminate time as a variable, the subjects were paced by a metronome at a rate of 66 clicks per minute. The metronome permitted the subject to use either the visual or auditory stimuli for pacing or both.

The experimental task was performed in the Industrial Engineering Department's human engineering laboratory at Kansas State University.

Equipment. The experimental equipment utilized a table that could be adjusted to different heights. The subjects were seated on a non-padded stool. There was no back on the stool as it was believed that this would interfere with the free motion of the body. The stool was placed on the force platform.

The primary windings of the LVDT's in the platform were provided with a 2000 cps current from the oscillator stages of three Sanborn recording amplifiers. The LVDT outputs were fed to the two Heathkit Model EC-1 analog computers shown in Fig. 8. Using the ability of the computer to integrate the area under a curve when wired according to the schematic diagram of Fig. 9, a numerical value of the force-time trace for a particular set of motions was obtained. The inverter shown in Fig. 9 was used so that work in one direction was not subtracted from work in the other direction. Fig. 10 was recorded by a Texas Instruments Oscilloriter recorder. This gave the experimenter a permanent paper record of the integration from which the experimental data was taken. The readings were obtained simultaneously for the three recording channels. Previous work had utilized the planimeter as a method of obtaining a numerical value of the area under the force trace. The error in the reading obtained from a planimeter is on the order of 12%. The error of the computer is of the order of 5%. The computer also reduced the amount of time required of the experimenter to obtain numerical values of the force-time relationship. Thus the experimenter was able to take more readings with a smaller amount of error in the readings.

Calibration of the equipment was performed by applying a two pound force along each orthogonal axis for five seconds. The force-time integration performed by the computer was noted by pen deflection on the Texas Instruments recorders in volts. The following calibration values were obtained for each axis: X = .33 volts/lb.-sec., Y = .19 volts/lb.-sec., Z = .39 volts/lb.-sec. All calculations of experimental data were done in volts except total force values. These total forces were the sum of the x, y and z forces after these forces had been adjusted.

With the subject seated on the stool which was on the platform, the necessary corrections were made on the recording equipment to readjust the equipment to an initial zero point, i.e. to balance out the effect of the subject's weight on the platform. The gain settings on the recorders were increased until large deflections on the three recording channels were obtained. Large deflections were obtained to reduce the percentage of error that would be obtained since the same absolute amount of error would be divided by a larger base. When these conditions had been obtained, the positions of the calibration level on the Texas Instruments recorders were noted on the subject's data sheet. This adjustment provided the experimenter with very reliable integration recordings. After the data was taken, each reading was multiplied by its appropriate calibration level to determine the energy exerted. The computer output in volts for each of the three force planes represented the total force exerted by the motion of the body in each of the three planes. To determine the total voltage or total amount of work for the task, the values obtained in each of the planes were arithmetically summed to find the "total" cost for the task (i.e. "total" is not a vector).

Subjects. The eighteen female subjects were members of the freshman women's dormitories, the home economics home management houses and patronizers of Kansas State University's student union. They ranged in height from 5'2" to 5'8" and in weight from 107 pounds to 160 pounds. The age range was from 18 yrs. to 28 yrs. Each subject was paid at the rate of $1.00 per hr. for participating in the experiment.

The Experimental Procedure. Upon entering the experimental room, the data of name, age, height, weight and length of the upper arm was collected from each subject. Length was measured from the tip of the elbow to the top of the shoulder. The measurement was obtained by instructing the subject to place her arm so that the upper and lower arm were at right angles with the elbow at the subject's side. A tape measure was then placed between the two measurement points to obtain the length of the upper arm. The subject was then instructed to seat herself on the stool positioned on the force platform. With the subject in position, work-table height was adjusted to a position of two inches above the elbow. This was found to be the best work-table height by Wu.

Next the subject was given the following instructions and allowed to ask questions pertaining to them as they were explained.

"You are about to perform a series of simple motor tasks. The purpose of this experiment is to determine the energy you expend in the performance of three experimental task conditions. In Condition A, you are to move a two pound weight, held in each hand, simultaneously from the black circles, A and B, in front of you to the circles C and D returning to the starting position. Condition B requires you to move the same weights simultaneously to circles C and E returning to the starting position. Condition C requires you to move the two pound weight in your right hand from circle B to circle D returning it to the starting position. Then after the right hand is in its original position, you move the weight in your left hand from circle A to circle C and back to circle A. Note that in condition C, the hands do not move simultaneously but in sequence.

All three conditions are performed to the rhythm of a metronome. Each time the metronome clicks, your hands should be placing the weight(s) on the appropriate circles for the condition you are performing.

You will be told which of the three conditions to perform and when to begin. Keep repeating the task until told to stop.

You are about to begin the task.

Put your feet on the rung of the stool on which you are sitting. Grasp the weights by placing the second finger of each hand through the ring on top.

The experimenter will say 'Ready' and then 'Start'. At the signal 'Start' begin to perform the task.

Now position yourself as if you are ready to begin."

After answering any questions, the subject was allowed to practice moving the weights between points so that she could learn the rhythm of the metronome. When the experimenter felt the subject could reproduce the rhythm, the subject was instructed to begin a particular condition. When the subject had completed two cycles, the readings were taken from the next five cycles.

Statistical Model. The analysis of variance of the "physiological cost" is based on Snedecor's (1962) "Model I" design. It is a subject by treatment analysis with a single case for each factor combination. The model being tested in each hypothesis was

$$X_{i,j} = u + A_i + B_j + \epsilon_{i,j}$$

$$i = 1.......a, \quad j = 1......b$$

$$\epsilon_{i,j} = N(0, \sigma)$$

Where

A_i = method effects

B_j = subject effects

$\epsilon_{i,j}$ = random variable of sample variation

For those comparisons where significance was found, the Duncan's Multiple Range test (Hicks, 1964) was used to test for differences between means.

RESULTS

A Model I analysis of variance was performed on the data of Table I. The first hypothesis tested was the force requirements for conditions A, B, and C for "out" motions and for "in" motions. Tables 2, 3, and 4 show the analysis of variance for the outward direction by force plane while tables 5, 6, and 7 are for the inward direction. Next the average forces recorded in the x, y and z planes were adjusted by the appropriate calibration factors so they could be added. The planes were then added arithmetically to obtain the "total force" values for each condition. These values are the total amount of force required to perform the task. For both inward and outward motions conditions are shown to be significant in the x and y planes at an alpha risk of .01 but not in the z plane. Table 8 shows that conditions were significant at an alpha risk of .01.

The results of the Duncan Multiple-Range Test on the means are shown in table 9. Conditions A, B and C are significantly different ($\alpha < .05$) from each other in the x plane for both the inward and outward movements. However, for the y plane, with inward motion, B was significantly ($\alpha < .05$) less than C but not significantly less than A. A was not significantly lower than C. B was significantly lower than A and C for outward motion but A was not significantly lower than C. Tables 4 and 7 indicated that conditions were not significant for the z plane. A, B and C were significantly different from each other when x, y and z were added.

On the basis of these calculations, hypothesis I was rejected since condition B (simultaneous and non-symmetrical) was significantly smaller than condition A (simultaneous and symmetrical). Hypothesis II was accepted since condition A (simultaneous and symmetrical) was found to be significantly smaller than condition C (non-simultaneous and symmetrical).

The third hypothesis was tested by comparisons of the inward and outward data. Table 22 gives the mean values for conditions A, B and C in the x, y and z planes. The value for each subject's in motion was compared versus the value for his out motion for condition A (simultaneous and symmetrical) in Tables 10, 11 and 12, for condition B (simultaneous and non-symmetrical) in Tables 13, 14 and 15, and for condition C (non-simultaneous and symmetrical) in Tables 16, 17 and 18. The effect of in versus out was significant ($\alpha < .01$) in the z plane for condition A, in the x and z planes for condition B and the x, y and z planes for condition C. It is also shown in Tables 10-18, that for conditions A, B and C, subjects within sequence were consistently significant in the x, y and z planes except for the x and y planes of condition A (Tables 10 and 11) where subjects within sequence were not significant. The effect of sequence was significant only in the x plane of condition C (Table 11). Tables 19, 20 and 21 show the analysis of variance of total (x + y + z) inward and total outward motions for conditions A, B and C. In was not different from out for condition A or C but was significant for condition B. Subjects were significant for condition B and C but not for A. From the significant values obtained from analysis of the x, y and z planes and the total of these planes for condition B, hypothesis III is rejected. Outward motions require more force than inward motions which is the converse of hypothesis III.

An additional analysis was made in Table 23 of the left versus right hand of condition C. It shows that there was a significant difference

($\alpha < .01$) in the "physiological cost" required of the right and left hand movements with the right hand being lower.

DISCUSSION

The results of the present experiment failed to show that the "physiological cost" is lower for simultaneous and symmetrical arm motions than for simultaneous and non-symmetrical arm motions. In fact, for the situation studied, condition B (simultaneous and non-symmetrical) required a significantly smaller amount of force than condition A (simultaneous and symmetrical).

This result contradicts the "principle of motion economy" established by Barnes. The difference might be explained by what Barnes called "this matter of balance." He is not referring to the balance of arm movement patterns but to the balance of the body during arm motions. In the performance of the experimental tasks, the subject's center of gravity is constantly being moved along the frontal plane between two extreme points caused by the extreme points of arm motion. When the arms are extended to the farthest point away from the subject's body, the subject is off balance. In the case of symmetrical motions, the arms are fully extended causing the body center of gravity to move forward to the farthest extreme point. When one arm, the left in this experiment, is rotated in the horizontal plane, the body's center of gravity is moved closer to the centerline of the body. This helps the subject to regain some of his balance. This greater degree of body balance is one explanation for the small force values of condition B. Another explanation is the effect of the angle at which the movements were performed. It can be shown from the work done by Wu, that as the right hand moved in the horizontal plane a "physiological optimum" angle was reached. It's possible that as the left hand rotated counterclockwise to its new position for condition B, that it moved toward an optimum angle. If this occurred, the forces would have been lower for condition B than A.

The results obtained for the x plane of condition A should not be thought of as the total force exerted in that plane. It is actually a measure of the non-simultaneity of the arm movements. The subjects were instructed to move their arms simultaneously, but it is difficult to perform arm movements that are perfectly simultaneous. If the arms performed in perfect unison, the forces one would expect to be exerted would nulify each other and a zero reading would be obtained for the x plane. If the subject moves one arm before the other, the body will be thrown in the opposite direction of the unbalanced force associated with the motion causing force to be exerted in the lateral plane. The force in the x plane is then not only an indicator of force but also an indication of the simultaneity of the motion.

The second hypothesis was accepted on the basis of the data in Table 9 that condition C was significantly different from A or B. This was expected because of the replication of body movement in each individual hand movement. It is interesting that when asked which experimental condition was easiest, sixteen of the eighteen subjects chose condition C. In condition C, the subject had the reinforcement of auditory pacing with visual direction of each hand. With condition A and B, the subject's attention was divided between her hands making it more difficult to place the weights directly on the black circles.

Hypothesis III was tested for significance in the inward and outward motions. Wu found that inward motions exerted more force than outward motions for the right hand at angles varying from 0° to 180° in the horizontal plane. It can be shown from Wu's data that the greatest amount of force is in the vertical plane. It is unusual that it is not in the plane of greatest motion, the y plane. The results of this experiment contradict those of Wu's. First, this author found that motions of the arms made away from the body exert more force than those made toward the body, although the differences were not statistically significant. Further, this author found the plane of greatest movement (y plane) contained the greatest total force exertion. This could be the result of the horizontal movement of the subject's center of gravity along the frontal plane to a greater degree than the vertical plane or the fact that a weight was in each hand while Wu's subjects used the right hand only.

The results obtained showing that the outward motions exerted more force than inward motions may be explained from Fig. 2. When the arm is at the position of best mechanical advantage, the brachialis muscle is in a contracted status and its "ability to develop tension is least" (Fig. 2). This would mean that the muscles' ability to aid in moving the arm forward would be reduced to a minimum. Consequently, for a forward movement ofthe arm other muscles in the arm will have to respond in order to move the limb along its path. An inward movement of the arm, however, would be initiated with the arm extended to a point approaching the point of maximum ability of the brachialis muscle to develop tension. The movement may be accomplished by a single contraction of the brachialis muscle. If the movement of the arm forward and backward requires two different sets of muscles, the set being used is dependent on direction of movement. Unequal amounts of force may be exerted by the in and out arm motions since it requires only one muscle to contract the arm where it might take several to extend it.

The difference between the right and left hand motions was expected since all subjects were right handed. This is because the right arm is more coordinated than the left. Since it is used more frequently than the left arm, the muscular action of the right arm is smoother resulting in a smaller amount of physical effort to use it.

CONCLUSIONS

From the results of this experiment, and the tasks studied, we may conclude (1) It is easier to perform simultaneous and non-symmetrical motions than simultaneous and symmetrical motions. (2) Simultaneous motions are easier to perform than non-simultaneous or sequential motions. (3) Outward motions of the arm may be considered to require more force than inward arm motions. (4) When the force platform is used to measure simultaneous and symmetrical hand motions, the x or lateral plane is a measure of the simultaneity of the movement. (5) Finally, for right-handed women, the left hand exerts more force than the right hand when both hands are working at an "equal" task.

Extension of these conclusions to motion patterns not yet studied should be made with caution until additional studies are made.

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Appendix

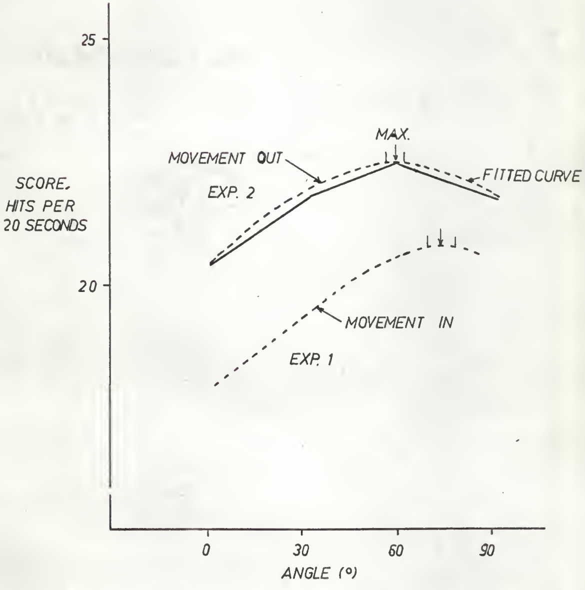
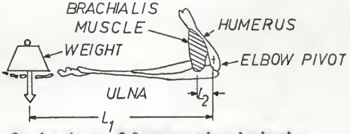
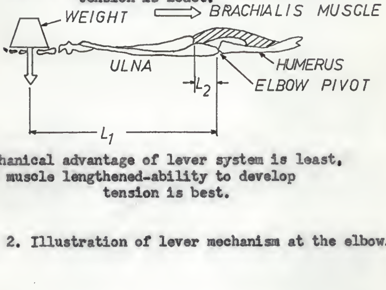


Fig. 1. Speed and accuracy of movement related to direction of movement in the investigations done by Briggs.



Mechanical advantage of lever system is best,
muscle shortened-ability to develop
tension is least.



Mechanical advantage of lever system is least,
muscle lengthened-ability to develop
tension is best.

Fig. 2. Illustration of lever mechanism at the elbow.

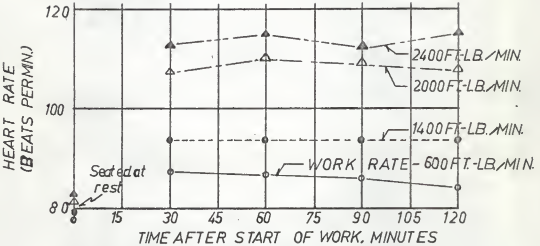


Fig. 3. Effect of time on heart beat rate under constant levels on energy exertion.

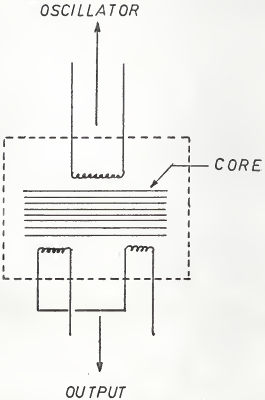


Fig. 4. LVDT wiring diagram.

Fig. 5. The force platform.

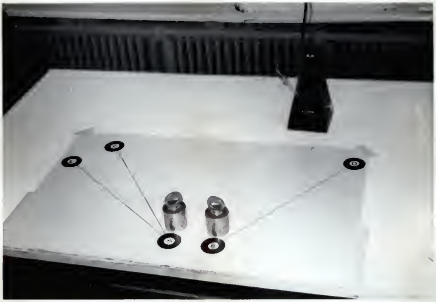


Fig. 6. The task layout of the three experimental conditions.

Subjects

Set of Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1st	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
2nd	B	C	A	C	A	B	B	C	A	C	A	B	B	C	A	C	A	B
3rd	C	A	B	B	C	A	C	A	B	B	C	A	C	A	B	B	C	A
4th	C	A	B	B	C	A	C	A	B	B	C	A	C	A	B	B	C	A
5th	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
6th	B	C	A	C	A	B	B	C	A	C	A	B	B	C	A	C	A	B
7th	B	C	A	C	A	B	B	C	A	C	A	B	B	C	A	C	A	B
8th	C	A	B	B	C	A	C	A	B	B	C	A	C	A	B	B	C	A
9th	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C

Fig. 7. Sequence of experimental conditions.

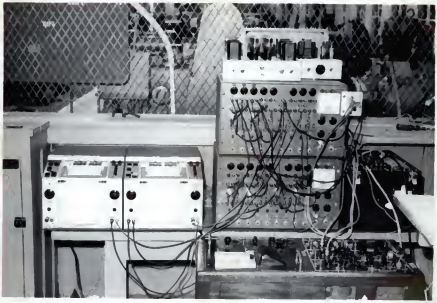


Fig. 8. Model EC-1 analog computers
and oscilloriter recorders.

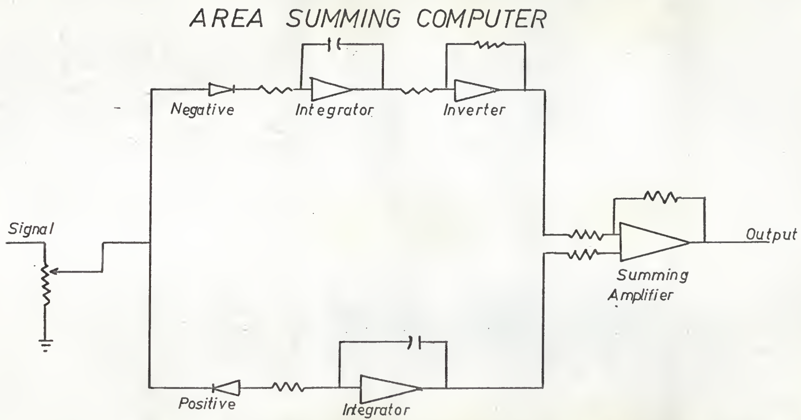


Fig. 9. Wiring schematic of Heathkit analog computer when integrating area.

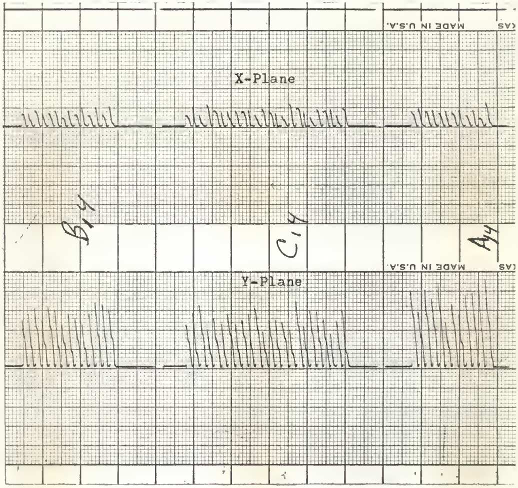


Fig. 10. Computer integrations for Subject No. 14 for the x and y planes

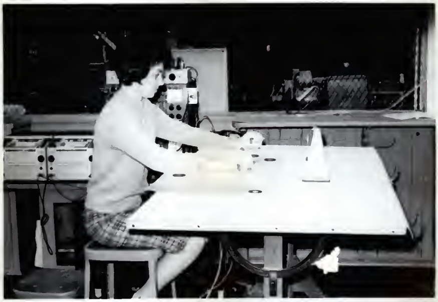


Fig. 11. Subject performing experimental task.

Table 1. Summary sheet of experimental data in volts.

Subj. No.	Condition A						Condition B					
	X_o	X_i	Y_o	Y_i	Z_o	Z_i	X_o	X_i	Y_o	Y_i	Z_o	Z_i
1	.26	.15	1.14	1.07	1.04	.78	.23	.11	.88	.91	.81	.68
2	.50	.26	1.55	1.54	1.44	1.26	.41	.28	1.30	1.25	.84	.63
3	.22	.14	1.15	1.28	1.42	1.10	.22	.18	.96	1.26	1.47	1.18
4	.09	.10	1.47	1.67	1.39	1.69	.10	.08	1.35	1.27	.76	.97
5	.23	.11	1.97	2.06	1.26	.87	.24	.20	1.81	1.96	1.33	.89
6	.76	.76	.59	1.36	1.08	2.54	2.39	.72	.58	.92	2.55	2.46
7	.21	.14	.69	.63	.88	.82	.26	.23	.41	.41	1.22	.98
8	.21	.16	1.21	1.15	.99	.80	.27	.22	1.01	1.10	1.16	.88
9	.23	.15	2.29	2.08	2.36	2.03	.27	.21	2.30	2.14	2.27	1.89
10	.42	.25	1.81	1.81	1.70	1.93	.39	.26	1.55	1.53	2.05	1.94
11	.18	.10	1.36	1.19	.40	.33	.18	.13	.97	.97	.39	.29
12	.20	.06	1.35	1.05	1.00	.77	.12	.07	1.20	1.03	1.13	.78
13	.50	.43	1.17	1.45	2.07	1.81	.47	.42	.93	1.03	2.14	1.86
14	.44	.33	1.71	1.83	1.62	1.43	.46	.30	1.55	1.64	1.73	1.58
15	.13	.05	1.94	1.91	.72	.69	.11	.04	1.69	1.71	.71	.66
16	.27	.21	1.23	1.29	1.46	1.21	.31	.31	1.04	1.11	1.25	.78
17	.28	.15	1.31	1.13	.74	.66	.28	.20	1.19	1.01	.70	.67
18	.25	.13	2.18	2.01	1.46	1.33	.22	.12	1.77	1.95	1.29	1.29

X_o is the outward force in the X plane.

X_i is the inward force in the X plane.

Y_o is the outward force in the Y plane.

Y_i is the inward force in the Y plane.

Z_o is the outward force in the Z plane.

Z_i is the inward force in the Z plane.

Table 1 (cont.). Summary sheet of experimental data in volts.

Subj. No.	Condition C											
	X_{or}	X_{ol}	X_{ir}	X_{il}	Y_{or}	Y_{ol}	Y_{ir}	Y_{il}	Z_{or}	Z_{ol}	Z_{ir}	Z_{il}
1	.09	.27	.12	.17	.46	.50	.55	.58	.20	.38	.16	.24
2	.26	.32	.20	.28	.81	.88	.81	.62	.25	.34	.18	.13
3	.18	.14	.14	.16	.53	.41	.99	.70	.45	.64	.61	.56
4	.09	.07	.11	.06	.70	.73	.91	.85	.66	.66	.62	.86
5	.21	.24	.05	.20	1.35	1.63	1.51	1.95	.69	.69	.54	.65
6	.64	.57	.57	.52	.50	.42	.56	.51	1.78	1.76	1.56	1.73
7	.08	.13	.05	.17	.54	.29	.41	.28	.30	.41	.11	.30
8	.18	.27	.17	.24	.50	.41	.49	.45	.50	.58	.34	.51
9	.16	.21	.10	.32	1.16	1.19	1.40	1.41	1.91	1.05	.84	.62
10	.30	.34	.23	.31	.76	.63	.88	.81	1.31	1.41	1.23	1.48
11	.19	.22	.15	.22	.79	.88	.76	.90	.18	.18	.12	.20
12	.11	.08	.06	.12	1.07	.81	.83	1.09	.44	.45	.35	.37
13	.35	.32	.45	.39	.88	.60	.80	.68	1.29	1.43	1.07	1.25
14	.43	.35	.26	.35	1.14	1.13	1.17	1.13	1.01	.92	.88	.92
15	.12	.11	.08	.13	1.02	1.36	1.01	1.34	.17	.23	.17	.25
16	.21	.51	.23	.24	.66	.50	.63	.50	.65	.51	.56	.34
17	.25	.24	.17	.18	.80	.80	.71	.79	.12	.13	.18	.12
18	.19	.24	.19	.25	.99	1.11	1.01	1.27	.56	.60	.41	.49

X_{or} is outward force in X plane caused by the right hand.
X_{ol} is outward force in X plane caused by the left hand.
X_{ir} is inward force in X plane caused by the right hand.
X_{il} is inward force in X plane caused by the left hand.

The same notation applies to the Y and Z planes for condition C.

Table 2. Analysis of variance of outward work in X plane.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.356	356.00**
Subject x Sequence	12	.001	.02
Conditions	2	.210	42.00**
Residual Error	34	.005	
Total	53		

** Significant at one percent level

Table 3. Analysis of variance of outward work in Y plane.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.728	1.183
Subject x Sequence	12	.615	11.826**
Conditions	2	.535	10.29**
Residual Error	34	.052	
Total	53		

** Significant at one percent level

Table 4. Analysis of variance of outward work in Z plane.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.028	.683
Subject x Sequence	12	1.505	17.705**
Conditions	2	.005	.058
Residual Error	34	.085	
Total	53		

** Significant at one percent level

Table 5. Analysis of variance of inward work in X plane.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.084	1.05
Subject x Sequence	12	.080	20.00**
Conditions	2	.285	71.25**
Residual Error	34	.004	
Total	53		

** Significant at one percent level

Table 6. Analysis of variance of inward work in Y plane.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.804	1.10
Subject x Sequence	12	.730	3.90**
Conditions	2	.955	5.106**
Residual Error	34	.187	
Total	53		

** Significant at one percent level

Table 7. Analysis of variance of inward work in Z plane.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.070	.783
Subject x Sequence	12	1.365	17.960**
Conditions	2	.030	.394
Residual Error	34	.076	
Total	53		

** Significant at one percent level

Table 8. Analysis of variance of "Total" Force.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	8.51	.484
Subject x Sequence	12	17.57	20.430**
Conditions	2	14.91	17.337**
Residual Error	34	.86	
Total	53		

** Significant at one percent level

Table 9. Duncan's Multiple Range test on means ($\alpha < .05$). Means are in volts.

Plane	Direction	Condition and Mean Force		
		A	B	C
X	Inward	.20	.22	.42
		B	A	C
Y	Inward	2.22	2.53	3.02
		B	C	A
Z	Inward	.955	.981	1.03
		B	A	C
X	Outward	.29	.30	.48
		B	A	C
Y	Outward	2.19	2.58	2.77
		C	B	A
Z	Outward	1.12	1.13	1.15
		B	A	C
X + Y + Z	In + Out	6.98	7.77	8.79

Table 10. Analysis of variance for condition A in the X plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.033	.687
Subject x Sequence	12	.048	.369
Conditions	1	.097	.746
Residual Error	17	.130	
Total	35		

**Significant at one percent level

Table 11. Analysis of variance for condition A in the Y plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.360	1.100
Subject x Sequence	12	.327	1.224
Conditions	1	.013	.048
Residual Error	17	.267	
Total	35		

** Significant at one percent level

Table 12. Analysis of variance for condition A in the A plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.610	.977
Subject x Sequence	12	.624	36.705**
Conditions	1	.180	10.588**
Residual Error	17	.017	
Total	35		

** Significant at one percent level

Table 13. Analysis of variance for condition B in the X plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.020	.416
Subject x Sequence	12	.048	480.000**
Conditions	1	.048	480.000**
Residual Error	17	.0001	
Total	35		

** Significant at one percent level

Table 14. Analysis of variance for condition B in the Y plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.514	1.472
Subject x Sequence	12	.349	45.921**
Conditions	1	.0016	.210
Residual Error	17	.0076	
Total	35		

** Significant at one percent level

Table 15. Analysis of variance for condition B in the Z plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.552	.725
Subject x Sequence	12	.761	63.416**
Conditions	1	.380	31.666**
Residual Error	17		
Total	35		

** Significant at one percent level

Table 16. Analysis of variance for condition C in the X plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.256	4.26**
Subject x Sequence	12	.060	12.00**
Conditions	1	.029	5.80**
Residual Error	17	.005	
Total	35		

** Significant at one percent level

Table 17. Analysis of variance for condition C in the Y plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	.898	1.10
Subjects x Sequence	12	.816	25.50**
Conditions	1	.160	5.00**
Residual Error	17	.032	
Total	35		

** Significant at one percent level

Table 18. Analysis of variance for condition C in the Z plane of the in and out motions.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.158	.648
Subject x Sequence	12	1.787	111.687**
Conditions	1	.240	15.00**
Residual Error	17	.016	
Total	35		

** Significant at one percent level

Table 19. Analysis of variance for total in and out motions of condition A.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.17	.696
Subject x Sequence	12	1.68	1.183
Conditions	1	.73	.514
Residual Error	17	1.42	
Total	35		

** Significant at one percent level

Table 20. Analysis of variance for total in and out motions of condition B.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.05	.600
Subject x Sequence	12	1.75	145.830**
Conditions	1	.63	53.500**
Residual Error	17	.012	
Total	35		

** Significant at one percent level

Table 21. Analysis of variance for total in and out motions of condition C.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.02	.262
Subject x Sequence	12	3.88	77.600**
Conditions	1	.07	1.400
Residual Error	17	.05	
Total	35		

** Significant at one percent level

Table 22. Summary of mean values for in and out motions in the x, y and z planes.

Plane	Direction of Movement	
	Condition A	
	In	Out
X	.20	.30
Y	2.53	2.58
Z	1.03	1.15
Total	3.76	4.03
	Condition B	
X	.22	.29
Y	2.22	3.92
Z	1.80	1.13
Total	4.24	5.34
	Condition C	
X	.42	.48
Y	3.02	2.79
Z	.98	1.12
Total	4.42	4.39

Table 23. Analysis of variance for right and left hand movements.

Source	d.f.	M.S.	F
Subjects	17		
Sequence	5	1.02	.262
Subject x Sequence	12	3.88	55.428**
Conditions	1	.29	5.140**
Residual Error	17	.07	
Total	35		

** Significant at one percent level

EXPERIMENTAL DATA SHEET

Name Mary Pratt
Age 18 yrs.
Height 5 ft. 4 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 22, 1965
Subject No. 1
Weight 120 lbs.

Table Height $40\frac{1}{4}$ in.
Upper Arm Length 13 3/4 in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.30	.30	.28	.31	.27	.24	.26	.34	.32	.27	.21	.14	.27	.25	.18
	Xi	.10	.11	.18	.19	.12	.10	.15	.02	.11	.18	.16	.20	.20	.18	.20
	Yo	1.00	1.35	1.28	1.20	1.38	1.32	1.16	1.31	1.15	1.00	1.00	.92	.90	.89	1.22
	Yi	1.21	1.12	1.17	1.05	1.08	.70	1.30	1.20	.81	1.10	1.10	1.18	1.17	1.15	.75
	Zo	.75	1.13	1.08	1.15	1.10	1.01	1.49	.75	.87	1.00	1.42	.98	1.00	.86	1.05
	Zi	.80	.65	.75	.61	.80	.68	.86	.98	.76	.89	.65	.75	.84	.63	1.05
Condition B	Xo	.25	.22	.21	.10	.18	.21	.22	.27	.28	.27	.26	.24	.27	.29	.22
	Xi	.18	.14	.05	.16	.19	.16	.04	.11	.10	.11	.10	.12	.11	.02	.09
	Yo	.95	.98	1.15	.79	.94	.70	.84	.72	.90	.65	.71	.96	1.10	1.15	.60
	Yi	1.12	.99	.65	1.05	1.03	.89	.78	.96	.84	.99	.95	.91	1.05	.54	.92
	Zo	.65	.98	.84	.89	.71	1.01	.71	.86	.64	.72	1.02	.95	.80	.80	.62
	Zi	.64	.75	.56	.96	.90	.61	.59	.67	.62	.58	.60	.59	.70	.68	.69
Condition C	Xo-rh	.12	.12	.07	.08	.20	.04	.09	.02	.04	.10	.10	.10	.12	.10	.05
	Xo-lh	.25	.15	.32	.35	.28	.38	.29	.28	.26	.25	.22	.30	.20	.26	.19
	Xi-rh	.10	.10	.12	.11	.12	.10	.12	.10	.09	.14	.08	.16	.17	.12	.15
	Xi-lh	.22	.26	.10	.19	.16	.02	.18	.18	.20	.15	.20	.17	.20	.17	.20
	Yo-rh	.38	.43	.44	.33	.30	.35	.50	.57	.55	.61	.48	.55	.35	.62	.46
	Yo-lh	.40	.52	.74	.72	.69	.55	.49	.32	.56	.30	.45	.49	.51	.51	.40
	Yi-rh	.58	.40	.81	.51	.65	.51	.45	.50	.53	.52	.49	.60	.69	.61	.45
	Yi-lh	.58	.60	.61	.80	.60	.53	.59	.56	.56	.45	.62	.51	.62	.50	.64
	Zo-rh	.23	.15	.14	.06	.24	.11	.14	.18	.19	.24	.20	.35	.25	.31	.25
	Zo-lh	.31	.50	.38	.48	.41	.20	.30	.25	.33	.20	.56	.37	.50	.56	.40
	Zi-rh	.19	.05	.25	.08	.20	.14	.10	.16	.18	.18	.20	.22	.20	.21	.10
	Zi-lh	.20	.14	.30	.34	.21	.32	.21	.21	.21	.23	.25	.25	.23	.31	.21

EXPERIMENTAL DATA SHEET

Name Judy North
Age 18 yrs.
Height 5 ft. 4 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 22, 1965
Subject No. 2
Weight 130 lbs.

Table Height 40 in.
Upper Arm Length 14 in.
Dist. from Table 6½ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.58	.54	.56	.58	.57	.54	.35	.38	.38	.46	.50	.48	.42	.48	.64
	Xi	.20	.21	.28	.30	.35	.28	.24	.16	.21	.30	.30	.28	.32	.25	.24
	Yo	2.00	2.05	1.64	1.50	1.50	2.16	1.10	1.18	1.26	1.40	1.69	1.25	1.50	1.64	1.36
	Yi	1.66	1.70	2.02	1.85	1.95	1.40	1.35	1.03	1.32	1.53	1.84	1.41	1.60	1.35	1.15
	Zo	2.60	2.60	2.58	2.60	2.60	1.35	.85	.82	.88	.78	1.06	.68	.80	.74	.70
	Zi	2.58	2.60	2.60	2.60	2.60	.58	.55	.56	.61	.62	.65	.55	.59	.57	.60
Condition B	Xo	.35	.39	.39	.41	.48	.45	.46	.40	.35	.61	.46	.28	.35	.31	.39
	Xi	.24	.20	.22	.24	.23	.32	.35	.25	.38	.38	.20	.28	.30	.36	.25
	Yo	1.39	1.45	1.29	1.64	1.75	1.49	1.15	1.15	.85	1.31	1.71	1.08	1.10	.94	1.20
	Yi	1.14	1.20	1.18	1.25	1.40	1.60	1.49	1.50	1.29	1.30	.76	1.10	1.42	1.09	1.01
	Zo	.90	.94	.82	.92	.95	1.12	.90	.85	.90	.74	.99	.68	.74	.60	.58
	Zi	.65	.71	.61	.63	.80	.76	.65	.70	.79	.74	.44	.50	.60	.40	.50
Condition C	Xo-rh	.35	.28	.22	.24	.19	.30	.28	.24	.20	.26	.30	.28	.30	.24	.20
	Xo-lh	.32	.31	.28	.32	.39	.38	.29	.30	.25	.30	.26	.39	.40	.30	.28
	Xi-rh	.10	.15	.23	.15	.19	.17	.21	.24	.30	.21	.18	.22	.21	.22	.24
	Xi-lh	.24	.22	.35	.34	.20	.29	.29	.30	.29	.38	.22	.15	.25	.40	.26
	Yo-rh	1.00	.99	.91	.90	.70	.62	.80	.74	.78	.90	.88	.92	.69	.82	.51
	Yo-lh	1.34	1.04	.92	.80	1.18	1.18	.88	.85	.70	.84	.75	.85	.64	.55	.61
	Yi-rh	.78	.64	1.21	1.05	1.00	1.02	.65	.70	1.18	.75	.80	.65	.62	.52	.59
	Yi-lh	.75	.72	.64	.60	.54	.72	.66	.59	.58	.63	.62	.55	.62	.55	.52
	Zo-rh	.34	.35	.31	.30	.25	.35	.28	.23	.26	.22	.38	.24	.07	.12	.08
	Zo-lh	.62	.54	.50	.35	.45	.50	.39	.32	.29	.30	.29	.26	.12	.11	.11
	Zi-rh	.21	.16	.28	.25	.22	.30	.10	.11	.26	.15	.18	.14	.20	.09	.08
	Zi-lh	.28	.25	.15	.08	.10	.24	.21	.05	.12	.08	.16	.14	.09	0.00	.07

EXPERIMENTAL DATA SHEET

Name Sherri Wilkinson Date November 22, 1965 Table Height $41\frac{1}{2}$ in.
Age 18 yrs. Subject No. 3 Upper Arm Length $12\frac{1}{2}$ in.
Height 5 ft. 3 3/4 in. Weight 109 lbs. Dist. from Table $6\frac{1}{2}$ in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Reading No.

Condition		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.25	.27	.21	.24	.22	.32	.25	.22	.20	.28	.15	.15	.16	.20	.15
	Xi	.12	.20	.20	.02	.15	.10	.20	.17	.18	.12	.17	.16	.12	.12	.11
	Yo	1.30	.80	1.25	1.16	.90	1.64	.85	1.19	1.12	1.45	1.55	1.08	1.21	.89	.89
	Yi	1.28	1.09	1.17	1.14	.80	1.65	1.20	1.44	1.50	1.49	1.10	1.19	1.34	1.50	1.25
	Zo	1.95	1.60	1.40	1.45	1.01	1.70	1.40	1.55	1.41	1.40	1.65	1.35	1.31	.90	1.24
	Zi	1.33	1.30	1.01	1.05	.84	1.12	1.21	1.35	1.15	1.25	1.00	.81	.92	1.10	1.00
Condition B	Xo	.23	.27	.21	.22	.23	.25	.26	.24	.25	.29	.14	.18	.22	.14	.19
	Xi	.25	.17	.19	.17	.18	.24	.17	.13	.18	.17	.15	.19	.12	.18	.18
	Yo	.68	.76	.79	.72	1.01	1.15	1.28	.88	.88	1.00	1.39	1.00	.95	1.10	.75
	Yi	1.60	1.46	.95	1.31	1.28	1.74	1.20	1.27	1.28	1.25	1.10	1.40	1.16	1.12	.80
	Zo	1.50	1.17	1.25	1.40	1.24	2.01	1.45	1.52	1.62	1.50	1.60	1.52	1.50	1.39	1.40
	Zi	1.15	1.23	1.18	.95	1.10	1.25	1.20	1.21	1.42	1.15	1.10	1.32	1.21	1.10	1.12
Condition C	Xo-rh	.15	.09	.50	.25	.10	.24	.09	.55	.15	.06	.12	.14	.12	.10	.10
	Xo-lh	.05	.09	.10	.21	.15	.07	.08	.12	.03	.12	.17	.30	.32	.15	.08
	Xi-rh	.05	.12	.20	.16	.08	.06	.12	.20	.22	.25	.10	.21	.10	.05	.15
	Xi-lh	.20	.10	.05	.05	.20	.20	.09	.25	.12	.15	.26	.11	.12	.40	.12
	Yo-rh	.55	.41	.64	.65	.48	.94	.81	.49	.47	.95	.43	.66	.51	.29	.22
	Yo-lh	.54	.40	.32	.39	.49	.35	.45	.60	.50	.56	.27	.20	.61	.30	.21
	Yi-rh	.88	.68	.75	.89	.79	.84	1.09	1.10	1.30	1.29	.58	1.07	1.01	1.42	1.21
	Yi-lh	.56	1.05	.71	.44	.38	.67	1.08	.68	.52	.65	.95	.80	.80	.68	.52
	Zo-rh	.32	.24	.51	.32	.49	.80	.75	.59	.64	.74	.20	.48	.40	.10	.12
	Zo-lh	.40	.75	.56	.59	.70	.92	1.00	1.05	.71	.70	.75	.48	.59	.20	.20
	Zi-rh	.41	.36	.59	.60	.45	.71	.65	.55	.76	.88	.40	.89	.60	.79	.58
	Zi-lh	.47	.40	.55	.40	.45	.60	.80	.70	.60	.38	.81	.60	.78	.40	.42

EXPERIMENTAL DATA SHEET

Name Nancy Rowe
Age 19 yrs.
Height 5 ft. 2 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 22, 1965
Subject No. 4
Weight 107 lbs.

Table Height 42 in.
Upper Arm Length 12 in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.15	.10	.02	.10	.12	.18	.10	.14	.11	.10	.05	.04	.09	.10	.02
	Xi	.03	.11	.14	.12	.12	.12	.05	.09	.14	.08	.10	.11	.12	.12	.10
	Yo	1.88	1.46	1.38	1.01	1.15	2.26	1.85	1.55	1.75	1.75	1.20	1.10	1.45	1.10	1.12
	Yi	1.88	1.72	1.70	1.55	1.50	2.00	2.05	1.59	2.55	1.95	1.10	1.38	1.48	1.39	1.30
	Zo	2.50	1.86	1.85	1.10	1.35	1.05	1.15	1.05	1.02	1.12	1.69	1.35	1.41	1.05	1.30
	Zi	2.20	1.95	2.01	1.75	1.61	2.45	2.05	1.90	1.76	1.75	1.01	1.20	1.31	1.24	1.22
Condition B	Xo	.09	.09	.09	.05	.08	.22	.14	.10	.15	.09	.12	.10	.05	.06	.12
	Xi	.12	.09	.10	.09	.06	.12	.05	.06	.09	.08	.08	.08	.04	.07	.10
	Yo	.50	.35	.45	.46	.50	2.39	1.80	1.50	1.70	1.35	2.40	1.75	1.75	1.50	1.90
	Yi	1.00	.70	.71	.79	.81	1.55	1.46	1.70	1.25	1.34	1.45	1.56	1.78	1.50	1.46
	Zo	.56	.70	.56	.60	.50	1.00	.92	.56	.75	.75	1.35	.65	.95	.85	.75
	Zi	.60	.54	.59	.75	.38	1.05	1.00	1.15	1.28	1.24	1.36	1.22	1.05	.96	1.35
Condition C	Xo-rh	.05	.05	.01	0.00	.02	.24	.10	.21	.18	.19	.05	.12	.04	.01	.01
	Xo-lh	.08	.06	.08	.07	.08	.05	.10	.05	.02	.10	.06	.06	.22	.02	.05
	Xi-rh	.05	.02	.05	.05	.08	.16	.19	.14	.20	.40	.01	.05	.09	.10	.02
	Xi-lh	.07	.12	.12	.11	.12	0.00	0.00	.02	.03	.05	.05	.12	.02	.01	.12
	Yo-rh	.48	.46	.49	.58	.50	.70	.90	1.10	1.45	1.31	.45	.49	.58	.70	.25
	Yo-lh	.35	.45	.38	.50	.54	.95	1.49	1.45	1.15	1.50	.42	.50	.55	.40	.35
	Yi-rh	1.00	.72	.81	.75	.90	1.80	1.70	1.80	.45	.61	.62	.70	.57	.69	.40
	Yi-lh	.70	.80	.78	.80	.84	1.25	1.20	.99	.54	1.45	.80	.75	.35	.48	.51
	Zo-rh	.55	.58	.50	.51	.71	1.25	.95	.95	.85	.70	.39	.55	.48	.58	.29
	Zo-lh	.70	.60	.58	.32	.68	1.20	.75	1.00	.74	.99	.50	.50	.54	.39	.45
	Zi-rh	.60	.59	.38	.45	.80	.64	.90	.76	1.09	1:08	.40	.52	.40	.45	.31
	Zi-lh	.52	.74	.74	.50	.95	1.10	1.10	1.05	1.11	2.50	.65	.52	.48	.35	.54

EXPERIMENTAL DATA SHEET

Name Vivian Bland   Date November 22, 1965   Table Height 42 in.
Age 20 yrs.   Subject No. 5   Upper Arm Length 12 in.
Height 5 ft. 2½ in.   Weight 150 lbs.   Dist. from Table 6½ in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.14	.19	.20	.21	.24	.30	.26	.22	.20	.20	.25	.40	.25	.28	.10
	Xi	.02	.05	.10	.05	.03	.12	.06	.08	.21	.16	.10	.16	.12	.10	.30
	Yo	2.15	1.51	1.48	1.62	1.08	2.15	2.18	2.38	2.40	2.20	1.68	2.34	1.76	2.28	2.38
	Yi	1.50	1.85	1.89	1.09	2.01	2.40	2.40	2.38	2.35	2.21	1.71	2.30	2.31	2.15	2.40
	Zo	1.22	.66	.67	.80	.73	1.60	1.56	1.55	1.61	1.60	1.40	1.30	1.25	1.40	1.50
	Zi	.42	.50	.60	.43	.61	1.06	1.08	1.10	1.10	.84	.95	1.08	1.08	1.10	1.12
Condition B	Xo	.35	.10	.06	.08	.07	.25	.30	.22	.22	.22	.33	.41	.24	.39	.40
	Xi	.23	.28	.19	.20	.14	.08	.19	.21	.21	.21	.20	.26	.15	.18	.25
	Yo	2.14	1.05	.84	1.50	1.15	2.33	1.84	2.15	2.12	1.99	2.32	1.55	2.38	1.99	1.80
	Yi	1.25	1.85	1.64	1.78	1.74	2.36	2.30	2.34	2.39	2.40	2.28	1.58	1.90	1.95	1.62
	Zo	1.22	1.00	1.99	.73	.84	1.55	1.20	1.46	1.29	1.50	1.72	1.29	1.60	1.30	1.30
	Zi	.47	.52	.55	.50	.56	1.15	.98	1.05	1.20	1.25	1.18	.85	1.15	1.15	.80
Condition C	Xo-rh	.20	.21	.19	.30	.25	.22	.20	.19	.24	.24	.12	.16	.24	.31	.15
	Xo-lh	.24	.35	.28	.28	.20	.30	.25	.15	.19	.20	.24	.24	.20	.29	.12
	Xi-rh	.04	.05	.04	.01	.09	.09	.05	.08	.05	.01	0.00	.04	0.00	.20	.05
	Xi-lh	.18	.12	.22	.19	.22	.18	.15	.21	.19	.28	.26	.38	.15	.11	.20
	Yo-rh	1.68	1.40	1.44	1.15	1.05	1.15	1.25	1.25	1.34	1.60	1.38	1.25	1.85	.98	1.45
	Yo-lh	1.50	1.60	1.46	1.68	1.55	1.45	1.10	1.64	1.65	1.58	1.51	2.01	2.00	1.86	1.90
	Yi-rh	1.20	1.50	1.76	1.55	1.25	1.55	1.50	1.65	1.60	1.68	1.36	1.90	1.10	1.75	1.35
	Yi-lh	1.94	1.65	2.00	1.55	1.82	1.95	2.10	1.85	1.78	2.35	2.10	2.15	2.35	1.78	1.89
	Zo-rh	.38	.62	.48	.52	.65	.38	.62	.48	.51	.65	.90	.99	1.05	1.08	1.05
	Zo-lh	.49	.55	.52	.54	.59	.48	.55	.51	.54	.59	.95	.90	1.00	1.08	1.05
	Zi-rh	.45	.34	.38	.49	.50	.45	.34	.37	.50	.49	.80	.85	.58	.85	.75
	Zi-lh	.49	.54	.50	.38	.60	.49	.55	.50	.38	.60	.84	1.05	.99	.95	.85

EXPERIMENTAL DATA SHEET

Name Mary Dickerson
Age 26 yrs.
Height 5 ft. 4 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 6
Weight 135 lbs.

Table Height 41 in.
Upper Arm Length 13 in.
Dist. from Table 6½ in.

Reading No.

Condition		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.76	.74	.62	.80	.79	.77	.65	.78	.85	.81	.85	.65	.80	.75	.72
	Xi	.45	.55	.44	.65	.58	.50	.71	.60	.52	.60	.51	.63	.69	.65	.79
	Yo	1.55	1.38	1.43	1.05	1.69	1.20	.95	1.55	1.68	1.44	1.24	1.45	1.36	1.19	1.19
	Yi	.85	.96	1.15	1.45	1.00	1.16	1.42	1.15	1.08	1.35	.70	.80	.88	1.30	1.00
	Zo	2.55	2.60	2.40	2.60	2.58	2.50	2.52	2.53	2.52	2.60	2.60	2.51	2.50	2.55	2.55
	Zi	2.20	2.50	2.35	2.50	2.22	2.30	2.31	2.36	2.22	2.25	2.48	2.50	2.50	2.55	2.55
Condition B	Xo	.80	.70	.70	.75	.73	.79	.58	.60	.70	.63	.90	.68	.73	.78	.72
	Xi	.59	.62	.65	.51	.61	.55	.50	.58	.64	.58	.50	.60	.52	.60	.63
	Yo	.74	1.05	.74	1.10	1.15	.70	.70	.78	1.10	1.00	1.35	.55	1.00	1.00	.88
	Yi	.76	.52	.95	.80	.98	.75	.55	.95	1.09	.99	.79	.76	.31	.62	.51
	Zo	2.60	2.50	2.52	2.50	2.50	2.60	2.40	2.58	2.60	2.52	2.60	2.60	2.55	2.60	2.58
	Zi	2.41	2.41	2.42	2.29	2.50	2.52	2.50	2.51	2.59	2.50	2.25	2.42	2.52	2.52	2.52
Condition C	Xo-rh	.65	.65	.51	.51	.52	.72	.60	.50	.54	.64	.80	.71	.70	.75	.75
	Xo-lh	.50	.49	.50	.50	.56	.65	.56	.55	.56	.51	.69	.68	.62	.52	.60
	Xi-rh	.42	.60	.55	.54	.58	.60	.44	.46	.52	.59	.58	.70	.68	.65	.65
	Xi-lh	.49	.21	.51	.49	.59	.42	.49	.48	.48	.49	.54	.61	.62	.65	.60
	Yo-rh	.64	.54	.38	.62	.38	.70	.48	.48	.44	.40	.58	.50	.44	.44	.50
	Yo-lh	.45	.49	.40	.25	.55	.40	.50	.40	.45	.56	.50	.45	.48	.24	.21
	Yi-rh	.43	.54	.95	.66	.64	.81	.35	.50	.60	.70	.38	.48	.64	.39	.32
	Yi-lh	.50	.59	.54	.72	.45	.42	.68	.50	.70	.55	.60	.30	.33	.38	.35
	Zo-rh	1.29	1.30	1.04	1.15	1.12	2.25	1.95	1.92	1.80	1.85	2.25	2.15	2.00	2.40	2.20
	Zo-lh	1.25	1.30	1.18	1.30	1.20	2.39	2.01	2.02	2.05	1.75	2.05	1.95	1.95	1.85	2.10
	Zi-rh	.89	1.24	.90	.95	1.05	1.95	1.65	1.58	1.72	1.70	2.08	2.05	1.80	2.00	1.88
	Zi-lh	1.15	1.25	1.12	1.25	1.10	2.10	2.05	1.92	1.80	2.05	2.10	1.97	2.06	2.15	1.95

EXPERIMENTAL DATA SHEET

Name Mary Alice Rossilon
Age 28 yrs.
Height 5 ft. 2 3/4 in.
Calibration: X 1 volts/cm
Y 2 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 7
Weight 120 lbs.

Table Height 41 in.
Upper Arm Length 13 in.
Dist. from Table 6½ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.15	.20	.08	.20	.14	.30	.31	.28	.28	.25	.21	.14	.18	.22	.21
	Xi	.06	.10	.11	.14	.10	.10	.17	.18	.20	.18	.20	.24	.10	.08	.20
	Yo	.72	.80	.56	.77	.60	.90	.82	.84	.90	.80	.56	.36	.36	.70	.60
	Yi	.50	.46	.70	.60	.56	.74	.79	.70	.72	.76	.60	.64	.50	.44	.70
	Zo	1.05	.65	.81	.65	.50	1.42	1.15	1.35	.98	1.21	.95	.74	.74	.40	.60
	Zi	.81	.70	.95	.88	.75	1.12	1.08	1.22	1.20	1.10	.55	.34	.62	.52	.45
Condition B	Xo	.17	.10	.10	.15	.08	.30	.41	.29	.26	.75	.22	.23	.38	.30	.22
	Xi	.02	.11	.20	.15	.19	.24	.30	.39	.39	.25	.24	.17	.24	.28	.30
	Yo	.76	.50	.48	.52	.20	.36	.45	.32	.32	.64	.30	.25	.39	.34	.28
	Yi	.30	.50	.60	.54	.56	.35	.42	.44	.45	.30	.34	.21	.33	.39	.39
	Zo	1.10	.84	.92	1.05	1.05	1.79	1.60	1.68	1.80	2.10	1.14	.92	.75	.80	.72
	Zi	.95	1.00	.88	.86	.80	1.42	1.58	1.30	1.64	.90	.82	.69	.69	.72	.50
Condition C	Xo-rh	.10	.09	.09	.15	.14	.20	.24	.20	.29	.15	.28	.22	.20	.14	.20
	Xo-lh	.35	.12	.20	.35	.30	.50	.22	.28	.30	.32	.31	.20	.30	.16	.18
	Xi-rh	.05	.08	.10	.07	.12	.24	.20	.26	.20	.21	.21	.18	.21	.16	.24
	Xi-lh	.10	.19	.30	.10	.10	.14	.32	.30	.29	.35	.20	.25	.34	.29	.33
	Yo-rh	.50	.40	.39	.42	.41	.56	.50	.42	.70	.48	.64	.62	.52	.40	.48
	Yo-lh	.40	.20	.32	.41	.40	.52	.42	.50	.50	.56	.39	.36	.52	.30	.32
	Yi-rh	.30	.36	.40	.30	.42	.44	.49	.78	.60	.60	.40	.40	.58	.60	.68
	Yi-lh	.24	.38	.40	.22	.20	.30	.56	.52	.56	.60	.42	.56	.59	.60	.58
	Zo-rh	.65	.59	.70	.65	.65	.80	.76	.65	.50	.64	.22	.18	.16	.11	.18
	Zo-lh	.74	.80	.85	.78	.63	.60	.62	.75	.80	.78	.24	.21	.30	.28	.36
	Zi-rh	.50	.50	.45	.50	.45	.55	.50	.30	.45	.50	.20	.08	.09	.03	.08
	Zi-lh	.78	.65	.70	.72	.69	.68	.55	.62	.79	.60	.15	.11	.18	.22	.20

EXPERIMENTAL DATA SHEET

Name Mary Steinbrink
Age 21 yrs.
Height 5 ft. 3 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 8
Weight 112 lbs.

Table Height 41 in.
Upper Arm Length 13 in.
Dist. from Table 6½ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.14	.22	.28	.15	.17	.25	.12	.24	.20	.17	.25	.19	.30	.25	.24
	Xi	.16	.17	.10	.10	.08	.15	.10	.16	.13	.21	.15	.22	.24	.18	.26
	Yo	1.08	1.30	1.15	1.05	1.28	1.38	1.00	1.25	1.30	.95	1.39	1.09	1.58	1.24	1.05
	Yi	1.15	.98	.64	1.10	1.45	1.05	.56	.95	1.25	1.55	.95	1.16	1.46	1.19	1.80
	Zo	1.09	.79	.86	.92	.71	1.20	.80	.98	.90	.94	1.09	1.10	1.35	1.09	1.01
	Zi	.78	.85	.84	.84	.69	.72	.65	.75	.80	.69	.79	.80	.95	.82	.99
Condition B	Xo	.40	.30	.35	.21	.24	.24	.25	.14	.25	.30	.23	.26	.32	.34	.22
	Xi	.26	.28	.25	.25	.20	.15	.22	.14	.24	.15	.24	.20	.29	.26	.25
	Yo	.96	.70	1.25	.56	1.00	1.30	1.48	.81	1.45	.79	1.00	1.08	.79	1.07	1.05
	Yi	.83	1.00	.95	1.00	1.20	1.25	1.40	1.10	1.51	.72	1.15	.90	1.35	1.17	1.01
	Zo	1.35	.82	.90	.94	.82	1.59	1.13	1.40	1.38	1.20	1.48	1.10	1.08	1.10	1.15
	Zi	.67	.68	.73	.70	.75	1.12	1.05	.80	.95	1.05	1.15	1.01	1.00	.80	.80
Condition C	Xo-rh	.10	0.00	.03	.02	.05	.14	.16	.05	.04	.12	.20	.10	0.00	.12	.14
	Xo-lh	.15	0.00	.18	.05	.02	.25	.15	.16	.03	.10	.12	.15	.26	.21	.15
	Xi-rh	.07	0.00	.05	.02	.01	.02	.02	.02	.03	.09	.10	.10	.12	.08	.06
	Xi-lh	.17	.25	.24	.15	.05	.14	.14	.17	.10	.12	.26	.25	.22	.19	.19
	Yo-rh	.59	.44	.73	.50	.65	.64	.45	.25	.50	.34	.81	.62	.65	.65	.35
	Yo-lh	.51	.41	.59	.40	.40	.09	.12	.32	.40	.15	.25	.12	.22	.12	.20
	Yi-rh	.27	.50	.45	.52	.48	.28	.38	.54	.59	.40	.30	.40	.48	.30	.28
	Yi-lh	.29	.50	.65	.25	.67	.30	.32	.28	.10	.10	.17	.25	.12	.12	.11
	Zo-rh	.22	.11	.19	.15	.17	.45	.42	.34	.46	.28	.41	.28	.30	.42	.36
	Zo-lh	.24	.21	.19	.22	.23	.48	.55	.38	.40	.44	.48	.42	.64	.74	.48
	Zi-rh	.09	.08	.05	.04	.07	.25	.18	.15	.12	.08	.15	.08	.09	.15	.10
	Zi-lh	.12	.05	.10	.06	.14	.40	.35	.32	.34	.35	.35	.22	.49	.65	.44

EXPERIMENTAL DATA SHEET

Name Sharon Pember
Age 22 yrs.
Height 5 ft. 6 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 9
Weight 135 lbs.

Table Height 40½ in.
Upper Arm Length 13½ in.
Dist. from Table 6¼ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.10	0.00	.12	.08	.06	.30	.25	.30	.17	.28	.50	.40	.30	.40	.24
	Xi	.04	.14	.09	.04	.12	.12	.22	.26	.29	.08	.21	.10	.12	.19	.19
	Yo	2.41	2.33	2.40	2.38	2.42	2.50	2.18	2.40	1.92	1.88	2.50	2.30	2.38	1.86	2.45
	Yi	2.20	2.39	1.99	2.43	2.40	1.68	2.10	1.80	1.61	1.85	2.42	2.15	2.09	2.18	1.85
	Zo	2.40	2.50	2.30	2.49	2.45	2.46	2.44	2.40	2.26	2.30	2.38	2.30	2.10	2.25	2.35
	Zi	2.22	2.40	2.10	2.40	2.05	1.88	2.15	1.81	1.20	1.99	2.28	2.10	1.85	2.15	1.86
Condition B	Xo	.28	.25	.28	.35	.30	.28	.29	.32	.21	.24	.25	.17	.28	.22	.28
	Xi	.16	.19	.13	.28	.20	.12	.19	.20	.25	.21	.32	.18	.22	.25	.20
	Yo	2.40	2.30	2.41	2.39	2.37	2.50	2.35	2.42	1.70	2.15	2.50	2.15	2.32	2.10	2.40
	Yi	2.02	2.09	2.40	2.39	2.37	1.50	2.09	2.22	2.30	1.90	2.10	2.35	2.05	1.95	2.35
	Zo	2.20	2.20	2.30	2.15	2.25	2.40	2.20	2.30	2.19	2.20	2.10	2.20	2.28	2.40	2.50
	Zi	1.95	1.70	2.10	1.99	2.05	1.68	1.85	2.10	1.62	1.61	2.00	2.10	1.95	1.50	2.10
Condition C	Xo-rh	.08	.10	.09	.05	.05	.20	.30	.20	.21	.26	.25	.20	.15	.10	.22
	Xo-lh	.09	.10	.10	.12	.10	.28	.29	.21	.19	.35	.34	.33	.22	.13	.36
	Xi-rh	.10	.05	.18	.08	.05	.05	.04	.11	.06	.12	.12	.06	.19	.08	.16
	Xi-lh	.12	.20	.12	0.00	.10	.43	.40	.45	.52	.42	.42	.45	.41	.50	.24
	Yo-rh	1.23	.99	.85	1.06	1.40	.96	1.61	1.15	1.65	1.16	1.45	.98	.70	1.20	1.00
	Yo-lh	.80	.95	1.20	1.40	1.00	1.31	1.36	1.10	1.84	1.90	1.10	.80	.98	.85	1.30
	Yi-rh	.90	1.60	1.08	1.65	1.00	1.06	1.94	1.39	1.80	2.30	1.25	.95	1.51	.99	1.58
	Yi-lh	.80	1.06	1.25	1.10	.28	2.10	1.64	1.75	2.00	2.30	1.15	1.30	1.36	1.55	.98
	Zo-rh	.91	.37	.48	.70	.54	1.30	1.05	.92	1.08	1.08	1.35	1.05	.95	.89	1.05
	Zo-lh	.75	.62	.84	.70	.91	1.26	1.12	.85	1.12	1.05	1.60	1.46	1.15	1.04	1.35
	Zi-rh	.45	.64	.60	.60	.45	.95	1.05	1.08	.89	.94	1.00	.90	.81	1.10	1.09
	Zi-lh	.45	.51	.60	.44	.65	.85	.65	.55	.90	.35	.67	.55	.63	.60	.84

EXPERIMENTAL DATA SHEET

Name Kathy Klein
Age 21 yrs.
Height 5 ft. 5 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 10
Weight 115 lbs.

Table Height 41 in.
Upper Arm Length 13 in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.31	.35	.40	.32	.32	.45	.39	.32	.41	.40	.50	.52	.50	.60	.55
	Xi	.20	.25	.21	.25	.20	.19	.24	.26	.24	.42	.34	.24	.25	.25	.20
	Yo	2.14	1.72	2.00	1.80	1.82	2.15	1.45	1.42	2.00	1.86	1.70	1.79	1.75	1.75	1.65
	Yi	1.68	2.25	1.92	2.09	2.05	1.05	1.86	1.68	1.81	2.41	1.86	1.55	1.90	1.35	1.30
	Zo	2.10	1.82	1.70	1.75	1.70	2.10	1.99	1.95	2.28	1.94	2.20	2.15	2.20	2.21	1.79
	Zi	1.54	1.54	1.50	1.51	1.51	2.05	2.11	2.09	2.27	2.16	2.25	2.10	2.19	2.20	1.95
Condition B	Xo	.29	.40	.23	.26	.21	.50	.40	.42	.49	.28	.60	.45	.45	.41	.41
	Xi	.22	.25	.18	.14	.30	.20	.39	.26	.21	.30	.28	.31	.28	.29	.29
	Yo	2.15	1.58	1.30	1.50	1.20	1.91	1.35	1.32	1.50	1.00	1.60	1.40	1.61	1.55	1.25
	Yi	1.95	1.53	1.25	1.45	1.50	1.62	1.90	1.70	1.50	1.70	1.30	1.37	1.45	1.50	1.22
	Zo	2.12	1.60	1.85	1.90	1.55	2.40	2.01	2.19	2.10	2.90	2.20	2.28	2.30	2.50	1.80
	Zi	1.76	1.45	1.40	1.55	1.30	2.10	2.30	2.05	2.02	2.20	2.25	2.20	2.05	2.42	2.08
Condition C	Xo-rh	.21	.22	.19	.27	.16	.35	.40	.30	.35	.30	.46	.35	.30	.30	.30
	Xo-lh	.29	.18	.26	.30	.30	.34	.41	.35	.38	.41	.40	.36	.39	.45	.30
	Xi-rh	.11	.10	.11	.12	.14	.22	.35	.35	.25	.35	.30	.25	.31	.30	.25
	Xi-lh	.19	.32	.20	.25	.21	.41	.28	.42	.38	.35	.31	.41	.40	.25	.29
	Yo-rh	1.00	.65	.45	.65	.70	.87	.95	.80	.80	1.10	.65	.80	.90	.58	.48
	Yo-lh	.30	.54	.66	.35	.50	.80	.92	.50	.79	.86	.74	.55	.70	.68	.59
	Yi-rh	.75	.66	.75	1.15	.90	.59	1.60	1.10	1.05	1.10	.66	.75	.84	.70	.60
	Yi-lh	.40	.43	.30	.65	.65	1.15	.75	1.05	1.02	1.20	.90	1.05	1.00	.60	.96
	Zo-rh	.81	.68	.70	.85	.85	1.56	1.44	1.30	1.45	1.25	2.15	1.78	1.55	1.70	1.55
	Zo-lh	.86	.98	.75	1.00	1.40	1.57	1.36	1.55	1.55	1.60	1.51	1.48	1.61	2.01	1.99
	Zi-rh	.82	.58	.45	.48	.72	1.80	1.64	1.40	1.20	1.35	1.59	1.50	1.70	1.75	1.50
	Zi-lh	1.14	1.14	.95	1.20	1.39	1.55	1.42	1.45	1.52	1.52	1.45	1.61	2.00	1.85	1.95

EXPERIMENTAL DATA SHEET

Name Mary Smaltz　　Date November 23, 1965　　Table Height 40 in.
Age 18 yrs.　　Subject No. 11　　Upper Arm Length 14 in.
Height 5 ft. 8 in.　　Weight 160 lbs.　　Dist. from Table $6\frac{1}{2}$ in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Reading No.

Condition		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.20	.26	.26	.22	.24	.11	.12	.13	.11	.10	.20	.20	.25	.22	.14
	Xi	.11	.12	.07	.13	.13	.08	.10	.10	.08	.09	.08	.14	.10	.12	.12
	Yo	1.40	1.50	1.49	1.32	1.70	1.38	1.04	1.19	1.20	1.12	1.68	1.28	1.55	1.50	1.07
	Yi	1.10	1.05	.80	1.10	1.30	1.05	1.26	1.09	1.04	1.18	1.47	1.20	1.28	1.34	1.56
	Zo	.42	.30	.34	.31	.31	.62	.30	.38	.26	.30	.71	.40	.49	.48	.39
	Zi	.39	.32	.31	.24	.26	.38	.32	.24	.22	.22	.49	.38	.42	.40	.30
Condition B	Xo	.24	.21	.12	.12	.19	.18	.12	.12	.14	.20	.19	.21	.18	.20	.24
	Xi	.15	.10	.15	.20	.10	.14	.09	.14	.13	.11	.12	.13	.19	.08	.08
	Yo	1.00	.76	.69	.82	.68	1.20	1.05	.81	1.19	1.25	1.08	.98	.84	1.10	1.18
	Yi	.90	.70	.92	.91	.98	1.00	.90	1.35	1.39	1.05	.80	.90	1.10	.85	.74
	Zo	.40	.30	.21	.29	.20	.65	.36	.40	.35	.25	.62	.39	.54	.44	.42
	Zi	.26	.22	.15	.18	.11	.40	.28	.38	.30	.20	.38	.38	.40	.42	.32
Condition C	Xo-rh	.28	.23	.24	.27	.22	.24	.11	.18	.19	.15	.15	.15	.11	.13	.15
	Xo-lh	.19	.20	.22	.28	.33	.20	.21	.21	.17	.20	.18	.17	.24	.23	.20
	Xi-rh	.20	.13	.18	.26	.21	.10	.10	.17	.12	.12	.12	.14	.12	.11	.18
	Xi-lh	.25	.24	.29	.22	.25	.18	.12	.18	.22	.21	.20	.27	.18	.24	.19
	Yo-rh	.95	.90	.71	.94	.64	.80	.68	.91	.71	.50	.89	.64	.79	.92	.80
	Yo-lh	.82	.75	.76	.84	.98	1.20	1.65	1.10	.74	.76	.96	.94	1.00	.99	.76
	Yi-rh	.68	.50	.72	.79	.71	.60	.69	.92	.84	.68	.62	.89	.80	.68	1.25
	Yi-lh	.90	.89	.95	.86	.88	.75	.70	.65	.74	.85	.95	1.25	1.00	1.08	1.10
	Zo-rh	.35	.19	.20	.21	.21	.33	.15	.08	.18	.11	.21	.12	.12	.14	.14
	Zo-lh	.20	.19	.20	.20	.20	.22	.10	.25	.20	.13	.20	.19	.18	.12	.11
	Zi-rh	.19	.15	.12	.17	.20	.14	.09	.02	.08	.05	.10	.08	.10	.10	.14
	Zi-lh	.21	.22	.22	.22	.15	.30	.17	.25	.19	.10	.22	.28	.18	.10	.20

EXPERIMENTAL DATA SHEET

Name Janet Suboter
Age 18 yrs.
Height 5 ft. 7 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 12
Weight 121 lbs.

Table Height 40 in.
Upper Arm Length 14 in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.30	.20	.09	.12	.12	.21	.22	.22	.15	.18	.18	.17	.19	.29	.25
	Xi	.05	.08	.01	.04	.04	.01	.10	.02	.02	.05	.08	.10	.06	.09	.09
	Yo	2.30	1.25	1.05	1.28	.82	1.22	1.40	1.30	1.11	1.19	1.21	1.18	1.29	1.70	1.35
	Yi	1.18	1.00	1.15	1.04	1.29	.65	.95	.89	.90	.99	1.11	1.30	1.12	.95	1.28
	Zo	2.10	1.12	1.04	.81	.94	.90	.61	.51	.55	.60	1.29	.99	1.08	1.30	1.11
	Zi	1.08	.60	.71	.74	.69	.60	.50	.45	.66	.66	.99	1.01	.84	1.15	.90
Condition B	Xo	.05	.06	.09	.03	.08	.14	.14	.12	.12	.15	.12	.16	.21	.19	.19
	Xi	.02	.04	.04	.04	.09	.05	.05	.02	.05	.01	.15	.10	.11	.09	.18
	Yo	1.20	.81	1.41	1.30	1.59	.56	1.22	1.30	.95	1.39	1.30	.95	1.13	.88	1.08
	Yi	1.05	.90	1.40	1.43	1.35	.80	1.10	.88	1.05	.82	1.25	1.35	1.34	.92	1.24
	Zo	1.05	1.08	.90	1.09	.59	1.00	.85	1.14	.88	1.08	1.41	1.15	1.14	.98	1.08
	Zi	.65	.78	.81	.72	.32	.55	.57	.86	.84	.88	.88	.92	1.03	.90	1.05
Condition C	Xo-rh	.11	.09	.08	.20	.07	.10	.07	.09	.10	.05	.14	.15	.22	.06	.09
	Xo-lh	.05	.04	.01	.05	.02	.10	.02	.11	.15	.11	.08	.15	.12	.10	.08
	Xi-rh	.01	.10	.01	.04	.02	.04	.05	.09	.04	0.00	.14	.14	.08	.01	.06
	Xi-lh	.10	.09	.08	.08	.11	.10	.15	.03	.16	.13	.12	.19	.11	.14	.14
	Yo-rh	.86	.85	.71	.95	.86	1.29	1.15	1.34	1.54	1.34	1.17	.72	1.22	1.09	.95
	Yo-lh	.71	.65	.60	.95	.52	1.14	.78	.70	1.28	.95	.61	1.02	.98	.69	.59
	Yi-rh	.80	.82	.71	.65	.70	.53	.85	.95	1.17	1.05	.71	.90	.82	.98	.84
	Yi-lh	.99	.90	.83	.90	1.02	1.08	1.10	.98	1.40	1.25	.82	1.60	1.11	1.21	1.18
	Zo-rh	.63	.55	.39	.35	.28	.30	.28	.38	.30	.19	.50	.53	.82	.46	.65
	Zo-lh	.59	.53	.42	.66	.36	.22	.35	.02	.28	.28	.65	.53	.50	.71	.59
	Zi-rh	.31	.45	.25	.21	.40	.20	.12	.65	.12	.05	.49	.52	.58	.45	.45
	Zi-lh	.29	.50	.40	.35	.35	.20	.26	.08	.22	.13	.54	.52	.59	.49	.66

EXPERIMENTAL DATA SHEET

Name Beverly Davin　　Date November 23, 1965　　Table Height 41 in.
Age 18 yrs.　　Subject No. 13　　Upper Arm Length 13 in.
Height 5 ft. 5 in.　　Weight 116 lbs.　　Dist. from Table $6\frac{1}{2}$ in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Reading No.

Condition		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.40	.42	.45	.42	.54	.48	.48	.49	.45	.40	.70	.58	.50	.56	.58
	Xi	.41	.44	.39	.39	.40	.31	.35	.42	.48	.42	.42	.44	.50	.56	.52
	Yo	1.70	1.49	1.48	1.39	1.25	1.29	1.25	.98	.92	.88	1.22	.90	.80	.98	1.00
	Yi	1.58	1.65	1.90	2.05	1.48	.85	1.48	.90	1.18	1.05	1.20	1.10	1.12	1.20	.95
	Zo	2.20	1.74	2.05	2.21	1.95	2.05	2.20	2.18	2.08	2.10	2.30	2.00	1.97	2.15	1.90
	Zi	1.50	1.85	2.08	1.94	1.75	1.91	2.00	2.10	1.85	1.65	1.74	1.70	1.70	1.80	1.60
Condition B	Xo	.38	.39	.42	.42	.35	.36	.34	.33	.40	.31	.72	.69	.75	.64	.61
	Xi	.24	.35	.40	.38	.40	.28	.32	.27	.30	.36	.62	.60	.50	.60	.74
	Yo	1.34	1.14	1.08	.92	.87	.81	.95	.70	.65	.88	1.00	.92	1.05	1.00	.59
	Yi	1.05	1.48	.98	1.08	1.15	.91	1.08	.80	.76	.82	1.20	1.00	.90	1.18	1.12
	Zo	2.08	2.02	2.00	2.32	2.20	2.30	1.80	1.70	1.95	1.88	2.50	2.48	2.45	2.25	2.11
	Zi	1.58	1.80	1.80	1.55	1.60	1.75	1.86	1.56	1.70	1.86	2.23	2.25	2.09	2.11	2.20
Condition C	Xo-rh	.44	.40	.44	.35	.32	.38	.35	.34	.30	.31	.34	.32	.32	.29	.32
	Xo-lh	.39	.30	.35	.40	.24	.24	.30	.33	.25	.28	.38	.36	.38	.31	.34
	Xi-rh	.28	.23	.25	.26	.29	.20	.25	.20	.28	.24	.30	.24	.22	.26	.24
	Xi-lh	.35	.37	.45	.41	.46	.36	.35	.42	.35	.46	.41	.39	.35	.39	.40
	Yo-rh	1.34	1.00	.61	.65	.80	1.18	.85	.55	.75	1.10	1.00	.84	.90	.83	.79
	Yo-lh	.85	.39	.50	.40	.64	.55	.68	.70	.66	.65	.49	.70	.40	.60	.86
	Yi-rh	.83	1.02	.90	.60	.73	.74	.84	.76	.84	.82	.64	.78	.73	.88	.85
	Yi-lh	.76	.61	.70	.76	.72	.60	.60	.75	.58	.78	.62	.72	.65	.75	.60
	Zo-rh	1.42	1.17	1.20	1.10	1.14	1.41	1.29	.94	1.18	1.20	1.55	1.47	1.44	1.48	1.41
	Zo-lh	1.18	1.30	1.40	1.44	1.50	1.38	1.35	1.50	1.25	1.44	1.40	1.80	1.45	1.50	1.60
	Zi-rh	.93	.94	.88	.80	.99	.89	1.00	.99	1.08	.97	1.10	1.12	1.38	1.37	1.62
	Zi-lh	1.20	.92	1.08	1.22	1.21	1.00	1.12	1.20	1.15	1.35	1.38	1.55	1.58	1.26	1.48

EXPERIMENTAL DATA SHEET

Name Kathy Webb
Age 18 yrs.
Height 5 ft. 5 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 14
Weight 115 lbs.

Table Height 41 in.
Upper Arm Length 13 in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.38	.29	.30	.30	.35	.65	.50	.51	.58	.55	.60	.42	.41	.40	.42
	Xi	.16	.20	.25	.22	.23	.41	.48	.45	.48	.40	.21	.30	.35	.35	.36
	Yo	1.94	1.49	1.65	1.70	1.85	1.80	1.39	1.65	1.71	1.85	2.30	1.95	1.39	1.20	1.80
	Yi	1.79	2.10	1.59	1.94	1.50	1.50	2.10	1.58	1.94	1.50	2.15	1.89	1.68	2.10	2.02
	Zo	1.75	1.10	1.09	1.29	1.50	2.10	1.75	1.65	1.79	1.62	2.15	1.51	1.70	1.65	1.67
	Zi	1.25	1.20	1.28	1.19	1.49	1.50	1.60	1.30	1.49	1.66	1.60	1.53	1.55	1.25	1.50
Condition B	Xo	.55	.39	.31	.34	.40	.62	.42	.50	.50	.49	.52	.50	.50	.43	.44
	Xi	.10	.20	.24	.32	.31	.28	.45	.32	.32	.49	.30	.30	.32	.25	.35
	Yo	1.49	1.70	1.45	1.50	1.75	2.10	1.30	1.65	1.50	1.49	1.51	1.70	1.15	1.44	1.50
	Yi	1.42	1.73	1.59	2.15	1.55	1.44	2.20	1.90	1.55	2.00	1.65	1.40	1.28	1.15	1.60
	Zo	2.01	1.08	1.50	1.42	1.50	2.15	1.64	1.66	1.55	1.70	2.10	1.75	1.90	1.65	1.65
	Zi	1.25	1.49	1.45	1.52	1.59	1.69	1.65	1.67	1.22	1.60	1.65	1.66	1.85	1.66	1.76
Condition C	Xo-rh	.48	.40	.35	.35	.34	.51	.40	.41	.40	.46	.48	.45	.60	.45	.40
	Xo-lh	.26	.32	.30	.34	.28	.35	.22	.32	.41	.48	.45	.38	.35	.44	.38
	Xi-rh	.24	.26	.22	.19	.26	.20	.13	.29	.20	.29	.30	.28	.30	.32	.39
	Xi-lh	.20	.24	.31	.30	.29	.36	.40	.34	.42	.35	.41	.50	.36	.40	.42
	Yo-rh	1.74	1.21	.90	1.12	1.10	1.30	1.00	.82	.80	.88	1.48	1.45	1.00	.95	1.39
	Yo-lh	.80	1.30	1.32	1.40	.94	1.14	.85	.70	1.20	1.42	.90	1.10	1.25	1.40	1.30
	Yi-rh	1.00	1.45	1.28	1.26	.95	.61	1.06	1.00	1.02	1.21	1.25	1.50	1.20	1.55	1.25
	Yi-lh	1.30	.92	1.05	1.02	.70	1.18	1.32	.90	1.10	.95	1.29	1.72	1.24	1.25	1.05
	Zo-rh	.85	.65	.61	.72	.75	1.25	.96	.99	1.10	1.17	1.40	1.15	1.15	1.25	1.15
	Zo-lh	.66	.61	.70	.80	.85	1.09	1.10	1.01	1.08	1.01	.75	1.05	1.14	1.01	.88
	Zi-rh	.65	.70	.58	.60	.80	.82	.75	.95	.75	.90	1.10	.95	1.25	1.14	1.30
	Zi-lh	.77	.75	.80	.95	.82	.95	.90	.90	.80	1.00	1.09	1.10	.95	1.00	1.01

EXPERIMENTAL DATA SHEET

Name Janet Osburn Date November 23, 1965 Table Height 41 in.
Age 19 yrs. Subject No. 15 Upper Arm Length 13 in.
Height 5 ft. 4 in. Weight 120 lbs. Dist. from Table 6½ in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Reading No.

Condition		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.15	.16	.19	.19	.20	.16	.07	.11	.10	.11	.09	.09	.11	.12	.09
	Xi	.02	.05	.04	.04	.05	.05	.08	.05	.05	.02	.05	.02	.04	.04	.08
	Yo	2.36	1.85	2.10	1.80	1.70	2.32	1.63	2.31	2.00	2.18	2.10	1.55	1.80	1.74	1.65
	Yi	1.74	1.63	2.00	2.20	2.15	1.68	2.40	2.00	2.05	1.60	1.75	1.90	1.91	1.76	1.85
	Zo	.85	.60	.80	.79	.75	.81	.55	.73	.80	.85	.78	.60	.55	.64	.64
	Zi	.71	.59	.82	.78	.79	.65	.84	.68	.65	.72	.58	.51	.69	.63	.72
Condition B	Xo	.19	.18	.10	.21	.15	.13	.09	.07	.10	.09	.11	.13	.04	.05	.03
	Xi	.04	.03	.05	.01	.01	.01	.01	.05	.05	.07	.04	.03	.03	.01	.05
	Yo	2.30	1.34	1.19	1.38	1.32	2.12	1.70	1.72	1.55	1.50	2.12	2.35	1.40	1.62	1.79
	Yi	1.08	1.55	1.90	1.40	2.15	1.57	1.60	1.76	1.75	2.09	1.75	1.84	1.34	2.05	1.78
	Zo	1.08	.69	.61	.78	.76	.80	.39	.60	.52	.51	1.08	.72	.61	.65	.83
	Zi	.75	.76	.75	.75	.88	.60	.45	.55	.49	.60	.55	.80	.70	.65	.60
Condition C	Xo-rh	.20	.16	.21	.19	.24	.10	.09	.14	.10	.08	.08	.05	.10	0.00	0.00
	Xo-lh	.19	.16	.18	.18	.16	.06	.11	.08	.04	.06	.12	.04	.12	.10	.08
	Xi-rh	.15	.12	.10	.14	.12	.05	.05	.09	.09	.10	.05	0.00	.08	.08	0.00
	Xi-lh	.08	.18	.19	.17	.20	.08	.16	.08	.20	.16	.06	.11	.10	.04	.20
	Yo-rh	1.09	1.10	.90	1.02	.70	1.42	1.18	1.05	1.09	.99	.92	.91	.98	.85	1.10
	Yo-lh	1.05	.88	1.23	1.16	1.13	1.64	1.12	1.42	1.83	1.39	.94	1.65	1.90	1.60	1.40
	Yi-rh	.64	.69	1.15	.68	.81	1.24	1.19	1.04	1.08	1.20	.95	1.30	1.29	.90	1.00
	Yi-lh	.85	.95	1.18	1.45	1.50	1.33	1.70	1.35	1.40	1.50	.93	1.58	1.39	1.30	1.70
	Zo-rh	.10	.17	.14	.18	.17	.27	.23	.18	.18	.12	.10	.18	.18	.16	.18
	Zo-lh	.31	.15	.20	.15	.20	.19	.12	.20	.34	.17	.20	.38	.30	.30	.28
	Zi-rh	.20	.10	.12	.12	.13	.18	.18	.17	.14	.15	.25	.34	.25	.16	.12
	Zi-lh	.36	.28	.20	.26	.28	.23	.39	.22	.22	.24	.12	.14	.20	.22	.38

EXPERIMENTAL DATA SHEET

Name Jan Olsson
Age 19 yrs.
Height 5 ft. 7 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 16
Weight 115 lbs.

Table Height 41 in.
Upper Arm Length 13 in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.36	.36	.38	.35	.29	.30	.22	.26	.30	.29	.28	.16	.18	.14	.20
	Xi	.25	.27	.29	.34	.30	.21	.25	.23	.23	.27	.13	.06	.10	.13	.14
	Yo	1.20	1.09	1.15	1.16	.70	1.33	1.00	1.08	1.24	1.59	2.00	1.04	1.00	1.26	1.60
	Yi	.88	1.00	1.40	1.65	1.18	1.18	1.76	1.09	1.18	1.52	1.70	1.03	1.23	1.30	1.31
	Zo	2.08	1.47	1.32	1.46	1.15	1.58	1.20	1.44	1.36	1.34	1.60	1.73	1.15	1.38	1.65
	Zi	.68	.94	1.45	1.64	1.00	.88	1.50	1.43	.99	1.28	1.40	.85	1.18	1.49	1.50
Condition B	Xo	.30	.28	.32	.35	.38	.43	.31	.38	.40	.38	.20	.26	.19	.21	.21
	Xi	.21	.29	.24	.29	.32	.25	.33	.31	.30	.36	.13	.12	1.12	.18	.19
	Yo	1.16	1.06	.80	1.08	1.08	1.05	.60	.81	1.05	1.24	1.00	1.20	1.30	1.14	1.08
	Yi	.58	1.20	1.13	1.24	1.44	1.01	1.21	1.30	.99	1.42	.89	1.10	.98	1.10	1.00
	Zo	1.40	.81	.95	1.12	1.45	2.05	1.45	1.54	1.43	1.28	1.38	.99	1.10	.78	1.05
	Zi	.60	.90	1.00	.81	1.10	.75	1.00	.75	.65	.56	.81	.90	.90	.50	.50
Condition C	Xo-rh	.23	.22	.19	.26	.28	.30	.18	.24	.28	.29	.10	.11	.12	.19	.22
	Xo-lh	.28	.32	.32	.41	.45	.34	.26	.35	.35	.30	.20	.19	.30	.28	.25
	Xi-rh	.24	.26	.29	.30	.29	.28	.22	.25	.25	.30	.14	.10	.15	.18	.19
	Xi-lh	.28	.29	.30	.32	.40	.18	.28	.18	.25	.26	.08	.14	.18	.22	.29
	Yo-rh	.55	.70	.55	.75	.74	.95	.45	.60	.60	.51	.98	.78	.59	.52	.68
	Yo-lh	.49	.42	.40	.75	.65	.61	.49	.22	.28	.32	.36	.49	.60	.64	.65
	Yi-rh	.41	.53	.76	.92	.88	.32	.36	.80	.65	.54	.75	.50	.54	.68	.80
	Yi-lh	.43	.48	.42	.58	.50	.21	.44	.58	.44	.60	.44	.65	.52	.60	.62
	Zo-rh	.84	.52	.60	.61	.50	1.05	.49	.64	.68	.65	.82	.82	.65	.41	.50
	Zo-lh	.39	.55	.50	.63	.58	.69	.44	.58	.44	.38	.32	.61	.50	.64	.44
	Zi-rh	.34	.45	.69	.56	.30	.35	.59	.84	.85	.70	.48	.55	.50	.51	.71
	Zi-lh	.40	.29	.45	.32	.21	.12	.49	.43	.32	.28	.38	.23	.30	.60	.28

EXPERIMENTAL DATA SHEET

Name Pat Haggard
Age 19 yrs.
Height 5 ft. 4 in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Date November 23, 1965
Subject No. 17
Weight 122 lbs.

Table Height $40\frac{1}{2}$ in.
Upper Arm Length $13\frac{1}{2}$ in.
Dist. from Table $6\frac{1}{2}$ in.

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.38	.28	.30	.35	.26	.40	.33	.30	.31	.30	.24	.20	.21	.19	.20
	Xi	.20	.18	.22	.24	.21	.11	.08	.20	.18	.12	.08	.12	.16	.10	.12
	Yo	1.84	1.80	1.24	1.65	1.85	1.69	1.46	.85	.88	1.45	1.40	.70	.76	.80	1.32
	Yi	1.29	1.09	1.45	1.34	1.45	1.10	.75	1.15	1.35	.79	.90	1.08	1.05	.98	1.15
	Zo	1.15	.90	.83	1.05	.80	.85	.81	.75	.62	.62	.70	.58	.51	.45	.45
	Zi	.75	.85	1.02	1.04	.85	.60	.60	.60	.60	.49	.49	.60	.48	.45	.55
Condition B	Xo	.38	.38	.35	.36	.36	.36	.28	.30	.35	.32	.19	.17	.13	.15	.12
	Xi	.22	.22	.25	.28	.24	.28	.28	.29	.30	.28	.05	.05	.05	.12	.09
	Yo	1.39	1.50	1.16	1.45	1.55	1.20	1.24	.85	.99	.65	1.16	1.06	1.15	1.05	1.45
	Yi	.90	1.04	1.26	.94	.80	.98	1.18	1.05	1.24	1.18	1.05	.91	.90	.99	.84
	Zo	1.11	1.00	1.04	1.19	.98	.20	.52	.65	.68	.69	.60	.49	.44	.49	.48
	Zi	.94	.95	.94	1.05	1.10	.61	.74	.72	.60	.49	.50	.40	.38	.34	.28
Condition C	Xo-rh	.32	.29	.28	.29	.25	.29	.26	.30	.30	.31	.20	.18	.18	.18	.16
	Xo-lh	.28	.29	.26	.25	.24	.25	.30	.35	.33	.33	.14	.10	.10	.19	.15
	Xi-rh	.20	.24	.21	.21	.20	.18	.20	.20	.22	.14	.14	.14	.13	.11	.10
	Xi-lh	.12	.20	.28	.12	.24	.22	.18	.16	.20	.15	.19	.19	.18	.11	.11
	Yo-rh	1.13	.82	.92	.49	.80	1.18	.96	.75	.50	.29	.72	1.02	.59	.90	.92
	Yo-lh	.99	.88	.78	.70	.58	1.04	.95	.58	.55	.48	.82	.98	.70	1.00	.95
	Yi-rh	.55	.92	.52	.40	.40	.65	.75	1.30	1.25	.75	.74	.72	.62	.55	.60
	Yi-lh	.54	.56	.82	.44	.78	1.10	.75	.95	.95	.66	.91	1.05	.88	.58	.85
	Zo-rh	.31	.18	.19	.09	.19	.18	.05	.03	.05	.02	.10	.13	.08	.10	.15
	Zo-lh	.25	.25	.23	.22	.20	.12	.11	.10	.08	.05	.08	.09	.01	.09	.08
	Zi-rh	.18	.10	.08	.04	.08	.18	.14	.30	.35	.20	.22	.19	.19	.24	.18
	Zi-lh	.15	.09	.06	.08	.08	.16	.09	.15	.14	.10	.15	.15	.20	.02	.10

EXPERIMENTAL DATA SHEET

Name Betty L. Jeans Date November 23, 1965 Table Height 41 in.
Age 26 yrs. Subject No. 18 Upper Arm Length 13 in.
Height 5 ft. 4½ in. Weight 117 lbs. Dist. from Table 6½ in.
Calibration: X 1 volts/cm
Y 1 volts/cm
Z 1 volts/cm

Reading No.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Condition A	Xo	.60	.17	.18	.20	.17	.34	.08	.12	.07	.08	.85	.29	.28	.23	.15
	Xi	.05	.03	.05	.09	.10	.09	.05	.08	.07	.09	.28	.25	.22	.30	.22
	Yo	2.42	2.05	2.07	1.88	1.78	1.90	2.32	1.59	1.80	2.10	2.50	2.01	2.80	2.75	2.79
	Yi	2.39	2.20	2.28	2.22	1.89	2.20	2.35	2.28	2.27	2.16	1.10	2.09	2.28	2.50	2.00
	Zo	2.55	1.19	1.41	1.26	1.62	1.86	1.80	1.15	1.40	1.41	2.10	.89	1.12	1.09	1.12
	Zi	1.60	1.37	1.20	1.11	.65	1.30	1.40	1.46	1.38	1.42	.93	1.85	1.63	1.99	.60
Condition B	Xo	.51	.30	.26	.18	.18	.10	.05	.17	.11	.04	.39	.30	.31	.28	.10
	Xi	.12	.09	.10	.10	.17	.08	.09	.10	.05	.04	.15	.20	.15	.19	.19
	Yo	2.40	2.30	2.36	1.71	1.78	1.66	1.70	1.44	.92	1.53	2.21	1.68	1.45	1.85	1.59
	Yi	2.42	2.20	2.00	2.23	2.28	1.69	1.85	1.61	1.83	1.70	2.05	2.25	2.10	1.29	1.71
	Zo	1.81	1.40	1.72	1.23	1.45	1.43	1.51	1.07	1.05	1.42	1.99	1.98	1.70	1.81	1.80
	Zi	1.63	1.35	1.50	1.53	1.36	1.01	1.25	1.22	1.04	1.15	1.28	1.59	1.38	1.08	.97
Condition C	Xo-rh	.05	.04	.07	.08	.02	.13	.09	.11	.11	.19	.40	.40	.33	.40	.41
	Xo-lh	.22	.09	.15	.20	.11	.15	.05	.05	.10	.11	.50	.49	.55	.42	.35
	Xi-rh	.12	.16	.20	.15	.17	.01	.10	0.00	.08	.09	.30	.39	.29	.35	.50
	Xi-lh	.21	.25	.10	.10	.13	.05	.15	.12	.10	.12	.53	.62	.60	.50	.22
	Yo-rh	1.16	1.23	.80	.95	.86	1.02	1.09	.68	.90	.39	1.60	1.00	1.16	1.05	.92
	Yo-lh	1.82	1.21	1.09	1.52	.90	1.05	.92	.84	.82	.82	.98	1.15	1.34	1.36	.86
	Yi-rh	1.14	.92	1.18	.92	1.10	.98	.80	1.15	1.19	1.01	.81	.98	.62	1.21	1.08
	Yi-lh	1.30	1.40	1.54	1.35	1.32	1.07	.84	1.16	1.35	1.45	1.36	1.45	1.20	1.22	1.08
	Zo-rh	.70	.59	.61	.68	.52	.66	.53	.41	.47	.24	.65	.50	.68	.58	.51
	Zo-lh	1.15	.47	.66	.89	.40	.81	.55	.35	.35	.40	.59	.68	.77	.61	.29
	Zi-rh	.50	.64	.51	.41	.47	.41	.39	.45	.44	.40	.40	.40	.22	.42	.42
	Zi-lh	.85	.79	.71	.46	.48	.60	.31	.39	.41	.39	.38	.40	.31	.44	.49

A STUDY OF THE PHYSIOLOGICAL COSTS OF SYMMETRICAL AND SIMULTANEOUS MOTIONS

by

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ABSTRACT

The principles of motion economy established by R. M. Barnes in 1937 state, "motions of the arms should be performed symmetrically and simultaneously" was investigated using physiological cost as measured by a force platform as a criterion. Three task conditions presented the combinations of symmetrical and simultaneous arm motions.

Eighteen female subjects performed in each of the three experimental conditions. The order of the task presentation was counterbalanced within each subject.

A subjects by conditions analysis of variance was calculated. Mean values were tested by the Duncan Multiple Range test.

It was concluded that for the task studied:

1) It is easier to perform simultaneous and non-symmetrical motions than simultaneous and symmetrical motions.
2) Simultaneous motions are easier to perform than non-simultaneous or sequential motions.
3) Outward motions of the arm require more force than inward motions.
4) Finally, for right-handed women, the left hand exerts more force than the right hand when both hands are working at an "equal" task.