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The effects of experimental design upon the ability to perceive and exert varying levels of submaximal force

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THE EFFECTS OF EXPERIMENTAL DESIGN UPON THE ABILITY TO PERCEIVE AND EXERT VARYING LEVELS OF SUBMAXIMAL FORCE

by

Ralph Kaplan

An Abstract

of a thesis submitted in partial fulfillment
of the requirements for the degree of
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ABSTRACT

The purpose of this investigation was to determine the effects of experimental design and various levels of force upon the accuracy and consistency of perceiving and exerting specific levels of submaximal forces. Seventy-two volunteers enrolled during the 1976 spring semester at Ithaca College served as subjects. The subjects were randomly assigned to one of six experimental groups consisting of 12 subjects each. Groups I, II, and III, all between-subjects groups, were required to perceive and exert 25, 50, or 75 percent of their maximum grip strength respectively. Groups IV, V, and VI, all within-subjects groups, experienced all three submaximal forces in a balanced order. The maximum grip strength for each subject was determined by averaging the scores of two maximum grip strength trials. The instrument selected to measure the grip strength perception trials was a cable-tensiometer attached to a T-5 orthopedic testing device.

The intraclass correlation method was used to determine reliability. Each of the perceptual groups and the maximum trial scores indicated adequate reliability.

A multivariate analysis of variance examined the effects of design and level of strength on constant and variable error scores. Significance was found for the level

of strength variable. To further facilitate analysis, constant error and variable error were each subjected to a univariate analysis of variance to study the previously mentioned variables. The level of strength variable was significant for the constant error scores. A post hoc analysis, the Scheffé S Test revealed constant error scores that showed the 25 and 50 percent groups to be significantly different from the 75 percent group. It was concluded that accurate perception of a submaximal grip force depended upon the level of strength of the criterion, rather than the testing sequence.

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UPON THE ABILITY TO PERCEIVE
AND EXERT VARYING LEVELS
OF SUBMAXIMAL FORCE

A Thesis Presented to the Faculty of
the School of Health, Physical
Education, and Recreation
Ithaca College

In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by
Ralph Kaplan
July 1976

Ithaca College
School of Health, Physical Education and Recreation
Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Ralph Kaplan

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

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Chapter 1

INTRODUCTION

Movement is usually thought of as the change in position of the body or body parts in space or time. This description, however, does not fully explain the complexities that underlie a successfully completed motor response. Every successfully performed skill reflects an intricately balanced integration of emotional, physical, amd mental interactions. If not for fine control of motor functions, maximal muscle contractions would result in awkward uncontrolled movements.

For an individual to be an effective and economical performer, he must be able to perceive the amount of movement necessary for successful completion of the task. Precise perceptual ability depends upon individual differences such as experience, personality, and emotional factors, as well as the effect of the environmental variable. Laabs (17) indicated that a major factor of successful motor performance is based upon similar past experiences. These experiences are recorded in memory and later serve as a model with which to compare present movement. If memory of a particular movement is unavailable, success in the skill would be improbable.

To competently complete a task, the individual must perceive and exert the submaximal forces necessary for efficient movement. The precise control of the force exerted for efficient movement is a basic requirement of successful performance. It is this ability, of predetermining submaximal force requirements and exerting such a force, that distinguishes successful from unsuccessful performance. It is, therefore, understandable that various investigators have used perceived force as a dependent variable in the study of human movement.

Past investigations utilizing force as a dependent variable have experienced certain methodological problems. Several factors found to influence the perception and exertion of submaximal levels of strength have been interference effects (23), level of force (37), and kinesthetic aftereffects (21, 22). An additional variable, the experimental design, could have an effect on the obtained results. It is possible that the nature of an observed relationship between variables may be dependent upon the particular design used to observe the relationship (35). For, as Grice stated (11:488):

> The nature of the relations observed between sets of variables is dependent upon the source of experimental variation employed. Recognition of this principle may lead to somewhat different research strategies which, in turn, may lead to the discovery of new and interesting relations or to theoretical clarification.

In his experiment, Grice (11) compared the two types of experimental designs, these being the within-subjects design and the between-subjects design. The within-subjects design was one in which the same subjects were observed under both experimental and control conditions. In the between-subjects design, the various treatments were administered to separate or independent groups of subjects.

Desirable reasons for obtaining a number of measures from the same subject (within-subjects design) were outlined by Grice (11:489):

> 1. Certain variables are inherently within-subjects effects.
>
> 2. The elimination of individual difference variance from differences between treatment means and from the associated error term may result in a more efficient and less costly experiment.

Certain dangers become apparent. This design may be more efficient, but otherwise not equivalent to an experiment in which the same treatments were administered to separate groups of subjects. In the within-subjects arrangement, "a subject who has served as his own control may not be the same subject that he would have been if he had not" (11:488). A different result may be obtained if a separate control group had been employed should the experience in the control condition influence performance in the experimental condition. A simultaneous investigation employing both the between-subjects and the within-subjects design is necessary for critical evaluation of the equivalence assumption. Often, the equivalence of the designs are implicit, rather than explicit.

How well we perceive and exert submaximal forces is an important and testable aspect of the skill acquisition process. Since submaximal force perception and exertion can be evaluated by either a between-subjects or within-subjects design, a contrast of these two designs could offer insight as to the effect of selecting either design upon the ability to perceive various levels of submaximal force.

Scope of the Problem

This study investigated the effect of experimental design and various levels of force upon the accuracy and consistency of perceiving and exerting specific levels of submaximal forces. Direct comparison of a within-subjects design and a between-subjects design was the main consideration. Six groups were utilized; three were within-subjects groups and the other three were between-subjects groups. The subjects assigned to the between-subjects groups experienced only one of the submaximal forces, which were either 25, 50, or 75 percent of their individual maximum grip strength. The subjects assigned to the within-subjects groups perceived and exerted all three of the submaximal forces. A separate group of subjects was provided for each value of the variable under study; thus, there were three between-subjects groups. Under these conditions, the researcher was able to compare the effect of the experimental design in a perceived force experiment.

Statement of the Problem

The purpose of this investigation was to determine the effects of variation in experimental design and of specific levels of force upon the accuracy and consistency of perceiving and exerting submaximal force. This investigation was based upon the proposal by Grice (11) that the nature of relationships observed between variables may be dependent upon the source of experimental variation. Specifically, this study examined the effects of between-subjects and within-subjects designs on the ability to perceive and exert 25, 50, or 75 percent of an individual's maximal dominant hand grip strength.

Null Hypothesis

There will be no significant differences in either constant or variable error in the perception and exertion of various levels of submaximal grip strength forces in either the between-subjects or within-subjects experimental conditions.

Assumptions of the Study

1. Motivation and concentration of the subject was constant throughout the experiment.

2. Rest intervals were of sufficient length to prevent the effects of fatigue upon the subject's performance.

Definition of Terms

1. Experimental design: a model used for the specific presentation of the independent variable under investigation. In this investigation within-subjects and between-subjects designs were used.

2. Between-subjects design: an experimental model that required subjects to perceive only one of the selected perception values.

3. Within-subjects design: an experimental model that required subjects to perceive and exert all selected values of the perception task in a specific order.

4. Maximum grip strength: the mean of two maximal grip strength trials.

5. Criterion forces: the force equal to either 25, 50, or 75 percent of the subject's maximum grip strength.

6. Trace-decay theory: during an unfilled interval a memory trace in the short-term memory system fades over time until it is lost from short-term memory.

7. Absolute error: the sum of the unsigned errors from the criterion score divided by the number of trials.

8. Algebraic error: the signed error indicating recall accuracy on a perception trial obtained by subtracting the criterion force from the exerted force.

9. Constant error: the mean of the algebraic error scores for the perception forces for each subject, indicating the overall accuracy on recall.

10. Variable error: the standard deviation of the algebraic error scores, indicating consistency of a subject on perception trials.

11. Isometric contraction: exercise taking place against a resistance but without significant shortening of the muscle fibers.

Delimitations of the Study

1. The subjects had no prior experience with the cable-tensiometer, the only tool in grip strength force perception.

2. Only the dominant hand was measured for grip strength.

3. The criterion forces were measured at 25, 50, and 75 percent of the maximum grip strength.

4. Maximum grip strength was determined to be the mean of two maximum grip trials.

Limitations of the Study

1. The accuracy of the cable-tensiometer is limited in measuring small force differences.

2. The results might be specific for only this type of motor activity.

3. Overshooting at the low criterion and undershooting at the high criterion was a constantly occurring process in a within-subjects design as explained by the range effect.

Chapter 2

REVIEW OF RELATED LITERATURE

The purpose of this chapter is to present a review of the literature pertinent to the topic of the present investigation. For purposes of organization, this chapter contains three major subdivisions: force perception and exertion; the effect of error scores upon data interpretation; and the effects of experimental design upon specified variables. A summary reviewed the literature in this chapter.

Force Perception and Exertion

Most research done to determine an individual's ability to perceive and exert a submaximal force (1, 2, 20, 24, 25, 26, 30, 31, 32, 33) used tasks involving the movement of a slide along a track or the movement of a lever a given distance along an arc. Generally, movement extent of the motor act has been limited by an artificial stop that is removed during the recall trial. This artificial stop determined the motor item to be recalled as the extent of movement from the starting point to the stop. The dependent variable most frequently employed in reproduction of the original movement has been the mean error. A variable whose movement extent was not available as a cue to the subject was necessary to generalize the findings of motor studies using movement extents. Force, the basis for all movement, would have been an appropriate dependent variable.

In an early study, Jenkins (14) used various aircraft controls to test the accuracy with which pilots and non-pilots could reproduce pressures ranging from one to 50 pounds. Constant errors for the low pressure forces, one to 20 pounds, were positive. Negative constant errors were reported for pressures over 20 pounds. Tasks requiring greater pressures recorded the largest constant error scores. The 20 pound pressure elicited the smallest constant error value. In addition, Jenkins concluded that the magnitude of the criterion force affected the consistency of the performance.

In an experiment by Annett (3), subjects were given 30 trials with knowledge of results to learn to exert a precise pressure after which they tried to exert the same force for 70 additional trials without knowledge of results. Results showed that subjects could apply a precise pressure with knowledge of results, but that the ability to exert this pressure precisely declines over a number of trials after knowledge of results was removed. All subjects experienced positive constant error scores. The range effect was apparent in both the studies by Annett and Jenkins (14). The range effect explained the tendency at recall to overestimate smaller forces and underestimate larger forces in a within-subjects design. Response scores were a function of the criterion value. Annett believed that the subjects were actually estimating something they have previously experienced. Laabs (17) agreed with this hypothesis. He believed that perception of a force was dependent upon an individual's similar movement experiences.

Norrie (22) investigated absolute changes and directional changes in short-term memory for the exertion of a force. Her experiment utilized a vertical steel bar that moved only .13 inches when the standard force was applied. The subject was told to reproduce the criterion score after a retention interval of either one-half, one and one-half, or four minutes. No significant differences were found when measured in terms of absolute error. The direction of the error changed significantly from a relatively large overestimation of force on immediate reproduction to only a slight overestimation after a delay of one-half minute. Absolute error approached zero after a retention period of one-half to four minutes. Norrie believed that immediate reproduction may be influenced by a kinesthetic aftereffect that may dissipate by the end of one-half minute. Norrie concluded that the direction of error showed considerable overshooting of the standard upon immediate reproduction. This was not found after retention intervals of one-half to four minutes.

In a later investigation, Norrie (21) examined the effects of multiple reinforcements on short-term memory for a kinesthetically monitored force reproduction task. The apparatus was the same as in her previous study (22). Three groups were used with subjects receiving either one, five, or nine reinforcements. Reproduction was either immediate or after a 30-second delay. Results concurred with earlier mentioned studies. For both the immediate and delayed reproduction conditions, overshooting of the standard occurred. Constant error analysis indicated that multiple reinforcements improved the accuracy of performance for immediate reproduction. However, this improvement was not retained over a retention interval of 30 seconds.

In a response to Norrie's (22) kinesthetic aftereffect approach, Whieldon (38) compared the influence of these aftereffects upon two testing sequences in the perception of a submaximal grip strength force. It was concluded from the study that kinesthetic aftereffects had no significant influence upon submaximal grip strength perception. Also shown was that total consistency of submaximal grip strength perception was not affected by the testing sequence or the grip strength level while the accuracy of submaximal perception was determined by the magnitude of the grip strength rather than the testing sequence.

Pepper and Herman (23) measured the short-term retention of force responses in a series of four experiments using an apparatus whose movement over the complete force range was only .08 mm.; therefore, movement extent was not available as a cue to the subject. During recall, the subject was required to apply the pressure he felt was correct to a criterion based upon the preceding experiences of applying that same force with visual feedback. Absolute and algebraic errors made by the subject during reproduction of the criterion force were the dependent variables. Experiment I measured retention over five unfilled intervals ranging from four to 60 seconds. An increase in errors, i.e., forgetting, was not found. Experiment II was basically a replication of experiment I with the addition of a backward counting activity during half of the retention intervals. Results showed a decrease in error for both the filled and unfilled conditions. Experiment III utilized the application of a second force during the retention interval. It was found that the recall response shifted in the direction of the relative magnitude of an interpolated force to the criterion force. Experiment IV examined the effects of successive repetitions of the criterion force prior to recall. This was found to produce an increased error in recall. All four experiments indicated positive algebraic errors at recall. Perhaps Norrie (21, 22) obtained the same constant error results as did Pepper and Herman due to the small amount of force used.

The previous studies (3, 14, 17, 21, 22, 23, 38) examined force perception as a dependent variable. Several methodological phenomena were discovered when examining force perception. To further confound the results, error terms were misused. The following section investigated force perception in an attempt to discern constant error and variable error.

Effect of Error Scores Upon Data Interpretation

Laabs (17) indicated that the assumptions made by Pepper and Herman (23) regarding proprioceptive information and its effect on a decaying motor trace accommodated only the positive constant error shift. Variable error was completely ignored. Also, Laabs indicated that several studies (15, 23, 24) did not separate the reproduction cues of distance and location. In Laabs' study, variable error was used to determine if an unfilled retention interval resulted in a decrease of reproduction accuracy of movement distances but had little effect on the reproduction of movement location. Also tested was the decay theory of motor short-term memory as presented by Pepper and Herman. Decay evaluated by a constant error index was also examined. Results of the experiment indicated the range effect. The constant error shift followed the assumptions outlined by Pepper and Herman only for larger movements in distance reproduction.

Marteniuk (19) investigated motor short-term memory and interpreted the results in terms of the models presented by Pepper and Herman (23) and Laabs (17). Studied were location, distance, and active and passive movements. It was found that absolute error was dependent upon both constant error and variable error. Absolute error, therefore, cannot be used as an index of variability. Variable error was not found to be a sensitive measure of trace decay. This was in direct contrast to Laabs. Marteniuk showed that an interpolated act tends to increase the intensity of the trace with an increase in constant error. Several studies (14, 17, 21, 22) used absolute error or variable error as their index of forgetting. Marteniuk's study used constant error and was comparable only to that of Pepper and Herman (23). Pepper and Herman showed a positive trend in constant error with an interpolated mental act. Marteniuk (19:257) concluded the following:

> 1. Different movement cues are initially represented in memory in varying degrees of exactness. This is especially so with location cues over distance cues.
>
> 2. Laabs' process of establishing a referent movement in the middle of the movement range directly influenced the reproduction of shorter and longer movements.
>
> 3. Any interpolated activity would augment the trace in a positive direction for a short movement. A large movement would not be influenced as much.

Laabs (16) commented on Marteniuk's observations. Marteniuk (19) failed to find retention characteristics for distance and location using variable error. Laabs found decay over an unfilled retention interval for distance but not end location. Laabs explained the different results as Marteniuk's failure to report the removing of subjects that employed a counting strategy. Variable error, as concluded by Marteniuk (19), may be an inadequate measure of trace decay on interference. Laabs believed that lack of statistical power is a better explanation.

Marteniuk (19) reported a central tendency effect. Constant error results were used to reject the conclusion that distance information was not rehearsable; a conclusion drawn by Laabs based upon variable error results. Marteniuk did not distinguish between constant error and variable error as measures of forgetting, while Laabs used constant error to index context effects and variable error to index forgetting. Laabs concluded that a distinction should be made between constant error and variable error.

In a rebuttal to Laabs, Marteniuk (18) offered some considerations. The interpretation of data should be what the investigator considered important based upon results of his own experiences. Also, Laabs' theory had too small of a data base from which to make predictions. In his conclusion, Marteniuk reminded the reader that the purpose of his previous study (19) was to test the prediction of both Pepper and Herman (23) and Laabs (17). Pepper and Herman used constant error as a measure of forgetting. Therefore, constant error must be used to test their prediction.

The Effect of Experimental Design Upon Specific Variables

Experimental design effects upon specified variables were first discussed in an investigation by Beck (5). In her study, Beck utilized the eyeblink technique. This consisted of the presentation of a puff of air to the eyelid (the unconditioned stimulus) followed by a tone of varying intensity (the conditioned stimulus). The conditioned stimulus intensity variable was placed in a factorial arrangement as a within-subjects effect. Results of this arrangement revealed extreme values for the conditioned stimulus intensity variable beyond those previously reported. From this finding, it was insinuated that greater effects are obtained if individual subjects were exposed to more than one intensity of the conditioned stimulus.

Beck's investigation prompted two experiments by Grice and Hunter (12). Under Beck's assumption, it was theorized that different results are to be expected from experimental designs using these different procedures. It is possible that exposing subjects to the two intensities of the conditioned stimulus within the experiment increased the magnitude of the effect over what is obtained when the subject experiences only one intensity value. Grice and Hunter directly compared the between-subjects group with the within-subjects group where the same values of the independent variable are used in two experiments. Experiment I was an investigation of conditioned stimulus intensity in eyelid conditioning. The between-subjects groups received either a loud or soft tone. The within-subjects groups received both tones in a randomly presented order. Procedures were similar to that of Beck's. The magnitude of the within-subjects group was significantly greater than the group with the single value condition. The authors concluded that exposure to both intensity values substantially increased the effect of the variable when compared with the use of single intensity values with separate groups.

Experiment II investigated simple reaction time using two intensity values of an auditory signal. Experimental design was the same as experiment I. Response of the two auditory values was the pressing of a telegraph key. Similar results were obtained as in experiment I. Significant difference was found between groups exposed to one stimulus as opposed to two. Also, slower reaction times were reported under the two stimulus condition; thus, showing the effect of differential treatments.

Both Beck (5) and Grice and Hunter (12) obtained results that demonstrated a significant conditioned stimulus intensity effect in the within-subjects design but not in the between-subjects design. Cermak (7), employing both the between-subjects design and the within-subjects design as did Grice and Hunter, conducted a similar experiment comparing stimulus intensity effects in a galvanic skin response. Two intensities of an auditory signal was the conditioned stimulus. The unconditioned stimulus was a shock delivered to the subject. Results revealed differential treatment effects between the two conditions. Single stimulus (between-subjects) was not significant whereas the two stimulus condition (within-subjects) was statistically significant. The author concluded that the use of experimental designs can result in different behavioral effects. Therefore, conditioned stimulus intensity was a function of the experimental design employed.

Behar and Adams (6) investigated intensities of a reaction time warning signal. Subject response was to a visual stimulus that was preceded by a warning signal of soft, moderate, or loud intensity. Between the warning signal and the response stimulus was a randomly varied interval of either one, three, or eight seconds. The between-subjects groups received only one of the three intensities while the within-subjects groups received all three intensities in random order. As the intensity of the warning signal increased, a significant difference was reported among warning signal intensities for the within-subjects groups with reaction times decreasing. Reaction times for all three intensities in the between-subjects design were not significantly different.

The experiment by Schnorr, Lipkin, and Myers (29) studied the role of incentive in human learning as a function of the type of experimental design employed. The three independent variables under consideration were level of incentive (one and 10 chips), method of incentive presentation (between-subjects or within-subjects), and sex. Subjects were required to predict whether each of 100 playing cards had a point or line on it. Depending upon the correctness of the subject's prediction, he either won or lost a previously designated number of chips. Method of presentation, amount of incentive, and interaction effect all produced significant differences. The authors concluded (29:499):

> Presenting levels of incentive as a between-subjects variable does not result in performance differences as measured by time-independent indexes of learning, but that manipulating levels of incentive as a within-subjects variable produces performance differences that are directly related to the amount of incentive.

Further, "these findings imply that future investigators of incentive effects should optimally employ a within-subjects design" (29:499).

Lueft (35) investigated the effect of experimental design upon expectancy and speed of response in a simple reaction time situation. An experiment was developed to determine if the type of experimental design would influence response to specified foreperiods. An added feature of Lueft's design allowed the testing of the hypothesis that variance in response delays could be attributed to an expectancy effect.

The task involved the release of a response key upon the onset of a visual stimulus. The stimulus was preceded by a warning signal informing the subject to depress the key. Duration of the interval between key depression and stimulus onset, the foreperiod, was either one, three, or five seconds. The within-subjects groups received all fore-periods presented in a balanced random order, while the between-subjects groups received only one of the three fore-periods.

The relationship between expectancy and experimental design was examined. Differences at the three and five second foreperiods were not significantly different.

significant difference was found at the one second foreperiod. Excessive delays were not evident over the entire range of foreperiods. It appeared that a relationship existed between the design of the experiment and expectancy. Delays in speed of response at the one second foreperiod may have been attributed to subject expectancy resulting from the method of foreperiod presentation.

Similar research, based on the model provided by Grice and Hunter (12), was conducted by Henrikson and Holmes (13). In a reaction time experiment, a ready signal was directly compared when treated as both a between-subjects and a within-subjects (present vs. absent) design. The ready signal was a light of 0.5 seconds duration. Foreperiods of either two, three, or four seconds preceded the onset of the tones. Depression of a conventional telegraph key was used to measure the reaction time. Results showed that the effects of the ready signal manipulation clearly depended upon the type of experimental design used. The assumption that the ready signal maximized the subject's state of readiness and thus lowered his threshold for responding must not be readily assumed. Results showed that the ready signal did not appear to be an effective variable when used in a between-subjects design. Before an assumption was accepted, the type of experimental design must be analyzed.

Poulton (27) believed that the range effect was a general characteristic of man serving in a within-subjects design. He believed that range effects can be avoided or bolstered by using a between-subjects design. Poulton's previous statement assumed that the between-subjects design provided a standard of validity. This can be questioned. Poulton himself said, "The influence of range of stimuli cannot always be prevented by restricting each man to a single stimulus" (27:115).

Greenwald (10) disagreed with Poulton's initial statement. He contended that even if extralaboratory context could be safely ignored, the presentation of a single treatment to each subject does not really achieve the absence of context. This in effect only provided the presence of the context effects as produced by the single treatment. There was not any validity that a between-subjects design provided a standard against which to evaluate a within-subjects design. Greenwald also believed that another aspect to be considered when choosing a design were the context effects generated by a within-subjects design such as practice, sensitization, and carry-over.

Practice

A within-subjects design should be avoided while studying the effects of several treatments when interested in the effects of treatments in the absence of practice, and when practice is likely to affect performance. This effect can be reduced by counter-balancing the sequence of treatments.

Sensitization

If juxtaposition of treatments enhances perception of treatment variation and these perceptions interfere with the processes the researcher desires to study, a within-subjects design should be avoided.

Carry-Over

In a within-subjects design, the effects of one treatment may still be in force at the moment of measuring another. Sufficient time between trials should control this effect.

Rothstein's (28) feelings toward experimental design were more radical than those of Poulton. He believed that psychologists interested in motor performance and magnitude estimation, areas that traditionally focused on range effects, should use a between-subjects design if they are not interested in the range effects. Rothstein summarized that repeated measure designs provided a good alternative to independent group designs when sampling error is likely to be high and/or the availability of the subjects is likely to be low.

Several of the previous studies (5, 7, 12) indicated that exposing individuals to more than one dependent variable increased the effect of that variable when compared with the use of single values with separate groups. Other studies (10, 27, 28) discussed the methodological problems associated with the within-subjects design. It became apparent that the relationship between certain variables was dependent upon the source of experimental design employed on the investigation.

Summary

The review of literature was divided into three major parts. Part I discussed perception and exertion of submaximal forces. It was noted that early studies (1, 2, 20, 24, 25, 26, 30, 31, 32, 33) utilized distance or location of lever devices as a test for perception of movement extent. Force was a superior dependent variable because extremely small movement extent of the testing device cannot be used as a cue to the subject.

The effect of error scores upon data interpretation (16, 17, 18, 19, 23) was discussed in part II. Conclusions indicated that indiscriminant use of absolute, constant, or variable error can have an effect upon the experimental outcome. Care should be taken when choosing the appropriate dependent variable.

Concluding the chapter was a discussion of the effect of experimental design upon specified variables. The reviewed literature (5, 6, 7, 10, 12, 13, 27, 28, 29, 35) implied that the experimental design utilized may be a significant factor in scientific experimentation. Different operation of the stated variable was apparent as a result of contrasting experimental designs. This has led to a re-evaluation of the operation of the stated variable.

Chapter 3

METHODS AND PROCEDURES

This chapter discusses the methods and procedures used in the collection and analysis of the data. The chapter is divided into the following major topics: selection and description of subjects, testing instrument, methods of data collection, scoring of the data, and treatment of the data. A summary of the methods and procedures completes the chapter.

Selection and Description of Subjects

Subjects were volunteer undergraduate and graduate students enrolled at Ithaca College during the spring semester of 1976. The 39 females ranged in age from 18.0 to 27.6 years with a mean age of 19.2. Male volunteers, 33 in number, ranged in age from 18.1 to 25.7 years with a mean age of 19.8. There were 12 subjects in each of the six experimental groups. Subjects were randomly assigned to specific groups by drawing a card from a specially designed deck. The dominant hand was used by all subjects.

Testing Instrument

The instrument used to record force perception scores was a cable-tensiometer attached to a T-5 orthopedic testing device. Morris and Brigham (36) found the cable-tensiometer to have the greatest reliability in the measurement of grip strength when compared with the Smedley and Collins Dynamometers. The testing device was essentially the same as reported by Ellis (34).

The cable-tensiometer was attached securely to a table top with the handle 42 inches from the floor. The instrument dial registered cable-tensiometer units of force. Similar to Ellis' procedure, calibration of the tensiometer was accomplished by adding weights ranging from four to 175 pounds. This allowed the reading to be converted to pounds-force.

Subjects utilized an arm rest during force perception trials and rest intervals. The top of the arm rest was at the same height as the bottom of the handle of the cable-tensiometer. A Kodak Clock Timer was used to time the inter-trial intervals.

Methods of Data Collection

The subject was seated with the dominant arm held at 90-degree shoulder-flexion with the forearm held in a pronated position. As suggested by Cotten and Bonnell (8) and by Cotten and Johnson (9), a medium-small grip width was adjusted for each subject. In similar studies, they used different settings of the cable-tensiometer to determine the optimum position for measuring grip strength. It was concluded that a medium-small setting be used each time an individual's strength was tested. Grip widths in this investigation were adjusted in a manner similar to that of Whieldon (38). Simply, the second phalange of the index finger on the dominant hand rested on the inside handle of the tensiometer. Following the adjustment of the gripping handle, directions were then read to each subject. Two maximum grip strength trials were given, with a one-minute rest between trials. Depending upon the random group assignment, volunteers perceived and exerted either 25, 50, or 75 percent of the average of the two maximum grip strength trials or a balanced order of these three criterion forces.

Experimental design was concerned with the direct comparison of two experimental procedures. Actually, there were two experiments occurring simultaneously; an experiment utilizing a between-subjects design and another utilizing a within-subjects design. The within-subjects design was structured so that each subject received all levels of the independent variable. In the between-subjects design, each group of subjects received only one level of the independent variable.

To facilitate analysis, the number of groups in the within-subjects design equalled the number of treatments. The within-subjects groups were comprised of randomly equal, but independent groups. The data from only one treatment for each of these groups were used. The other information was considered irrelevant and subject only to the experimental design. This, however, did not put the within-subjects design in jeopardy. It was still a within-subjects design since all the subjects experienced all the treatments. Each group exerted all submaximal forces, but only one force was used in the statistical analysis. Submaximal forces were presented in a balanced order with replication.

Thus, three groups were required for the within-subjects design and three groups for the between-subjects design. There were 12 subjects per group.

Between-Subjects Procedure

The between-subjects experiment was comprised of three groups, each of which perceived only one of the criterion forces. Group I perceived the 25 percent force, group II the 50 percent force, and group III the 75 percent force. Subjects perceived and exerted their particular force a total of 15 times. There was a one minute unfilled interval between trials.

Within-Subjects Procedure

Subjects were randomly assigned to either group IV, V, or VI. In an attempt to control for the possibility of order effects, subjects were randomly assigned to one of six possible orders.

Subjects perceived and exerted a total of 45 forces, with 15 trials at each force. There was a one-minute unfilled interval between trials.

Scoring of the Data

Perception force scores were recorded in cable-tensiometer units and then converted into pounds-force by using the calibration scale. The criterion force was subtracted from the perception force to compute the algebraic error. This was done for each perception score. A positive sign was given any error score above the criterion and a negative sign to any error score for a perception force smaller than the criterion force. Constant error was computed for each subject. This was the same as the mean algebraic deviation from the criterion. Variable error score was the standard deviation of error scores about their mean. Variable error measured the consistency of the perception trials. Constant error was an accuracy measure of the subjects in their effort of perceiving and exerting the criterion force.

Treatment of the Data

Constant and variable error of the criterion forces were considered at three levels: 25 percent, 50 percent, and 75 percent of the mean of two maximum grip strength trials. The type of experimental design was considered at two levels: between-subjects and within-subjects. Between-groups I, II, and III were compared to the within-groups IV, V, and VI respectively. Only that particular criterion force of the between-subjects design corresponding to the chosen within-subjects design was utilized. The other two forces were discarded. An average of that particular score was used in the analysis.

A multivariate analysis of variance was used to analyze the constant error and variable error scores in this 2x3 factorial design. The multivariate analysis of variance maximized the chance to find significant differences between treatment conditions.

As recommended by Baumgartner (4), the intraclass correlation method was used to determine the reliability of the data. The intraclass correlation coefficient (R) was the best estimate of test reliability with multiple trial tests. This method took into account sources of variation in test scores. The analysis employed an analysis of variance of a treatment by subjects design for the individual trials of all variables.

Where any significant differences were realized, a Scheffé S Test was used to compare the constant and variable error scores obtained under specific treatment conditions. All tests of significance were made at the .05 level of confidence.

Summary

Two experiments, conducted simultaneously, allowed the investigator to secure simple force perception measures. A within-subjects design was used where the subjects perceived forces of 25, 50, or 75 percent of maximum grip strength in a balanced order design with replication. In the between-subjects design, the subjects perceived only the criterion force which was exclusive for that particular group, either 25, 50, or 75 percent of maximum grip strength. A cable-tensiometer was used to record these measures.

All subjects were volunteers enrolled at Ithaca College during the spring, 1976 semester. Twelve subjects were randomly assigned to one of the six groups.

A multivariate analysis of variance evaluated treatment effects. The intraclass correlation method was used to compute the reliability of the data.

All tests of significance were conducted at the .05 level of confidence.

Chapter 4

ANALYSIS OF THE DATA

This chapter presents the statistical analysis of the data. The chapter is divided into two major subdivisions: reliability of the data and analysis of the data. A summary completes the chapter.

Reliability of the Data

As recommended by Baumgartner (4), the intraclass correlation method was used to determine the reliability of the data. Reliability was equal to the mean square for subjects minus the mean square for error divided by the mean square for subjects. This was done for groups I through VI and once for all the maximum trial scores. Maximum trial scores revealed a reliability coefficent of .98. Reliability coefficients of the within-subjects and between-subjects groups ranged from .93 for group II and .98 for group IV. Reliability coefficients are shown in Table 1. These coefficients showed that the data were reliable.

Analysis of the Data

A multivariate analysis of variance was used due to the presence of more than one dependent variable. This analysis examined the effects of design and level of strength

Table 1

Intraclass Correlation Coefficients for Maximum Scores and Submaximal Scores for Groups I through IV

	Mean Squares Error	Mean Squares Subjects	R
Maximum	26.73	1124.84	.98
Group I	31.00	802.57	.96
Group II	38.67	560.35	.93
Group III	72.83	1606.45	.96
Group IV	104.97	1494.55	.93
Group V	28.73	718.22	.96
Group VI	31.99	1679.26	.98

on constant and variable error. Table 2 summarizes the results of this analysis. There was no significance for the design variable; however, an approximate F-statistic of 5.55 was recorded for the level of strength variable. With four and 130 degrees of freedom, an approximate F-statistic of 2.43 was needed for significance. This value was exceeded; therefore, the null hypothesis was rejected. The interaction effect was not significant.

Constant error and variable error were each subjected to univariate analyses of variance to study the effects of design and level of strength. Table 3 summarizes the univariate analysis for the forementioned effects on variable error. No significant F-ratios were reported. Table 4 presents a summary of these effects for constant error. With two and 66 degrees of freedom, an F-value of 3.14 was needed for significance at the .05 level for the level of strength variable. The obtained F-ratio of 11.23 exceeded this value.

A Scheffé S Test was performed on the constant error variable. An S score of 7.68 was necessary between force levels to show significance. Significance was realized for constant error scores between the 75 and 25 percent levels as well as between the 75 and 50 percent levels. This is indicated in Table 5.

Summary

This chapter discussed the reliability and the analysis of the data. An intraclass correlation was used

Table 2

Summary of the Multivariate Analysis of Variance for the Effects of Design and Level of Strength on Constant and Variable Error

Source	Degrees of Freedom	Approximate F-Statistic
Design	2, 65	0.19
Percentage of Strength	4, 130	5.55*
DxP	4, 130	0.79

*Significant at the .05 level.

Table 3

Summary of the Univariate Analysis for the Effect of Design and Level of Strength on Variable Error

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F
Design	0.02	1	0.02	0.001
Percent of Strength	5.22	2	2.61	0.16
DxP	44.16	2	22.08	1.32
Full Model	1,103.51	66	16.72	

Table 4

Summary of the Univariate Analysis for the Effect of Design and Level of Strength on Constant Error

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F
Design	41.16	1	41.16	0.37
Percent of Strength	2,531.30	2	1,265.65	11.23*
DxP	117.04	2	58.52	0.52
S(DP)	7,441.04	66	112.74	

*Significant at the .05 level.

Table 5

Scheffé S Analysis for the Constant Error
Percentage of Strength Variable

	75%	25%	50%
	-6.99	5.44	5.73
75%		12.43*	12.72*
25%			.29
50%			

*Exceeds the S value of 7.68 required for significance at the .05 level.

to determine the reliability of the data. Reliability coefficients for all groups including the maximum trial scores ranged from .93 to .98. This showed that the data were reliable.

A multivariate analysis of variance examined the effects of design and level of strength on constant and variable error. The design variable did not reveal statistical significance; however, the level of force variable was significant.

Univariate analyses were performed on the constant and variable error scores to study the effects of design and level of strength. No significnat F-ratios were reported for the variable error scores. Constant error was significant for the level of strength variable. Due to this significance, a Scheffé S Test was performed. Significance was shown between two distinct force perception levels. The 25 and 50 percent groups recorded constant error scores that were significantly different from the 75 percent group.

Chapter 5

DISCUSSION OF THE RESULTS

This chapter discusses the results reported in chapter 4. The following topics are discussed: reliability of the data; analysis of the constant and variable error scores; possible explanations of nonsignificant results, and a summary of the discussion.

Reliability of the Data

As suggested by Baumgartner (4), intraclass correlations were done for groups I through VI and for the maximum grip scores to determine the reliability of the data. These coefficients were .96, .93, .96, .93, .96, .98, and .98 respectively. Overall, these values were higher than those obtained by Morris and McEachran (37) and Whieldon (38). It can be safely assumed that the data were reliable.

Analysis of the Constant Error and Variable Error Scores

A multivariate analysis of variance examined the effects of the design and level of strength variables. There were no significant differences for the design variable or interaction effects. However, with an approximate F-statistic of 5.55, the level of strength variable was statistically significant at the .05 level. An approximate F-statistic of 2.43 was necessary for significance.

To further facilitate analysis, constant error and variable error were subjected to separate univariate analyses of variance to examine the effects of the level of strength variable. Variable error indicated the consistency with which an individual could perceive and exert a submaximal force. Jenkins (14) concluded that the magnitude of the criterion force affected the consistency of the performance. However, in this study, there were no significant differences for any of the dependent variables in relation to variable error. Constant error, the measure of accuracy for perception tasks, was positive for all groups. Similar constant error findings were reported by Norrie (21, 22) and Adams and Dijkstra (2). Both Ellis (34) and Whieldon (38), who employed the same apparatus as was used in this study, found a similar overshooting pattern in the perception of submaximal grip strength. Pepper and Herman (23) also reported overshooting in a force reproduction task. They explained the tendency to overshoot or undershoot the criterion force at recall as a result of the subject's response set. The univariate analysis of variance for the constant error scores revealed no significant differences for the effect of the design variable. The reported F-ratio of 11.23 exceeded the necessary value of 3.14 for statistical significance at the .05 level for the level of strength variable. A post hoc analysis, the Scheffé S Test, revealed constant error scores that showed the 25 and 50 percent groups to be significantly different from the 75 percent group. This was in agreement with the studies of Morris and McEachran (37) and Whieldon (38).

Possible Explanations of Nonsignificant Results

Design effects were not significant for either the constant error or variable error scores. Apparently the experimental design did not have an effect upon the perception and exertion of a submaximal grip strength task. It appeared that accurate perception of a submaximal force depends upon the level of strength of the criterion, rather than the testing sequence.

The level of strength variable was then considered in terms of variable error. No significant differences were found in the consistency of perceiving a submaximal force depending upon the level of strength variable. This was in contrast with Jenkins (14) who found that subjects were inconsistent in their perception of submaximal forces. However, the findings of this investigation agreed with the studies of Morris and McEachran (37) and Whieldon (38). The findings of this investigation indicated that subjects were consistent in their perception and exertion of a submaximal grip strength task.

Summary

This chapter discussed the results of the investigation. Intraclass correlation values for the maximum grip scores and all the perception groups indicated adequate reliability.

A multivariate analysis of variance examined the effects of design and level of strength variables. Only the level of strength variable was statistically significant. Constant error and variable error were each subject to univariate analyses of variance to further facilitate analysis. Neither dependent variable was statistically significant as calculated by variable error. The level of strength variable was significant as reported by constant error. A post hoc analysis, the Scheffé S Test, revealed significantly different constant error scores between specific levels of force. Perception of a submaximal force depended upon the level of strength of the criterion, rather than the testing sequenee.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this investigation was to determine the effects of experimental design and various levels of force upon the accuracy and consistency of perceiving and exerting specific levels of submaximal forces. Seventy-two volunteers enrolled during the 1976 spring semester at Ithaca College served as subjects. The subjects were randomly assigned to one of six experimental groups consisting of 12 subjects each. Groups I, II, and III were required to perceive and exert 25, 50, and 75 percent of their maximum grip strength respectively. Groups IV, V, and VI experienced all three submaximal forces in a balanced order. The maximum grip strength for each subject was determined by averaging the scores of two maximum grip strength trials. The instrument selected to measure the grip strength perception trials was a cable-tensiometer attached to a T-5 orthopedic testing device. The T-5 device was attached firmly to a table directly in front of the subjects at shoulder height. A Kodak Timer was used to time all rest intervals.

The intraclass correlation method was used to determine the reliability of each of the perceptual groups and the maximum trial scores. The reliability of these groups calculated through seven separate intraclass correlation tests reported adequate reliability for all groups.

A multivariate analysis of variance examined the effects of design and level of strength on constant and variable error scores. Significance was found only for the level of strength variable. To further facilitate analysis, constant and variable error were each subjected to univariate analysis of variance. The level of strength variable was significant for the constant error scores. A post hoc analysis using the Scheffé S Test indicated significant differences between two of the three perception levels.

Conclusions

Within the limitations of this investigation the following conclusions were made:

1. A response set of overshooting occurred for an individual's perception and exertion of submaximal grip strength forces.

2. Neither the experimental design nor the level of strength variable had any significant influence upon the consistency with which an individual perceived and exerted a specific submaximal grip strength force.

3. The grip strength level had a significant influence upon the accuracy with which an individual could perceive and exert a submaximal grip strength force.

Recommendations

1. A replication of the study should be done using only athletes.

2. A more sensitive measuring device should be used in a similar study.

3. Knowledge of results should be investigated for its influences upon the perception and exertion of a submaximal force.

APPENDICES

APPENDIX A

CABLE-TENSIOMETER CALIBRATION

Ralph Kaplan
July, 1976

1.	6.31	21.	36.74	41.	69.80	61.	116.39
2.	7.78	22.	41.35	42.	75.65	62.	119.40
3.	10.64	23.	42.70	43.	76.24	63.	124.07
4.	12.50	24.	44.05	44.	76.76	64.	126.61
5.	13.13	25.	44.68	45.	79.19	65.	129.08
6.	13.75	26.	50.00	46.	80.85	66.	134.39
7.	14.38	27.	51.13	47.	82.53	67.	137.51
8.	15.00	28.	52.50	48.	84.20	68.	140.62
9.	18.94	29.	53.33	49.	84.69	69.	142.71
10.	22.20	30.	54.17	50.	85.17	70.	144.79
11.	25.94	31.	55.00	51.	87.68	71.	148.19
12.	27.27	32.	58.18	52.	90.18	72.	151.59
13.	27.87	33.	62.00	53.	94.64	73.	155.00
14.	29.23	34.	63.13	54.	98.28	74.	157.19
15.	30.59	35.	64.86	55.	101.92	75.	158.51
16.	33.30	36.	65.40	56.	105.57	76.	159.82
17.	33.90	37.	66.17	57.	107.42	77.	162.29
18.	35.30	38.	67.02	58.	109.26	78.	164.79
19.	35.58	39.	68.06	59.	112.13	79.	169.88
20.	36.21	40.	68.70	60.	115.00	80.	175.00

APPENDIX B

General Directions

The purpose of this experiment is to determine your ability to perceive and exert a submaximal grip strength force. The device we will be using is a cable tensiometer. As you can see, after the handle is squeezed, there is a marker that tells what force you perceived. The marker is then reset for the next trial. During the experiment, simply squeeze the device to the desired position and relax. Please use your dominant hand for this experiment.

There are two parts to this experiment. The first part will determine your maximum grip strength. The second part will determine your ability to perceive and exert a submaximal grip strength. Rest your arm on the support. Grip the handle without squeezing. I will adjust the grip.

It is important that you do not talk during the experiment. I will be happy to discuss the results with you when my analysis is complete.

Part I All Subjects

The first part of the experiment will determine your maximum grip strength. The handle should be adjusted to a comfortable width. Your maximum grip strength will be determined through two all-out trials with one minute rest between trials. With three or four seconds remaining in the rest interval, I will tell you "ready;" and at the end of the interval "go." You will then squeeze the device as hard as possible. Do you have any questions? Remember, you do not have to hold the squeeze for any period of time. Just squeeze and relax. Ready for the first trial?

Part II Between-Subjects

The second part of the experiment will determine your ability to perceive and exert a submaximal force, this force being equal to ___ percent of your maximum strength. There will be five trials. During the one minute rest between trials, you may use the support for the arm. However, do not remove your hand from the handle. With about three or four seconds remaining in the rest interval, I will say "ready." On the command "go," try to perceive and exert a ___ percent force. The arm can then relax for the one minute rest interval. Again, please do not talk during the experiment. I will be happy to discuss my results with you after analysis of the data. Remember, you will be trying to perceive a force of ___ percent of your maximum grip force.

Part II Within-Subjects

The second part of the experiment will determine your ability to perceive and exert a series of submaximal forces, these forces being equal to 25, 50, and 75 percent of your maximum grip strength. There will be five trials at each force. During the one minute rest interval between trials, you may use the support for your arm. However, do not remove your hand from the handle. With about three or four seconds remaining in the rest interval, I will say, "'Perceive a 25 percent force. Go.' or 'Perceive a 50 percent force. Go.' or 'Perceive a 75 percent force. Go.'" On the command "go," try to produce the specified force. Listen carefully. The arm can then relax for the one minute rest interval. Again, please do not talk during the experiment. I will be happy to discuss my results with you after analysis of the data. Are there any questions? Remember, during each trial you will be trying to perceive and exert a different submaximal force. Listen carefully. Ready?

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